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# Biological Suppression of Diseases of Plantation Crops and Spices - Present Status and Future Strategies

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## ABSTRACT

Diseases and pests are the major production constraints in plantation crops and spices. Since high degree of host resistance is lacking at present for many of these, the major focus of disease management has been through chemical control which has limitations because of leaching off problems during heavy rains. Since these high value crops, specially spices being export oriented, biocontrol options have become more attractive. Though there are several disease problems which are amenable to biocontrol, the investigations on these are very recent, and are being pursued at different research institutions. The initial leads obtained in stem bleeding of coconut, foot rot of black pepper, capsule rot of cardamom and rhizome rot of ginger are highly encouraging and indicated the potential of biocontrol in disease management on these crops. *Trichoderma* spp. and *Gliocladium virens* were found to be more efficient in suppressing root rots in many of these crops. Besides, fluorescent pseudomonads and *Glomus fasciculatum* -a vesicular arbuscular mycorrhizal fungus (VAM) were also found effective against combined infections of *Phytophthora* and plant parasitic nematodes in black pepper. Similar studies are warranted in root rots of coffee and tea. The present status of biocontrol in disease management in these crops and future strategies are discussed in the present paper.

## INTRODUCTION

Plantation crops and spices are very important for the economy of India because of their export potential and the foreign exchange earnings. Crop loss due to pests and diseases has been identified as a major production constraint. Lack of high degree of host resistance led to the chemical control as a major focus of disease management in these crops. Many of the diseases are soil-borne and are serious. Soil application of fungicides has limitations since they get leached off during heavy rainfall period and make the crop more vulnerable to disease. Biocontrol options have become more attractive in view of their ecofriendly nature and their ability to fit into organic agriculture system (Sarma *et al.* 1996a,b). Pesticide free spice products are in great demand by the importing countries. Hence, biocontrol has become more relevant for high value crops like plantation crops and spices, which are in general, perennial in nature.

Biological control is the use of organism, genes and gene products to regulate a pathogen and can be used with strategies intended to keep (i) inoculum density below an economic threshold level. (ii) retard or exclude infection, (iii) and maximize the plants system for self defense (Cook 1988). The triad, exclude, extinguish or expunge have become the basic concepts of biocontrol where antagonism can play a major role and antagonists should be sought in areas where disease does not occur, has declined or cannot develop despite the presence of a susceptible host rather than where the disease occurs (Baker and Cook 1974, Cook and Baker 1983). The moisture status, the organic matter content and acidic nature of soils have become added advantages specially for biocontrol of these diseases. Biocontrol options for foliar disease like rust in coffee, blister blight in tea, abnormal leaf fall of rubber are not attractive and promising. Chemical control options ensure better protection and are economically viable. However, the biocontrol options for these also need be pursued on priority basis in view of the pesticide residue problems. Since biocontrol has become more specialized subject, an attempt has been made to review its present status in disease management of the plantation crops and spices (Table 1) and project future strategies. In spite of great potential for biocontrol, it is only recently that biocontrol programmes have been intensified in disease management in these crops and results at least in few crops are encouraging. In general *Trichoderma* spp. and *Gliocladium virens* have been reported as potential biocontrol agents besides fluorescent pseudomonads and vesicular arbuscular mycorrhiza. Integrated Disease Management (IDM) consisting of cultural practices, chemical control, biocontrol coupled with host resistance has been realized as a practical and viable strategy. Biocontrol assumes major importance in sustainable agriculture specially where soil-borne plant disease problems are serious. However, its success depends upon the implementation of cultural practices that reduce the inoculum build up of target pathogens.

## COCONUT (*Cocos nucifera* )

Among the four major diseases of coconut (Table 1) stem bleeding of coconut caused by *Thielaviopsis paradoxa* (Nambiar 1996) and basal stem rot caused by *Ganoderma lucidum* are amenable to biocontrol and the information available is very recent.

### Stem bleeding disease (*Thielaviopsis paradoxa*)

Disease occurs as dark brown patches at the base of the palm from which reddish brown fluid oozes out. The fungus enters through cracks at the base of the stem and gradually progresses upwards (Ramanujam *et al.* 1997). The disease is debilitating and prevalent in many of the coconut growing tracts of India and is serious in Kerala.

### Biocontrol

The *in vitro* and *in vivo* antagonism of *Trichoderma* spp. to *T. paradoxa* was established earlier (Gowda 1987, Usman 1988, Sanalkumar 1990). Recent studies established the prevalence of high population of *G. virens* and *T. harzianum* and lower population of *T. paradoxa* in the soils of healthy palms. Out of 32 fungal isolates tested, *G. virens*, *T. harzianum*, *T. viride* and *T. hamatum* showed reduction of lesion length caused by *T. paradoxa* by 69.9, 66.8, 66.3 and 57.61% respectively. These grew very well in rice bran and neem cake (1:1W/W) and reduced *T. paradoxa* in infected soil when applied. Neem cake and farm yard manure (FYM) mixed with above biocontrol agents showed reduction of *T. paradoxa* population varying from 21.9-31.3% and *G. virens* was the most effective. The biocontrol programmes were tested in integrated disease management trials along with Carbendazim and Tridemorph and no synergistic protection was observed (Ramanujam 1997). The results obtained need field evaluation. It is also possible to apply biocontrol inoculum to trunks of the palm after removal of infected portions.

