REVIEW OF LITERATURE

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The literature on VAM has become so voluminous in the last two decades, that is practically not possible to review it entirely. Several reviews and books have appeared recently giving a comprehensive account of the different aspects of VAM (Mosse, 1981; Harley and Smith, 1983; Mukerji *et al.*, 1984; Powell and Bagyaraj, 1984; Gianinazzi-Pearson and Gianinazzi, 1986; Hall, 1988; Sieverding, 1991; Read *et al.,* 1993). In this context, an attempt has been made to give a brief review of literature relevant to the present work.

2.1. Importance of mycorrhizae :

The mycorrhizae are vital for uptake and accumulation of ions from soil and translocation to host because of their high metabolic rate and strategically diffuse distribution in the upper soil layers (Mukerji *et al.*, 1982). In fact, the fungus serves as a highly efficient extension of the host root system. Minerals like N, P, Ca, S, Zn, Cu and Fe absorbed from soil mycorrhizal fungi and translocated to the host plant (Smith *et al.,* 1994). Minerals more than 4 cm distant from the nearest host root can be absorbed by the fungal hyphae and translocated to roots in the mycorrhizal plants (Trappe, 1981). Bieleski (1973), calculated that VAM fungi may increase the effective absorbing surface of the host root by as much as ten times.

Ions such as P, Zn and Cu do not diffuse readily through soil. Because of this poor diffusion, roots deplete the immobile soil nutrients from a zone immediately surrounding the root. Mycorrhizal fungal hyphae extend into the soil, penetrating the zone of nutrient depletion and can increase the effectiveness of absorption of immobile elements by as much as 60 times.

The mycorrhizal fungi also produce enzymes, auxins, vitamins, cytokinins and other substances that increase rootlet size and longevity (Dixon, 1988). They also protect the rootlets from pathogens and they absorb water and translocate to the host (Mexal and Reid, 1973). Two types of mycorrhizal fungal hyphae regulate nutrient movement, absorbing hyphae are fine, highly branched hyphae that explore substrates, absorbing nutrients released from adjacent soil or organic matter substances. In some instances, they also secrete enzymes capable of breaking down organic materials (Haselwandter, 1987). VAM fungi also alter the kinetic properties of the root, thereby changing its nutrient uptake abilities (Barea, et al., 1993).

2.2. Occurrence of VAM in plant communities - plants :

The term 'mycorrhizae' was coined by Frank (1885), for the mutualistic symbiosis between roots of vascular plants and certain fungi. The VAM fungi are present in practically all soils and associated with a great variety of plants of different taxonomic groups (Jeffries, 1987). VAM has been reported in many plant communities such as forests (Diem *et al.*, 1981; Tamin, 1984; Sharma *et al.*, 1986; Louis and Lim, 1987; Mohankumar and Mahadevan, 1988; Narayana Bhat, 1993b; Raman *et al.*, 1993; Byra Reddy *et al.*, 1994), grasslands, steppes and prairies (Christensen and Williams, 1977; Anderson *et al.*, 1984; Gibson and Hetrick, 1988; Sanders and Fitter, 1992; Dhillion, 1992), heathlands (Sward *et al.*, 1978), rangeland (Trappe, 1981), coal mine spoils (Allen and Allen, 1980; Zak *et al.*, 1982; Arines and Vilarino, 1991), deserts (Bethlenfalvay *et al.*, 1984; Khalil, 1988; Rao *et al.*, 1988), mangroves (Khan, 1974; Mohankumar and Mahadevan, 1986; Rozema *et al.*, 1986; Sengupta and

Chaudhuri,1989; Selvaraj *et al.*, 1994), savannas (Cuenca and Lovera, 1992), sand dunes (Koske, 1987; Koske and Tews, 1987; Gemma *et al.*, 1989; Kannan, 1989; Sylvia, 1989; Koske and Gemma, 1990; Sieguenza *et al.*, 1996) and hydrophytes (Bagyaraj *et al.*, 1979; Chaubal *et al.*, 1982; Clayton and Bagyaraj, 1984; Ragupathy *et.al.*, 1990; Dharmarajan *et al.*, 1993).

