5. REVIEW OF LITERATURE

Frank (1885) gave the name “mycorrhiza” to the peculiar association between tree roots and ectomycorrhizal fungi. Kelley (1931, 1950) has made a thorough discussion on the origin of the word “mycorrhiza”. Frank (1887) recognized a distinction between ectotrophic and endotrophic mycorrhizas, which included only ericaceous and orchid mycorrhizas. The name for the arbuscular mycorrhizal symbiosis has changed through the years. Dagneard (1896) was the first to describe an arbuscular mycorrhiza, which happened to have formed from poplar roots. Danbgeard (1900) was the first to use the name vesicular arbuscular fungus by isolating it from poplar, proposed the name *Rhizophagus populinus* which was a typical vesicular arbuscular mycorrhizae but placed it in Chytridiales. Peyronel (1923, 1924, 1937) showed the regular occurrence and associations of spores and sporocarps of the Endogonaceae with vesicular-arbuscular mycorrhizae of plants and suggested that these fungi are mycorrhizae. Mosse (1953, 1956) used sporocarps or spores as inoculums and he was the first to demonstrate experimentally that the species of *Endogone* could produce VAM. In 1973, Rambelli suggested the term myorrhizosphere, as a substitute to rhizosphere because of the significant and dynamic microbial interaction in soil of the root.

**Taxonomy**

Taxonomy is an essential step in the biological sciences. VAM fungal taxonomy has advanced greatly during the last 30 years. Today, the basic taxonomic categories of genus and species are well-defined and reasonably stable nomenclature is available for an accurate identification of taxa. Traditional taxonomy in the Glomeromycota has mainly based on spore morphology and ontogeny. The structures and characters of the mycelia, *e.g.* arbuscules, vesicles, coils, are of exiguous taxonomical value.

The history of the naming of our fungi is certainly an interesting one. Link (1809, cited in Gerdemann 1971), established the genus *Endogone*. Arbuscular mycorrhizas have been described as early as 1842. The first description of an arbuscular mycorrhiza come by Nageli 1842 (cited in Roger *et al.*, 2004), most of his drawings resemble arbuscular mycorrhiza. Tulasne and Tulasne (1845) were the first to describe the genus *Glomus*, known only from spore clusters found in the soil, comprised two species (*Glomus microcarpum* & *Glomus macrocarpum*). No connection to the mycorrhizal symbiosis was suggested. Tulasne brothers considered *Glomus* to be closely related to *Endogone*. Fries (1849) proposed the family
Endogonaceae and placed it in Tuberales but Bucholtz (1912) transferred the family to the Mucorales.

Earlier it was thought that large, globose zygospores, Chlamydospores, or sporangia in the endogonaceous fungi were asci. Hence, they were included under Ascomycetes (Gerdemann and Trappe, 1974). The genus *Sclerocystis* was described by Berkeley & Broome (1873). They considered *Endogone* to contain both zygosporic (notably *Endogone lactiflua*) and chlamydosporic species, observing that at least one species apparently produced both kinds of spores. The first accurate classification came from studies on sexual reproduction. These studies indicated the Endogonaceae belong to the Mucorales due to the affinities of *Endogone* with the members of the Mortierellaceae. Bucholtz (1922) placed Endogonaceae in the Mucorales.

In 1922, Thaxter revised the family Endogonaceae and placed it under the order Mucorales (Zygomycetes) and placed the genus *Glomus* into *Endogone* which contained both zygosporic (notably *Endogone lactiflua*) and chlamydosporic species, observing that at least one species apparently produced both kinds of spores. This family included four genera producing spores in sporocarps: *Endogone* Link: Fries, *Glaziella* Berk., *Sclerocystis* Berk. & Br. and *Sphaerocreas* Sacc.& Ellis. In 1935, Zycha transferred the one species of *Sphaerocreas* to *Endogone*. The existing genera included both chlamydosporic and zygosporic species. Thaxter (1922) and Godfrey (1957) considered chlamydosporic species were the anamorphs of those producing zygospores, following the finding of both types of spores in sporocarps of *Glomus fasciculatum* (at that time known as *Endogone fasciculata* and *E. microcarpa*).

In 1939, Butler, in reviewing the identity of arbuscular mycorrhizal fungi, classified them as probable imperfect members of the Endogonaceae. He nevertheless accepted the name *Rhizophagus* for such fungi because of the earlier naming by Dangeard (1900).

The family Endogonaceae was placed in its own order, Endogonales by Moreau (1953), which was later validated by Benjamin (1979). The order Endogonales (Zygomycotina) consisted of only one family, the Endogonaceae (Benjamin, 1979; Morton, 1988). The genus *Endogone*, the type genus for the family, is undoubtedly a member of the Zygomycetes. This genus produced characteristic zygospores by the fusion of two gametangia.

