Chapter V

Discussion

5:1 The Area and Species

The Western Ghats extend over 0.14 million sq. km covering five southern states. This mountain range influences the well being of the entire population of this region, through modulating climate, river water flow, ground water charge, providing fertility to soil and supporting quite a big macroflora i.e. plants and trees as well as microflora population in the forest soil. The congregation of such biodiversity at its maximum exists in the southern most part of the Western Ghats, in the Agasthyamalai ranges. The components of the macroflora in this region include a wide range of shrubs, trees including indicator as well as key stone species of plants. Most of such members in the Agasthyamalai ranges have been well documented (Nair, 1991). But no documentation of diversity existing in microflora in the soil and in the rhizosphere of plant population has been made. However it will be herculian task to isolate, identify and document the microbial population of entire flora existing in the forest soils of the study area. The attempts made in the present study, though very small, can contribute immensely to the knowledge of science and will be helpful in laying a foundation for future contributions in this direction.

Sampling sites located in the Agasthyamalai range comprising of 30 sites in 12 R.F. provide quite a diverse area having variation in plant population, rainfall, soil type, nutrient status of soil, elevation etc. and this phenomenon may be contributing strongly to the diversity in macroflora existing there. Identification of this area as hottest biodiversity spot by the International Forum and suggesting to conserve this ecosystem endorses the above view. (UNESCO 1974).
Attempts to study only yams and aroids from the vast diverse plant population were based on the following facts.

1. Studying the microbial population in an area with immense plant diversity, becomes too large to complete. However, the present study forms the basis for a major investigation in future.

2. The use of yams and aroids by the local and habitat people, both for medicine and food, prompted studies to understand the interaction between plant and supporting microbial system with a view to popularize them.

3. To understand the exact interaction between the tuber crops and the supporting microbial system in the forest ecosystem.

The distribution of yams in 12 R.F. areas was not uniform. Though nine Dioscorea species have been reported in the work, *D. pentaphylla* and *D. wallichii* were dominant and growing well in all the different ecosystems naturally, *D. bulbifera* and *D. tomentosa* come next in the order. The other *Dioscorea* spp, the distribution seems to be selective to certain R.F. only. The wide existence of *D.pentaphylla* and *D. wallichii* in all the R.F. and selective existence of other species in certain areas is indicative of the close interaction of ecosystem, the root zone of these plants and microflora residing in the root zone.

Under given uniform situation, the preference to one species over another in nature, truly reflects the interaction between the soil microflora and the plant (Allen *et al.* 1992) along with other edaphic factors. They opined that not only did different species of AM fungi cause different plant responses, but population of the same fungal species produced different sized shrubs within the same site. Similar results were formed in physiological response of *Agropyron smithi* to different populations of AM fungi, where plants shared improved water relations from the fungal
populations, collecting from droughtier soils (Stahl and Christiensen 1991).

Further, the community of plants/trees and individual species of fungi are
determined by the local environmental conditions and *vice versa*. Interestingly, many of these species crossed into different ecological
regions and indicate that their dispersal was root limiting. For other more
localised species, local edaphic factors might have played a role in
establishment as well as dispersal for some other species of fungi. (Allen
and Allen 1992). The tripartite interaction between soil, microbes and plant
decides the fate of the macroflora to be supported in the soil (Read 1983).

The profile of total microbial population in soils of forest ecosystem
varied with the locality. The components of total microbial population, viz.
Actinomycetes, bacteria and fungi also showed variation. Among the
locations, Kottur extension and Mangamalai harboured maximum microbial
activity. The variation in the total microbial activity may be due to the
difference in soil type mainly forest loam and laterite and the elevation of
the locality. The influence of elevation of the terrain and soil type in
moulding the microbial profile is well established (Allen and Allen 1992).