Basal stem rot (*Ganoderma lucidum*)

This is prevalent in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. The disease causes extensive root rot leading to gradual decline in vigour and productivity of palms. With time the affected palm exhibits yellowing/drooping of the outer whorl of leaves. In advanced stages reddish brown fluid exudes from the base of the palms with rotting of the trunk and finally leads to death of the palm (Bhaskaran *et al.* 1989). *Ganoderma* fructifications are noticed on the dead trunks of the palm. Provision of better drainage, phytosanitation and application of organic amendments like FYM and neem cake are some of the disease management practices suggested.

Biocontrol

Field trials carried out at Veppankulam, Tamil Nadu by soil application of inoculum of *Azospirillum*, phosphobacteria and *Gigaspora calospora*, along with 10 kg. FYM reduced the disease index and increased the yield (Table 2) (Nambiar 1996). The efficacy of neem cake amendments to soil, consequent increase in soil microflora, specially of *Trichoderma* and reduction in disease have been reported (Bhaskaran *et al.* 1984, 1988). The antagonistic activity of *T. harzianum* on *G. lucidum* (Bhaskaran *et al.* 1988) and *T. harzianum* applied along with Neem cake reduced the disease index and increased the yield (Bhaskaran *et al.* 1993) of coconut.

There is no information on biocontrol of *Phytophthora* caused bud rot of coconut, grey leaf spot caused by *Pestalotia palmarum* and leaf rot caused by *Helminthosporium halodes*. The potential of phylloplane microflora on biocontrol has been emphasized (Kohl and Fokkema 1998). Studies on phylloplane microflora specifically antagonistic bacteria would be rewarding in future programmes.

ARECANUT (*Areca catechu*)

Yellow leaf disease caused by *Phytoplasma*, bud rot and fruit rot caused *P. arecae* and *P. meadii*, foot rot (anabe) caused by *Ganoderma lucidum*, inflorescence blight caused by *Colletotrichum gloeosporioides* are important (Table 1).

Biocontrol

Except for reporting antagonism of *Trichoderma* spp., *Bacillus coaguleaus*, *Streptomyces* sp. and *Mucor* sp. on *G. lucidum* (Anonymous 1963, 1967, Menon 1963) further investigations were never attempted. However, there is a potential scope for the management of foot rot and stem bleeding through biocontrol similar to the lines suggested on coconut. For *Phytophthora* fruit rot there is a necessity to study the surface microflora of the fruit for their antagonistic potential. In addition soil application of biocontrol agents in arecanut would help in reducing *Phytophthora* propagules in the soil. For stem bleeding similar strategies suggested for coconut would be useful.

## COCOA (*Theobroma cacao* )

Black pod, canker, charcoal pod rot and vascular streak die-back are the important diseases but the former causes serious crop losses during south west monsoon period (Table 1).

### Black pod (*Phytophthora palmivora, P. capsici, P. nicotianae* var. *nicotianae*)

The disease occurs as brown spot at any point of the pod and the lesion enlarges fast turns dark brown and causes pod rot. Besides, stem cankers are also seen. Prophylactic premonsoon spray is the suggested disease management strategy.

### Biocontrol

In Brazil the metabolites of *Cladobotryum amazonese*, were found inhibitory to sporangial formation in *P. palmivora* (Bastos *et al.* 1986). *Penicillium citrinum* was found highly antagonistic to *P. palmivora* and its partially purified metabolite was inhibitory to mycelial growth *in vitro* and on lesion formation *in vivo* (Bastos 1987). *Pseudomonas fluorescens* an epiphytic bacterium isolated from abandoned cocoa gardens in Costa Rica reduced infection on five cultivars under greenhouse condition (Galindo 1992). Detailed studies on the pod microflora are warranted to identify organism antagonistic or hyperparasitic to *P. palmivora*. Both black pod rot disease and stem canker occur during south-west monsoon period. The primary source of inoculum for both diseases is the contaminated soil. Reduction of initial inoculum and inoculum build up could be done by using biocontrol agents. Studies are now are in progress under National Network of *Phytophthora* Diseases of Horticultural Crops (PHYTONET).

## TEA (*Camellia sinensis*)

Blister blight and root disease (Table 1) are serious. However studies on biocontrol of the latter are only recent.

### Biocontrol

Screening of *Trichoderma* spp. and *G. virens* against four major root pathogens *viz.* *Fomes noxius, Poria hypolateritia, Roselinia arcuata* and *Armillaria mellia* showed variable reaction. While *G. virens* colonized all the four equally, *T. harzianum* colonized *Poria* and *Armillaria*, and *T. viride* was the best on *Roselinia*. The antibiosis of these on the above root pathogens has been established (Baby and Chandramouli 1996). *Chaetomium sp., Aspergillus sp., Fusarium* sp., *T. viride, Gliocladium* sp., *Cladosporium* sp., *Penicillium* sp., *Mucor* sp., *Scopulariopsis* sp., *Rhizoctonia* sp., *Cylindrocarpon* sp. and *Phoma* sp. are some of the organisms associated with rhizosphere of tea in North-East India (Chakraborty and Chakraborty 1997) and need to be studied for their biocontrol potential against root diseases of tea.