The occurrence of VAM has been reported in several cultivated crops (Godse *et al.*, 1976; Ammani *et al.*, 1986; Rathi and Singh, 1990; Johnson *et al.*, 1991; Talukdar and Germida, 1993; Kurle and Pfleger, 1994) and oil yielding plants such as sesame (Sulochana *et al.*, 1988; Vijayalakishmi and Rao, 1988; Selvaraj, 1989; Manoharachary *et al.*, 1990; Selvaraj and Subramanian., 1995), groundnut (Krishna, 1981), castor and safflower (Sulochana and Manoharachary, 1989; Janaki Rani and Manoharachary, 1994), soybean (Khalil *et al.*, 1992; Khalil and Loynachan, 1994) and sunflower (Vijayalakshmi and Rao, 1982. Chandrasekara *et al.*, 1995). Reports are relatively very few on plantation and tuber crops such as cardomom (Manjunath and Bagyaraj, 1982; Mallesha and Bagyaraj, 1991), lime (Michel-Rosales and Valde's, 1996), cassava (Potty, 1988; Sivaprasad *et al.*, 1990), banana (Girija and Nair, 1988), cashewnut (Krishna *et al.*, 1983), chinese potato (Potty, 1985) and mulberry (Rajagopal *et al.*, 1989; Padma and Sullia, 1991; Katiyar *et al.*, 1995; Kumaresan *et al.*, 1993). The occurrence of VAM in ornamental plants (Selvaraj *et al.*, 1986; Rekha Rani *et al.*, 1987; Muthukumar and Udaiyan, 1994), vegetable crops (Selvaraj, 1989) and medicinal plants (Mohankumar and Mahadevan, 1984; Govinda Rao *et al.*, 1989; Berch *et al.*, 1988; Selvaraj, 1989; Barthakur and Bordoloi, 1990) have also been reported.

Several workers have reported the presence of VAM fungal spores in root-zone soils from different parts of India. Various species of ***Glomus, Sclerocystis, Gigaspora*** and ***Acaulospora*** in Indian soils have been reported (Battacharjee and Mukerji, 1980; Singh and Varma,1981; Battacharjee *et al.*, 1982; Tewari *et al.*, 1982; Sharma *et al.*, 1986; Selvaraj and Subramanian, 1988; Janardhanan *et al.*, 1994; Joshi and Singh, 1995; Selvaraj and Bhaskaran, 1995).

2.3. Occurrence of VAM in relation to soil abiotic characters and seasons :

Nicolson and Johnston (1979) was first to identify the VAM fungal species in saline soils. The presence of ***Glomus fasciculatum*** as the endophyte of pioneer grasses in a maritime sand dune was reported. Pond *et al.* (1984) were also to collect and identify a number of VAM fungi from saline locations throughout southern and central California and Nevada. Samples were taken from 57 sites and 30 different plant species. Soil EC_{se} ranged from a 199 to a low of $IdSm^{-1}$. Soils are high sodic and Na content with high of 93,000 mg/ha.

Kim and Weber (1985) reported the presence of VAM in West American desert halophytes, ***Salicornia pacifica*** and ***S. rubra*** were the degree of mycorrhization decreased with a high soil salinity. Mohankumar and Mahadevan (1986) based on their work with 25 mangrove plants reported the absence of VAM status in their roots and root-zone soils at Pitchavaram of India and concluded that the absence was due to the accumulation of salinity in the roots of mangroves and root-zone soils.

Most of the investigations of VAM of sand dunes have done in temperate climates and only a few are from dunes in mediterranean climates (Giovannetti and Avio, 1983; Giovannetti and Nicolson, 1983; Giovannetti, 1985). Sylvia (1986) reported eight species of VAM fungi associated with ***Uniola paniculata*** in sand dunes along the north eastern coast of Florida.

Mycorrhizae were hypothesized to play an important role in plant growth in several dune restoration studies (Sylvia, 1989; Will and Sylvia, 1990). Seasonal variations have been observed in spore population as well as root colonization of dune plants (Sylvia, 1986; Gemma and Koske, 1988; Gemma *et al.*, 1989; Puppi *et al.*, 1986).

Louis (1990) reported the occurrence of VAM fungi in coastal reclaimed land soils of Singapore. Sidhu *et al.* (1990) reported that two VAM fungi namely ***Glomus fasciculatum*** and ***Scutellospora calospora*** were found to colonize the roots of ***Casuarina equeisetifolia*** growing in alkaline soils.

Cooke *et al.* (1993) reported that some observations on the vertical distribution of VAM in roots of salt marsh grasses growing in saturated soils of eastern Connecticut.

