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ROOT DISEASES AND MYCORRHIZAE—A REVIEW

SAMPANGI RAMAIAH, K. and D. J. BAGYARAJ.*
Dept. of Plant Pathology, Univ. of Agril. Sciences, GKVK, Bangalore-560 065, India.
*Dept. of Agricultural Microbiology, Univ. of Agril. Sciences, GKVK, Bangalore-560 065, India.

The current status of mycorrhizae, both ecto and VA, as deterrents of root diseases is briefly reviewed. Past and current research indicates that mycorrhizal seedlings are capable of resisting the parasitic invasion or minimise the losses caused by soil borne plant pathogens. Mechanisms of supression of pathogens and disease by mycorrhizae are discussed. The protective influence of mycorrhizal fungi are reported to have variations depending on host plant, pathogen involved, species of mycorrhizae and soil environment. The mycorrhizae, an integral part of plant, offers a natural potential for biological control. This potential can be exploited in field scale by further understanding the defense mechanisms and the conditions favouring the expression of these protective ability.

Keywords : Symbiosis; Biological control; Rhizosphere; Root pathology; Fungal mantle; Antibiotic production.

Introduction

The plant root hosts diverse groups of microorganisms which play an important role in root development. The plant roots provide conditions for selective stimulation of certain soil microbes which in turn may have beneficial or deleterious effects on plants. The rhizosphere, the region of soil influenced by plant roots, is characterized by a particular type of microbial fauna and flora that is unique in its qualitative and quantitative composition. It is well established that almost all green plants grow and flourish in close association with other beneficial organisms living symbiotically. It is increasingly realized that mutually beneficial symbiotic systems in nature are very common and are of greater biological significance than previously believed (Bowen and Rovira, 1976).

Since Frank's (1885) original description and recognition of a symbiotic relationship between tree roots and fungi and his coinage of the term "Mycorrhiza" or "Fungus-root", impressive progress has been achieved on this interesting phenomenon. Mycorrhizae have received considerable attention in recent years because mycorrhizal plants have several advantages over non-mycorrhizal plants. Mycorrhizal plants grow better in infertile soils because of improved mineral nutrition through hyphae exploring greater volume of soil beyond root hairs. Mycorrhizal fungi enhance water transport in plants, decrease transplant injury, help withstand high temperatures, promote establishment of plants in waste lands and mine soils and reduce the effects of root-borne diseases (Trappe, 1977). Mycorrhizal investigation has developed in the last 20 years as an independent subject paralleling Root Pathology and Biological Control.

In a broad sense, biocontrol comes into operation when one biotic agent acts upon another in such a manner to either limit its population or its pathogenic activity. Numerous recent studies have demonstrated the naturally occurring biological phenomena–such as antagonistic microorg anisms, supressive soils, mycorrhizae etc. offering important means to augment crop yields by supression or destruction of plant pathogens.

For many diseases, especially the low economic value field crops, the emphasis has been shifted from absolute control to economically acceptable control and it is realized that elimination of last trace of the disease costs more than the benefits of return. It is in this context that biocontrol of plant pathogens is generally accepted and used today. Chemical control, once considered the ultimate weapon is being integrated into other cultural and biological methods of disease control (Cook and Baker, 1983).

The mycorrhizal association which is an integral part of the plant constitutes a method of biocontrol of considerable importance. Fungal diseases of roots and mycorrhizal associations of roots are similar in that both involve the succulent fir roots of their hosts; hence they might be expected to play some significant role in the microbial interactions in the rhizosphere (Harley and Smith, 1983).

Effect of Mycorrhizae on plant diseases

Early field observations that seedlings and trees with considerable amount of ectomycorrhizae were most resistant to feeder root infections by fungi than seedlings with few or no mycorrhizae lead to the conclusion that mycorrhizae decreases or mitigated the disease severity. Marx (1972) had demonstrated that the mantle of ectomycorrhiza of pine roots not only formed antibiotics and a physical barrier but as well increased production by the host of volatile and nonvolatile compounds inhibitory to pathogens. Such production effectively decreased the disease incidence while increasing the longevity of roots. It is now well established that endomycorrhiza also reduce or mitigate the disease severity while assisting the plant establishment in drought conditions and in waste lands. Root protection was demonstrated against parasitic invasion by *Rhizoctonia solani* on *Pinus taeda* and *Phytophthora cinnamomi* on short leaf pine. Mycorrhizal association of these hosts with *Pisolithus tinctorius* and *Cenococcum graniforme* protected the roots and also reduced the population of infective propagules of pathogen in the soil (Marx, 1970). It was experimentally demonstrated that roots of *Pinus taeda* mycorrhizal with *Laccaria laccata*, *Leucopaxillus cereals*, *Suillus luteus* escaped the infections by *P. cinnamomi* whereas *Pinus tinctorius* forming incomplete mycelial mat protected only 81% of the mycorrhizal roots; 75% of these roots were resistant to infections when the associated mycorrhiza was *Leucopaxillus cerealis*. This proportion was reduced to a mere 23% when the symbiote involved was *Suillus luteus* (Marx, 1969).