Key to recognise endogonaceous spores were prepared by Mosse and Bowen (1968), who considered developmental stages of spores as major characteristics, avoided the use of
production of sporocarps as a major characteristic in their classification. The mode of germination of spores of these fungi, their life cycles, subcellular spore structure, and the manner of colonization of roots were recognized (Mosse 1959, 1970). It was also found that some taxa formed vesicles and arbuscules, whereas other species lacked vesicles. (Gerdemann and Trappe, 1974; Fassi, 1965; Walker, 1985).

The first comprehensive mycorrhizal classification was proposed by Gerdemann and Trappe (1974), separated the genera of the family Endogonaceae based on the spore morphology and their associated structures and sporocarp morphology. Based on these characters, several species of *Endogone* were transferred to *Glomus*. Since the genus *Endogone* was heterogenous, they segregated this largest genus into four genera: *Endogone* (Link, 1809) which produces zygospores and does not form VAM fungal associations; *Glomus* (Tulasne and Tulasne, 1845) which produces sporocarpic or nonsporocarpic Chlamydomspores; *Gigaspora* (Gerdemann and Trappe, 1974) which is nonsporocarpic and produces azygospores. The genus *Modicella* (Kanouse, 1936) produces thin-walled sporangia and was not known to form mycorrhizal associations. Gerdemann and Trappe (1974) described *Acaulospora* as a new genus of VAM fungi. This genus was characterized as nonsporocarpic, and produced spores borne singly and laterally on a hypha that terminates in a large thin-walled vesicle, formed VAM associations. According to Gerdemann and Trappe (1974), the other *Endogone* species were ectomycorrhizal or saprotrophic fungi.

The genus *Gigaspora* was introduced by Gerd. & Trappe (1974) in the family Endogonaceae which formed arbuscular Mycorrhiza and produced spores on a bulbous suspensor-like cell. The genus *Gigaspora* was split into two genera, *Gigaspora* Gerd. & Trappe *emend*. Walker & Sanders and *Scutellospora*. This separation was based on spore wall structure, germination characteristics of the spores and ornamentation of auxiliary cells (Walker & Sanders, 1986). Fungal spores which closely resembled *Glomus infrequens* (Hall, 1977) collected from California. Ames & Schneider (1979) described *Entrophospora*, with *E. infrequens* (Hall) Ames & Schneider in the family *Endogonaceae*, based on the mode of spore formation (Gerdemann and Trappe, 1974). Initially, a vesicle similar to that of *Acaulospora* spp. (Gerdemann and Trappe, 1974; Ames and Linderman, 1976; Trappe, 1977) was formed but the spore developed inside the vesicular stalk rather than laterally.

Trappe (1982) used morphological characteristics and spore germination as major characters in his synoptic key for VAM fungal classification. The genus *Endogone* is still classified according to its teleomorphic characteristics (sporocarps and zygospores). The
genus *Glaziella*, was included as a member of the Endogonaceae. However, Gibson *et al.* (1986) found that the teleomorphic stage of this fungus was an Ascomycete. They transferred entire genus *Glaziella* to the Ascomycetes in a new family, Glaziellaceae, and a new order, Glaziellales. In 1984, Trappe and Schenck transferred the genus *Modicella* to the family Mortierellaceae in the order Mucorales of the Zygomycetes. Six genera (*Acaulospora* Gerdemann & Trappe *emend.* Berch, *Entrophospora* Ames & Schneider, *Gigaspora* Gerdemann & Trappe, *Glomus* Tulasne & Tulasne, *Sclerocystis* Berkeley & Broome and *Scutellospora* (Walker & Sanders) were included because of the formation of arbuscular mutualistic symbiosis with many terrestrial plant families (Trappe, 1987) and the genus (*Endogone* Link:Fr.), whose members were saprobic (Gerdemann and Trappe, 1974) or formed putative ectomycorrhizal associations (Chu-Chou and Grace, 1979; Fassi *et al.*, 1969). The historical reasons for combining this heterogeneous assemblage in the same order have been documented by Berch (1986), Gerdemann and Trappe (1974; 1975), Morton (1988) and Walker (1987).

Pirozynski and Dalpe (1989) separated *Glomus* and *Sclerocystis* into a separate family, the Glomaceae. Spelling of scientific names of Glomales was corrected in accordance with recommendations of Almeida (1989).

Recently Tommerup and Sivasithamparam (1990) described zygospore formation in *Gigaspora*. Zygosporangia, zygospores or asexual sporangiospores are not reported in the other five genera, viz., *Glomus, Sclerocystis, Acaulospora, Entrophospora* and *Scutellospora*. Therefore these five genera cannot be placed in the Zygomycetes with certainty (Walker, 1987).

