Unit - IV
Lichen And Mycorrhiza

A Lichen is an association between an alga and a fungus, in which the two organisms jointly form a thallus that is distinct from both ~~(parents)~~ partners.

- The lichens are small group of plants.
- It consists about 400 genera and about 15,000 species.
- They are composite or dual organisms, formed by a close association of two different plant.
- One is filamentous fungus and other is alga.
- These two organisms lives in a close association, so much so that they appear to be a single plant.
- The fungal component is called the mycobiont and the algal component is called the phycobiont.
- The fungal component forms the bulk of the lichen thallus.

- Theophrastus first used the term lichen to denote a superficial growth on bark of the trees.
- The study of lichen morphology began with the work of Arik Acharium who is regarded as father of lichenology.

- The science of lichen is termed as lichenology and one who studies this science is known as lichenologist.

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Nature of Association:

- There is a bit of controversy with regards to the nature of relationship between algal & fungal components in the lichen thallus.
- There are three different views regarding the nature of association of the two components in the lichen thallus.

1. First view: Parasitic nature

According to the first view the fungal component lives as a parasite on the algal partner.

- The parasitism is of a mild nature as it permits most of the algal cells to survive.
- This view is based on the following two facts –

i) In some lichens the fungal hyphae give out haustoria or appressoria.
· These penetrate the algal cells to obtain the nutrition.

ii) When the two components of the lichen thallus are artificially separated, the algal component is able to live as an independent individual. But fungal component fails to live independently. Thus the association is parasitic one.

2. Second View: Symbiotic nature

- According to the second hypothesis the two partners in the lichen thallus derive mutual benefits from each other.

- There are advantages on both sides. The fungus absorbs water and minerals from the substratum with its rhizoids.
- It also absorbs moisture from the fog and moist air.
- The fungal hyphae form the body of the lichen & provide shelter to the alga.
- They thus protect algal component from intense light, drought and other adverse weather conditions.
- The algal member gets shelter and water for photosynthesis from the fungal member and in turn the fungal member gets ready made food material from algal member showing the symbiosis.

3. Third view: Master & slave nature
- According to the third view the association of the fungal and the algal partner in the lichen thallus is an example of the symbiosis but the fungal partner lives with upper hand and the algal partner lives as a subordinate partner or as a slave.
- This type of association is called as Helotism or Master & slave relationship.

CLASSIFICATION OF LICHENS:

The systematic position of lichens ever has been a problem on account of two different components.

Bold (1959) grouped the lichens in a Division-Mycophycophyta due to their dual nature.Most of the scientists classify them on the basis of nature of fungal component, habitat and forms.

Classification on the basis of nature of fungal partner:

On the basis of nature of fungal partner lichens are classified into two groups such as

i) Ascolichens.

ii) Basidiolichens.

Ascolichens:

The lichens in which the fungal components belong to the ascomycetes are called the ascolichens. The ascolichens are subdivided into two sub-classes

i) Gymnocarpae (in which the ascocarp is disc like **e.g.** ***Parmelia flavicens***)

ii) Pyrenocarpae (in which the ascocarp is flask shaped **e.g.** ***Physcia sp***)

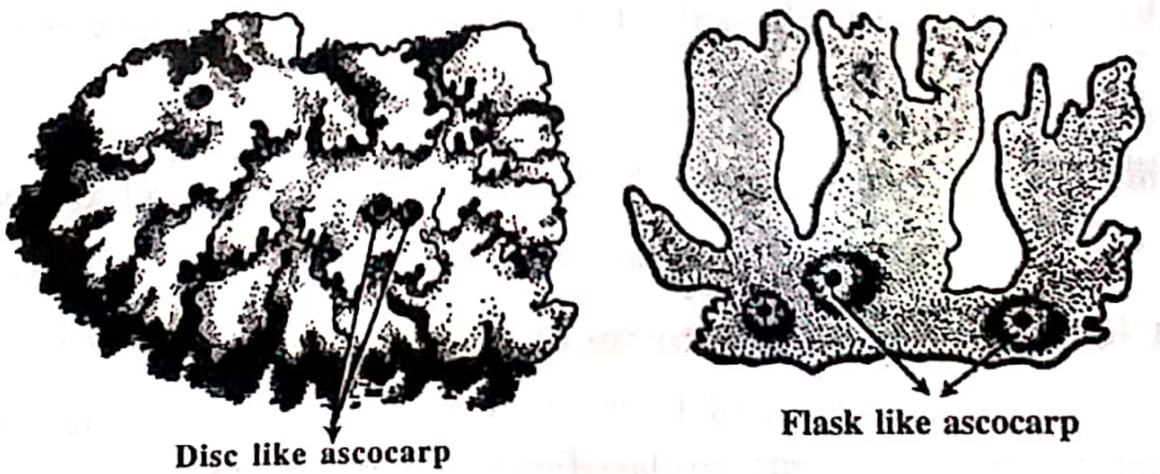

Fig. 4.12 (A-B). LICHENS: Ascolichens-A. Thallus of Parmelia; B. Thallus of Physcia

Basidiolichens:

A group of lichens in which the fungal component belongs to the basidiomycetes is called as the basidiolichens. It is represented by only three genera such as *Cora*, *Corella* and *Dictyonema*.

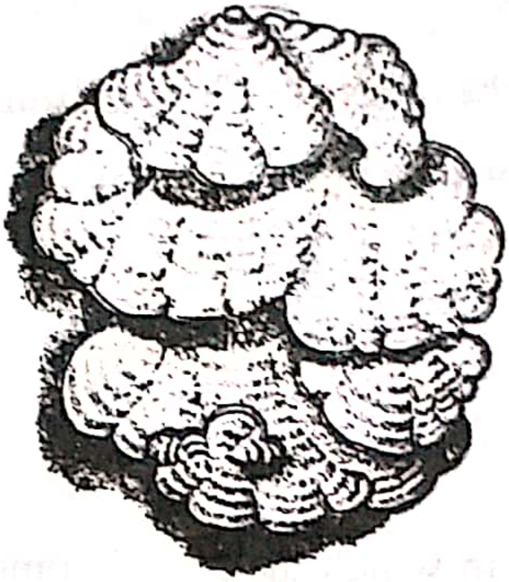

Fig. 4.13. LICHENS: Basidiolichen – Thallus of Cora povonia.