Janardhanan *et al.* (1994) reported the occurrence of VAM fungi in root-zone and roots of saline plant species in alkaline *usar* land ecosystem in north Indian plains.

The distribution and occurrence of VAM fungi in different ecological condition is belived to be influenced by a number of factors such as soil texture (Ianson and Allen, 1986; Sambandan *et al.,* 1991; Joshi and Singh, 1995), soil fertility (Schenck and Kinloch, 1980; Iqbal and Taugir, 1982; Mc Graw and Hendrix, 1984), soil moisture (Iqbal and Taugir, 1982; Anderson *et al.*, 1984; Dickman *et al.*, 1984), soil pH

(Green *et al.*, 1976; Selvaraj, 1989) and soil temperature (Tommerup 1983; Abbott and Robson, 1984; Manterson, 1994).

In an intensive study, Anderson *et al.* (1984) reported significant negative correlation between VAM spore numbers and soil pH, Ca, Mg, P and percent soil moisture. Dickman *et al.* (1984) obtained significant positive correlation of spore count with soil moisture when they analysed the rhizosphere soil samples of little blue stem. Seasonal colonization pattern of VAM fungi were monitored in the roots of winter wheat and spring wheat throughout, from October to August growing seasons, spring wheat becomes very soon colonization than winter wheat, suggested that when the temperature was too low in an inadequate growth of the fungus to the host. The same type of colonization development was observed in winter cereals (Grey, 1991) and cupressus trees (Dubey and Nagi, 1995).

Seasonality of plant response to different VAM fungal species caused maximum growth in spring and some in early summer (Allen *et al.*, 1992). Singh *et al.* (1992) reported that the variation in spore density and VAM root colonization of lemon seedlings were correlated with the change of season and soil depth, VAM colonization and spore density also declined beyond 30cm soil depth have also been reported. Seasonal fluctuation in number of VAM spores in soils of sand dunes (Giovannetti, 1985; Koske, 1987; Kannan, 1989), tropical forest (Louis and Lim, 1987) and decidious forest (Brundrett and Kendrick, 1988) have been reported.

Mago and Mukerji (1994) observed that percent root colonization with VAM fungi in relation to seasonal changes in some members of Lamiaceae. VAM colonization was found to be the lowest during winter and higher during late summer.

Sturmer and Bellei (1994) observed that VAM fungi associated with ***Spartina ciliata. Glomus*** and ***Acaulospora*** was observed maximal in winter season whereas ***Gigaspora*** was higher in summer season.

Selvaraj *et al.* (1994) reported the seasonal variation of incidence of VAM fungi in roots and rhizosphere clay loam alkaline soils of Pitchavaram, India.

Joshi and Singh (1995) reported that population of VAM propagules in different types of soils and correlated with soil properties and VAM root colonization.

Siguenza *et al.* (1996) reported that the occurrence of VAM fungi associated with seven plant species in coastal dunes at Baja California in relation to different seasons. The seasonal patterns of percent root colonization were also described in some plant species during the wet and dry seasons.

2.4. VAM-concept of host preference :

It is well known fact that VAM are not host-specific. Any VAM plant species can be infected by any VAM fungal species but the degree of VAM infection and its effect can differ with different host-endophyte combinations (Mosse, 1973).

Since the early endophyte screening trials of Mosse (1972), it has become more and more obvious that VAM fungi differ greatly in their symbiotic effectiveness. Though a particular VAM fungi can infect and colonize many host plants, it has preferred host which exhibits maximum symbiotic response when colonized by that particular VAM fungus. This led to the concept of 'host preference' in VAM fungi. Several recent studies support the notion of host preference by VAM fungi (Powell, 1982; Bagyaraj *et al.*, 1988; Reena and Bagyaraj, 1990; Vinayak and Bagyaraj, 1990).

Dhillion (1992) made to investigated the host-mycorrhizal preference exists between native prairie grasses and indigenous isolates of VAM fungi.

Crop species can exert a selective effect in determining which VAM species becomes predominant in a mixed indigenous population (Schenck and Kinloch, 1980). In growth chamber studies, pretransplant rice plants (Dhillion, 1992) and forage legumes (Giovannetti and Hepper, 1985) exhibited considerable affinity for colonization by VAM fungi and results of these studies suggested the presence of host-mycorrhizal specificity. Out of nineteen plant species tested, Graw *et al.* (1979) found that ***Glomus gerdemanii*** infected only one plant species.