Sandy loam and alluvial soil are found to be supporting high soil
microflora population in coconut rhizosphere. The high organic carbon
content in the soil by excessive decay of coconut roots due to the root wilt
disease of coconut (Potty 1978) has caused high incidence of soil flora. The
high organic content can be useful in the proliferation of gram +ve bacteria
for the above phenomenon. Further, the influence of season was also
profound in manipulating microbial population. Premonsoon as well as
postmonsoon periods facilitated maximum incidence of microflora
invariably in all the sampling localities for yam in Agasthyamalai range.
Among the components, high incidence of bacterial flora observed may be attributed again to the high organic carbon content. Clark (1940) noticed that high organic content was invariably related to the occurrence of gram +ve bacteria in the soil. In forest ecosystem, it is quite natural that forest litter constitutes top layer of the soil. The incidence of actinomycetes and fungal flora in soil more or less related to one another, as many of the natural actinomycete flora are antagonistic to both fungus and bacteria which may be contributing to the maintenance of microbial equilibrium. Similarly, the qualitative distribution of fungal flora has also shown profound variation in the occurrence in the rhizosphere of yams.

Among the dominant fungal species, *Rhizopus oryzae* was major one followed by *Aspergillus* sp and *Cunninghamella* sp. The frequency of occurrence of fungal flora in different sampled sites showed that locations at Veerapuli, Kottur, Peppara, and Kulathupuzha had large number of fungal genera in the rhizosphere. Perhaps, the organic carbon content in the top soil and soil type may be contributing to the high incidence of qualitatively different fungal flora in the rhizosphere of yams. While Mahendragiri R.F. supported very low population of different fungal flora. It is pertinent to mention that the Veerapuli R.F. supported diverse *Dioscorea* sp in its ecosystem. The qualitative distribution of bacterial flora in the above R.F. also followed more or less similar trend. The high organic carbon in the rhizosphere might have influenced the occurrence of gram+ve *Bacillus* sp. (Clark 1940, Potty 1978) which is contradictory to the normal observation. The forest ecosystem may not be supporting the gram –ve flora in its rhizosphere because of the existing macro environment.

The profile of actinomycete flora in the rhizosphere of yam consists of *Waksmania* sp, *Micromonospora* sp and *Nocardia* sp. The *Micromonospora* sp. was more in rhizosphere compared to other
actinomycete species. The reduction in the gram –ve bacteria in the rhizosphere of yams may be due to the high incidence of *Micromonospora* species of *Actinomycetes* species which is antagonistic to gram –ve bacteria (Rangaswamy 1968). The ability of elaborating amylolytic and cellulolytic enzyme by *Micromonospora* sp. may be one of the contributing factor for higher incidence of gram positive bacteria, in addition to other edaphic criteria.

Apart from the total microbial activity in the rhizosphere, the plant growth promoting rhizobacteria and fungi also have a great role in the macroflora to be supported in the locality and *vice versa* (Read 1983). Beneficial organisms like nitrogen fixers, ‘P’ solubilizers, organism capable of elaborating various enzymes to digest macromolecules to the simplest form so as to have maximum microbial activity in the rootzone, will be co-existing in the rhizosphere.

The succession of microbes in the decomposition of forest litter and successive degradation of organic waste into easily accessible form has been well demonstrated. (Kononova, 1961) The distribution of different species of Dioscorea in different reserve forest though the edaphic factors are same in general, showed significant variation. Perhaps, the profile of microbes in the soil may be playing an important role in modulating the distribution of plant species (Pate 1994). Conspicuous variation in the distribution of different beneficial microflora in the root zone of both cultivated crops and in general vegetation lead to the understanding of the status of beneficial flora in the rhizosphere of yams.

Among the fungal flora, seven species viz. *Achlya* sp, *Aspergillus niger*, *Mucor* sp, *Aspergillus fumigatus*, *Rhizopus oryzae*, *Mennoniella* sp. and *Cunninghamella* sp. demonstrated phosphate solubilizing capacity and
the *Mucor* sp and *Aspergillus fumigatus* digested maximum insoluble tricalcium phosphate in the soil. Similar reports of harbouring beneficial microflora in the rhizosphere are available elsewhere (Pal, 1998., Illmer and Schinner, 1995). However, in the bacterial flora, approximately fifty percent are phosphate solubilizers irrespective of qualitative differences. Both gram +ve and gram –ve isolates showed phosphate solubilizing capacity. The rhizosphere micro niche may be favouring such beneficial flora in the root zone more than the non-rhizosphere soils (Illmer *et al.* 1995).