Classification based on habitat:

According to habitat the lichens are classified into three categories.

i) **Saxicolous lichens** (The saxicoles are commonly rock lovers and grow on firm substratum of cold regions).

ii) **Corticolous lichens** (The Corticoles are commonly grow on barks of the trees).

iii) **Terricolous lichens** (The Terricoles are terrestrial and commonly grow on soil of hot areas with scanty rains).

Classification based on forms of lichen thallus:

On the basis of forms and nature of attachment to the substratum, the lichens are classified into three groups

i) Crustose (Crustaceous) lichens.

ii) Foliose (Folioceous) lichens.

iii) Fruticose (Shruby) lichens.

Crustose lichens:

The thallus is of insignificant size. It is flat, thin and closely adherent to the substratum. It is just like a thin layer or crust closely attached to stones, rocks or bark of trees. The surface of the thallus is usually divided into more or less hexagonal areas called the aerolae. In many species the thallus is partly buried in the substratum.Some of the common examples are *Graphic scripta, Haematomma puniceum and Lecidea platycarpa.*

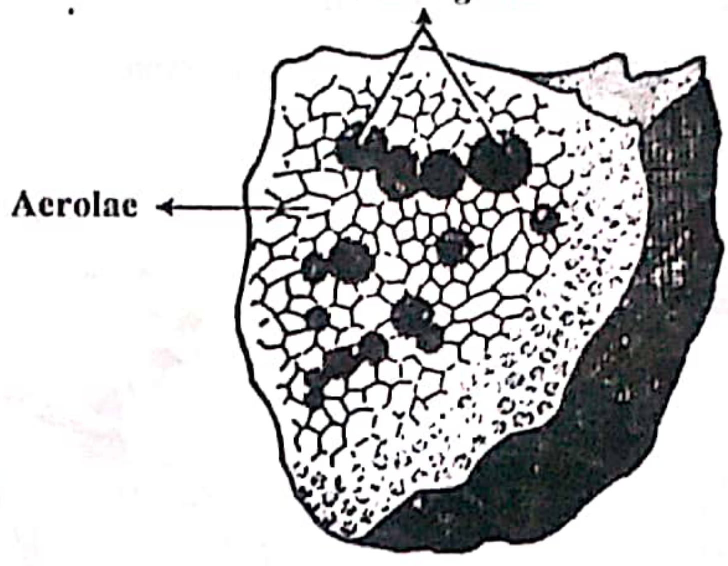

Fig.4.14. LICHENS: Thallus of Lecidea platycarpa

Foliose lichens:

The foliose thallus is flat, broad, much lobed and leaf like. It resembles crinkled and twisted leaves. The foliose thallus is attached to rocks and twigs by rhizoid like outgrowths called the **rhizinae**. The rhizinae arise from the lower surface. The free end of the rhizinae broadens to form a flat disc. The disc secretes

Fig. 4.14a. LICHENS: Thallus of Parmelia flavicens

mucilage and attaches itself firmly to the substratum. The **rhizinae** thus function as anchorage and absorptive organs. The foliose thallus has distinct upper and lower surface. It grows free from the substratum. The lower surface is white or sooty black. Some of the common examples are ***Parmelia, Peltigera, Xanthoria, Physcia, Cetraria and Chaudhuria.***

Fruticose lichens:

The thallus is most complex, slender and freely branched. The branches are cylindrical or ribbon like. They are either upright or pendulous. They are attached to the substrates by a disc like structure at the base. There is no differentiation into upper and lower surfaces in the thallus. Some of the common examples are ***Usnea, Cladonia*** and ***Ramalina.***