Brown blight *(Glomerella cingulata)*

This is an important foliar disease causing rotting of leaves starting from margins as yellowish to chocolate brown and gradually turns grey.

Biocontrol

*Bacillus* sp. isolated from phylloplane of tea was found antagonistic to *G. cingulata.* Spraying the detached leaves with bacterial suspensions and cell free culture filtrate did check brown blight (Chakrabory *et al.* 1996 a,b). Similarly *Pseudomonas* sp. and *Micrococcus listeus* were found antagonistic to *G. cingulata* and their cell free culture metabolites extracted were found inhibitory. Prior inoculation of leaves with these resulted in reduced disease severity (Chakraborty *et. al.* 1994, 1998).

These studies being basic in nature, the identified antagonists need be field tested for their efficacy and stability. Tea being export oriented crop, biocontrol methods need be given high priority in future disease management programmes.

**COFFEE** (*Coffea arabica* **and** *C. robusta* )

Among the diseases which affect coffee, leaf rust and root rots are the major disease problems that affect coffee (Table 1).

Leaf rust ( *Hemileia vastatrix*)

Pale yellow spots on the lower surface of leaves which later turn to orange yellow powdery mass consisting of uredospores, are the symptoms. Chemical control as Bordeaux mixture spray is the major disease management strategy.

Biocontrol

Biocontrol did not receive attention in India. *Cladosporium hemileiae* as a mycoparasite of coffee rust has been reported from Zaire (Steyart 1930). In Malaysia *Verticillium psalliotae* has been reported as hyperparasite of *H. vastatrix* (Lim and Nik 1983). Studies on phylloplane microflora of coffee to identify the hyper parasites or antagonists would be rewarding.

Black rot ( *Koleroga noxia* ( =*Corticium koleroga*)

Rotting of leaves twigs and developing berries are the symptoms of the disease. Shade regulation and Bordeaux mixture spray are the disease management practices.

Biocontrol

Biocontrol programmes on coffee have been reviewed recently (Barthakur and Dutta 1992). The antagonism of *Bacillus subtilis* to *Corticium invisum,* the leaf rot pathogen of tea is of considerable interest (Barthakur *et. al.* 1992) in the present context and detailed studies on phylloplane microflora need be pursued.

Root diseases

Brown root, red root, black root and Santiveri root disease are important soil-born diseases. Due to root rot, affected plants show foliar yellowing, and wilting ultimatel leading to death.

Biocontrol

It is only recently biocontrol studies have been initiated at Central Coffee Researc Station, Balehonnur. *T. harzianum* and *T. viride* were found antagonistic to these pathogen and soil application of inoculum of these has been reported to be effective in reducing the disease (Nirmalakannan *et al.* 1997). However, detailed investigations are called for. The classical biocontrol developed against *Fomes annosus* with *Peniophora gigantea* (Rishbeth 1963) is an outstanding example which needs to be studied in coffee root diseases. The potential of *Trichoderma, Gliocladium* spp. (Papavizas 1985) non pathogenic *Fusarium* (Garibaldi *et al.* 1992), the fluorescent pseudomonads and *Bacillus* sp. need be exploited fo the biocontrol of these pathogens.

RUBBER (*Hevea brasiliensis*)

Abnormal leaf fall and powdery mildew are the two important foliar diseases that cause severe damage to rubber (Table 1).

Abnormal leaf fall (*Phytophthora meadii, P. palmivora, P. nicotianae* var. *nicotianae*)

The disease occurs during south west monsoon period. Infection occurs on petioles as dark spot from which latex oozes out. Leaf rot also is noticed leading to heavy defoliation. This would add up to the soil-borne *Phytophthora* inoculum. In addition *Phytophthora* also causes black stripe on the trunk. Prophylactic premonsoon spray with Bordeaux mixture or oil based copper are the disease management practices.

Biocontrol

Studies on phylloplane microflora for their antagonistic potential to suppress are warranted. Recent studies have shown the *in vitro* antagonistic potential of *T. viride, T. koningii, T. harzianum* and *T. hamatum* on *P. meadii*. Besides they also caused lysis of oospores (Vanitha *et al.* 1994). Further studies are warranted on their establishment on foliage to cause disease suppression.

BLACK PEPPER (*Piper nigrum*)

Among 17 diseases recorded on black pepper in India (Sarma *et al.* 1991) foot rot and slow decline continue to be the major production constraints, besides Anthracnose, the important foliar disease. Stunted disease caused by cucumber mosaic virus (CMV) is becoming serious in recent times (Table 1).

