Cotton (*Gossypium herbaceum* L.) belonging to the family Malvacae is one of the important fibre crop of global significance, which is cultivated in tropical and sub-tropical regions of more than seventy countries of the world. It is known as ‘King of Fibres’. The major producers of cotton are China, India, USA, Pakistan, Uzbekistan, Argentina, Australia, Greece, Brazil, Mexico, and Turkey. These countries contribute about 85% to the global cotton production. India has the largest acreage (10.33 m. ha) under cotton at global level and has the productivity of 486 kg Lint /ha and ranks second in production 295 lakh bales (5.02 m MT) after China during 2009-10. Cotton plays a key role in the National economy in terms of generation of direct and indirect employment in the Agricultural and Industrial sectors (http:/www.cicr.org).

Cotton is a natural vegetable fibre of great economic importance as a raw material for cloth. Its widespread use is largely due to the ease with which its fibres are spun into yarns. Cotton's strength, absorbency, and capacity to be washed and dyed also make it adaptable to a considerable variety of textile products. Besides being a major natural fibre crop, cotton also provides edible oil and seed by-products for livestock food. Cottonseed oil is a vegetable oil ranking fifth in world use among edible oils (accounting for about 4% of world consumption of vegetable oil). The cotton seed meal is usually used as roughage in the diet of cattle for its high protein and energetic value.

About fifty species of cotton plants is known within the world of these only four are domestically cultivated for their fibres. The most commonly cultivated species of cotton in the world include *Gossypium hirsutum* and *G. barbadense* (also referred to as "New World" species), *G. herbaceum*, *G. hirsutum* originated in Mexico. It is the most important agricultural cotton, accounting for more than 90% of world fibre production. *Gossypium barbadense*, of Peruvian origin, accounts for about 5% of world fibre. It includes cotton fibres of the highest quality, such as the Jumel variety (from the Barbados), among the finest cotton in terms of quality and fibre length.

History

The genus *Gossypium* has a long history of taxonomic and evolutionary study. Our taxonomic understanding of the cotton tribe developed from more than a century of study involving traditional taxonomic methods as well as modern tools such as comparative analysis of DNA sequences. Speculation regarding the time and place of origin of *Gossypium* has a long history (Hutchinson *et al.,* 1947; Saunders, 1961; Fryxell, 1965; Edwards *et al.,* 1974; Valiček, 1978).

The place of origin of the genus *Gossypium* is not known, however the primary centers of diversity are west-central and southern Mexico (18 species), north-east Africa and Arabia (14 species) and Australia (17 species). DNA sequence data from the existing *Gossypium* species suggests that the genus arose about 10-20 million years ago (Wendel and Albert 1992; Seelanan *et al*., 1999). The antiquity of cotton in the Indian subcontinent has been traced to the 4th millennium BC (Santhanam and Sundaran, 1997). The first reference to cotton is found in Rig Veda hymn (Khadi and Kulkarni, 2001). Most commercially cultivated cotton is derived from two species, *G. hirsutum* (Upland cotton, 90% of world plantings) and *G. barbadense* (Pima, or Long-staple cotton). Two other species, *G. arboreum* and *G. herbaceum*, are indigenous to Asia and Africa and are popularly referred as desi cottons in India.

India is the only country in the world where all the four cultivated species of cotton, viz. *G.hirsutum, G.arboreum, G.herbaceum* and *G.barbadense,* are cultivated on commercial scale, besides their hybrid combinations. The diversity of cotton cultivars and cotton agroclimatic zones in India is considerably larger as compared to other major cotton growing countries in the world.

Asiatic Cotton (*Gossypium arboreum, Gossypium herbaceum)*

India, China and the near east are the places which are the growers of this kind of cotton. It has coarse and harsh fibres and thus, is suitable for manufacturing products like blankets, filters, coarse clothes, padding materials and the like.

Under the rain fed growing conditions rainfall ranges from <400 to > 900 mm coupled with aberrant precipitation patterns over the years leading to large-scale fluctuations in production. In the irrigated tract canal and well irrigation is practiced including the use of micro-irrigation system.

The cultivated *G. herbaceum* was derived from the truly wild form of the diploid, *G. herbaceum* race *africanum* which has distribution in South Africa. It has been assumed that traders sailing between Mozambique and Western India introduced this wild form of *G. herbaceum* into Southern Arabia, where the first domestication in the Old World cotton took place. From here, the spread of the species led to the development of new races (Biology of cotton: www.dbtbiosafety.nic.in).

G. herbaceum is known primarily as a crop plant (grown from Ethiopia to Western India), with the exception of an endemic form from southern Africa, *G. herbaceum* sp. *africanum*. This morphologically distinct entity, which occurs in regions far removed from historical or present diploid cotton cultivation, has a unique ecological status in that it is fully established in natural vegetation in open forests and grasslands. Its small fruit, thick, impervious seed coats, sparse lint, and absence of sympatric cultivated *G. herbaceum* suggest that *G. herbaceum* sp. *africanum* is a wild plant. Consistent with the expectation that the site of original domestication lies within the range of the wild progenitors, this is generally accepted as the source of the original *G. herbaceum* cultigens (Hutchinson, 1954). The most agronomically primitive *G. herbaceum* cultivars, the perennial race *acerifolium* forms, are distributed along the coasts boarding the Indian Ocean trade routes. This suggests that the primary dispersion involved the diffusion of *G. herbaceum* northward into northern Africa, Arabia and Persia. Hutchinson (1954) suggests that secondary agronomic development and diffusion led to expansion into western Africa and the development of annualized forms in more northerly temperate climates. The agronomic success of the annualized *G. herbaceum* races fostered a later dispersal into peninsular India that replaced perennial *G. arboreum* cultigens (Wendel *et al.,* 2010).

Cotton Cultivation in India

There has been a significant enhancement in production from 2004-05 onwards as compared to the earlier years (from 17.7 m bales in 2003-04 to nearly 29.5 m bales in 2009-10). Adoption of improved technologies IPM, IRM, new chemistry (including Bt cotton) coupled with favourable weather and low insect pest pressure in major cotton growing tracts has enabled this transformation in production and productivity. Punjab and Gujarat states recorded much higher productivity than national average and contributed to a large measure in enhancing productivity and production at the national level. The average national productivity showed a remarkable spurt from nearly 309 kg lint/ha (2001-02) to 560 kg lint per ha in 2007-08 and 486 kg lint/ha in 2009-10. A trend of continuous improvement is quite clear from 2002-03 onwards(Biology of cotton: www.dbtbiosafety.nic.in).

Bt cotton

Advancement of biotechnological tools and genetic engineering paved the way for development of transgenic cotton (Boll guard), which offers great promise in the control of bollworms. The commercial cultivation of such transgenic cotton conferring pest resistance began during 1996.

Bt cotton, which confers resistance to Lepidopteron pests of cotton, was first adopted in India as hybrid in 2002 after stringent assessment for bio-safety and profitability. In India, after extensive testing of Bt cotton hybrids (with Cry1 Ac gene) in All India Coordinated Cotton Improvement Project (AICCIP) and farmers field, Government of India has approved commercial cultivation of Bt cotton hybrid with effect from 2002 crop season. The transgenic hybrids released in the country can be categorized in different ways on the basis of transgene involved. They can be categorized into two groups *viz*., (i) Bollgard I (single gene) and (ii) Bollgard II (double gene).