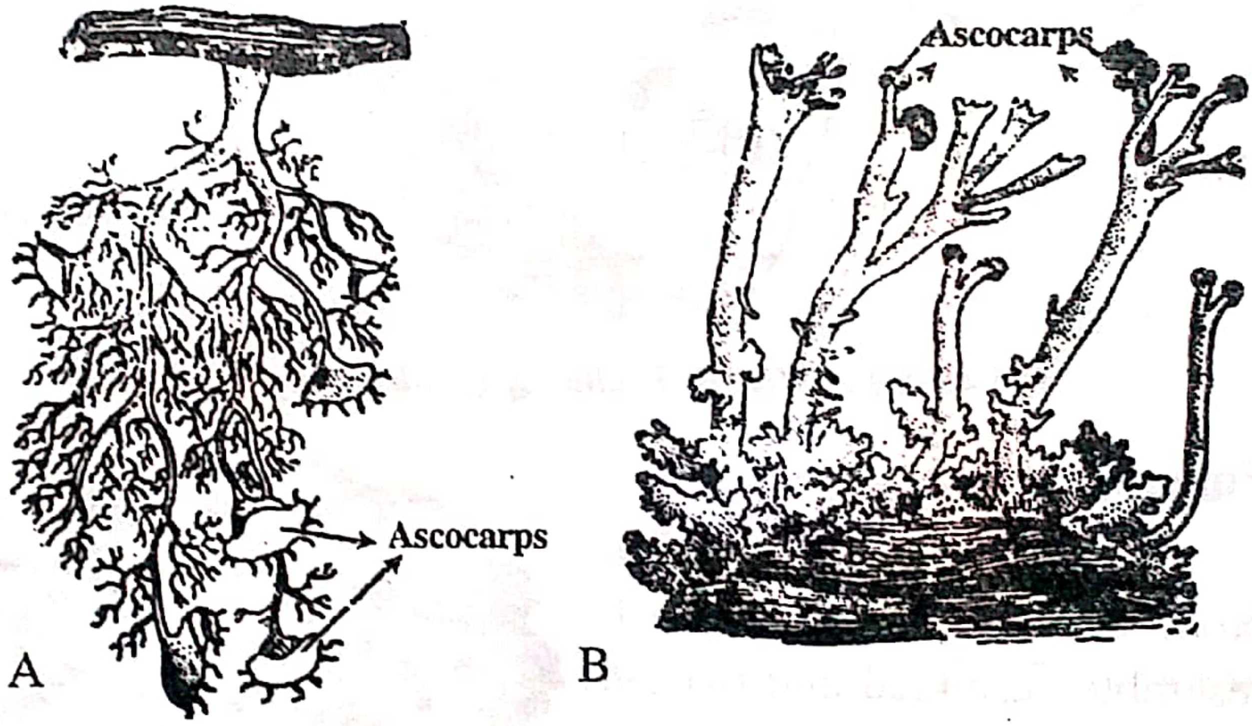

Fig. 4.15. LICHENS: A. Thallus of Usnea; B. Thallus of Cladonia

Internal structure. The gelatinous thalli of crustose lichens have algal and fungal components uniformly distributed through a gelatinous matrix. Thalli of such lichens are not differentiated into layers of tissues and therefore, known as **homomerous.** Thalli or most foliose and fruticose lichens are differentiated into several layers of tissues, and therefore known a **heteromerous.** Thalli of foliose lichens have four layers of different tissues. The uppermost layer, **upper cortex,** is composed of more or less vertical hyphae. The intercellular spaces between the hyphae are either absent or filled with gelatinous substance. An epidermis-like layer formed of closely packed hyphae may or may not be present external to the upper cortex. Beneath this cortical layer is **algal layer.** In this layer algal cells lie intermingled with the loosely interwoven fungal hyphae. At one time these algal cells were thought to be reproductive cells of lichens and were known as **gonidia,** and therefore, even today the algal layer is often called **gonidial layer.** Beneath the gonidial layer is **medulla** composed of very loosely interwoven hyphae with very large interspaces. Below medulla is the **lower cortex.** It is made of compact hyphae which may be parallel to perpendicular to the surface of the thallus. The interspaces between the

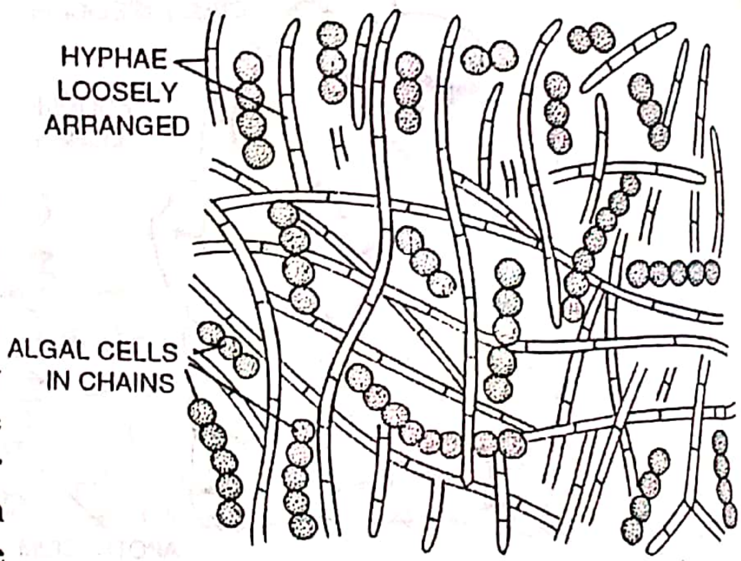

Fig. 18.5. V.S. of homomerous lichen.

hyphae are either absent or filled with gelatinous material. The rhizines grow out from the underside of the lower cortex and attach the thallus to the substratum. Basidiolichen has uppermost layer of loose perpendicular hyphae (**superior layer**), below it **algal layer** and the lowermost is the **inferior layer** made of dense mass of hyphae.

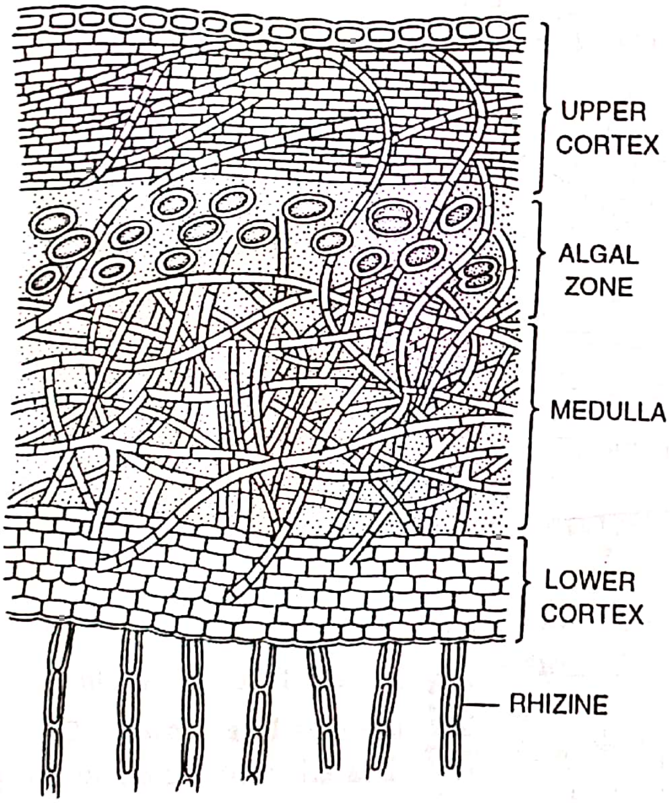

Fig. 18.6. V.S. of heteromerous lichen.

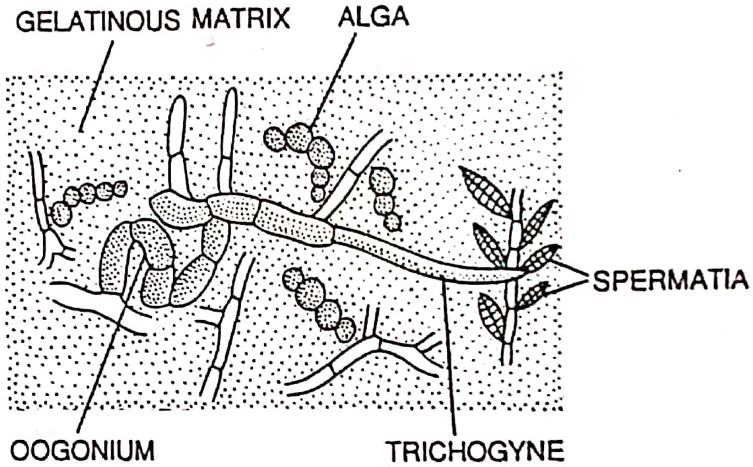

Fig. 18.7. V.S. thallus-crustose lichen.

In addition to the structure described above, lichens bear certain peculiar vegetative structures. These structures are:

(a) Breathing pores. In the upper cortex of some foliose and fruticose lichens, the hyphae are very loosely interwoven to facilitate the gaseous exchange between the thallus and the atmosphere. These localized areas may be depressions or cone like and are known as **breathing pores.**

Importance of Lichens:

A. Economic Importance of Lichens:

The lichens are useful as well as harmful to mankind. The useful activities are much more than harmful ones. They are useful to mankind in various ways: as food and fodder, as medicine and industrial uses of various kinds.