In 1990, Morton & Benny revised Endogonales (sensu lato) by proposing the order Glomales and considered two suborders, Glomineae and Gigasporineae, and two families, Acaulosporaceae and Gigasporaceae. The order Glomales includes the fungi which form arbuscules in obligate mutualistic associations with terrestrial plants. In this, the suborder Glomineae includes Glomaceae (type family) and Acaulosporaceae. *Glomus* and *Sclerocystis* are the genera under Glomaceae, characterized by 'Chlamydospores' borne singly, in aggregation or in compact sporocarps on one or more cylindrical to flared subtending hyphae. *Acaulospora* and *Entrophospora* of Acaulosporaceae are historically equivalent sister groups. Species in these genera are distinguished by 'Chlamydospores' formed laterally from or within a hypha terminating in a soporiferous saccule. Intermediate species in Acaulosporaceae show a progressive transformation from spores resembling *Glomus* to those
which are uniquely sessile. Gigasporineae includes the family Gigasporaceae. Both the genera of this family (Gigaspora and Scutellospora) produce 'azygospores' borne terminally on a sporogenous cell.

Taxa in Gigasporineae lack intraradical vesicles but form auxiliary cells in the extra radial mycelium (Gerdemann & Trappe, 1974; Morton & Benny, 1990) whereas taxa in Glomineae form intraradical vesicles and arbuscules. The Endogonales comprises the family, Endogonaceae with a genus Endogone.

Morton (1990) used all the available data and selected morphological characters of somatic (hyphae, arbuscules, vesicles) and reproductive (resting spores) structures of known arbuscular species to hypothesize explicit geneological trends. A revised species concept to accommodate phenotypic variability as well as historical and contemporary evolutionary processes was elaborated. Schenck and Pérez (1990) monographed 148 species of VAM fungi.

There were 13 species of Sclerocystis known till 1990. Almida and Schenck (1990) have studied the the genera: Sclerocystis and Glomus and found that in Sclerocystis spores were arranged in hemispherical layer, forming head and short stalk but without a spore at the base. Hence, they synonymised Sclerocystis alba, S. dusii, S cocogena with those of Sclerocystis coremioides. The five other species of the genus Sclerocystis, namely, S clavispora, S. lequdambaris, S. rubiformis, S. sinosum and S. taianensis were made as the species Glomus, namely, Glomus clavispora, G. lequdambaris, G. rubiformis, G. sinosum and G. taianensis. Wu (1993) resisted this change because there are several transitional species between these two genera.

The genus Gigaspora was studeid by Bentivenga and Morten (1995), incorporated the developmental pattern of morphological characters. Molecular, morphological and cytological study revealed that Glomus scintillans is more closely related to the genera Gigaspora and Scutellospora (Gigasporaceae) than it is to Glomus s. str., and consequently it contributes to the non-monophyly of the genus Glomus. Walker et al. (2004) proposed the genus Gerdemannia to accommodate Glomus scintillans under the newly proposed family Gerdemanniaceae. Based on the (SSU) rDNA analysis, the families, Gerdemanniaceae and Gigasporaceae placed under the order Diversisporales (Glomeromycota). Glomus dominikii is considered conspecific to G. scintillans. Glomus chimonobambusae transferred to Gerdemannia chimonobambusae.
The Gigasporaceae revised (Oehl Souza and Sieverding, 2008) on the basis of spore characters and 18S and 25S rRNA gene sequences, proposed three new families and five new genera. The family Gigasporaceae represents a single genus *Gigaspora* and 36 species of the genus *Scutellospora* were accommodated in five genera in three families as: Scutellosporaceae (*Scutellospora*), Racocetraceae (*Racocetra, Cetraspora*) and Dentiscutataceae (*Dentiscutata, Fuscutata, Quatunica*). It was also stated that the genus *Gigaspora* derived from the genus *Scutellospora*. The family Scutellosporaceae forms the most ancestral one, while Gigasporaceae is phylogenetically not much distinct from Racocetraceae and Dentiscutataceae.

The phylogenetic studies showed that several Glomeromycota species should be separated from the existing taxa, as they comprise independent phylogenetic lineages within the AMF (Redecker *et al.* 2000b). From molecular and morphological data, two new monogeneric families, Archaeosporaceae and Paraglomeraceae, were erected (Morton & Redecker, 2001) to accommodate the new genera *Archaeospora* and *Paraglomus*. However, it was already shown from studies of *A. leptoticha* (at the time named as *Acaulospora gerdemannii*) (Schüßler, 1999; Kramadibrata *et al.* 2000), that the ‘*Archaeospora* lineage’ also contains *Geosiphon pyriformis*, a fungus in the Geosiphonaceae that forms an ‘AM-like’ symbiosis with Cyanobacteria. Recently, the new genus *Intraspora* was erected (Sieverding & Oehl, 2006) to accommodate *I. schenckii* (basionym *Entrophospora schenckii*), placed in the Archaeosporaceae as a sister taxon to *A. trappei*. Two ancestral species previously classified in *Glomus, G. occultum,* and *G. brasiliatum* (*sensu lato*) were grouped into para glomaceae in a sister family Paraglomaceae.