Bt Cotton is a genetically engineered form of natural cotton. The main advantage of utilizing biotechnology in agriculture are the possibilities of increase in productivity through the use of newer varieties that possess properties such as resistance to pests, diseases, and other stressful conditions like drought, salinity, or water logging. Of these measures, imparting the property of insect (specific) resistance through the transfer of a gene from *Bacillus thuringiensis* Berliner (Bt) into target plants by modern biotech methods is presently considered to be one of the most advanced applications of biotechnology.

Bt or *Bacillus thuringiensis* is a gram positive, ubiquitous soil bacterium first discovered in 1901 by Ishiwata, a Japanese Microbiologist (Kumar *et al.*, 1996). Later it was found that some Bt strains (Cry+) were highly toxic to larvae of certain insect species which are also plant pests. Bt was first sold as a spray formulation in 1938 in France for the management of European corn borer. Subsequent research has revealed that Bt carries proteinaceous crystals that cause mortality in those insects which carry receptor proteins in gut membranes that bind to Bt proteins. Other organisms that do not contain receptors to Bt proteins are not affected by the toxin. The advent of genetic transformation technology made it possible to incorporate cry genes and thus the ability to produce Bt proteins in plant cells so that target insect larvae infesting the crop plants are effectively killed. The first Bt crops *viz.,* Bt cotton, Bt corn and Bt potato were commercialized in USA in 1996. Bt crops are currently cultivated in 23 countries over an area of 46 mha (James, 2008).

Agro climatic conditions

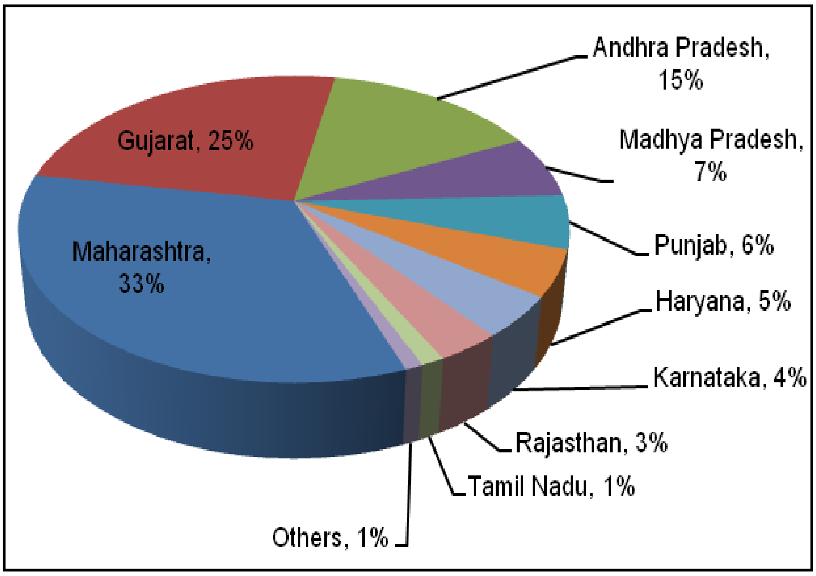
Cotton requires a daily minimum temperature of 16°C for germination and 21°C to 27°C for proper crop growth. During the fruiting phase, the day temperature ranging from 27°C to 32°C and cool nights are needed. The sowing season of cotton varies considerably from tract to tract and is generally early (April-May) in northern India where it is mostly irrigated. It is delayed on proceeding to down south. It is cultivated largely under rainfed or dryland conditions. An annual rainfall of atleast 50 cm distributed through-out the growing season is required for good yield. It is mainly raised during tropical monsoon season, although in southern India it is cultivated during late-monsoon season in winter.

Cotton is successfully grown on all soils except sandy, saline or water logged types. It is grown in well drained deep alluvial soils in the north to black clayey soils of varying depth in central zone and in the black and mixed black and red soils in south zone. It is moderately tolerant to salinity and is sensitive to water logging as well as frost and chilling temperature in winter.

Zonal Distribution

Cotton is grown in India in three distinct agro-ecological zones *viz*., north zone (Punjab, Haryana, Rajasthan and Western Uttar Pradesh), central zone (Gujarat, Madhya Pradesh, Maharashtra and Orissa) and south zone (Karnataka, Andhra Pradesh and Tamil Nadu). The northern zone is totally irrigated, while the percentage of irrigated area in the central and southern zones is much lower, the lowest being in the central zone which has nearly 60% of cotton area. It is also grown in small area in the eastern region in Sundarbans of West Bengal and in north-eastern states. Nearly 60% of cotton area is accounted by Central zone even though the irrigation source and potential are very much limited in central zone, ideal temperatures and ample sunshine during growth and maturity periods and the extended moderately cool, rain free dry weather prevailing during October to February are favourable for obtaining higher yields.

Fig 1. Pie chart showing state wise cotton acreage in India



Source: (www.dbtbiosafety.nic.in).

Table showing list of Bt cotton varieties grown in Gujarat

Sr. No.	Variety	Company Name
1	MECH 12 Bt*	M/s Mahyco
2	MECH 162 Bt*	M/s Mahyco
3	MECH 184 Bt*	M/s Mahyco
4	RCH 2 Bt	M/s Rasi Seeds Ltd
5	NCS –207 Mallika Bt	M/s Nuziveedu Seeds Ltd
6	NCS –145 Bunny Bt	M/s Nuziveedu Seeds Ltd
7	RCH –144 Bt	M/s Rasi Seeds Ltd
8	RCH –118 Bt	M/s Rasi Seeds Ltd
9	RCH -138 Bt	M/s Rasi Seeds Ltd
10	RCH –20 Bt	M/s Rasi Seeds Ltd
11	Ankur –651 Bt	M/s Ankur Seeds Ltd
12	Ankur – 09	M/s Ankur Seeds Ltd
13	RCH 377 Bt	M/s Rasi Seeds Ltd
14	GK 205 Bt	M/s Ganga Kaveri Seeds PvtLtd
15	GK 205 Bt	M/s Ganga Kaveri Seeds PvtLtd
16	KDCHH 9632 Bt	M/s Krishidhan Seeds Pvt Ltd
17	KDCHH 9821 Bt	M/s Krishidhan Seeds Pvt Ltd
18	ACH-33-1 Bt	M/s Ajeet Seeds Ltd
19	ACH-155-1	M/s Ajeet Seeds Ltd
20	Tulasi 4 Bt	M/s Tulasi Seeds Pvt Ltd
21	ACH-11-2 BG II	M/s Ajeet Seeds Ltd
22	JK Varun Bt	M/s JKAgri Genetics Seeds Ltd
23	Ankur 2226 BG	M/s Ankur Seeds Ltd
24	Sigma Bt	M/s Vibha Agrotech Ltd
25	VBCH-1010 Bt	M/s Vibha Seeds (P) Ltd
26	SP 504BI (Dhanno) Bt	M/s Proagro Seeds Co (P) Ltd
27	VICH-15 Bt cotton	M/s Vikram Seeds Ltd
28	322 Bt cotton	M/s Bioseeds Research India Pvt Ltd
29	NCHB-992	M/s Nuziveedu Seeds Pvt Ltd
30	Ajeet 155 BG II	M/s Ajeet Seeds Ltd
31	RCH-515 BG II	M/s Rasi Seeds (P) Ltd
32	JK Durga Bt	M/s J K Agri Genetics Ltd
33	Atal BG II	M/s Monsanto Genetics Pvt Ltd
34	Paras Lakshmi BG II	M/s Monsanto Genetics Pvt Ltd
35	Sarju BG	M/s Solar Agrotech Pvt Ltd

Table showing different parameters of cotton production in Gujarat (2008-2012)

Sr. No.	Parameters	2008-09	2009-10	2010-11	2011-12
1	Cotton area (lakh ha)	23.54	26.25	26.33	30.23
2	Cotton production (lakh bales)	90.00	98.00	103.00	114.00
3	Cotton productivity (kg/ha)	650	634	685	659

Source: www.cicr.org.in

Economic Importance of Cotton

The bulk of cotton production is consumed in the manufacture of woven goods, alone or in combination with other fibers. Cotton constitutes of one of the basic raw materials for cellulose industries including plastics, rayon and explosives. Sterilized absorbent cotton finds use in medical and surgical practice.