1. As Food and Fodder:

Lichens are used as food by human being in many parts of the world and also by different animals like snail, catterpiliars, slugs, termites etc. They contain polysaccharide, lichenin; cellulose, vitamin and certain enzymes.

Some uses of lichens are:

(i) As Food:

Some species of Parmelia are used as curry powder in India, Endocarpon miniatum is used as vegetable in Japan, Evernia prunastri for making bread in Egypt, and Cetraria islandica as food in Iceland. Others like species of Umbillicaria, Parmelia and Leanora are used as food in different parts of the world. In France, some of the lichens are used in the preparation of chocolates and pastries.

Lichens like Lecanora saxicola and Aspicilia calcarea etc. are used as food by snails, caterpillars, termites, slugs etc.

(ii) As Fodder:

Ramalina traxinea, R. fastigiata, Evernia prunastri, Lobaria pulmo- naria are used as fodder for animals, due to the presence of lichenin, a polysaccharide. Animals of Tundra region, especially reindeer and muskox use Cladonia rangifera (reindeer moss) as their common food. Dried lichens are fed to horses and other animals.

2. As Medicine:

Lichens are medicinally important due to the presence of lichenin and some bitter or astringent substances. The lichens are being used as medicine since pre-Christian time. They have been used in the treatment of jaundice, diarrhoea, fevers, epilepsy, hydrophobia and skin diseases.

Cetraria islandica and Lobaria pulmonaria are used for tuberculosis and other lung diseases; Parmelia sexatilisfor epilepsy; Parmelia perlata for dyspepsia. Cladonia pyxidata for whooping cough; Xanthoria parietina for jaundice and several species of Pertusaria, Cladonia and Cetraria islandica for the treatment of intermittent fever.

Usnic acid, a broad spectrum antibiotic obtained from species of Usnea and Cladonia, are used against various bacterial diseases. Usnea and Evernia furfuracea have been used as astringents in haemorrhages. Some lichens are used as important ingredients of many antiseptic creams, because of having spasmolytic and tumour-inhibiting properties.

3. Industrial Uses:

Lichens of various types are used in different kinds of industries.

(i) Tanning Industry:

Some lichens like Lobaria pulmonaria and Cetraria islandica are used in tanning leather.

(ii) Brewery and Distillation:

Lichens like Lobaria pulmonaria are used in brewing of beer. In Russia and Sweden, Usneaflorida, Cladonia rangiferina and Ramalina fraxinea are used in production of alcohol due to rich content of "lichenin", a carbohydrate.

(iii) Preparation of Dye:

Dyes obtained from some lichens have been used since pre- Christian times for colouring fabrics etc.

Dyes may be of different colours like brown, red, purple, blue etc. The brown dye obtained from Parmelia omphalodes is used for dyeing of wool and silk fabrics.

The blue dye "Orchil", obtained from Cetraria islandica and others, is used for dyeing woollen goods. Orcein, the active principal content of orchil-dye, is used extensively in laboratory during histological studies and for dyeing coir.

Litmus, an acid-base indicator dye, is extracted from Roccella tinctoria, R. montagnei and also from Lasallia pustulata.

(iv) Cosmetics and Perfumery:

The aromatic compounds available in lichen thallus are extracted and used in the preparation of cosmetic articles and perfumes. Essential oils extracted from species of Ramalina and Evernia are used in the manufacture of cosmetic soap.

Ramalina calicaris is used to whiten hair of wigs. Species of Usnea have the capacity of retaining scent and are commercially utilised in perfumery. Evernia prunastri and Pseudevernia furfuracea are used widely in perfumes.

B. Ecological Importance of Lichens:

Lichens have some ecological importance.

Some of the activities in this respect are:

1. Pioneer of Rock Vegetation:

Lichens are pioneer colonisers on dry rocks. Due to their ability to grow with minimum nutrients and water, the crustose lichens colonise with luxuriant growth. The lichens secrete some acids which disintegrate the rocks.

After the death of the lichen, it mixes with the rock particles and forms thin layer of soil. The soil provides the plants like mosses to grow on it as the first successor, but, later, vascular plants begin to grow in the soil. In plant succession, Lecanora saxicola, a lichen, grows first; then the moss Crtmmia pulvinata, after its death, forms a compact cushion on which Poa compressor grows later.

2. Accumulation of Radioactive Substance:

Lichens are efficient for absorption of different substances. The Cladonia rangiferina, the 'reindeer moss', and Cetraria islandica, the 'Iceland moss' are the commonly available lichens in Tundra region. The fallout of radioactive strontium (^{90}Sr) and caesium ($^{137}C_S$) from the atomic research centres are absorbed by lichen. Thus, lichen can purify the atmosphere from radioactive substances.

The lichens are eaten by caribou and reindeer and pass on into the food-chain, especially to the Lapps and Eskimos. Thus, the radioactive substances are accumulated by the human beings.

3. Sensitivity to Air Pollutants:

Lichens are very much sensitive to air pollutants like SO_2, CO, CO_2 etc.; thereby the number of lichen thalli in the polluted area is gradually reduced and, ultimately, comes down to nil. The crustose lichens can tolerate much more in polluted area than the other two types. For the above facts, the lichens are markedly absent in cities and industrial areas. Thus, lichens are used as "pollution indicators".

Harmful Activities of Lichens:

1. Some lichens like Amphiloma and Cladonia parasitise on mosses and cause total destruction of moss colonies.

2. Lichen like Usnea, with its holdfast hyphae, can penetrate deep into the cortex or deeper, and destroy the middle lamella and inner content of the cell causing total destruction.

3. Different lichens, mainly crustose type, cause serious damage to window glasses and marble stones of old buildings.

4. Lichens like Letharia vulpina (wolf moss) are highly poisonous. Vulpinic acid is the poisonous substance present in this lichen.

MYCORRHIZA (FUNGUS ROOT) (*mykes* = fungus, *rhiza* = root)

Under agricultural field conditions crops do not, strictly speaking, have roots, they have mycorrhiza. S. Whilhelm (1966)

Mycorrhizas (sing. mycorrhiza), discovered by the German botanist, **Frank** in 1885, are structures formed by association of fungi and roots of plants.