Foot rot and root rot (*Phytophthora capsici*)

Infection of aerial parts like leaf, spikes and stems leading to varying degrees of defoliation, root rot and collar rot leading to death of the vine are the major symptoms of the disease. Pre and post monsoon prophylactic spray with Bordeaux mixture and soil drenching with 0.2% copper oxychloride apart from cultural practices like phytosanitation, shade regulation, minimum tillage and provision of better drainage are some of the recommended practices of disease management. (Sarma *et al.* 1991, 1994a)

Biocontrol

The biocontrol strategies in disease management in spice crops are gaining importance particularly in view of the demand for zero pesticide residue spice produce from foreign buyers. The status of biocontrol in disease management has been reviewed (Anandaraj and Sarma 1994, Sarma *et al.* 1996a, Sarma 1997). The importance of biological control of foot rot was realized when the presence of *Phytophthora* was noticed in the rhizosphere of black pepper in Silent valley forests of Western ghats, the centre of origin of black pepper and the absence of disease, which indicated the existence of biological balance between *Phytophthora* and pepper in a natural ecosystems (Sarma *et al.* 1994a). Eight species of *Trichoderma* and *G. virens* were isolated from different pepper plantation of Kerala and Karnataka. Based on their bioefficacy both *in vitro* and *in vivo* (Pot culture) large-scale field demonstrations were undertaken in farmers field during 1994-1998 and data did establish the potential of biocontrol of foot rot as indicated by slow but steady decrease in foliar yellowing and death of vines in both Karnataka and Kerala (Table 3 & 4) (Sarma and Anandaraj 1997). The biocontrol was further integrated with potassium phosphonate (Akomin) (Table 5) since the latter was compatible with *T. harzianum* and *G. virens* (Rajan and Sarma 1997a).

Incidentally these BCAs showed some suppressive effect on *M. incognita* and *R. similis* which are associated with slow decline of black pepper (Anonymous 1997). *Verticillium chlamydosporium* isolated from roots of black pepper also was found effective against these nematodes (Sreeja *et al.* 1996) and also against *P. capsici* (Veena and Peethambaran 1997). Increased growth and effective protection (90-100%) of root rot by *V. tenerum* has been reported (Rajan and Sarma 1997b). Besides, several fluorescent pseudomonad isolates were found effective in suppression of root rot of black pepper (Sarma and others unpublished). *In vitro* antagonism of *Bacillus* sp. and *in vivo* reduction of lesions caused by *P. capsici* in black pepper has been reported (Girija and Jubina 1997). VAM association with plantation crops received considerable attention in recent years (Manjunath and Bagyaraj 1982) and its potential in biocontrol are indicated in some of the recent studies. The role of VAM in suppression of soil borne diseases has been highlighted earlier (Schenk 1977). The association of VAM with black pepper (Manjunath and Bagyaraj 1982) and their growth promoting activity has been reported earlier (Bopaiah and Khader 1989). Varying degrees of suppression of root rot due to *P. capsici* in different varieties of black pepper has been reported (Table 6) (Anonymous 1997). *Glomus fasciculatum* was found to suppress infection not only caused by *P. capsici* (Sivaprasad *et al.* 1995) but also that of *M. incognita* and *R. similis* in black pepper (Anandaraj *et al.* 1996) and this was evident by reduced root rot score and increased yield (Anandaraj *et al.* 1996, Sarma *et al.* 1996).

In black pepper three methods of treatment with biocontrol inoculum *viz.* applicati to the nursery, preplant application and field application to the standing crop has b suggested (Sarma *et al.* 1996). Fortification of solarized nursery mixture with VA *T. harzianum* or *G. virens* and using this nursery mixture to raise the nursery stock, ens healthy and robust plants. Pre-plant application of biocontrol inoculum to the planting along with FYM and also field application of neem cake (1kg/vine) mixed with 50 inoculum to the standing crop, during May-June and subsequently one more dose of inocu @50g/vine during August, did decrease the foliar yellowing and vine death.

BETEL VINE (*Piper betel*)

Foot rot and stem rot are the two important diseases that cause severe damag betel vine crop (Table 1).

Foot rot and leaf rot (*P. palmivora, P. capsici, P. parasitica*)

Leaf rot and vine death due to foot rot are similar to that are seen in black pep

Biocontrol

Pre and post planting treatment of the soil with biocontrol agents like *T. viride* *T. harzianum* was found effective (Anonymous 1992). In North India where it is grown 'BareJas' (Closed green houses) soil solarization prior to construction of 'BareJas' treatment with biocontrol agents would be advantageous. Dipping of stem cuttings suspension of *Trichoderma* gave good control (Tiwari and Mehrotra 1968). The efficac biocontrol on foot rot management through *Trichoderma* soil application has been am demonstrated in several trials of All India Coordinated Research Project on Betel (AICRPB).

Stem rot (*Sclerotium rolfsii*)

The infection occurs on the stems more often at the base of the vine leading death of the vine. Soil amendment with sesame and ground nut cake was found effective disease control apart from several fungicides like pentachloro nitrobenzene.

Biocontrol

*In vitro* antagonism of *T. lignorum, T. harzianum* and *Bacillus subtilis* again *S. rolfsii* was established (Agarwal *et al.* 1997). Soil application of *T. harzianum* resul in good protection against betel vine stem rot (Mohapatra and Das 1990, Maiti *et al.* 199 This was further field tested under AICRPB. There is a need to investigate the biocont potential of phylloplane microflora against anthracnose, one of the important foliar disea of betel vine.

CARDAMOM (*Elettaria cardamomum*)

Capsule rot and rhizome rot are the two important diseases of cardamom th cause varying degrees of crop loss during south- west monsoon period (Table 1).