Cotton waste is a by-product of the spinning and weaving mills and consists principally of short fibres rejected by combing and carding machines. The amount of waste given by cotton is an important factor in its quality evaluation. Cotton waste of good grade is employed in making cotton blankets, sheets, towels and flannelettes. The stalks of the plant contain a fibre that can be used in paper making or for fuel, and the roots possess a crude drug. The seeds are of the greatest importance as oil is utilized. The hulls are used for stock feed; as fertilizer; for lining oil wells; as a source of xylose, a sugar that can be converted into alcohol and for many other purposes. The kernels yield one of the most important fatty oils, cottonseed oil and an oil cake and meal, which are use for fertilizer, stock feed, flour and as a dyestuff.

➢ Cotton Pests and Diseases

Cotton pests

Cotton insects are the principal cause of yield losses. Estimates indicate that the yield losses due to insect infections would amount to almost 15% of world annual production.

More than 1300 different species of insect pests attack the crop. Among the most common and endogenous species found in cotton fields are:

• **The pink bollworm** (*Pectinophora gossypiella* Saunders) was first described in 1843 by W.W. Saunders as *Depressaria gossypiella*, from specimens found to be damaging cotton in India in 1842. The pink worm withdraws nutrients from the inside of the cottonseed and may cause serious yield losses. Although the most sever infestations have occurred in Africa and India, the pink bollworm has been recorded in nearly all cotton-producing countries and is a key pest in many of these areas. Infestations may be reduced by the heating of cottonseeds at about 55°C, as well as by other management tactics, including plantation treatment and destruction of the infested crop.

• **The boll weevil** (*Anthonomus grandis* Boheman), also known as bollworm, is most common in American cotton plantations.

• The Egyptian (spiny) bollworm (*Earias insulana* Boisduval) and the red bollworm (*Diparopsis castanea* Hmp.) feed on the developing cotton bolls.

• **Cotton stainers** (*Dysdercus superstitious* Fabr.) attack maturing cotton bolls and seeds. They may cause the staining of the lint. In addition, feeding wounds may allow the entry to the boll of saprophytic fungi (organisms which draw nutrients from the host, but do not harm it, contrary to parasites).

• Other insect pests of cotton, such as the white flies (*Bemisia gossypiella* Saund.), may adversely affect lint quality and yield potential. They suck sap from leaves and pose the most serious threat in India and Africa.

• **The cotton aphid** (*Aphis gossypii* Glover), also known as the melon aphid, infests the cotton seedlings. Cotton aphids are among the most injuring insects found in cotton. They suck sap from leaves and secret honeydew on the undersides of leaves. Honeydew secretions may burn the leaves and interfere with photosynthesis. In addition, aphid is a vector of viruses and a carrier of other insects. In Africa, aphid infestations are among the most injuring insect pests in terms of economic yield lost.

• Nematodes: Nematodes or round worms are a diverse group of animanls belonging to the phylum Nematoda inhibiting a very broad range of environments. They are found in almost all habitats. There are approximately 128 species of nematodes associated with cotton. Five parasitic forms pose the most serious threat to the crop, including the *Meloidogyne incognita* Goldi (or root knot nematode) and the *Rotylenchulus reniformis* Lindford and Oliveria (or reniform nematode). These two species can become serious pests (in the United States, particularly in the State of Virginia, they accounted for 99% of the damage caused by cotton parasitic nematodes). These parasites live in the soil (the root knot nematode favours rough and arenaceous soil) and withdraw nutrients from the plant roots. Symptom patterns associated with nematodes include stunting, potassic deficiency or early maturity. Nematodes can reduce yields (in Alabama, United States, yield losses are estimated to average 10% or 20%, but can peak to 50% in arenaceous dry soil). In addition, depending upon the stage of development of the infested crop, they can hamper the quality of cotton. Root knot nematodes do produce plant damage symptoms that are rather easy to recognise, such as the yellowing or whitening of normally green plant tissue because of a decreased amount of chlorophyll.

Damage symptoms caused by other kinds of nematodes (for example, the reniform nematode) are more difficult to detect, since they are generally small and sparse. Besides the direct damage, nematodes are also an important factor in the incidence of *Fusarium* and other wilts of cotton. Nematodes may be controlled by cultural practices, such as crop rotations, soil tilling, and use of resistant varieties, or by chemical treatment through nematicides. The two types of nematodes seldom coexist in the same fields.

- **Bacterial and Fungal diseases in the cotton plant**

  - **Bacterial blight of cotton**

Also called angular leaf spot (*Xanthomonas malvacearum (*E.F. Smith) Dowson) is favoured by wet weather conditions (temperature above 25°C and relative humidity exceeding 85%). Disease incidence is higher in plants with injured tissues (due to insect pests or cold temperatures). The disease causes stunting and yellowing of the leaves (mainly lower leaves). As diseases progresses, it may result in defoliation. Affected bolls are smaller than normal and exhibit small black spots on their surface. Bolls may fail to open or produce bad quality lint.

Use of copper oxychloride and streptomycin sulphate has been suggested against the disease Singh *et al*., (2010) suggested use of fungicides against foliar pathogens.

  - **Boll rots** (*Diplodia gossypina* Berk and M.A. Curtis, *Colletotrichum* spp., *Fusarium* spp.)

Attacks lower bolls near maturity. Warm, humid conditions favour the disease. Affected bolls are dark brown, with a white to salmon-pink overgrowth. The fungus is capable of giving a brownish tint to the lint. This disease is a stress-related one, in the sense that it infects plants that have been previously damaged by insect pests.

- **Verticillium wilt of cotton**

The *Verticillium dahlia* Kleb, a common soil inhabitant, penetrates though roots and grows up along the stem tissue. Cooler temperatures, excessive soil moisture and excessive soil nitrogen levels favour the fungus. Symptoms first appear on the lower leaves, which turn yellow. Larger plants are stunted (as diseases progresses, defoliation may occur), whereas younger seedlings may die.

Management strategies include proper management of irrigation and the selection of resistant varieties. Under conditions favorable to the development of the disease, yield reductions of up to 30% are possible. Seedling diseases (fungi *Rhizoctonia solani*, *Pythium* spp.) may result in to seed and root rott. In the case of *Rhizoctonia solani*, girdling of the stem at ground level is observed. *Pythium spp.* is characterized by the similar symptom patterns, with a water soaked lesion at the soil line.