Root protection of Douglas-fir and Norway spruce by different isolates of ectomycorrhizal *Laccaria lacatta* against root rot by *Fusarium oxysporum* was recently studied. (Sampangi *et al.*, 1986 b). Individual inoculation by isolates of *L. laccata* resulted in enhanced plant growth with significant reduction in the root rot index. Mycorrhizal isolates slightly reduced the pathogen populations and infectivity potentials of *Fusarium* infected forest nursery soils. The infectivity potential and inoculum densities of the same soil infested with *Pythium sp.* were significantly reduced as a result of mycorrhizal symbiosis (Sampangi, 1985). Experiments under controlled conditions indicated that in general (with a few exceptions), roots with VA mycorrhizae are less damaged by pathogenic fungi and nematodes than the non-mycorrhizal roots (Schenek, 1981). *Theleviopsis basicola* caused less damage to cotton and tobacco plants mycorrhizal with *Glomus mosseae* than to roots lacking mycorrhizae (Baltruschat and Schonbeck, 1975). Effective biological control of *Phytophthora cinnamomi* root rot of woody ornamental *Chamaecyparis lawsoniana* was obtained by inoculation of the roots with spores of a mixed population of VA Mycorrhizal fungi (Bartschi *et al*, 1981). Among pathogenic nematodes, *Glomus fasciculatum* established on roots of tomato seedlings significantly reduced the number and size of galls caused by the root-knot nematodes *Meloidogyne incognita* and *M. javanica* (Bagyaraj *et al.*, 1979). VA Mycorrhizal fungi reducing the severity of diseases caused by the bacterial pathogen *Pseudomonas solancearum* has also been reported (Halos and Zorilla, 1979).

Mechanism of suppression of root Pathogens

The mode of action by which mycorrhizae affect pathogens and diseases are not completely understood although several mechanisms have been postulated but a few are only demonstrated (Zak, 1964; Marx, 1972; Schoenbeck, 1977). In order to arrive at the root, all the pathogens must successively or simultaneously proceed through different host defense mechanisms. Once in the vicinity of roots, the different barriers, a pathogen has to successfully cross before attaining host roots, are sequentially discussed below :

Pre-entry mechanisms :— Ectomycorrhizal fungi produces the fungal mantle composed of tightly interwoven hyphae in several layers covering the root meristem and cortical tissues thereby creating mechanical barrier for the pathogen penetration and the subsequent spread in host tissues, In common with many soil fungi, actinomycetes and bacteria, few mycorrhizal fungi are capable of producing antifungal and antibacterial antibiotics (Marx, 1972). The composition of rhizosphere under the influence of mycorrhizae (mycorrhizosphere) stimulate the microbial competition in the root zone, thereby, making it more difficult for the pathogen to gain access to the host roots (Rambelli, 1973). Recently, it was reported that roots colonised by VAM harbour more actinomycetes antagonistic to root pathogens (Secilia and Bagyaraj, 1987).

Post entry mechanisms — Mycorrhizal fungi are known to stimulate host roots to produce and accumulate sufficient concentrations of metabolites : volatiles (terpenes etc.) or non volatiles (phenols etc) which are known to impart resistance to the host tissue against pathogen invasion (Krupa *et al.*, 1973; Sampangi and Perrin, 1988). In a recent study (Sampangi and Perrin, 1986 a), it was observed that infection of feeder roots of *Picea abies* by ectomycorrhizal fungi *Laccaria laccata* and *L. bicolor* resulted in considerable increase in the concentration of certain volatile terpenes : limonene, myrcene, terpinolene and an undetermined substance. A good correlation was established between the increased concentration of these metabolites in the mycorrhizal root system and the corresponding reduction in the root rot incidence by the soil borne *Fusarium oxysporum*.

The interaction between VA mycorrhizal fungi and plant pathogens has recently been reviewed by Bagyaraj (1984). VA mycorrhizal fungi do not produce a protective mantle around the roots, but they are known to induce thickening of the cell wall through lignification and production of other polysaccharides which in turn hinder the entry of root pathogens (Dehne and Schoenbeck, 1979). Colonization by VAM fungi is also known to increase the concentration of ortho-dihydroxyphenols in roots which deter the activity of pathogens (Krishna and Bagyaraj, 1983). Increased concentrations of sulphur containing amino acids, methionine and cysteine, in tomato plants roduced the number of galls formed by the root-knot nematodes (Suresh and Bagyaraj, 1984). There are few reports wherein VA mycorrhizal fungi had no effect on either pathogen development or disease severity and in others, disease was actually worsened. Mycorrhizal plants of citrus were found susceptible to *Phytophthora parasitica* and *Theleviopsis basicola* as compared to non-mycorrhizal plants (Dehne, 1982).