Mc Gonigle and Fitter (1990) reported in two native grasses and forbs in England that VAM in the field demonstrated a degree of 'ecological specificity'. Attempts have been made to use the genetic variability in fungal efficiency and host response to select VAM fungal isolates that are able to improve plant production (Trouvelot *et al.*, 1986). Variations in the effect of VAM colonization have also been linked to the genotype of the host plant (Krishna *et al.*, 1983; Lakie *et al.*, 1987). The recent isolation of myco-plant mutants (Duc *et al.*, 1989) and the discovery that VAM colonization is a heritable trait (Mercy *et al.*, 1990) suggested the possibility of tailoring plant-fungus combinations for maximum efficiency. This may lead to developing plants that will form endomycorrhiza specificity with certain VAM fungi (Gianinazzi *et al.*, 1989). Different levels of host mycorrhizal affinity existed when ***Asparagus officinalis, Tagetes erecta, Trifolium pratense, Sorghum vulgare*** and ***Lycopersicum esculentum*** plants were inoculated with number of VAM species (Hetrick and Bloom, 1986). Sylvia (1987) also observed that some specificity, since the intensity of VAM fungal colonization was affected strongly by the plant. Subhashini *et al.*(1988) reported that genotype differences among fortyseven diverse varieties and exotic germplasm of ***Sorghum*** showing different levels of VAM colonization and P content in shoot and roots were varied in different cultivars.

Dhillion (1992) found that indigenous VAM fungal isolates tested showed a considerable amount of host preference. Host- mycorrhizal preference was examined between the native prairie grasses and native VAM fungal species, ***Glomus geosporum*** and ***G. fasciculatum.***

2.5. Mass inoculum production of VAM :

The application of VAM technology is to obtain a good starter culture. Such cultures can be isolated spores of VAM fungi from any soil and must be checked for the occurrence of mycoparasites. They are then surface sterlized and introduced into pot cultures by the use of the funnel technique (Nicolson, 1967). These pot culture can be maintained in a green house or glass house on a suitable host plants.

Numerous techniques are available for the production of vesicular-arbuscular mycorrhizal inoculum in an almost sterile environment through nutrient film technique, circulation hydrophonic culture system, aerophonic culture system, root organ culture and tissue culture (Menge, 1984; Naparnornbodi *et al.,* 1988). For large scale field trails, however, the only convenient method of producing large quantities of inoculum is by traditional 'pot culture-technique' (Wood, 1985). Several host plants including sudan grass (***Sorghum bicolor*** var. ***Sudanese***), bahia grass (***Paspalum notatum***), guinea grass (***Panicum maximum***), cenchrus grass (***Cenchrus ciliaris***), clover (***Trifolium subteraneum***), strawberry (***Fragaria*** sp.), sorghum (***Sorghum vulgare***), maize (***Zea mays***) and onion (***Allium cepa)*** have been studied for their suitability in producing VAM inoculum. Recently, it was reported that rhodes grass (***Chloris gayana***) is the best host for mass production of ***Glomus fasciculatum*** (Sreenivasa and Bagyaraj, 1988 a). In view of the disadvantage of using soil as the substrate for producing VAM inocula recently it was reported that perlite: soilrite (1:1) was the best substrate for mass production of ***G. fasciculatum*** (Sreenivasa and Bagyaraj, 1988 b). Dehne and Backhaus (1986) suggested that the use of expanded clay for multiplying VAM fungi. Moisture content and temperature of the substrate as well as irradiance, mineral content, pot size, presence of mycoparasites and associated organisms can all influence VAM inoculum production (Bagyaraj, 1984).

2.6. Selection of efficient VAM fungi using host plants :

VAM fungi selected for inoculation into agricultural soils must be able both to enhance nutrient uptake by plants and to persist in soils. An excellent discussion on the selection of VAM fungi for possible use in agriculture has been first reported by Abbott and Robson (1982) and Powell (1982). Govinda Rao *et al.* (1983) suggested that several fungi can be screened for symbiotic response using a test host through pot culture followed by microplot and than field trails. Many studies have been led to the selection of VAM fungi for many economically important forest trees such as ***Leucaena*** sp. (Nalini *et al.*, 1986; Bagyaraj *et al.*, 1989), ***Tamarindus indica*** (Reena and Bagyaraj, 1990 a), ***Acacia nilotica*** and ***Calliandra colothyrsus*** (Reena and Bagyaraj, 1990 b), mango (Balakrishna Reddy and Bagyaraj, 1994), root stocks of ***Citrus*** (Vinayak and Bagyaraj, 1990), sea oats, ***Uniola paniculata*** (Sylvia and Burks, 1988), tomato (Mallesha *et al.*, 1994), ***Coleus aromaticus*** (Selvaraj *et al.*, 1996) and siratro (Medina *et al.*, 1988).