- **Fusarium wilts** (*Fusarium oxysporum f. sp. . vasinfectum*)

Wet weather conditions (temperature above 23°C and relative humidity exceeding 85%) are particularly conducive for disease development. Disease incidence can be higher in plants with injured tissues (for example, plants damaged by nematodes). The disease can affect plants at any stage during the season. The vascular tissue of infected plants exhibits a brown/chocolate discoloration through the main stem. Infected water-conducting stem tissues become inactive, causing wilted foliage. Plant death, wilting, yellowing and defoliation are typical of disease symptoms. Leaves turn yellow between veins and eventually shed to leave bare stems. Once the fungus has colonized the plant (diagnosis is confirmed by splitting the stem to reveal dark brown), it most likely causes the death of the host. There is no commercially viable way to eradicate the disease once established (apart from soil fumigation, which is excessively expensive).

The impact of the disease may nonetheless be reduced by the use of varieties with high levels of resistance *to Fusarium* wilt, or by avoiding crop stresses such as over-irrigation and over-application of nitrogen. *Fusarium* wilt is now an important constraint to sustainable cotton production, especially in Australia.

Fusarium wilt of cotton, caused by *F. oxysporum f sp.vasinfectum*, was first recognized in Australia in 1993. It is a soil-inhabiting fungus that invades cotton plants via the roots and causes a blockage of the water conducting tissues resulting in wilting and eventual death of affected plants. The pathogen can also be seed borne.

SYMPTOMS

External: Growth is stunted and leaves initially appear dull and wilted, before yellowing or browning progresses to eventual death from the top of the plant. Some affected plants may re-shoot from the base of the stem. External symptoms can appear in the crop at any stage but most commonly become apparent in the seedling phase when the plants begin to develop true leaves and after flowering when the bolls are filling.

Internal: Lengthwise cutting of the stem of an affected plant will reveal continuous brown discolouration of the stem running from the main root up into the stem. The internal discolouration is similar to that of Verticillium wilt but usually appears as continuous browning rather than flecking in the stem tissue. The severity of external symptoms does not always reflect the degree of internal discolouration that might be seen when the plant is cut open. Often the discolouration might only be visible up one side of the plant. Symptoms can appear as only a few individual plants or as a small patch, often but not always in the tail drain or low-lying (waterlogged) areas of a field.

Other Fungal Diseases

Of all diseases known to occur in cotton, cotton root rot (*Phymatotrichum omnivorum* (Duggar) Hennebert) is one of the most destructive and difficult to control. The fungus lives in alkaline soils low in organic matter. It occurs only at elevations below 1500m. The fungus has unique biological characteristics that contribute to management difficulties. Fungus *P. omnivorum* has a remarkably wide host range, although it attacks only mature plants and does not easily spread from field to field. Second, the fungus survives for long periods in the soil (much of the fungus is found as deep as 60cm to 2m in soils). This explains why fungicides are not effective treatment. The fungus is only active when air and soil temperatures are high (respectively above 40°C and 27°C). When environmental conditions are conducive to its development, the fungus invades the plants through the root system. Infected plants can die in two weeks. The first disease symptom is slight yellowing of the leaves, which then quickly turn to a bronze colour and begin to wilt.

List of Fungi already reported from *G. herbaceum* includes (Bilgrami *et al.*, 1981)

Chaetomium spiralotrichum Lodha.
Colletotrichum sp.
Helminthosporium gossypii Tucker
Myrothecium roridum Tode.
Sclerotium rolfsii Sacc.
Trichothecium roseum (Pers.)Link
Verticillium alboatrum var dahliae Reinke and Berthold.

Soil forms a rich and dynamic medium for all microorganisms. Soil being a complex ecosystem, is composed of multiple, minute habitat and harbours almost all major taxonomic groups of fungi. Considering all living forms, the diversity of soil microorganisms in general is more extensive than any other environment in the world. It has been found that more number of genera and species of fungi exists in soil than any other environment, as soil is exposed to various conditions and basically receives all microorganisms present on this plane (Stotzky, 1997). Along with the bacteria, actinomycetes and algae , fungi are primary decomposers ; agents of biogeochemical transforms and recyclers of stored energy and nutrients of the organic matter already degraded by invertebrates and other microbes for plant growth. Fungi occur in soil either in mycelia state or reproductive stage (Nagamani *et al.,* 2006).

- **Rhizosphere Mycoflora**

The rhizosphere may be defined as that portion of the soil which is adjacent to the root system of a plant and is influenced by the root exudates. The area of this zone depends on the soil type and host plant under study and soil environment conditions. The roots exert influences on various type of microorganisms. The stimulatory effect on microorganisms is known as the "Rhizosphere effect" as indicated by the interaction of soil and rhizosphere microbes and their ratio. The chemical and physical nature of the root zone is quite different from the soil away from the root zone and the biology of this complex zone has been studied extensively. The term 'Rhizosphere' was proposed by Hiltner (1904). The phenomenon of accumulation of microorganisms around the root zone was reported by a number of earlier workers (Agnihothrudu 1955; Starkey 1958; Rouatt 1959; Katznelson 1946). Various compounds such as amino acids, vitamins, sugars, tannins etc. are exuded by the roots. Some root exudates are also known to affect certain microbial species adversely leading to their decrease in the root zone and, in return, microorganisms are known to exert profound influence on the plant itself by decomposition, affecting nutrient uptake, antagonistic effect on other microbes and by parasitism.

Interestingly different types of microbes like fungi, bacteria, nematodes and viruses may interact with the same plant simultaneously either independently, synergistically or antagonistically. Factors such as soil type, soil moisture, pH, temperature, plant age, relative humidity and several other factors are known to influence the rhizosphere effect.

According to Pinton *et al.* (2001), rhizosphere represents a poorly defined zone of soil with a microbiological gradient in which maximum changes in the population of microflora in soil is evident adjacent to root and decline with distance away from it (Newman 1978; Bowen and Rovira 1991). Root exudates stimulate microbial activity selectively in rhizosphere and rhizoplane regions (Bansal and Mukerji 1994). There is an intense competitive activity by the obligate saprobes, unspecialized root parasites and root inhabiting fungi depending on their behaviour towards exudates. In case of root diseases the pathogen has to react with the rhizosphere and rhizoplane fungi before entering the root tissues. These may show antagonism and check its advancement. Plant microbe interaction is a regular and continuous feature of the biological world. The beneficial fallouts of such interactions have been extensively exploited for economic gain in recent years.

The term ‘rhizoplane’ was proposed by Clark (1949) to refer to the immediate surface of plant roots together with any closely adhering particles of soil or debris. Using different isolation techniques microorganisms have been isolated and identified by a number of Mycologists.

Fungi are very large and diverse group of organisms which have a unique lifestyle. They have worldwide distribution and successfully exploit many different habitats. They are extremely variable in form and versatile in the ways they solve the problems posed by the environments they inhabit (Susan, 1992). Fungi are ubiquitous; some having beneficial effects on plants, while others may be detrimental (Anderson and Cairney, 2004; Ipsilantis and Sylvia, 2007).