The rhizosphere soils of yams from different RF, though differed in general, their physiochemical, edaphic factors and distribution of plant populations, supported uniformly the ‘P’ solubilizing bacteria except in Kottur extension and lower Kodayar. Similarly, N₂ fixing bacterial survey also exhibited more or less similar frequency. Among 19 isolates, only 9 showed N₂ fixing capacity. However the occurrence was limited to the rhizosphere soils of few R.F. only. The presence was observed in Palode, Peppara, Kottur extension, Lower Kodayar and Kodayar only.

The interaction of environment with other agencies, soil factors and influence of host may be the resultant contribution to the successful colonization of the microflora (Hetrik *et al.* 1988). It has been demonstrated that the microflora population was different in the rhizosphere of plants as compared to non rhizosphere soil (Ames *et al.* 1984), and positive effects on the root colonization by microflora and plant growth (Meyer and Linderman, 1986). Moreover the influence and their interaction and *vice versa* and its relation to growth of the plants has not been assessed fully. Among the nitrogen fixing capacity of asymbiotic nitrogen fixers in the root zone, the isolate from lower Kodayar was significantly better, and this observation again confirms the selectiveness of host plant in harbouring
these beneficial organism at their rhizosphere, interacting with other soil and environmental factors (Allen et al. 1995).

A large group of yet another microflora supported by the yams are mycorrhizal fungi. The frequency of occurrence of these fungi varied with host plants as well as the environmental factors. All the reserve forests irrespective of difference in physio chemical, climatic and environmental factors, supported the growth and establishment of AM fungi in varying degrees. Among the nine Dioscorea species, D. wallichii, D. pentaphylla, D. tomentosa, D. spicata and D. oppositifolia were harbouring more number of AM fungi in their root system. Out of 103 isolates, occurrence of more number of AM fungal spores was observed only in the above mentioned Dioscorea sp. Again the distribution of maximum number of the species of AM fungi was encountered only in Papanasam, Palode, Mahendragiri and Kottur extension.

The occurrence of Glomus mosseae was predominant in most of the rhizosphere samples collected from the whole study area. Glomus aggregatum and Gigaspora margarita also been found among the AM fungi dominating in the rhizosphere of yams. All the beneficial organisms viz. 'P' solubilising fungi, nitrogen fixing bacteria and AM fungi were distributed in different ecological zones and influence of which decides the macro as well as microbial population and vice versa. The percentage of colonization in the roots of yams was very much evinced by the influence of ecological factors as mentioned earlier. Unlike in the case of bacteria and fungi, heavy rainfall, high soil organic carbon, pH of the soil are some of soil factors known to inhibit the growth and establishment of AM fungi.

In most of the reserve forests, the pH of the soil was acidic ranging from 3.8 to 5.9 and organic carbon content was very high. Except in few
cases, the colonization percentage of AM fungi in yam roots is 22-54. The development of appendages like vesicle formation is limited in AM fungi in some of the locations like Kottur extension, Lower Kodayar, Veerpuli and upper Kodayar whereas arbuscule formation is uniform in all the places. Recent report on the genetic make up of host on signalling from root and the response by the AM fungi and their interaction actually decides the pre infection and growth and establishment of AM fungi in host plants. The non-existence of vesicles in certain localities and in certain spp of Dioscorea may be due to the interaction between the genes responsible for signaling in the host and the invading AM fungi (Smith et al. 1992, Wilson and Tommerup. 1992). Further, the infection sites in the root cortex may also be contributing to this phenomenon of selective encouragement, growth and establishment of an organism from a group of AM fungal population (Tagu and Barker 1997).

Similarly in spore production also, great variation was seen and percentage of colonization and spore production did not show any relation. However in some cases occurrence of high spore population in rhizosphere may be due to the influence of environment and host plants. The forest ecosystem can not be compared with the ecosystem of cultivated areas, where the density of plant population will be limited as well as uniform. The diversified plant population may be extending a greater role in the microbial activity of the micro niche. The closeness and interaction of roots of different plant population stimulate the growth of specific group microflora (Allen et al. 1995).

As mentioned earlier, D. pentaphylla produces a good number of aerial tubers of varying size ranging from 10g to 500g. The germination studies and polarity studies clearly indicated that plants from 50g seed tuber were much better than plants from 10g seed tuber. George (1993) clearly
established that higher seed tuber mass gave maximum initial boost to the plants than the lower seed tuber mass in *D. esculenta* and *D. alata*. Mohankumar *et. al.* (1973) observed that 500g seed tuber gave significantly higher tuber as well as plant biomass than plants from 100g seed tuber in *Amorphophallus paeoniiolius*. The tuber biomass as well as total biomass was significantly higher in plants from 50g seed tuber and this observation has resulted in the usage of 50g seed tuber for further studies.