Capsule rot (Azhukal) (*P. meadii, P. nicotianae* var. *nicotianae*)

Rotting of spikes and capsules during South-West monsoon are the symptoms. Foliar infection resulting in leaf rot and occasional root and clump rot are also noticed. Pre- and post monsoon prophylactic spraying with Bordeaux mixture (1%) is the recommended disease management practice.

Biocontrol

Studies were initiated with exotic isolates of *T. viride, T. harzianum, B. subtilis* and *Latiseria aravalis* which were effective both *in vitro* and *in vivo*. When these were applied to soil, *Phytophthora* population was reduced and disease suppression of 30-50% was achieved (Suseela Bhai *et al.* 1993, Joseph Thomas *et al.* 1993). For field application, inoculum in decomposed coffee pulp and farm yard manure in 1:1 ratio was found to be the best (Suseela Bhai *et al.* 1994). Studies carried out on quantity and frequency of field application of inoculum ($28 \times 10^8$ cfu/g) showed that two application of inoculum @1 kg /plant during May and July significantly reduced *Phytophthora* and consequently disease (Table 7) (Suseela Bhai 1998). Similarly this was further tested in integrated disease management (IDM) along with Potassium phosphonate (Akomin), and gave good protection (Table 11). Though the reduction of disease in biocontrol treated plot was on par with Potassium phosphonate and Bordeaux treated plot, the former is preferred because of the pesticide free product it offers (Suseela Bhai 1998).

Similarly these BCAs reduced the rhizome rot caused by *P. vexans* and *R. solani*. Percentage of mortality ranged from 8-10% compared to 16.5 in untreated control in the case of *P. vexans* and it was 13-27% in the case of *R. solani*. In combined infection it ranged from 8-11% compared to 38% in control, which indicated its biocontrol potential. (Joseph Thomas *et al.* 1996). This was further field evaluated in the nurseries and found highly successful (Sarma and Anandaraj 1998). Thus the leads obtained on the efficacy of biocontrol of these diseases in cardamom need large scale field testing.

GINGER (*Zingiber officinale*)

Rhizome rot, yellows and bacterial wilt are the three major soil-borne diseases and cause severe crop losses in different ginger growing states in India (Table 1). The diseases are generally seen during South-West monsoon period causing varying degrees of foliar yellowing and in all the cases the plant rots causing total loss of rhizomes. However causal agent profile differs from place to place. Soft rot or rhizome rot is caused by *Pythium aphanidermatum* in Kerala or *P. myriotylum* either alone or in combination with *Fusarium solani* as in the case of Rajasthan or *F. oxysporium* f. sp. *zingiberi* as in Himachal Pradesh or in combination with four nematode species like *Meloidogyne incognita* or *Pratylenchus coffeae* (Sarma 1994).

Rhizome rot (*P. aphanidermatum, P. myriotylum + Fusarium solani, F. oxysporium* f. sp. *zingiberi*)

Rhizome rot is very serious in Kerala and the potential of biocontrol of this disea received considerable attention in recent years (Sarma *et al.* 1994a). The potential *T. lignorum* as biocontrol agent was suggested much earlier (Thomas 1938). About eig *Trichoderma* spp. and *G. virens* were isolated from rhizosphere and rhizoplane of ging and these showed various degrees of interaction with *P. aphanidermatum* in dual cultu. (Table 8) (Usman *et al.* 1997). *Trichoderma viride, T. harzianum, T. hamatum* an *G. virens* as seed treatment and also as soil application along with neem cake at 1kg/l showed varying degrees of protection and increased yield (Table 9). The treatment w even superior to mancozeb treatment. The population stability of biocontrol was maintain up to 60 days and later decreased and this calls for increased application of inoculu Efficacy of neem cake application on detection of rhizome rot has been reported earli (Sadanandan and Iyer 1986). Similar results were obtained in Rajasthan where *P. myriotylu and F. solani* are involved in rhizome rot. *T. viride* applied along with wood saw dust karanj or neem cake has been effective (Lodha *et al.* 1994a). In both the cases soil solarizati prior to planting and followed by biocontrol showed synergistic effects in disease reducti and increased yield (Sarma *et al.* 1996, Usman *et al.* 1996). The efficacy of soil solarizati in rhizome rot suppression was reported (Lodha *et al.* 1994a&b, Lodha and Mathur 19 Mathur *et al.* 1992). Importance of soil solarization in suppression of soil borne pla diseases has been well established (Katan and De Vay 1991).

The biocontrol was further integrated with chemical control using metalaxyl as see treatment since it is compatible with *Trichoderma* (Balakrishnan 1996, Sarma 1997, Lodh and Mathur 1997). The seed treatment with biocontrol agents like *Trichoderma* also h been reported (Bharadwaj and Gupta 1987). *Pythium acanthaphoron* as a hyper parasite *Pythium myriotylum* has been reported (Lodha and Webster 1990) and needs its exploitati for biocontrol against rhizome rot of ginger since it shares almost the same ecological nic of pathogenic *Pythium* sp. Large scale field evaluation of biocontrol agents in Kerala we successful.