Micro organisms are beneficial in increasing the soil fertility and plant growth as they are involved in several biochemical transformation and mineralization activities in soil. Type of cultivation and crop management practices found to have greater influence on the activity of soil microflora (Mc Gill *et al.,* 1980).

The relationship between biodiversity of soil fungi and ecosystem function is an issue of paramount importance; particularly in the face of global climate change and human alteration of ecosystem processes. Fungi are the important component of the soil micro biota typically constituting more of the soil biomass than bacteria, depending on soil depth and nutrient conditions (Ainsworth and Bisby, 1995, Saravanakumar and Kaviyarasan 2010). Soil is an important panorama of interactions between microbes and plants (Shekh *et al.,* 2012). It is one of the most important habitats for filamentous fungi are major contributors to soil biomass (Pandey *et al.,* 2013).

The term rhizosphere was first introduced by a German microbiologist, L. Hiltner (1904). It is describe the zone of metabolically active soil which contains higher microbial community that surrounds and is influenced by the roots of plants (Mishra, 1967; Chamle *et al.,* 2011). Microbial population size and community structure are sensitive to changes in chemical properties of the surrounding soil (Pansombat *et al.,* 1997; Tokuda and Hayatsu, 2002).

Microbial communities, particularly bacteria and fungi constitute an essential component of biological characteristics in soil ecosystems. It has been estimated that 1.5 million fungal species are present in natural ecosystems, but only 5 –10% have been described formally (Hawksworth 2001). Schmit and Mueller (2007) estimated that there is a minimum of 7, 12,000 fungal species worldwide. The actual number of fungi is still unknown; however, only 5-13 % of the total estimated global fungal species have been described (Wang *et al.* 2008). Research on fungal diversity provides a basis for estimating the functional role of fungi in ecosystems.

One of the most important factors responsible for the growth of microorganisms is organic substances exuded by roots i.e. root exudates (Liljeroth and Baath, 1988). The exudates include simple sugars, amino acids, organic acids, vitamins and many other compounds (Singleton and Sainsbury, 1991; Klein, 1992). The influence of exudates upon rhizosphere microorganisms varies with plant age as well as plant type (Abdel-Rahim *et al.,* 1983; Oyeyiola 2009). However soil factors, such as moisture influences the amount of exudation and hence colonization of the roots (Whipps and Lynch, 1986). The organisms inhabiting soil includes microalgae, fungi, bacteria, actinomycetes, protozoa etc (Garrett, 1981). They carry out numerous transformations as a part of their normal activities like addition of organic matter, nitrogen fixation, solubilization and immobilization of several nutrients (Katayama *et al.,* 1998; Lal, 1998; Muller *et al.,* 1998; Brady and Weil, 1999).

The fungi responsible primarily for the decomposition of organic compounds (Paul and Clark, 1989) actively participate in processes related to biodeterioration and biodegradation (Allsop and Seal, 1986; Eggins and Allsopp, 1975; Molin and Molin, 1997; Trevors, 1998; Wall and Virginia, 1999) and also influence above- ground ecosystem by contributing to soil fertility (Yao *et. al.,* 2000; O'Donnell, 2001; Van der Heijden, 1998; Cairney,2000; Klironomos *et.al.,* 2000; Ovreas, 2000).

Besides this soil type, macro and micronutrients may also adversely affect the mycoflora (Rama Rao, 1957). The plant type, age and soil type have a significant influence the nature and number of mycoflora. (Wahegaonkar 2009; Namdas and Bhosale, 2009; Abdul-Hafez, 1982). Most rhizosphere fungi are highly dependent on association with plants that are regulated by root exudates (Bais, 2004).

The rate of biodegradation depends on environmental factors, numbers and types of microorganisms present and the enzymatic processes leading to the disappearance of the parent molecular structure and the formation of smaller organic species (Sharma and Raju 2013).

Soil micro-organism has the capacity to detoxify and inactivate pesticide present in the soil (Hill *et al.,* 1995). The micro-organisms present in soil depend on many environmental factors such as the amount and type of nutrients, moisture, degree of aeration pH and temperature etc. The main focus of the study is to isolate mycoflora from different agricultural fields and to observe the percentage contribution of different fungal species

Soil bore plant pathogenic fungi a major economic loss, which is a major problem among the agricultural community. Nowadays the diseases are managed with the application of chemical pesticides. Use of chemical pesticides causes environmental problem, as they don't undergo biodegradation. So minimizing the application of pesticides has become order of the day. To achieve this goal the biological control methods can be effectively used along with other methods of disease control. Antagonistic interactions and cell free culture filtrate have been used to demonstrate the role of antibiotics in biological control.

Knowledge on the modes of survival of pathogens and the ways by which they could be suppressed are important especially in the control of plant diseases. The pathogens, in the absence of their hosts, survive either as dormant propagules or actively as saprophytes on dead organic substrates of the host in the soil. The survival structures of the pathogens in the soil are suppressed either due to manipulation of the soil environment. The pathogen suppression in the soil is considered as important step in the control of diseases as it involves the direct disinfestations of the soil.

A decrease in crop yield as a result of a plant disease caused by a pathogen is a negative effect. Some fungi are the main pathogens responsible for plant diseases and they may cause high yield losses. There are many ways to reduce yield losses caused by fungal diseases, with the application of chemical fungicides, presently being the most common method. Chemical fungicides however, have a negative effect on human health and on the environment. The application of such fungicides over a long period may result in plant pathogenic fungi developing resistance. When this happens the chemical fungicides become ineffective and other fungicides must be used for effective disease control. The use of microorganisms as biological control agents to control plant disease is a potentially powerful alternative method (Kulkarni *et al*., 2007). Over the past 30 years, microorganisms have been described, characterized, and tested for their use as biocontrol agents against diseases caused by soil borne plant pathogens. A wide range of biological control agents have been developed as commercial mycofungicide products in past few years (Benítez *et al*., 2004; Kim and Hwang, 2004; Fravel, 2005).

An alternative way to increase the crop yield besides using chemical fertilizers is biofertilizers. Biofertilizers promote increased absorption of nutrients in plants (Vessey, 2003; Hart and Trevors, 2005; Chen, 2006). Biofertilizers include materials derived from living organisms and microbial sources (Rola, 2000; Chen, 2006). Biofertilizers have various benefits, such as increased access to nutrients, providing growth-promoting factors for plants, and composting and effective recycling of solid wastes (Gaur and Adholeya, 2004; Das *et al*., 2007). Biofertilizers, commonly known as microbial inoculants are produced from cultures of certain soil organisms that can improve soil fertility and crop productivity such as mycorrhizae (Malik *et al*., 2005; Marin, 2006).

- **Use ofBiofertilizer and Mycorrhiza to increase the yield of cotton**

Complex interactions take place in the volume of soil around roots, which traditionally has been termed the ‘‘rhizosphere.’’ More appropriately, that soil volume constitutes a *mycorhizosphere* (Rambelli 1973) because of the dramatic influence an abundance of fungal external hyphae has on root and soil associated microorganisms, as well as the effects of those microorganisms, on the establishment and spread of mycorrhizae

(Bagyaraj 1984). Mycorrhizal roots also have altered root exudation patterns (Marschner 1998). The *Rhizobium -Bradyrhizobium* association with legumes most notably is affected by mycorrhizal fungi, largely as a result of increased availability of phosphorus in host roots, which drives nitrogenase activity in nodules (Aźcon 1994). Other indirect interactions affect both pathogens and beneficial organisms, either through effects of mycorrhizal formation on root exudates or through competition (Linderman 1988; Garbaye 1994).