5.2 Pot Culture Studies

Assessing the interaction of different treatments under controlled conditions pot culture experiments are laid out.

5.2.1 Growth and establishment of *Glomus mosseae* in wild yams under different fertilizer levels

The role of AM fungi in enhancing plant growth and yield of many cultivated crops (*Bagyaraj and Manjunath 1980; Bolan 1991*) including tuber crops viz. cassava, sweet potato, coleus and yams (*Potty 1995*) has been well documented. The AM fungus *Glomus mosseae* took 14 to 15 days for infection in *D. pentaphylla*. The colonization in Yam was to the tune of 54% which is much lower than onion-the original host. The seasonal effect on the colonization was minimized as it was grown on pot culture condition and no external influence was anticipated. This might have favoured uniform infection in both the experimental periods. The growth response and mycorrhizal colonization in pot culture under different levels of phosphate fertilizer application indicated the favourable influence of P. Addition of ‘P’ favoured mycorrhizal colonization. Similarly fertilizer application at incremental doze also enhanced colonization significantly (30.17 to 62.3%).
The interaction of biofertilizers like phosphate solublizing organisms and N₂ fixing micro organisms stimulated the colonization individually. However combined inoculation has not added any additional advantage over the individual inoculation. Though these beneficial organisms are combatible with mycorrhizal fungi, the inhibition of growth of AM fungi was observed at higher level of application of either fertilizer (NPK) or ‘P’ alone. No perfect correlation was observed between colonization and spore production in the rhizosphere and more or less same trend was observed in the case of spore production (Kehri et al, 1987)

5.2.2 Biomass production

The benefit of mycorrhizal inoculation could be seen in the biomass production in _D. pentaphylla_. The components like shoot biomass and tuber biomass were significantly increased in mycorrhizal plants. But as the addition of fertilizer dose, the enhancement of biomass was visible only up to half the recommended dose of fertilizer application. Combined application of phosphate fertilizers retaining other macro elements _viz._ Nitrogen and Potassium at full levels also followed same trend. Schwob et al. (1998) demonstrated that benefit of mycorrhizal inoculation on dry and fresh biomass production and established perfect correlation with the growth and establishment of AM fungi. The reduced dry matter at higher levels of fertilizer as well as ‘P’ may be due to the selective inhibition of mycorrhizal growth. Lu and Miller (1989) postulated that mere colonization is not important but the reduction in extramatrical mycelial spread may be causing the low nutrient uptake and reduction in biomass production. Enhancing ‘P’ or N₂ through fertilizer application or through substitutes with the addition of bio fertilizers, the result of interaction exhibited more or less same trend in shoot biomass production.
Optimum fertilizer dose which supports both mycorrhizal growth as well as shoot biomass production was half the recommended dose either as chemical fertilizers or supplements through biofertilizers. *D. pentaphylla* produces lots of aerial tubers (weighing up to 0.500 gm) in its vine which can be used as seed material for next planting season. The influence of mycorrhizal inoculation was assayed and the mycorrhizal plants produced significantly higher and larger aerial tubers than non-mycorrhizal yam plants. The *D.pentaphylla* distinctly showed the beneficial effects of mycorrhization on incremental addition of fertilizer or addition of P. The significant increase in the aerial tuber biomass in mycorrhizal plant may be attributed to the improved photosynthetic fixation of CO₂ and immediate translocation to the aerial tuber primordia (axillary buds) in the leaf axil apart from the underground tubers. Potty and Indira (1990) demonstrated that mycorrhizal sweet potato had high photosynthetic rate and respiration and resulted in narrow root: tuber ratio indicating number of roots were converted to tuber biomass production. The axillary buds are modified into aerial tuber primordia and starch deposition initiates in the tuber primordia and later develops in to aerial tuber. Higher number of aerial primordia and larger weight / tuber in mycorrhizal plants is indicative of high rate of photosynthetic fixation of CO₂ and respiration (Reid *et al.* 1983) taking place.