Since root system also is vulnerable to infection reduction of rhizome rot wi VAM application has been reported particularly with *Glomus fasciculatum* (Balakrishna *et al.* 1997, Rohini Iyer and Sundarraju 1973) and with *G. constrictum* (Joseph and Sivapras 1997). Increased nutrients and phenolics have been attributed as probable reasons for th disease control. However, contradictory results were also reported with *G. fasciculatum* (Mathur *et al.* 1992).

Field demonstration undertaken during 1997-98 by IISR, Calicut in five maj districts of Kerala showed consistent results on the reduction of rhizome rot and increase yield (Table 10).

Apart from this *Aspergillus niger, A. terreus, Penicillium* sp. and *Absidi cylindrospora* showed disease reduction ranging from 7-100% (Table 14) (Balakrishna *et al.* 1997) and this needs field evaluation.

Efficacy of biocontrol either alone or in combination with soil solarization with *Trichoderma* and *G. virens* also has been reported in yellows disease in Himachal Pradesh where in addition to *Fusarium*, association of *Pratylenchus coffeae* also has been reported (Dohroo 1995). This would imply the dual role of biocontrol agents suppressing both pathogens, fungi and nematode. Similar results have been reported (Santhosh J Eapen and Ramana 1996). *Bacillus subtilis, Memnoniella echinata* and *A. niger* were found effective in suppressing yellows of ginger. *B. subtilis* strain II reduced disease from 58.2 to 8.3% and increased yield (Sharma and Jain 1978).

## TURMERIC (*Curcuma longa*)

Rhizome rot caused by *Pythium graminicolum* and *P. aphanidermatum* is a serious disease problem in Andhra Pradesh and Tamil Nadu. Leaf spot and leaf blotch are important foliar diseases (Table 1). Studies on biocontrol of rhizome rot are in progress at Acharya N G Ranga Agricultural University, Hyderabad under All India Coordinated Research Project on Spices. *T. viride, T. harzianum* and *G. virens* have a great potential and need be studied on the similar lines of biocontrol of rhizome rot of ginger (Sarma 1994).

## SEED SPICES (Cumin - *Cuminum cyminum* L., Coriander - *Coriandrum sativum* L., Fennel - *Foeniculum vulgare* Mill., Fenugreek- *Trigonella foenum-graecum* L.)

Wilt of cumin and coriander, root rot of fenugreek are some of the important soil borne diseases apart from foliar problem like powdery mildew and leaf blight in seed spices (Table 1).

### Biocontrol

In the case of cumin wilt soil amendments with neem, castor and mustard cakes resulted in reduction in disease (Champawat and Pathak 1990, Jain *et al.* 1990). Similar results were reported for coriander wilt (Srivastava and Sinha 1971).

In the case of fenugreek root rot caused by *Rhizoctonia solani*, the efficacy of seed pelletting with *Trichoderma* and soil application of *Trichoderma* along with neem cake @ 1.5kg/ha showed greater protection (Table 11) (Anonymous 1993). Besides these *T.viride, B. subtilis* and *Pseudomonas fluorescens* were also found effective in reducing coriander wilt (Table 12) and increased yield.

The potential of biocontrol of this disease has been little exploited. Seed pelletting with biocontrol agents like *P. fluorescens, Trichoderma* and *G. virens* and combining these with organic amendments would be of great promise. Besides the phylloplane microflora also need be studied since foliar blights caused by *Alternaria* and powdery mildews are also important and biocontrol potential need be exploited.

## BOTANICALS

The use of botanical pesticides is gaining importance in recent years. Except for reporting the biological activity through *in vitro* tests, their practical application in disease management has not received enough attention in contrast to exploitation of neem produc for insect pest control. Biologically active phytochemicals from *Brassica campestris* *Lantana camera* L and *Cajanus cajan* L. Mulls. showed varying degrees of inhibition (1. 7.5%) to various *Fusarium* sp. and is relevant to fusarial problems in seed spices, ginger coffee. Soil application of garlic and mustard aqueous extracts to black pepper plants been reported to reduce slow decline (Shivaram 1991). Incidentally, increase in *Trichode* population in treated soils was noticed and might be the possible reason for root rot suppress. The compound ajoene, from garlic showed high efficacy in checking the sporangial format: and germination in *P. drechsleri* f. sp. *cajani* (Singh and *Chauhan* 1992) and needs furt investigation to utilize the same for *Phytophthora* disease management of plantation cr Water extracts of *Azadirachta indica, Chromolaena odorata, Lantana camara, P. colubrinum* and *Strychnos nuxvomica* were tested *in vitro* against *P. capsici* of black pep They showed different degrees of inhibition but the extracts of *A. indica* and *C. odor* were effective in checking sporulation and zoospore germination (Anandaraj and Leela 19 Similarly aqueous extracts of *Uvaria narum* were inhibitory to *P. capsici* of black pep and the active principle was found to be benzoic acid which inhibited sporangial format: liberation and zoospore germination (Bindu *et al.* 1998). There is a necessity to stud detail these biomolecules, if we intend to involve these for efficient disease manageme many of these crops.