The AM fungal family Archaeosporaceae and the genus *Archaeospora* are rendered paraphyletic by the relationship with the Geosiphonaceae. This problem led to a more detailed study of the Archaeosporales. Members of the Archaeosporaceae were forming both Glomoid and Acaulosporoid spores, and solely Acaulosporoid spores. The species *Glomus callosum* fell into the same phylogenetic clade as *A. leptoticha* and *A. gerdemannii* but exclusively formed glomoid spores. To resolve these inconsistencies, the genus *Ambispora* with its type *A. Fennica* was proposed by Walker *et al.*, (2007), based on morphological evidence and SSU and ITS region rDNA data. *Ambispora* contains three species known to produce both acaulosporoid and glomoid spores, namely, *A. fennica, A. leptoticha* (based on *G. leptotichum*) and *A. gerdemannii* (based on *G. gerdemannii*). Another species, *A. callosawas* proposed based on *G. callosum* havingonly glomoid spores. *Ambispora* is placed
in a family Ambisporaceae. The family Archaeosporaceae includes the two genera, namely, *Archaeospora* and *Intraspora*. *Acaulospora nicolsonii*, known to produce acaulosporoid spores but is retained within its present genus because of its inadequate morphological information and a lack of molecular data.

Spain *et al.* (2003) placed *Acaulospora trappei* in Archaeosporaceae based on molecular findings and morphological characters. These observations made from the study of water-mounted spores of the type species of *Archaeospora*, *A. trappei*. A distinctive interior wall configuration, novel germination structure and dimorphism are reported.

Later, Redecker *et al.* (2000b) carried out the phylogenetic analysis of 18s ribosomal unit of *Glomus sinosam* (*Sclerocystis sinosam*) and *Sclerocystis coremioides* and stated that both species are closely related and fall within the *Glomus* clade. These studies reported that formation of sporocarp is an advanced character of some *Glomus* species but sporocarpic trait is not sufficient to segregate it into a separate genus *Sclerocystis*.

Schubler *et al.* (2001) transferred AM fungi from the ploy phyletic phylum Zygomycotina to monophyletic phylum *Glomeromycota* and stated that Glomeromycota probably diverged from the same common ancestor as Ascomycota and Basidiomycota (James *et al.*, 2006; Lutzoni *et al.*, 2004; Tehler *et al.* 2003). Based on the above studies, four orders: Archaeosporales (*Archaeosporaceae, Geosiphonaceae*), Paraglomerales (*Paraglomeraceae*), Diversisporales (*Acaulosporaceae, Gigasporaceae*) and Glomerales were recognised.

Molecular evidence carried out by Simon *et al.* (1993), Gehring *et al.* (1996) and Redecker *et al.* (2000a) suggested that *Glomus* is polyphyletic conglomeration and the present morphological characters are not adequate.
**National status**

Mycorrhizal study in India was started around 1960s. The result was come out in the form of a few papers were contributed at the 6th NACOM 1984 at Oregon and 7th NACOM 1987 Gainesville Florida one national work shop held at Delhi in March 1987 and first Asian Conference in mycorrhizae in 1988.


Battcharjee and Mukerji in 1980 described a new species *Glomus reticulatum* from Bangalore and also reported *Glomus caledonius* from Srinagar; *Glomus fulvus* from Bangalore and Belgaum, *Glomus invermaius* from Bangalore and *Glomus microcarpum* from Bangalore and Delhi. Bhattacharjee et al. (1980) added *Sclerocystis dussi*, *S. rubiformis*, *Gigaspora corolloidea* and also described *Sclerocystis indicus* from India. Bhattacharjee et al. (1982) reported the structure and hyperparasitism of *Gigaspora candida*, while, Bhattacharjee and Mukerji (1982) carried out the ultrastructural studies of sporocarps of *Sclerocystis coremioides*. Mukerji et al. (1983) reported *Glomus multisubstensum* and *G. delhiense* from Delhi.