Kinds of Mycorrhizas

Mycorrhizas are classified into three categories: **ectotophic**, **endotrophic** and **ectendotrophic**. In ectotrophic mycorrhiza, the fungus forms a mantle or hyphal sheath around the rootlets and also enters the roots forming an intercellular net of hyphae, called the **Hartig net** (named after Hartig who described it in 1851, without knowing its fungal nature). The hyphae of the Hartig net do not form haustoria. In the endotrophic mycorrhiza, which is the predominant type, the fungus invades and forms hyphal knots in the cells of the root cortex. A portion of the fungus lives in the soil, but no external sheath is formed. The ectendotrophic mycorrhizas share characters of both; form the hyphal mantle and, inside the root, form intercellular, as well as intracellular hyphae.

ECTOTROPHIC MYCORRHIZAS

The ectotrophic mycorrhizas occur only in about 3 per cent of plant species, majority of which are forest trees, *viz,* pines, spruces, larches, firs, oaks, beeches, birches, sweet chest-nut, eucalyptus, etc. These are more common in temperate regions. The associated fungi usually belong to *Basidiomycota* which are common in the forest litter.

Morphology and Anatomy

The ectotrophic mycorrhizas are conspicuous and easily recognizable by the fungus mantle that gives the roots a swollen and stumpy look (Figure 10.1).

While the uninfected rootlets remain unbranched and are short-lived, the mycorrhizal roots, by repeated branching, form a crowded cluster of swollen stumps that persist for several years. The new rootlets that emerge from the mycorrhizal roots become infected during their passage through the cortex and the hyphal sheath. The two partners, the fungus and the host root, grow in an organized manner with equal pace. However, occasionally, during spring season, some of the root apices grow out of the hyphal sheath and extend beyond it, though temporarily. The ways in which the mycorrhizal branches grow and ramify is shown in Figure 10.2. In *Pinus*, the mycorrhizal rootlets branch dichotomously, while in *Fagus* and all other species, the branching is racemose.

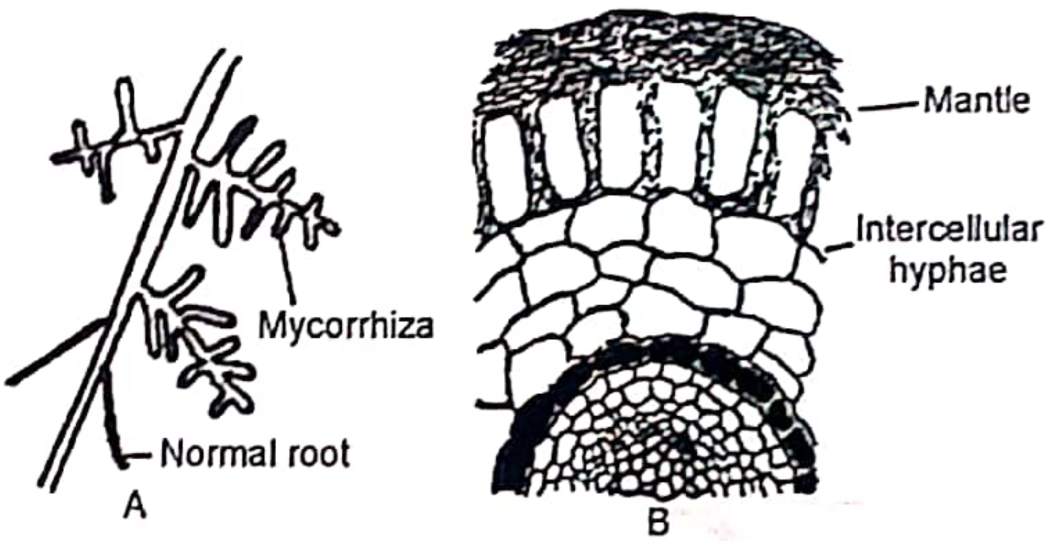

Fig. 10.1: Showing: A. Mycorrhiza on a portion of root and B. Fungus mantle and the hyphae in intercellular spaces of cortex.

A transverse section of an ectotrophic mycorrhiza (see Figure 10.1) shows that the fungus forms a pseudoparenchymatous (occasionally prosenchymatous) sheath around the root and sends branches inwards (between the cortical cells) as well as outside into the soil. The hyphae which penetrate the cortex form the **Hartig net** in the intercellular spaces. The cells of the cortex, which are in close contact with the Hartig net, are larger and more radially elongated than the healthy cells. The mycorrhizal roots have a poorly developed apical meristem. The hyphae in the soil give rise to the fruit bodies above ground during fruiting season (Figure 10.3). The ectotrophic mycorrhizas are differentiated and classified on the basis of their mode of ramification, colour and the structure of their sheath.

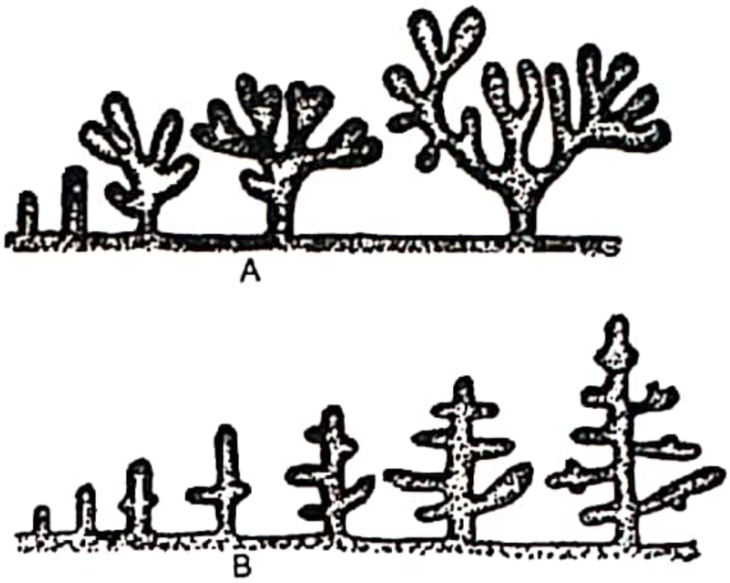

Fig. 10.2: Showing modes of growth and branching of mycorrhizal rootlets. A. dichotomous (in *Pinus*); B. racemose (in *Fagus* and all other species).