The influence of fungal hyphae in the mycorrhizosphere is much greater than previously thought (Tisdall *et al*., 1997) with the discovery of 'glomalin,' a heat stable glycoprotein that coats hyphae and spore surfaces and accumulates in soil (Wright and Upadhyaya 1996). Evidence indicates a strong involvement of glomalin in soil aggregate stability; researches have revealed found a highly significant correlation between glomalin concentration and soil aggregate stability (Wright and Upadhyaya 1996).

Perhaps the largest obstacle to understanding the biology and ecology of Arbuscular Mycorrhiza (AM) fungi is our inability to culture them apart from their plant hosts. The plant provides carbon to the fungus largely via an arbuscule – plant cell plasmalemma interface. It also provides a protected site in root cells where the fungus can live. The external fungal hyphae improve phosphorus acquisition by the plant in soils with low levels of phosphorus (Safir 1987; Smith and Gianinazzi-Pearson 1988; Smith and Read 1997). In soils in which phosphorus levels exceed requirements of the host, however the AM symbiosis often is inhibited. Under those conditions for certain host-soil interactions, mycorrhizal development can reduce plant growth and thus become pathogenic (Modjo and Hendrix 1986).

In nature, fungal communities are taxonomically complex and rarely, if ever, consist of only one species (Morton 1988). When individual AM fungi are cultured on plants, host specificity appears to be minimal or absent (Smith and Gianinazzi-Pearson 1988; Brundrett

1991; Smith and Read 1997). Investigators at the International Culture collection of (vesicular) Arbuscular Mycorrhizal Fungi (IN VAM) in West Virginia showed that more than 1000 isolates of 98 species of fungi in all genera were able to grow and sporulate on one plant host, *Sorghum sudanese*, or Sudan grass (Morton *et al.*, 1993). Roots of Sudan grass accommodate colonization by as many as 10 species of fungi at one time in pot culture using field soil as inoculum. And those fungi can be members of any genus (Morton 1988). Lack of host specialization may be the result of mutualistic co evolution of the plants and their fungal partners over the 400 million years since their origin (Simon *et al*., 1993; Taylor *et al.*, 1995).

A combination of host and environmental factors can differentially influence rates and degrees of colonization and/or sporulation by different AM fungi in a community (Johnson *et al*., 1992; Bever *et al*., 1996), which are manifested as changes in species richness and relative abundance in sporulation. In general, those responses represent compatibility adjustments rather than specificity, although Mc Gonigle and Fitter (1990) and Brundett (1991) explained the ‘ecological specificity,’ respectively. Divergence in physiological and life –history traits within a fungus species and between species is expected in these asexual organisms as a natural response to local and regional selection pressures (Morton *et al.*,1990).

Members of a small number of plants do not form AM associations (Tester *et al.*,1987). Many other orders, however, include both mycorrhizal and non-mycorrhizal families and genera. Non mycorrhizal taxa are assumed to have evolved away from the symbiosis, based on evidence from their distributions, relative to those of their mycorrhizal relatives (Trappe 1987), and from the presence of activated defense mechanisms in chemically induced mycorrhizal-resistant mutants (Peterson and Bradbury 1999). A few genera, however, support both arbuscular fungi and ecto mycorrhizaal fungi. One of the most widely studied plant being *Eucalyptus* (Lapeyrie and Chilvers 1985).

Mycorrhiza is a mutualistic beneficial association between fungi and plant roots. It is more or less a universal phenomenon throughout the plant kingdom (Mosse 1981). More than 80% of all land plant families are thought to have a symbiotic relationship with AM Fungi that belong to Glomeromycota. This interaction of AM symbiosis is the evolutionary precursor of most of the mutualistic root-microbe associations (House and Fester, 2005).

Arbuscular Mycorrhozal association with plants is an ancient (>460 million years BC) and widespread terrestrial symbiotic association formed between fungi of the phylum Glomeromycota and the roots of vascular plants (Schussler *et al.*, 2001, Redecker *et al.*, 2000 a, b, Toljander, 2006) and they, therefore, represent an ancient phylogenetic clade within the fungi. It is estimated that about 250,000 species of plants, are capable of forming the symbiosis with AM fungi worldwide (Smith and Read 1997). The colonization of terrestrial ecosystems by the ancestors of modern vascular plants was facilitated by symbiotic fungi similar to modern endomycorrhizae. AM comprise of over 150 species that are not host specific and form symbiotic associations with a wide range of host species. AM bestow a selective advantage on their host over competing non-host species by making available nutrients, providing defence against several pathogenic organisms and by influencing the composition of the microflora of the rhizosphere (Kothamasi *et al.*, 2001).

The symbiotic relationship benefits both- the individual plant and the fungus (Francis and Read, 1995). Exchange of nutrients-mineral nutrients supplied by the fungal microsymbiont versus carbohydrates provided by the plant-is considered to be the main benefit for the symbiotic partners (Smith and Read 1997). According to the phylogenetic position of these partners and according to the symbiotic structures, several types of mycorrhiza have been defined such as arbuscular mycorrhiza (AM), ectomycorrhiza, ericoid mycorrhiza, and orchid mycorrhiza. The efficiency of each AM Fungi for increasing plant growth, nutrient contents, water stress tolerance (Vazquez *et al*., 2001) and providing defense against several pathogenic organisms (Kothamasi *et al.*, 2001) is well documented. In endomycorrhiza, the fungus grows inter- and/or intra cellularly. Specific fungal structures of endomycorriza are produced within the cortical cells by non septate fungi which are commonly known as vesicles and arbuscules, hence it was called earlier as vesicular-arbuscular mycorrhiza (VAM). As many of the endomycorrhiza fungi do not necessarily form internal vesicles, the abbreviated term 'VAM' was suggested to be replaced by 'AM' (Strack *et al.,* 2003).

Growth in plant communities is often governed by the availability of nutrients such as P and N. In contrast, C is growth-limiting element in fungal communities. It was but obvious for natural selection to have favoured the development of symbiotic associations between plants and fungi. Plants provide C to fungal symbionts and the fungi transfer nutrients from the soil to the host (Kumar *et al.* 1999; Pierzynski *et al.* 2000; Read 1990; Sen 2000). Mycorrhizae have been associated with vascular plants since the Palaeozoic era (Taylor 1990). The colonization of land by the ancestors of modern vascular plants seems to have been hastened by the origin of symbiotic associations between these plants and some phycomycetous fungi similar to those of modern endomycorrhizae (Malloch *et al.* 1980; Phipps and Taylor 1996; Simon *et al.* 1993). AM, the most prevalent plant-fungus association, comprise about 150 species, belonging to the order Glomales of Zygomycotina (Morton and Bentivenga 1994; Myrold 2000; Perry *et al.* 1989; Schenck 1981; Simon 1996). AM are one of the few plant-fungus associations with a fossil record (Taylor 1990) and are believed to have assisted vascular plants in their growth and survival (Simon *et al.* 1993). AM are present in most soils and are generally not considered to be host specific. However, population sizes and species composition are highly variable and influenced by plant characteristics and a number of environmental factors such as temperature, soil pH, soil moisture, P and N levels, heavy metal concentration (Boddington and Dodd 1999), the presence of other microorganisms, application of fertilizers and soil salinity (Barea and Azcon-Aguilar 1983; Bationo *et al.,* 2000). Species and strains of AM differ in their ability of tolerance to physical and chemical properties of soil (Abbot and Robson 1991), as a result they also differ in their effectiveness in improving plant growth.