Conclusions

The ecological significance of mycorrhizae are extended from a primary physiological function of improving plant growth to their role as biological deterrents against plant pathogens. It is apparent from the investigations that mycorrhiza can usually deter or minimise the losses caused by soil borne plant pathogens. Most of these evidences are however from laboratory, green house or microplot studies which needs further testing under field conditions. Our present knowledge shows that the protective effect when it exists is limited to the actual site of interaction of the host and symbiont, hence better demonstrated for soil borne diseases. It appears that the protective ability of different mycorrhizae is influenced by the nature of the host plant, type of mycorrhizae, the pathogen and conditions of soil environment (Perrin, 1985).

Mycorrhizal fungi are known to occur naturally on a majority of crop plants, hence the present beneficial effect on plant health may be considerable. Specialization and diversity among mycorrhizal fungi offers possibilities for selection of strains for a specific purpose depending on the host, location, soil type etc. Species of mycorrhizal fungi stimulating plant growth while maximising disease control could thus be selected. The mass inoculation programmes involving mycorrhizal fungi in agriculture necessitates the large scale production of inoculum. VA mycorrhizal fungi being obligate symbionts can not be cultured on artificial media and needs to be multiplied on the live plant roots. However, attempts are being made to mass produce VAM inoculum in pot cultures with maximum number of infective propagules and least contaminants (Wood, 1987; Sreenivasa and Bagyaraj,1988). Ectomycorrhizal fungi on other hand can be grown on laboratory media and successfully multiplied in industrial containers. Commercial preparations of ectomycorrhizal fungi such as *Pisolithus tinctorius* has been successfully used on pines (Trappe, 1977).

The mycorrhizae, an integral part of plant, offers a natural potential for biological protection. Like most instances of biocontrol, mycorrhizae can not offer complete immunity against any root disease. They could only impart a degree of resistance against soil borne pathogenic fungi, bacteria and nematodes. However, this potential can be exploited further through field investigations to know the possibility of reducing root diseases through mycorrhizae and thereby increasing crop production.

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References

Bagyaraj D J 1984, *In : VA Mycorrhiza* C L Powell and DJ Bagyaraj (eds) CRC Press, Boca Raton, USA, p **131**

Bagyaraj DJ, Manjunath A and Reddy D D R 1979, *Plant and Soil* **51** 397

Baltruschat H and Schoenbeck F 1975, *Phytopathol. Z.* **84** 172

Bartschi H, Gianinazzi Pearson V and Vegh I 1981, *Phytopathol Z.* **102** 213

Bowen G D and Rovira A D 1976, *Ann. Rev. Phytopathol.* **14** 121

Cook R J and Baker K P 1983, *The nature and practice of biological control of Plant pathogens.* The American Phytopathological Society p 539

Dehne H W 1982, *Phytopathology* **72** 1115

Dehne H W and Schoenbeck F 1979, *Phytopothol. Z.* **95** 105

Frank A B 1885, *Pilze. Ber. Qeutrch. Bot. Ces.* 3 128

Halos PM and Zorilla R H 1979, *Phillip. Agric.* **62** 309

Harley J L and Smith S E 1983, *Mycorrhizal symbiosis* Academic Press, London.

Krishna K R and Bagyaraj D J 1983, *Can J Bot* **61** 2349

Krupa S, Anderson J and Marx D H 1973, *Eur. J. For. Path.* 3 194

Marx D H 1969, *Phytopathology* **59** 411

Marx D H 1970, *Phytopatholosy* **60** 1472

Marx D H 1972, *Ann. Rev. Phytopathol* **10** 429

Perrin R 1985, *Eur. J. For. Pathol.* **15** 372

Rambelli A 1973, In : *Ectomycorhizae* C G Marks and T T Kozlowski (Eds) Academic Press, New York p 299

Sampangi Ramaiah K 1985, Ph.D Thesis, University of Orsay, Paris, France

Sampangi R and Perrin R 1986, In: *Mycorrhizae : Physiology and Genetics* Proc. First European Symposium on Mycorrhizae, Gianinazzi-Pearson V (ed) Inra, Paris p 807

Sampangi R, Perrin R and LE TACON F 1986 b, In : *Mycorrhizae, Physiology and Genetics* Proc. First European Symposium on Mycorrhizae, Gianinazzi-Pearson V (ed) Inra, Paris p 799

Sampangi Ramaiah K and Perrin R 1988, In : *Proc. Natl. Workshop on Mycorrhizae* New Delhi

Schenck NC 1981, *Plant Disease* **65** 230

Schoenbeck F 1977, In : *Soil-borne plant pathogens* B Schippers and W Gams (eds) Academic Press, New York p 271

Secilia J and Bagyaraj DJ 1987, *Can. J. Microbiol.* 33 1069

Sreenivasa M N and Bagyaraj D J 1988, *Plant and Soil* **106** 289

Suresh C K and Bagyaraj D J 1984, *Nematologia Mediterranea* **12** 31

Trappe JM 1977, *Ann. Rev. Phytopathol.* **15** 203

Wood T 198 , In : *Mycorrhizea in the next decade — Practical Applications and Research Priorities* D M Sylvia, L L Hung and J H Graham (eds), Univ. of Florida, Gainesville p 274

Zak B 1964, *Ann. Rev. Phytopathol.* **2** 377