The occurrence of AM fungi in a natural forest was recorded in the Old Delhi Ridge, Saraswati Range of Haryana (Thapar & Uniyal, 1996), forest soils and coastal regions of Andhra Pradesh (Manoharachary & Rrao, 1991), Kodayar forest, Tamil Nadu (Genasen et al., 1991), forest plants of Nilgiris (Raja et al., 1991), Coastal tropical forest (Kodikkarai Reserv Forest) of Tamil Nadu (Raghupathy & Mahadevan, 1991), Servarayan Hills of Tamil Nadu (Raman & Nagarajan, 1995), Forest soils of Andhra Pradesh (Vijaya et al., 1995) and black pepper grown in the forest soils of Kerala (Lekha et al., 1995).

The diversity of AM fungi has also been studied in the coastal regions of Konkan and Servaravan Hills of Tamil Nadu (Gopinathan et al., 1991); Coromandel coast of Tamil Nadu (Raghupathy & Mahadevan, 1992); coastal sand dunes at Someshwara, Mangalore coast of
Karnataka (Kulkarni et al., 1997), coastal sand dunes of the west coast of India (Beena et al., 2000) and Western Ghats of Goa (Khade & Rodrigus, 2003).

Sengupta and Chaudhari (1989, 1990) studied the occurrence of AM fungi in *Sueda maritima* (a pioneer mangrove) in terminal, seabound Gangetic delta in West Bengal. Mangrove of Muthupet estuary was surveyed by Selvaraj and Subramaniam (1991).

The occurrences of AM fungi in arid and semi-arid regions were studied in Tamil Nadu (Parthipon et al., 1991), deserts (Neeraj and Verma, 1991), arid zones of Rajasthan (Mohan, and Verma, 1995), semi-arid grasslands of Maruthamalai hills, Tamil Nadu (Muthukumar and Udaiyan, 1994).

The diversity of AM fungi in agricultural fields was reported on *Leucaena leucocephala* from Bangalore (Nalini et al., 1987) ornamentals and cultivated plants at Allahabad and adjoining areas (Kehri, et al., 1987), crop fields of Konkan and Solapur (Dalal and Hippalgaonkar, 1995), tea plantation at Nilgiris, Tamil Nadu (Kumaranand Santhanakrishnan, 1995), pearl millet, maize, wheat, pigeonpea and chick pea in Gwalior (Singh & Pandya, 1995) and different agro climatic regions of India (Singh and Adholeya, 2002). The distribution of AM fungi in stressed ecosystems has also been reported from coal, lignite and calcite mine spoils of India (Ganesan et al., 1991; Mehrotra, 1995), Kothagudam coal mine spoil, Andhra Pradesh (Rani et al., 1991), heavy metal polluted soils in Tamil Nadu (Sambadan et al., 1991), petro-effluent irrigated fields, soils polluted with industrial and sewage effluents (Reddy et al., 1995), tannery effluent polluted soils of Tamil Nadu (Sambadan et al., 1991) and stressed soils of Bailadila iron ore sites in Madhya Pradesh. All these studies reveal an account of 102 taxa from India (Bagyajai & Padmavati Revindra, 1995; Mukerji & Kapoor, 1990; Mukerji et al., 1992; Raghupathy & Mahadevan, 1993; Raja et al., 1993; Rama Pulla Reddy et al., 1995; Rani & Mukerji, 1988).

**The genus Acaulospora**

The genus *Acaulospora* was proposed by Gerdemann & Trappe (1974) with the characters: Azygospores borne laterally on the stalk of a large, terminal thin walled vesicle. The type being *A. laevis* Gerdemann & Trappe. Subsequently, Berch (1985) emended the generic description. *A. elegans* was isolated from the roots of *Fragaria chiloensis* in dune sand of Oregon (Gerdemann & Trappe, 1974). Ames et al. (1976) added *A. trappei* isolated from the field of *Lilium longiflorum*. Trappe (1977) added *A. scrobiculata* from Mexico. A.

The genus *Entrophospora*

The genus *Entrophospora* was proposed by Ames & Schneider (1979) with the characters: wall of the vesicular stalk expands to accommodate spore, forming a clear outer membrane tightly apprised to the spore. The type being *E. infrequens* (Hall) Ames & Schneider, from New Zealand. It was previously described as *Glomus infrequens* by Hall (1977). Since the mode of spore formation was different, it was accommodated in a new genus. The spore develops inside the vesicular stalk rather than laterally. Subsequently, Schenck et al. (1986) added *E. colombiana*. It was originally isolated from Cassava roots and
native grass in Carimagua, Colombia. Sieverding & Toro (1987) described *E. schenckii* from Colombia. Till now this genus represents about 3 species.