AM forms the connecting link between the biotic and geochemical portions of the ecosystem (Miller and Jastrow 1994). Mycorrhizae aid the plant in better growth by assisting it in absorbing useful nutrients from the soil, in the competition between plants and in increasing the diversity of a given area. A number of reviews have appeared recently on AM, particularly dealing with the application of AM in agriculture. Information on the role of AM in plant adaptations has been scattered and the present review deals with the critical appraisal of the role of AM in plant community dynamics, nutrient mobilization and overcoming both abiotic and biotic stresses.

AM fungi are known to infect a wide range of host species. They have a large geographical distribution (Malloch *et al.,* 1980), being found even in the Arctic tundras and the Antarctic region (DeMars and Boerner 1995b; Gardes and Dahlberg 1996). Unlike most ectomycorrhizal species, AM are not host specific. This enables them to form associations with a large number of plant species. Mycorrhizae owing to their role in nutrient cycling, keep more nutrients in the biomass and in doing so increase the productivity of the ecosystem (Newman 1988). AM fungi regulate plant communities by affecting competition, composition and succession (Allen and Allen 1984; Kumar *et al*,. 1999).

- **Classification of Mycorrhizae**

Mycorrhizal fungal association widely varies in structure and function, but the AM fungi exhibit most common associations (Harrier, 2001). Six genera of AM fungi have been recognized based on the morphological characteristics of sexual spores and also based on various biochemical studies as well as molecular methods (Peterson *et al.,* 2004). Further, various criterion has been used for the identification of AMGF like hyphal charaters, auxillary cells subtending hyphae, spore or sporocarp ontogeny, morphology, germination, shield spore wall *etc*. (Mukherji *et al.,* 2002). AMF are zygomycetous belonging to the genera *Glomus, Gigaspora, Sclerocystis, Acaulospora, Enterophospora* and *Scutellospora* (Garbaye, 1994).

The classification of AMF is based on the structure of their soil borne resting spore, biochemical properties and molecular studies (Morton and Benny, 1990). The latest classification of AMF contains 4 orders and 9 families (Siverding and Ohel, 2006). Plant species belonging to the Cruciferae, Chenopodiaceae and Cactaceae are not known to form AMF symbiosis (Smith and Read, 1997). AMF reproduce asexually by spore production. There is no evidence that AMF reproduce sexually (Kuhn *et al.*, 2001).

Table showing Recent Classification of Arbuscular Mycorrhizal Fungi (Siverding and Ohel, 2006)

Phylum Glomeromycota		
Class Glomeromycetes		
Orders	**Families**	**Genera**
1 – Glomerales	Glomeraceae	*Glomus*
2 – Diversisiporales	Gigaspraceae Acaulospraceae Entrophosporaceae Pascisporaceae Diversisporaceae	*Gigaspora, Scutellospora* *Acaulospora, Kuklospora* *Entrophospora* *Pacispora* *Diversispora*
3 - Paralomerales	Paraglomeraceae Geosiphonaceae	*Paraglomus* *Geosiphon*
4 - Archaeosporales	Arthaeosporaceae	*Archaeospora, Inraospora*

- **Types of Mycorrhizae:**

Several types of mycorrhizal fungi have been recognized and the most important types are mentioned below:

- **Endomycorrhizae:**

Endomycorrhizae represents a group of fungi that are associated with most of the agricultural crops and provide biochemical protection against soil borne diseases (Smith and Read, 2008). They occur in most of the ecosystems of the world and are found in many important crop species i.e. (cotton, wheat, maize, rice and soyabean) and horticultural species like grapes, roses and petunias etc. (Peterson *et al*., 2004). AMF are obligate biotrophs feeding on the products of their live host and those fungi are not specialized to their potential hosts. The host plants receive mineral nutrients from outside the root depletion zone via the extraradical mycelium, while the AMF obtains photo-synthetically produced carbon compounds from the host (Smith and Read, 1997).

Many endomycorrhizal fungi form terminal or intercalary vescicles in the root cortex. When the vesicles are expanded the thin walled structures, contain large quantity of lipids (Tahat *et al*., 2010). They may be oval, spherical or lobed in shapes and may become thick walled and resting spores (Pirozynski and Dalphe, 1989).

- **Ectomycorrhizae (ECM):**

ECM fungi form a thick mantle like structure and within the intracellular spaces of root cortex form network. These fungi do not penetrate living cells in the host roots, but can only surround them. They are most common in ornamental and forest tree species in the family Pinaceae, Myrtaceae, Salicaceae, Dipterocarpaceae, Fagaceae and *Gnetum* plants (Shalini *et al.*, 2000). Ectomycorrhizas are distinguished by the presence of mantle and harting net. Harting net develops in cortical cells or epidermal cells. Harting net consists of branch system which can provide a large surface contact between cells of the two symbionts

(Peterson *et al*., 2004). Other type of mycorrhizal fungi includes Ecto-endo Mycorrhizae, Ericoid Mycorrhizae, Monotropoind, Arbutoid and Orchid mycorrhizae (Smith and Read, 2008).

- **Uptake of the nutrient by AM Fungi:**

When soil resources, such as P or N, limit photosynthesis, C is in excess, mycorrhizal fungal hyphae explore the soil volume for P and N, and transport the nutrient (over distances of cm to m) in exchange for excess plant C. Mycorrhizal hyphae are more efficient at exploring the soil volume then even fine roots. As long as P or N are limiting plants will support mycorrhizal fungi. Even as the availability of the limiting resources shifts through time, mycorrhizal fungi similarly shift resource provisioning (Molina *et al*., 1992). Linking space and time is important because of exploring a neighboring patch (Aikkio and Ruotsalainen, 2002). Since a complex network of fungal mycelia and plant roots are distributed horizontally across a landscape and extend vertically into the soil and rock substrate (Egerton-Warburton *et al.,* 2003), resource extraction becomes dynamic.

Energy, in the form of C compounds is the currency for exchange of soil resources. This connection occur at the (fungus) membrane: interspace: (plant) membrane interface in the form of simple sugars or amino acids. Photosynthetic rates depend on the concentrations of N (as RuBP carboxylase and other enzymes), P (for ATP, ADP). Fe and Mg (for cholorophyll), internal CO_2 , and water (to keep stomata open to fix CO_2). These interactions create several important and well known linear and curvilinear relationships that form that basis of stoichiometeric ratios between elements. Mycorrhizae, by increasing P and N uptake, create a C sink and enhance the photosynthetic machinery. Mycorrhizae also increase water release through transpiration by, opening the stomata. Together these increase rates of total carbon gain by 10% to 40% (Allen *et al.,* 1981). In the field, this increased CO_2 fixation is associated with environmental change, such as drought, or as a function of particular fungal – plant species combination.