## INOCULUM PRODUCTION

Mass multiplication of *T. harzianum* and *G. virens* was tried on coffee pulp. waste neem cake and FYM and of these tea waste supported maximum growth and sporula (Table 13 &14) (Prakash *et al.* 1997). Similar results were obtained with *T. harzianum* u for the cardamom programmes (Suseela Bhai *et al.* 1997). Production of *Trichode* inoculum in coffee pulp and its utilization for *Phytophthora* infection in citrus has b reported (Sawant and Sawant 1990, Sawant *et al.* 1995). Similarly potential of coconut w. and coir pith as a substrate for multiplication of *Trichoderma* and *Gliocladium* has b reported (Anandaraj and Sarma 1997, Kumar and Marimuthu 1997). The locally availa low cost carrier media would be cost effective and easily accessible. Since requirement biocontrol of the soil application are greater unlike for seed treatment, large-scale product in fermentors and formulations would be practical.

# FUTURE STRATEGIES

There is an urgent necessity to intensify the studies on the feasibility of biocontr options for several diseases of plantation crops and spices since majority of them are soilbor in nature and elusive for effective disease management. The following programme ne priority

1. Isolation and identification of native biocontrol agents (BCA) with high competi saprophytic ability and rhizosphere competence, which possess wide spectrum of biolog suppressive activity against more than one pathogen, particularly effective against fun and nematode plant pathogens.
2. Standardization of inoculum dose with native isolates based on the location spec requirements.

3. Improvement of bioefficacy of identified antagonists/hyperparasites either through mutation or through other known biotechnological approaches.
4. Development of a biocontrol consortium which would have wider adaptability to different ecological niches.
5. Monitoring the population stability of the BCA in relation to pathogen population and their ecological parameters that would ensure biological balance. This is essential to regulate the augmentation of biocontrol inoculum.
6. Large-scale production of inoculum and developing suitable inexpensive delivery systems.
7. Standardization of quality parameters for various biocontrol formulations, specifically, the viability of propagules and the minimum inoculum requirement based on cfu/g and their keeping quality
8. Developing BCAs with greater compatibility with agrochemicals is essential to develop Integrated Disease Management (IDM) strategies.
9. Popularization of this ecofriendly technology among farming community with proper instructions for use.

In view of the recent report on induction of sexual reproduction of *S. rolfsi* by *B. subtilis* (Prithviraj and Singh 1997), which was found to be effective against the former, calls for greater caution and careful observations so that any biocontrol agents with such undesirable traits can be withdrawn.

While priority would be definitely for the management of soilborne pathogens affecting these crops, in view of their seriousness, it is essential to pursue the programmes for foliar pathogens specially through investigation on phylloplane microflora. There is an abundant potential to exploit biocontrol for the management of diseases of plantation crops and spices and researches need to be intensified.

Table 1. Status of biocontrol in management of major diseases of plantation crops and spices

| Disease | Causal agent | Amenability for biocontrol | Biocontrol agents reported/ programmes initiated |
|---|---|---|---|
| COCONUT | | | |
| Root wilt | *Phytoplasma* | ? | No information |
| Bud rot/Fruit rot | *Phytophthora palmivora* | + | No information |
| Stem bleeding | *Thielaviopsis paradoxa* (*Ceratostomella paradoxa*) | ++ | *Gliocladium virens*<br>*Trichoderma harzianum* |
| Basal stem rot | *Ganoderma lucidum* | ++ | *T. harzianum*<br>*Gliocladium* |
| ARECANUT | | | |
| Fruit rot and Bud rot | *P. arecae, P. meadii* | + | No information |
| Anabe roga (Foot rot) | *Ganoderma lucidum* | + | No information |
| Inflorescence die back | *Colletotrichum gloeosporioides* | + | No information |
| COCOA | | | |
| Black pod | *P. palmivora*<br>*P. citrophthora*<br>*P. capsici* | + | No information<br>(Work initiated) |

contd...

Table 1 (contd.)