**The genus Gigaspora**


**The genus Sclerocytsis**

The genus *Scutellospora*


The genus *Glomus*

Tulasne & Tulasne (1845) described the genus *Glomus*. This organism was also described latter by other workers in different names, Saccardo et al (1882) described *Sphaerocreas*, Dangeard (1900) as *Rhizophagus*, West (1916) as *Stigeosporium* and later Rosendahl (1943) described *Rhizophagites*. The genus *Glomus* is characterized by having chlamydospires borne terminally on single (rarely two) undifferentiated, non gametangial hyphae in sporocarps or individually in soil. Spore content at maturity separated from attached hyphae by a septum or occluded by spore wall thickening (Gerdemann & Trappe, 1974; Mosse, 1956, 1959; Godfrey, 1957). The type species of this genus is *Glomus microcarpum* Tulasne & Tulasne.


The genus *Redeckera*

The species of the genus *Glomus*, which are possessing glomoid spores having large sporocarps with peridium were placed under the newly proposed genus *Redeckera* (Walker & Schubler, 2010). The type being *R. megalocarpum* (D. Redeker) Walker & Schubler. Further, Walker & Schubler (2010) added two more species, *R. Pulvinatum* and *R. fulvum*, based on *Glomus pulvinatum* (Henn) Trappe & Gerdemann (1974) and *Glomus fulvum* (Berkely & Broome) Trappe & Gerdemann. This genus represents 3 species.

The genus *Funneliformis*

Walker & Schubler (2010) segregated the genus *Funneliformis* from *Glomus* to accommodate the species having coloured spores formed in sporocarps (upto 20 spores) surrounded by an entire or partial coarse mycelial mantle, ectocarpic spores single or in loose clusters, spore often with a funnel-shaped with spore base, wall 2-3, outer wall colourless, often disappearing as the spore matures. The type being *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schubler. Further, they transferred 10 more species,

**The genus Claroideoglomus**

The genus *Claroideoglomus* is also an off-shoot of the genus *Glomus* was proposed by Walker & Schubler (2010), with the characters: spores glomoid, formed in soil or substrate, rarely in decaying roots and with a combination of an evanescent outer wall component and an inner semi-flexible component that seemingly form an endospore at maturity. The type being *Claroideoglomus claroideum* (N.C. Schenck & G.S.Sm.) Walker & Schubler. They transferred the following five species of the genus *Glomus* to their newly formed genus, namely, *Claroideoglomus walkeri* (Blaszk. & C. Renker) Walker & Schubler, *C. luteum* (L.J.Kenn., J.C. Stuts & J.B. Morton) Walker & Schubler, *C. lamellosum* (Dalpe, Koske & Tews) Walker & Schubler, *C. etunicatum* (W.N. Becker & Gerd.) Walker & Schubler, *C. drummondii* (Blaszk. & Renker) Walker & Schubler. This genus represents 6 species.

**The genus Ambispora**

The genus *Ambispora* was proposed by Walker et al. (2007). The species exhibit dimorphism in spore formation, possessing both glomoid and acaulosporoid spores characters. The type being *Ambispora fennica* Walker et al. The genus includes some species of the genera *Glomus*, *Acaulospora* and *Archaeospora*. Till now this genus represents 9 species.

**The genus Racocetra**

The genus *Racocetra* was proposed by Oehl et al. (2008) with the characters: spores formed singly on bulbous suspensor cell, which arise terminally on mycelial hyphae. Outer spore wall three layered and continuous with walls of the suspensor cells. Germination shield arises on the outer surface beneath a thin outer layer of the inner wall, hyaline, subhyaline to yellow, oval, ellipsoid to subglobose, several (4-12) lobed projections formed on the outer
surface of the shield, folds separate the lobes on the shield, each lobe possess germ pore. The type being *Racocetra coralloidea* (Trappe, Gerdemann & Ho) Oehl *et al*. They transferred eight more species to this genus from the *Gigaspora* and *Scutellospora*. Goto & Oehl (2009) added *Racocetra intraornata* from Northen Brasil. *Racocetra beninensis* was proposed by Tchabiet *et al*. (2010) from Sub-Saharan savannas. This genus represents 11 species.

The genus *Dentiscutata*

Oehl *et al*. (2008) the genus *Dentiscutata* by segregating it from the genus *Scutellospora* having the characters: spores formed singly on bulbous suspensor cells which are formed terminally on subtending hyphae that arise from mycelium. Germination shield generally formed on the outer surface of the inner most wall or beneath a thin outer layer of the inner wall, yellowish brown to brown, ellipsoid, oval, reniform to cardiform, with many large folds separating the shield into 8-30 small compartments; each compartment with one circular germ tube initiation; germ tube arise from the germ pore by penetrating the other walls. The periphery of the germination shield generally dentate. The type being *Dentiscutata nigra* (J.F. Redhead) Sieverd. Six more species were added to this genus by transferring the species from the genera *Gigaspora* or *Scutellospora*. This genus represents 7 species.