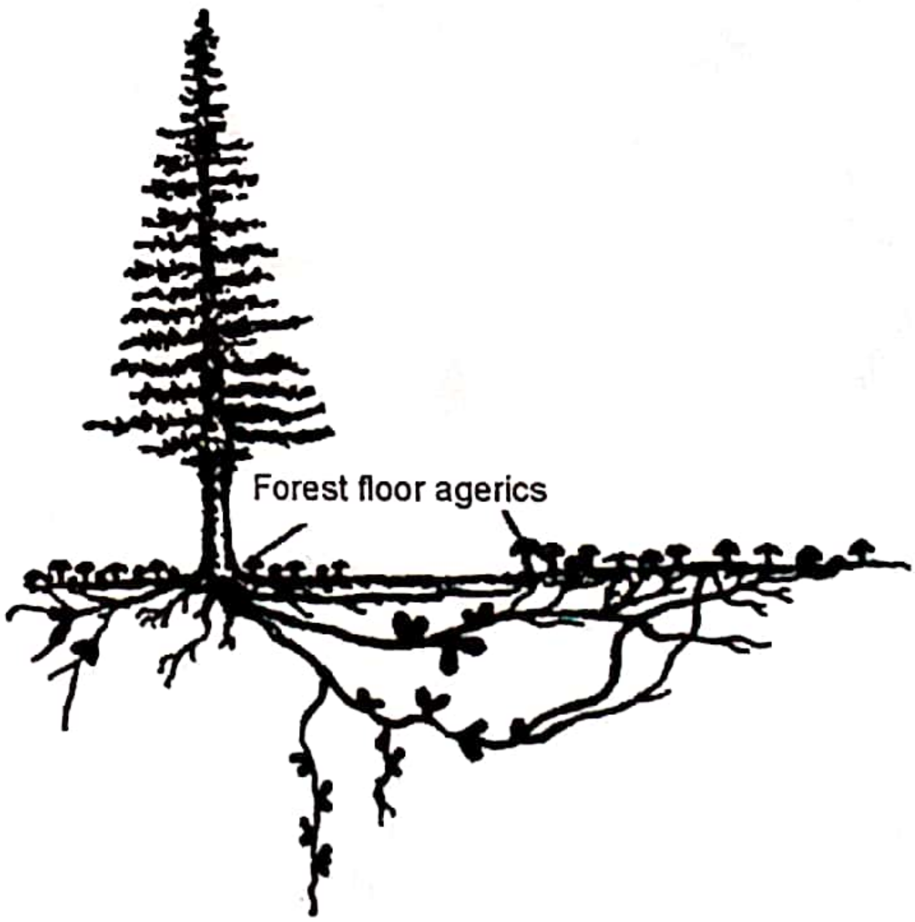

Fig. 10.3: Shows formation of forest-floor agarics.

The Fungi

The fungi associated with ectotrophic mycorrhizas belong to *Basidiomycota*, especially *Basidiomycetes* (*Agaricales* and *Boletaceae*). Some belong to the *Ascomycota* e.g., *Tuber* and *Elaphomyces*.

ENDOTROPHIC MYCORRHIZAS

The fungi of endotrophic mycorrhizas invade the cells of the root cortex, with a portion lying externally as a loose mass of hyphae in the soil. The endotrophic mycorrhizas are separated into two groups on the basis of the nature of the fungi: (1) those produced by septate fungi belonging to *Basidiomycota*, and (2) those produced by aseptate fungi, belonging to *Zygomycota*.

Endotrophic Mycorrhizas with Septate Fungi

These mycorrhizas are found in the plants belonging to plant families *Ericaceae*, *Orchidaceae* and *Gentianaceae*. The orchids, which are obligately dependent on mycorrhizal association for germination and further development (either temporarily or for the entire life), exemplify the importance of symbiotic mode of life.

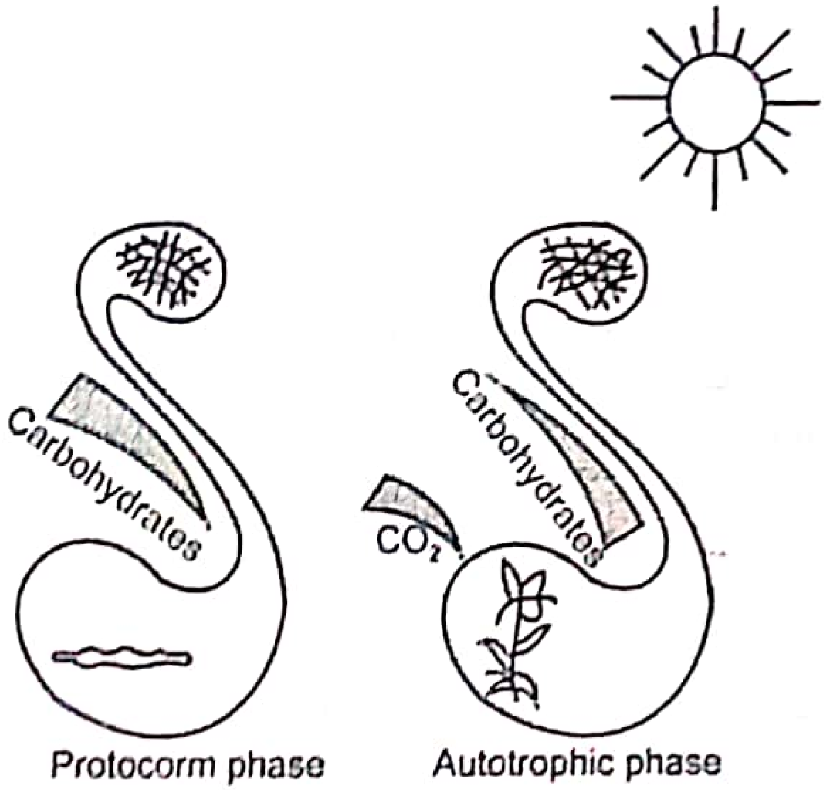

Fig. 10.4: Showing "Phase separation symbiosis" in orchids. In protocorm phase the orchid receives carbohydrates from the fungus; in autotrophic phase it "pays off".

Seeds of orchids are typically minute and are produced in enormous numbers (up to several millions in a single capsule). These have undifferentiated small embryo and with little or no reserve food material. They require prolonged soaking in water (2–3 months) for germination. Only seeds with infected embryos can germinate. The infection occurs through specific entrance cells in the suspensor when the imbibed seeds rupture. Growth and cell division are dependent on external source of carbohydrate, which is supplied by the fungus. The symbiosis exemplified by the orchids is called **phase separation symbiosis**. As soon as the orchid becomes an independent photosynthetic unit, the carbohydrate diffusion gradient is reversed (Figure 10.4) and the orchid starts supplying food, at least partly, to the fungus.