- **Effects and processes involved in the growth enhancement by Vesicular Arbuscular Mycorrhizas (Tinker *et al.*, 1994)**

1. Growth increase occurs by improved supply of elements of low mobility in growth medium, predominantly phosphate.
2. This arises by increased uptake rate per unit amount of root length (inflow).
3. This is caused by proliferation of a considerable length of external hyphae.
4. Hyphae absorb, translocate and transfer P to host, from soil outside the root depletion zone.
5. Uptake is normally from the isotopically labile pool of nutrient, from which the root also absorbs.
6. There is a feedback effect by absorbed Phosphorus on the percentage of infected root.
7. Infection of phosphate-deficient plants is accompanied by a rapid but temporary increase in internal P concentration.
8. Much of phosphorus in the fungal partners is in the form of phosphate.
9. The fungus is maintained by carbon supplies from its host, and infection results in a large proportion of total fixed carbon being allocated below ground.
10. The uptake efficiency should be large for this mechanism than for uptake by the uninfected root system.

- **Plants used for Biocontrol**

Plants are the richest source of renewable bioactive organic chemicals. The total number of plant based chemicals may exceed 4,00,000 of these 10,000 are secondary metabolites, whose major role in the plants is reportedly defensive (Swain, 1977).

The screening of plant extracts for antimicrobial activity has shown that a great number of these plants contain active compounds. The presence of antibacterial, antifungal, and other biological activities has been demonstrated in extracts of different plant species used in traditional medicine practices (Hashem, 2011).

Basic researches for over more than forty years in the fields of biological and biochemical have made it possible to envisaged not only how new pesticides may be synthesized but also a completely new approach for the protection of plants using secondary plant products, which may be toxic to a specific pest yet harmless to man. There has been a renewed interest in botanical pesticides because of several distinct advantages (1) Pesticidal plants are generally much safer than conventionally used synthetic pesticides. These pesticides will not cause harm in nature. (2) Plant based pesticides will be renewal in nature and would be economical. (3) Some plants have more than one chemical as an active principle responsible for their biological properties. These may either be selected for one particular biological effect or may have diverse biological effects (Singh, 1993).

Efforts are being made these days to shift from the conventional use of chemicals to the use of eco-friendly botanicals for the management of plant parasitic nematodes. Organic amendments are not only safe to use but also have the capacity to improve soil structure and fertility (Trivedi, 2002).

Leaves of following plants were used to study the biocontrol activity:

1. *Annona reticulata* L.
Family: Annonaceae

It is a small deciduous or semi-evergreen tree reaching 8 metres to 10 metres tall with an open, irregular crown. The slender leaves are not hairy, straight and pointed at the apex 10 cm to 20 cm long and 2 cm to 7 cm wide. The yellow-green flowers are generally produced in clusters of three or four 2 cm to 3 cm diameter, with three long outer petals and three very small inner ones. The fruits are variable in shape: heart-shaped, spherical, oblong or irregular.

2. *Sapindus emarginatus* Vahl.
Family: Sapindaceae

Sapindus emarginatus is a deciduous tree. Commonly called as Soapnut tree and is the south Indian species of genus *Sapindus*. It is an economically significant tropical tree species meagerly distributed in diverse geographical provinces like Gangetic Plains, Western Ghats, and Deccan Plateau in India. The trunk of the tree is straight and cylindrical, approximately 4-5 m in height. 5-10 pairs of leaves, solitary alternate, 15–40 cm long, pinnate, with 14-30 leaflets, the terminal leaflet often absent. The flowers form in large panicles and each flower is small and creamy white in colour. It flowers during summer. The fruit is small leathery-skinned drupe which is 1–2 cm in diameter, which is yellow and turn blackish when ripen, containing one to three seeds. The members of genus *Sapindus* are well known for their medicinal values. Traditionally it is used as anti-inflammatory and antipyretic. Its fruits are natural substitute for chemical soaps and hair dyes.

3. *Cochlospermum religiosum* (L.) Alston
Family: Bixaceae

It is a flowering plant from the tropical region of Southeast Asia and the Indian Subcontinent. In India it is commonly found in Andhra Pradesh, Maharashtra, Madhya Pradesh, Uttar Pradesh and Bihar. It is a small tree growing to a height of 7.5 m usually found in dry deciduous forests. Also known as Silk-Cotton Tree because the capsules containing the seeds have a fluffy cotton-like substance similar to kapok. Plant can be identified by deeply furrowed bark, palmately 5-lobed leaves and bright golden yellow bisexual flowers. Quick growing tree yield a gum known as gum katira from a juice orange in colour exudes from the bark. The dried leafves and flowers are used as stimulants, antipyretic, laxative and sedative. Root powder mixed with water when applied to face reduce wrinkles.

4. *Gliricidia sepium* (Jacq.) Kunth ex Walp.
Family: Fabaceae

It is a medium-sized tree, semi deciduous tree that grows from 10 to 12 meters high. The bark is smooth and its color can range from a whitish gray to deep red-brown. It has compound leaves that can be 30 cm long. Flowers have a bright pink to lilac color that is tinged with white. Leaves are rich in protein and highly digestible for ruminants like goat and cattle, as they are low in fibre and tannin. There is evidence of improved animal production (both milk and meat) in large and small ruminants when *Gliricidia* is used as a supplement to fodder. However, non-ruminants fed on *Gliricidia sepium* have shown clear signs of poisoning. The flowers attract honeybees (*Apis* spp.), hence it is an important species for honey production. Good for firewood and charcoal production. The wood burns slowly without sparking and with little smoke. Very durable and termite resistant; used for railway sleepers, farm implements, furniture, house construction and as mother posts in live-fence establishment. A traditional remedy for hair loss, boils, bruises, burns, cold, cough, debility, eruptions, erysipelas, fever, fractures, gangrene, headache, itch, prickly heat, rheumatism, skin tumours, ulcers and wounds

5. *Feronia accidissima* (L.) Swingle
Family: Rutaceae

The tree is native and common in India, Sri Lanka, China and Indonesia and widely distributed in most tropical and subtropical countries. Commonly known in India as wood-apple. It has economic as well as medicinal value. It contains important medicinal compounds like umbelliferol, dictamnine, xanthotoxol, scoparone etc. those could be used in the pharmaceuticals industries. The fruit is used in India as a liver and cardiac tonic. and when unripe, as an astringent means of halting diarrhoea and dysentery and effective treatment for hiccough, sore throat and diseases of the gums. Juice of young leaves is mixed with milk and sugar candy and given as a remedy for biliousness and intestinal troubles of children. Oil derived from the crushed leaves is applied on itch and the leaf decoction is given to children as an aid to digestion.

6. *Balanites roxburghii* Planch.
Family: Zygophyllaceae

It is a spiny, evergreen tree. It is common in open sandy plains. Commonly called as Hingoli/ Hingoru. Bark, Friuts, Seeds and Leaves are used. Fruits are used in treatment of whooping cough, skin diseases and in antifertility. Leaves are used for the treatment of jaundice. In case of pain and swelling, the bark of plants is used as traditional healers. The paste of bark is prepared and applied externally on the affected part of the body to treat snake-bite and dog bite.

7. *Tephrosia jamnagarensis* Sant.
Family: Fabaceae

It ia an annual herb of 1mt with simple linear leaved covered by hairs. Flowers purplish blue in colour. Pods densely hairy and oblique at both the ends. Seeds reniform, brownish. Leaves contain glycosides and favanoides. The leaves could be used as insecticide, pesticide and is having hepatoprotective properties.