Factors influencing mycorrhizal fungi

1. Propagules of Mycorrhizal Fungi

The environmental factors, host and fungal effects are influencing the root colonization and spore production by VAM fungi. The spread to new roots, long-range dispersal and persistence of mycorrhizal fungi in ecosystems is dependent on the formation of propagules and their interactions with soil and environmental conditions. Rapid colonization of the root system is required for an effective association (Abbott and Robson, 1984a; Bowen, 1987). The infective propagules are present when root growth activity occurs, since roots have a limited period of susceptibility (Brundrett and Kendrick, 1990a; Hepper, 1985).

A clearing and staining procedure (Brundrett *et al*., 1990; Kormanik and McGraw, 1982) was used to measure the activity of mycorrhizal formation within roots. Abbott and Robson (1991) used to quantify propagules of mycorrhizal fungi to consider the total length as well as the proportion of host root occupied by VAM colonies. Nicolson (1972) said that
spore number might be the effective measure of the root colonization. Hyphal spread along roots and colony extension within roots contributes to total colonization levels (Sanders and Sheikh, 1983; Smith and Walker, 1981).

Propagules of VAM fungi include spores, root fragments containing hyphae and vesicles and soil hyphae (Biermann and Lindermann, 1983; Manjunath and Bagyaraj, 1981; Tommerup and Abbott, 1981). The spores of VAM fungi are the important type of propagules but their numbers are often poorly correlated with mycorrhizal formation in soils (Abbott and Robson, 1984a, 1991a; Ebbers et al., 1987; McGee, 1989; Mukerji and Kapoor, 1986; Schmidt and Reeves, 1984).

Spore production in VAM fungi is influenced by factors including the host plant and soils in ecosystems often contain low numbers of living spores (Brundrett and Kendrick, 1988; Gay et al., 1982; Janos, 1980b; Read et al., 1976; Schenck and Kinloch, 1980). Living spores of VAM fungi present in the soil may not function as propagules, if they are quiescent (inactive because soil conditions are unsuitable) or have an innate period of dormancy-mechanisms which may help them to survive during periods of adverse soil conditions (Tommerup, 1987). Melanins (fungal pigments) within their relatively thick walls may help to protect the contents of VAM spores, which sometimes receive further protection by forming within structures such as old seed coats (Daniels Hetrick, 1984). Spores are generally considered to be more resistant to adverse conditions than other VAM fungus propagules (Abbott and Robson, 1990).

Fragments of dead roots present in the soil can initiate VAM, provided they are in close proximity to the new roots (McGee, 1987; Rives et al., 1980), which would happen if they occupy the same soil channels (Went and Stark, 1968). The vesicles produced by many VAM fungi can function as propagules when isolated from roots (Biermann and Lindermann, 1983). Some plants in a deciduous forest community were found to have roots which maintained a living cortex for 2-10 years without undergoing secondary growth and still contained inactive hyphae and vesicles of VAM fungi (Brundrett and Kendrick, 1988).

These species with long-lived roots may function as keystone mutualists (Gilbert, 1980) benefiting all host plants by allowing VAM fungi to penetrate within them (Brundrett and Kendrick, 1990a). Coarse soil organic matter colonized by VAM fungus hyphae can also contribute to their survival (Warner, 1984) and function as propagules (Koske, 1987b; Nicolson, 1960).

The mycorrhizal infectivity of soils can be estimated by most probable number of methods (serial dilutions using increasing proportions of sterilized soil), or "bioassays"
(where the degree of colonization of a bait plants are measured) but it is difficult to interpret the results obtained by these methods (Abbott and Robson, 1991a). Mycorrhizal fungus activity, measured by the presence of mycorrhizal roots and spores, is generally thought to be concentrated near the soil surface, but propagules can be more numerous at greater depths (up to 2-4 m) in arid ecosystems (Virginia et al., 1986; Zajicek et al., 1986).

2. Dispersal of Mycorrhizal Fungi

Dispersal mechanisms are responsible for introduction of mycorrhizal fungi to new geographic locations and the transfer of genetic information. The spread of mycorrhizal fungi can occur by active disposal by hyphal growth through soil (Powell, 1979) or passive dispersal mechanisms (Daniels Hetrick, 1984). Hyphae of VAM fungi radiate outward from mycorrhizal plants and thus can slowly spread the association to adjacent plants (Warner and Mosse, 1982; Scheltema et al., 1985b). High rate of fungal spread have been reported in non-sterile soil (Wallace, 1978). Soil factor such as soil fertility, seasonal fluctuation in moisture and temperature, microbial activity will influence the rate of spread of VAM fungi (Bagyaraj & Powell, 2000). The large spores of VAM fungi can be suspended in moving air currents (Tommerup & Carter, 1982) and wind dispersal has been observed in arid ecosystems (Allen, 1988; Warner et al., 1987). Transportation of spores by water erosion and human activities (transport of soil and living plants) probably also occurs (Daniels Hetrick, 1984; Walker, 1988). Koske and Gemma (1990) observed that VAM fungal spores produced in rhizome leaf sheaths or quiescent fungal structures within old roots could function as inoculum, even after exposure to sea water. They suggested that this provides a mechanism for the dispersal of mycorrhizal fungi along with fragments of plants which occupy early successional coastal habitats.