The Fungi

The fungi that form endotrophic mycorrhizas with orchids are all members of *Basidiomycota*, e.g., *Armillaria mellea*, species of *Fomes*, *Xerotinus*, *Corticium*, and *Marasmius*.

Endotrophic Mycorrhizas with Aseptate Fungi (Vesicular–Arbuscular Mycorrhizas)

The Vesicular-Arbuscular type of mycorrhiza (VAM) is most common among all mycorrhizas. These are ubiquitous and occur in about 70 per cent of plant species, belonging to all groups of plants–bryophytes (especially *Hepaticae*), pteridophytes, gymnosperms (except *Pinaceae*), and angiosperms. Large number of agricultural crops form VA–type mycorrhiza : e.g., maize, forage-legumes, soyabean, cotton, tobacco, potato, sugarcane, tomato, peas, apples, strawberry, avocado, citrus, coffee, cacao, tea, coconut, rubber tree, sugar, maple and so on. The economic importance can, therefore, never be overemphasized.

An important feature of VA mycorrhizas is the formation by the fungus of two characteristic organs in the root cortex (Figure 10.5): **arbuscules** (dichotomously branched, bush-like haustoria), and **vesicles**, formed intra, and intercellularly.

Some **external hyphae** extend into the soil up to a distance of about 1cm around the roots. Sometimes, these external hyphae grow closely appressed to the root surface but they never form a mantle. The roots do not show any morphological changes.

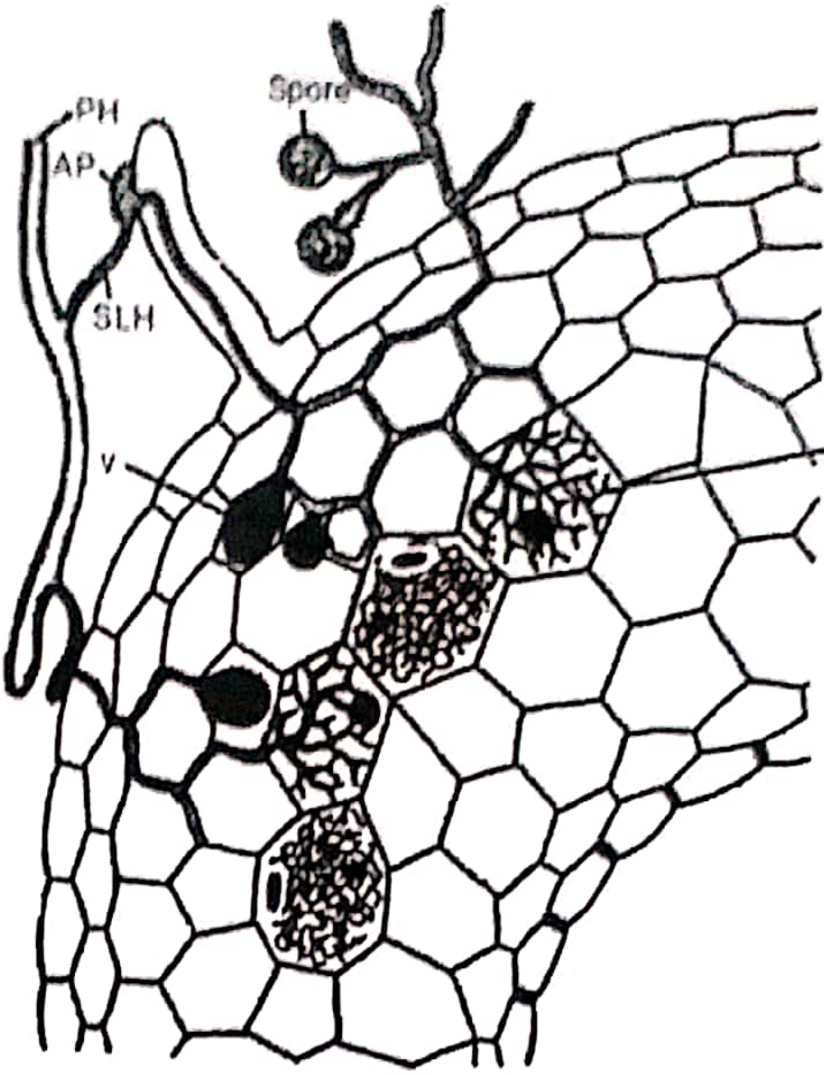

Fig. 10.5: T.S. of a Vesicular-Arbuscular mycorrhiza. (A. arbuscules, A.P. appresorium, PH. permanent hyphae, SLH. short-lived hyphae, V. vesicle).

The external hyphae. These are characteristically dimorphic and are composed of 1) 'thick-walled' or 'permanent hyphae' (20–30 μm wide), and 2) 'thin walled' or 'short-lived' hyphae' (2–7 μm wide), which arise as lateral branches of the former. The external hyphae bear various kinds of spores, auxillary cells and sporocarps in the soil. The hyphae form appresoria at the site of penetration of the root (i.e., on root hair or epiblema cells). The fungus invades the cortex but never encroaches upon the endodermis, stele or meristem.

Arbuscules. Shortly after infection, the hyphae form arbuscules, the dichotomously branched, bush-like haustoria in the cortical cells. These are later digested by the host cells. First, the tips are eroded and soon the entire arbuscule is degraded and digested. The host nucleus responds to the formation of arbuscules by swelling in size with the degradation of the arbuscules.

Vesicles. These are spherical or oval, thick-walled structures formed terminally in the intercellular spaces or occasionally in the cortical cells.

These contain fat granules and serve as storage organs. In old mycorrhizal roots, the vesicles are produced in enormous numbers which completely obliterate the cortex cells. The roots, in extreme cases, may also get deformed.

The Fungi

There are six genera that form the VA mycorrhiza, and all belong to the order *Glomales* (formerly *Endogonales*) of class *Zygomycetes*. The six genera fall in 3 families (2 in each).

family *Glomaceae*	:	*Glomus, Sclerocystis*
family *Acaulosporaceae*	:	*Acaulospora, Entrophospora*
family *Gigasporaceae*	:	*Gigaspora, Scutellospora*

While the four genera belonging to *Glomaceae* and *Acaulosporaceae* form both arbuscules and vesicles, the two genera under *Gigasporaceae* (*Gigaspora* and *Scutellospora*) form only arbuscules (and not vesicles). The genera are identified on the basis of formation of chlamydospores, auxillary cells, spores and sporocarps (Figure 10.6).