2.7. VAM and plant growth :

Several workers have reported increased plant growth and uptake of mineral nutrients in several crop plants associated with VAM fungi such as wheat (Azcon and Ocampo, 1981 Caude-Menun *et al.,* 1991) soybean and maize (Louis and Lim, 1987; Simpson and Daft, 1990; Hamel *et al.*, 1991; Sylvia *et al.,* 1993; Kurle and Pfleger, 1994), barley (Champawat *et al.*, 1987), chillies (Sreeramulu and Bagyaraj, 1986; Survercha and Mukerji, 1988), groundnut (Krishna and Bagyaraj, 1982; Parvathi, *et al.*, 1985; Itag, *et al.*, 1987; Champawat, 1988; Manoharachary and Prakash, 1991; Gupta and Krishnamurthy, 1996) and sesame (Sulochana *et al.*, 1989; Selvaraj and Subramanian, 1995). Similar reports have also appeared with other plants including plantation and tuber crops (Nemec, 1980; Sivaprasad *et al.,* 1990); onion (Ojala *et al.*, 1983), tomato (Pond *et al.*, 1984; Poss *et al.*, 1985; Mallesha *et al.,* 1994), cashew (Krishna *et al.*, 1983), crocus and cassava (Howler *et al.*, 1987; Potty, 1988), potato (Porter, 1979), sweet potatoes (Potty, 1988), papaya (Sukhada, 1988), banana (Girija and Nair, 1988), blackgram and greengram (Umamaheswara Rao and Rao, 1994), forage legumes viz., ***Leucaena*** and ***Stylosanthes*** (Habate and Manjunath, 1987, Medina *et al.,* 1990), castor and sunflower (Sulochana and Manoharachary, 1989; Jalali *et al.*, 1990; Manoharachary and Prakash, 1991; Chandrashekara *et al.,* 1995). The improvement of plant growth has been considered to be due to increased uptake of phosphorus and other mineral nutrients especially in soils of low fertility (Abbott and Robson, 1982; Tinker, 1984). VAM increased not only the uptake of P, also a number of other elements such as potassium (Sieverding and Toro, 1988; Bethlenfalvay *et al.*, 1989; Selvaraj and Subramanian, 1995) zinc and copper (Gildon and Tinker, 1983; Habate and Manjunath, 1987; Kothari *et al.*, 1991; Lambert and Weidensaul, 1991;

Li *et al.*, 1991; Champawat and Pathak, 1993), nitrogen (Ames *et al.*, 1983; Johanson *et al.*, 1991; Frey and Schuepp, 1993; Roldan Fajardo, 1994), manganese and sulphur (Tinker, 1984; Ho, 1993).

Considerable differences between mycorrhizal and non-mycorrhizal plants have been found with respect to total carbohydrates (Krishna and Bagyaraj, 1982a; Selvaraj, 1989; Amijee *et al.*, 1993; Pearson *et al.*, 1994), aminoacids (Nemec and Meridith, 1981) , lipids (Cooper and Losel, 1978; Nagy *et al.*, 1980; Jabaji-Hare *et al.*, 1984; Selvaraj and Subramanian, 1990), phenolics (Dehne and Schonbeck, 1979; Krishna and Bagyaraj, 1984; Selvaraj and Subramanian, 1990) and qualitative and quantitative expression of proteins (Dumas *et al.*, 1989; Pacovskey 1989; Wyss *et al.*, 1990; Arines *et al.*, 1993, 1994; Schellenbaum *et al.*, 1993; Mathur and Vyas, 1995). Certain enzymes like acid and alkaline phosphatases in onion (Gianinazzi-Pearson and Gianinazzi, 1978), groundnut (Krishna and Bagyaraj, 1983), cowpea (Ubalthoose Raja *et al.*, 1988), ***Trigonella*** (Anita *et al.*, 1988) and sesame (Selvaraj and Subramanian, 1995) showed enhanced levels in mycorrhizal plants.