The underground tuber biomass production was also stimulated in mycorrhizal plants. Additional fertilizer application either by NPK at half and full level or ‘P’ alone at different level keeping N and K nutrients constant, the mycorrhizal yam plants responded favorably and produced higher dry and fresh tuber biomass. Combined inoculation of ‘P’ solubilizing organism with mycorrhizal fungi as well as N₂ fixers with mycorrhizal fungi also produced higher biomass compared to control plants. However, under different fertilizer levels, the increase in tuber
biomass production was observed only up to half the dose of fertilizer application. Further similar trend could be observed with incremental addition of phosphatic fertilizers also. Addition of fertilizer or phosphorus source above half the dose generally did not show any significant increase in tuber biomass production.

Mycorrhizal fungi prefer low phosphorus, and low organic carbon for their growth. The resultant increase in tuber biomass production is indicative of successful establishment of mycorrhizal fungi as well as other two biofertilizers. But insignificant difference between the medium to high level of fertilization either by chemical or supplementing through biofertilizers in certain cases may be due to the partial inhibition of growth and establishment of AM fungi (Miyasaka and Habte 2001). Triggering of enhanced photosynthetic activity and translocating to root region within 3-4 hrs was typical phenomenon of mycorrhizal association in plants (Reid et al, 1983).

Increased photosynthetic fixation of CO₂ and corresponding translocation to roots and tubers are the result of the ecological modification by which the plant respond to excessive demand for carbon by both segments and growing roots. (Harold 1980). A definite influence of mycorrhizal association was observed in enhancing root biomass of yam plants. Positive correlation observed between the root fresh as well as dry biomass production under different levels of fertilizer application as well as phosphorus alone, suggestive of roots of AM fungi in modifying root morphology and spread. Schellonbaum et al. (1991) clearly demonstrated the influence of Glomus sp on the root length modification and spread of the root in mycorrhizal Chinese potato Solenostemon rotundifolius (Sreekumar 1999) and in Pachyrhizus erosus (Rajith kumar 1999). The root
length modification was due to the AM fungal colonization so as to scavenge more area in order to have maximum nutrient absorption.

The total biomass produced by the mycorrhizal yam plant is much higher and fertilizer application as well as ‘P’ fertilization did not show much advantage over half the recommended dose generally. But the interaction of biofertilizers with mycorrhizal fungi has added more biomass than control. The significant increase in total biomass was observed only up to half the dose of NPK or ‘P’ alone or substituted by the addition of biofertilizers. Bath and Spokes (1989) and Sylvia (1990) showed that AM fungi *Glomus microcarpum* induce more nitrogen utilization than control plants from soil, which lead to increased synthesis of amino acids and proteins (Sreekumar 1999).

The Harvest index (HI) is one of the important agronomic criteria to assess the growth of cultivated crop. The HI of mycorrhizal plant was much higher than the control plant. The interaction of biofertilizers with mycorrhizal fungi also showed similar trend. The interaction product of biofertilizers and mycorrhizal fungi showed a gradual increase in HI when ‘P’ solubilizing flora was co-inoculated where N2 fixing bacteria, the rate of increase of HI was only up to the half the dose of fertilizers. No additional benefit was observed when ‘P’ fertilizer level was increased in the combined inoculation.

Another important criteria related to growth parameters is Leaf Area Index (LAI) which was high in mycorrhizal yams. Better LAI is an indication of the foliage retention, positively related to the photosynthetic activity of the leaves. As mentioned earlier, LAI was also found to increase as the addition of fertilizers/phosphorus to the half recommended dose only. Irrespective of addition of fertilizer or P or substitution by biofertilizers did
not improve the LAI over half the recommended dose. Interaction of biofertilizers at different levels of fertilizer application did not show any response over half the dose of nutrients application.

The correlation studies between the colonization and growth parameters also showed a perfect positive correlation with aerial tuber production, total biomass production in support of above observation. This phenomenon was recorded by many workers (Potty 1985, Harikumar and Potty 2000) in tuber crops like cassava and sweet potato. An increase in photosynthetic fixation of atmospheric CO₂ by mycorrhizal sweet potato (Potty 1990a) observed is in support of the present investigation.