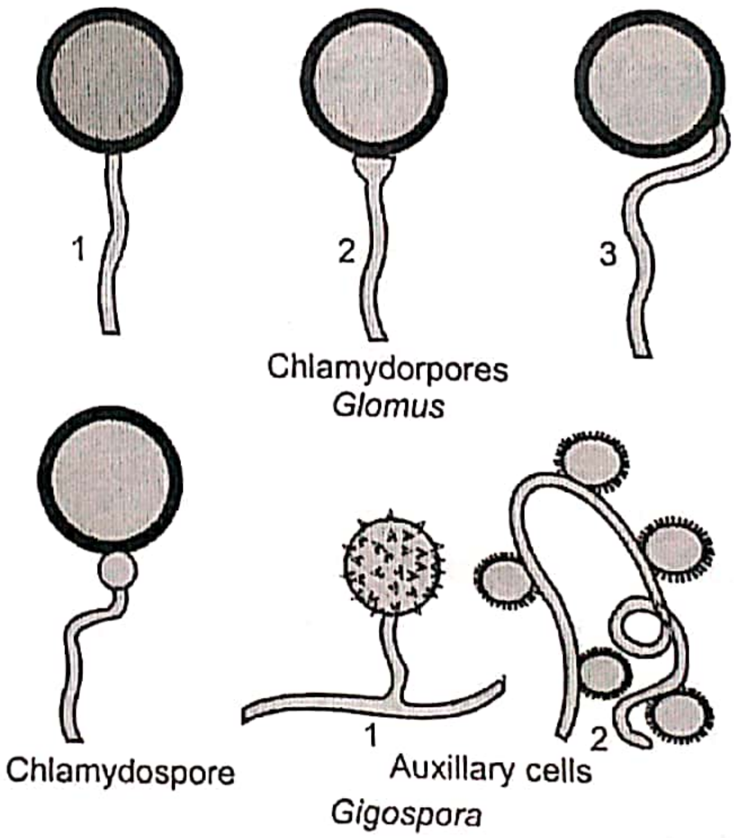

Fig. 10.6: *Glomus*, chlamydospores of 3 types, based on subtending hypha (straight 1, funnel-shaped 2, recurved 3). *Gigaspora*, chlamydospore with bulbous suspensor held in vertical position, and 2 types of auxiliary cells: papillate 1, and echinulate 2.

ECTENDOTROPHIC MYCORRHIZAS

Mycorrhizas sharing characteristics of both ecto-and endotrophic mycorrhizas are called **ectendotrophic**. The fungus forms a hyphal mantle and **Hartig net**, as do the ectotrophic mycorrhiza, and also establish haustoria and hyphal coils in the epidermal and cortical cells, like the endotrophic mycorrhizas. The external hyphae deliver organic compounds absorbed from the humus to the root cells.

One of the best studied examples of ectendotrophic mycorrhizas is the mycorrhiza of *Monotropa indica*, the Indian pipe (Figure 10.7). It is a non-chlorophyllous plant which grows on forest floors under *Fagus*, *Pinus*, *Quercus*, *Carpinus*, *Salex*, and other trees. Earlier *M. indica* was thought to be a root parasite of these trees but now, it is known for sure that *Monotropa* and the associated tree are connected by a common mycorrhizal fungus, *Boletus*. The fungus forms ectendotrophic mycorrhiza with *Monotropa* and ectotropic mycorrhiza with the trees. **Bjorkman** (1960) by using tracer carbon technique, proved that the common mycorrhizal fungus conducts nutrients from forest trees to *Monotropa*. If labelled sugars or 32 P–phosphate are introduced into the phloem of the trees, some of them find their way into the fungus, and from there into *Monotropa*. The *Monotropa* symbiosis is, thus, a three-tier system, involving chlorophyllous and non-chlorophyllous symbionts and a **fungal bridge** connecting the two.

Importance of Mycorrhiza:

Mycorrhizal fungi allow plants to draw more nutrients and water from the soil. They also increase plant tolerance to different environmental stresses. Moreover, these fungi play a major role in soil aggregation process and stimulate microbial activity. According to the plant species and to the growing practices and conditions, mycorrhizae provide different benefits to the plants and to the environment:

- Produce more vigorous and healthy plants
- Increase plant establishment and survival at seeding or transplanting
- Increase yields and crop quality
- Improve drought tolerance, allowing watering reduction
- Enhance flowering and fruiting
- Optimize fertilizers use, especially phosphorus
- Increase tolerance to soil salinity
- Reduce disease occurrence
- Contribute to maintain soil quality and nutrient cycling
- Contribute to control soil erosion

➢ Reduced nutritional deficiencies:

Endomycorrhizae mine out the growing medium to efficiently bring nutrients (particularly phosphorus, copper, manganese and zinc) to the plant where plant roots are not present. This delays nutrient deficiencies and their visual symptoms from appearing.

➢ Potential reduction in fertilizer use:

Since endomycorrhizae mine out the growing medium for fertilizer elements, it is possible to reduce fertilizer application rates.

➢ Delayed wilting:

Endomycorrhizae acquire water from the growing medium where plant roots may not access it, which delays wilting from water stress.

➢ Improved growth:

Efficient acquisition of nutrients helps the plant maintain its optimal growing rate longer, so top growth and root growth are not compromised.

➢ Resistance to salt toxicity:

Endomycorrhizae fungi have been found to protect plants from high salt and micronutrient toxicities.

➢ Reduced root disease attack:

Endomycorrhizal fungi help to reduce the effects of stress on plants, making them less susceptible to attack by root rot pathogens. Not only do endomycorrhizae serve as competition to root rot pathogens by being present on plant roots and consuming root exudates (such as carbohydrates), but they cause the cell walls of the cortex to thicken, making pathogen penetration more difficult.

➢ Increased fruit and flowers:

Since plants grow at their optimum rate with endomycorrhizae as a result of reduced stress effects, edibles have the ability and resources to produce more vegetables/fruit per plant and or larger vegetables/fruit. Flowering plants often produce more flowers. Overall plants are often larger when grown with endomycorrhizal fungi, especially if plants are grown in poor quality, low fertility soils.