Mycorrhizal fungal spores have been found within organisms which may act as vectors that belong to many trophic levels, but the distances involved and the importance of these dispersal mechanisms in ecosystems is usually not known. Allen (1988) observed that ingestion and subsequent defecation of spores by animals to introduce VAM into new locations. Animals which probably transport VAM fungus spores include small mammals, grasshoppers, worms, ants, wasps and birds macroarthropod detritivores such as woodlice (Isopoda) and millipedes (Diplopoda) ingest and disperse mycorrhizal inoculum and may in turn be eaten by predatory beetles(Hansen & Ueckert, 1970; Mc Ilveen & Cole, 1976; Rabatin and Stinner, 1988, Taber, 1982; Taxter, 1922). Trappe and Maser (1976) observed
that VAM spores remained viable after passage through the digestive tract of a rodent. Earthworms which ingest VAM fungi and expel their spores in casts are eaten by many small animals which may thus act as vectors for the mycorrhizal fungi (Rabatin and Stinner, 1988).

3. Climatic or Edaphic specificity of Mycorrhizal Fungi

Environmental factors and soil conditions influence the occurrence of mycorrhizal associations in ecosystems. The physiological diversity of mycorrhizal fungi has been provided by comparing experimental responses to soil pH, soil nutrient levels, soil moisture, salinity, temperature and other factors (Abbott and Robson, 1991a; Daniels Hetrick, 1984; Morton, 1988; Slankis, 1974; Trappe and Molina, 1986; Bethenfalvay et al., 1982; Gerschefske Kitt et al., 1987; Puppi and Reiss, 1987; Rose, 1988). There is limited evidence that climatic factors can influence the distribution of mycorrhizal fungi (Ebbers et al., 1987) and Anderson et al. (1984) discovered changes in predominate species of VAM fungi across a soil moisture (soil fertility) gradient in a prairie site, which had a much greater influence on plant populations. Henkel et al., (1989) observed that isolates of four VAM fungi from adjacent ridgetop, mid-slope and basal sites in an arid plant community were most infective in the soil from which they were collected and less infective in soil from the other two sites. They suggested that these isolates had adapted to phosphorus levels or other factors in the soil where they occur. Adelman and Morton (1986), Graham et al. (1982b), Molina et al. (1978), Porter et al. (1987b) and Stahl et al. (1988) also observed that clonal isolates of VAM fungi were more effective when used in their native soil type.

Wang et al., (1985). Porter et al., (1987a) found the distribution of VAM fungus taxa in Western Australia to be highly correlated with soil pH. Bethlenfalvay et al., (1989) proposed that the term "edaphotype" be used to describe intraspecific variants of mycorrhizal fungi isolated from different soils that differ in their physiological response to various conditions. There are many statements in the mycorrhizal literature about the physiological, ecological, or mutualistic characteristics of species of VAM fungi that actually only describe one particular clonal isolate (Morton, 1990).
Previous works in Silent Valley National Park

There was no detailed study till first two decades of nineteenth century. Since 1840, Robert White, Beddome and Gamble and several others have studied the plant wealth of this area. In 1860, T.C. Jerdon discovered an orchid Malabar Daffodil (*Ipsea malabarica*), which remained unknown for 120 years. During the period of 1981-1985, Manilal (1988) and Vajravelu (1990) have studied the plant wealth of Silent Valley and reported the diversity of flowering and non flowering plants. 1979-80, Zoological Survey of India described 20 new species from Silent Valley including new frog species, *Alsonia rubijina* and *Micrasalus thambi*. Bhat (2010) has enumerated fungi from this region. Hosagoudar (1985, 2003, 2006a, b, 2007), Hosagoudar and Biju (2006), Hosagoudar and Archana (2009a,b,c), Hosagoudar and Chandra Prabha (2009), Hosagoudar and Jacob Thomas (2009) and Hosagoudaret et al. (2001, 2009) have contributed towards the foliicolous fungi of this region. Though Mohanan (2003) has studied several mycorrhizal fungi of commercially timber yielding plants in Kerala state but as such there is no study in the compact forest like Silent valley. Hence, the present study has got much importance.