Improved growth parameters and growth physiology of mycorrhizal yam plants reflect the optimum absorption of nutrients from the soil by mycorrhizal roots. Nitrogen is major essential element for growth of any organism. Leaf nitrogen content was significantly higher in mycorrhiza inoculated plants. Fertilizer application has increased the N₂ uptake in mycorrhizal plant, but the response ceased at F1 level. Further addition did not show any beneficial effect of nitrogen accumulation in leaf tops.

Incorporation of ‘P’ solubilizing flora along with myccorhizae exhibited accumulation of nitrogen in leaf tops and association of N₂ fixing bacteria along with mycorrhizal fungi showed similar trend in Nitrogen assimilation. Incorporation of fertilizer at different levels and interaction with biofertilizers like ‘P’ solubilizers and AM fungi as well as N₂ fixers the mycorrhizal fungi favoured the absorption and accumulation in leaf tops. In general, same trend was observed when mycorrhizal yam plants were fertilized with different levels of phosphate fertilizers.
On addition of fertilizers either NPK or P alone at different levels or supplementing with biofertilizers, the effective optimum absorption by mycorrhizal inoculated yam plants was found to be at half the dose of recommendation. Enhancement of nitrogen by mycorrhizal fungi is well documented in maize (Margaret Reeves, 1992), in sorghum (Potty & Subhashini, 1985), in coleus (Sreekumar, 1999) and in some leguminous plants (Rajith Kumar, 2000). Increased nitrogen content in beans reflects the concentration of different nitrogenous compounds like proteins, amino acids. Nitrogen assimilation is supported by the availability of P (Kucey et al., 1989).

The addition of 'P' as well as combined inoculation with 'P' solubilizing flora enhanced the nitrogen content in mycorrhizal yam. Though the trend in nitrogen content of vine followed more or less same as that of leaf nitrogen, there was no definite significant improvement of N content in mycorrhizal plant by the addition of fertilizer or supplementing with biofertilizers. However, interaction with 'P' solubilizers and N₂ fixers under different fertilizer levels as well as phosphate solubilizers the mycorrhizal plant did not show any marked variation. It is believed that difference in variation of nitrogen content of vine in different treatment may be due to the temporary block in the vine portion so as to increase or decrease in nitrogen concentration.

The benefit of mycorrhizal inoculation in yam significantly improved the N₂ content in tuber. The enhancement of nitrogen in mycorrhizal tuber tissue was seen in the presence of 'P' solubilizing flora as well as nitrogen fixing flora either alone or in combination. It is also observed that incremental addition of fertilizer as well as phosphatic fertilizers has a positive response to the N₂ uptake and content in tubers. Uptake of N and P is important as far as possible in tissue nitrogen is
concerned. The mycorrhizal plants in nature regulated $N_2$ uptake, however nitrogen fertilization affects nitrogen fixation leading to optimization of nitrogen absorption. (Miyasaka and Habte 2001).

Though mycorrhizal fungus is responsible for ‘P’ nutrition in plants under marginal soil (Potty 1985), other edaphic and soil factors sometimes interfere in the uptake of ‘P’ (Miyasaka and Habte 2001). Phosphorous assimilation in a living system is of prime important as it forms major energy rich compound and expends energy, wherever biological reactions are taking place. The ‘P’ content in leaf, vine and tuber is high in mycorrhizal plant, but increase in application of fertilizers or ‘P’ alone at different intervals or supplying through biofertilizers did not show any improvement in ‘P’ accumulation in any of the above mentioned tissues. In some interactions, particularly when tripartite interactions with fertilizers levels and ‘P’ levels, mycorrhizal plants accumulated less ‘P’ than non-mycorrhizal plants. Perhaps, mycorrhizal associations with yam as a single entity might have regulated the absorption of ‘P’ in its system. The improper distribution of ‘P’ may also be one of the contributing factor in low ‘P’ content in mycorrhizal plants (Johansen and Jensen. 1996).

Kulkarni and Joshi (1988) opined that, moisture, ‘P’ content, ‘N’ content are interrelated and either singly or in combination could decide the effect of rhizobial infection. The absorption pattern of N and P are similar in mycorrhizal yam and the interaction product may be deciding the absorption of one element to other.

The behaviour of potassium absorption in mycorrhizal plant was akin to the phenomenon exhibited in the case of N and P. irrespective of the application of phosphate fertilizers at various levels, fertilizers NPK at different levels or making available of NP through bio fertilizers, the
optimization of absorption is regulated in mycorrhiza inoculated yam plants. Though numerical increase in ‘K’ content in non mycorrhizal plants in many interactions was observed but not to the significant level. Between F1 and F2 level as well as P1 and P2 levels no drastic enhancement or decrease was observed. Enhanced uptake of ‘K’ upto F1 and P1 level deserved to be recognized as its involvement in carbohydrate transport from the site of synthesis to different parts of the plant body. Yam being a tuber yielding plant both having aerial and underground tubers, the role of ‘K’ deserves merit. It is understood that the interaction of N and K is very important in translocation and storage of carbohydrate, particularly N:K ratio decides bulking of tubers. All the macro elements viz. N.P.K. content in the plant tissue was optimised in the tissue by regulated absorption and the response of mycorrhizal yam for added source of NPK or P either singly or in combination was regulated up to F1 or P1 level.

In this context it is pertinent that the observed positive correlation between mycorrhizal colonization and enhanced uptake of K and N at F1 levels in yam plants merits consideration with particular reference to transport of photosynthate from the site of synthesis to the roots and tubers leading tuber bulking.

5:3 Micro nutrients

5:3:1 Copper

Micro nutrient copper being prosthetic group of many metabolic enzyme in the living system, its importance can not be under evaluated. Though mycorrhizal interaction with host plant did not show any definite trend, influence of bio fertilizers particularly ‘P’ solubilizing flora on the host mycorrhizal interaction is favourable. As the NPK addition increased from F0 to F1 and to F2 level, the copper content in the leaf top also showed an increasing trend. No influence was exerted by the incorporation
of N2 fixing bacteria in the above interaction. Same situation was observed with different levels of ‘P’ application keeping N and K nutrients constant. It is well documented fact that copper uptake is positively related with the availability of P. ‘P’ content in the host tissue may be deciding the quantum of Cu absorption by the plant (Barsoom, 1998). The copper content in the vine tissue has not shown any affinity towards different treatments either with fertilizer application and enhanced availability of NPK though ‘P’ solubilizing flora and N2 fixing bacteria either. In the tuber tissue though mycorrhizal plant had more copper concentration in general neither fertilizer interaction with mycorrhiza nor biofertilizer with mycorrhiza has not shown any benefit. The tripartite interaction individually or in combination with host plant too had very little influence on copper uptake. Mycorrhizal fungi is a major scavenger of micro nutrients particularly copper through its extramatrical mycelium. Accumulation of copper in the tuber may be due to its vicinity to the absorbing zone.

5:3:2 Zinc

Moreorless, zinc concentration in the leaf tissue, vine tissue and tuber tissue followed same trend of copper accumulation. In general, mycorrhizal yam had high concentrations of Zn in their leaf tops but vine and tuber tissues showed no extra concentration in mycorrhizal plants. ‘P’ solubilizers with mycorrhizal fungi as well as N2 fixing bacteria with AM fungi interacted with host plant and stimulated enhanced uptake and stored Zn in leaf tops only but not in other tissues. The fertilizer interaction and interaction of P with mycorrhizal fungi and bio fertilizers (P solubilizers and N2 fixers) has regulated the uptake and highest concentration of Zn in leaf tops was observed at F1 and P1 levels. Further addition or supply of P and N through biofertilizer also could not stimulate the enhanced absorption. The reason for the low absorption of copper and Zn may be
cumulative effect and interaction of environment, plant age and other nutritional factors (Marschner and Dell, 1994)

Further the concentration micronutrients in the leaf tops of yam plants observed also showed a positive correlation not to significant level in some of the cases. It is well documented that the micronutrients like Cu and Zn are major components of the prosthetic group of many of the biologically active enzymes. Enhanced uptake below the toxic level will be useful for the growth and establishment of the mycorrhizal fungi as well as the host plant.

The biological material under natural conditions may be behaving differently under various situations. Major player in the scenario is soil and edaphic factors and host physiology. Other contributing factors along with the above ones are interacting with other microbes and chemical components existing in the micro environment, which ultimately decides the host and its symbionts and optimizes the association.