| Disease | Causal agent | Amenability for biocontrol | Biocontrol agents reported/ programmes initiated |
|---|---|---|---|
| Charcoal pod rot | *Botryodiplodia theobromae* | + | No information |
| Canker | *P. palmivora, P. citrophthora, P. capsici* | + | No information |
| Vascular streak die back | *Oncobasidium theobromae* | + | No information |
| TEA | | | |
| Blister blight | *Exobasidium vexans* | ? | No information |
| Red root rot | *Poria hypolateritia* | + | *T. harzianum* |
| Charcoal stump rot | *Ustulina destuta* | + | No information |
| Brown rot | *Fomes noxius* | + | *T. harzianum, G. virens* |
| Black root rot | *Rosellina arcuata* | + | *Trichoderma, G. virens* |
| Wood rot | *Hypoxylon serpens* | + | No information |
| Collar canker | *Phomopsis theae* | + | No information |
| COFFEE | | | |
| Rust | *Hemileia vastatrix* | + | No information |
| Black rot | *Pellicularia koleroga* | + | *Trichoderma, G. virens* |
| Brown rot | *Fomes noxius* | + | -do- |
| Black root rot | *Rosellina* sp. | + | -do- |
| Santhiveri wilt | *Fusarium oxysporum* f. sp. *coffeae* | + | -do- |
| RUBBER | | | |
| Abnormal leaf fall | *P. meadii* | +? | Work with *Trichoderma* initiated at RRI, Kottayam |
| Powder mildew | *Oidium heveae* | +? | No information |
| Brown bast | Etiology not understood | ? | No information |
| Brown rot | *Fomes noxius* | + | No information |
| BLACK PEPPER | | | |
| Foot rot | *P. capsici* | +++ | *T. harzianum, G. virens,* VAM, Fluorescent |
| pseudomonads | | | |
| Slow decline | *Radopholus similis* | ++ | *T. harzianum, G. virens* |
| | *Meloidogyne incognita* | ++ | *Paecilomyces lilacinus* |
| | *P. capsici* | ++ | *Verticillium chlamydosporium* |
| Anthracnose | *Colletotrichum gloeosporioides* | + | No information |
| BETEL VINE | | | |
| Foot rot | *P. palmivora,* | ++ | *T. viride* |
| | *P. capsici,* | ++ | -do- |
| | *P. parasitica,* | ++ | -do- |
| Anthracnose | *C. capsici* | + | *No information* |
| Stem rot | *Sclerotium rolfsii* | +++ | *T. lignorum* |
| | | | *T. harzianum* |
| | | | *B. subtilis* |
| CARDAMOM | | | |
| Capsule rot ('Azhukal') | *P. meadii* | +++ | *T. harzianum* |
| | *P. nicotianae* var. *nicotianae* | | *T. hamatum* |
| | | | *G. virens* |

contd...

Table I (contd.)

| Disease | Causal agent | Amenability for biocontrol | Biocontrol agents reported/ programmes initiated |
|---|---|---|---|
| Clump rot | *Pythium vexans*<br>*R.. solani*<br>*M. incognita* | +++ | *T. harzianum* |
| GINGER | | | |
| Soft rot/ Rhizome rot | *Pythium aphanidermatum*<br>*P. myriotylum*<br>*Fusarium solani*<br>*F. oxysporium* f. sp. *zingiberi* | +++ | *T. harzianum*<br>*G. virens*<br>Fluorescent pseudomonads |
| Bacterial wilt | *Ralstonia* (*Pseudomonas*) *solanacearum* | + | Avirulent, *R. solanacearum* |
| Leaf spot | *Phyllosticta zingiberi* | + | No information |
| TURMERIC | | | |
| Rhizome rot | *Pythium graminicolum*<br>*Fusarium* sp. | + | *Trichoderma* sp., *G. virens* |
| Leaf blotch | *Taphrina maculans* | + | No information |
| Leaf spot | *C. gloeosporioides*, *C. capsici* | + | No information |
| CUMIN | | | |
| Wilt | *F. oxysporium f sp. cumini* | + | *Trichoderma/Gliocladium* work initiated. |
| Blight | *Alternaria burnsii* | + | No information |
| Powdery mildew | *Erysiphe polygoni* | + | No information |
| CORIANDER | | | |
| Wilt | *F. oxysporum* f sp. *coriander* | ++ | *Streptomyces* sp., *Trichoderma* |
| Powdery mildew | *E. polygoni* | + | No information |
| FENUGREEK | | | |
| Root rot | *Rhizoctonia solani* | +++ | *T. viride*,<br>*Pseudomonas fluorescens* |
| Powdery mildew | *E. polygoni* | + | No information |

? : Not tested, + : Possible, ++ : Amenable, +++ : Highly amenable

Table 2. Effect of biofertilizers on basal stem rot disease of coconut and nut yield (Veppanakulam)

| Treatments | Disease index | | Nut yield/palm | |
|---|---|---|---|---|
| | 1990 (Initial) | 1993 | 1990-91 | 1992-93 |
| *Azospirillum* inoculum 200 g/palm | 0.4 | 56.5 | 90 | 90 |
| Phosphobacteria inoculum 200g/palm | 0.6 | 9.2 | 86 | 102 |
| *Gigaspora calospora* inoculum 500g/palm | 0.1 | 49.8 | 96 | 89 |
| Control | 20.8 | 74.3 | 80 | 76 |
| C.D (p = 0.05) | 2.7 | 4.5 | NS | 3 |

Source : Basal stem rot of coconut Tech. Bulletin No. 30 Nambiar K K N. (ed.), Central Plantation Crops Research Institute, Kasaragod, Kerala.

Table 3. Effect of Trichoderma harzianum on foot rot of black pepper (1994-96)

| Plantation | Pre-treatment status (1994) Death (%) | Yellowing (%) | Post-treatment status (1996) Death (%) | Yellowing (%) |
|---|---|---|---|---|
| Boikeri estate (1963 vines) | 2.95 | 13.80 | 1.95 | 9.63 |
| Dwaraka estate (4384 vines) | 0.64 | 3.37 | 0.52 | 2.31 |
| Lakshmi estate (10048 vines) | 0.38 | 2.85 | 0.13 | 1.61 |
| Total (16395 vines) | 3.97 | 20.02 | 2.60 | 13.55 |

Table 4. Effect of biocontrol agents on foot rot disease of black pepper

| District | Pre- Treatment 1994 No. of vines | No. of vines dead | % | Post- Treatment 1996 No of vines | No. of vines dead | % |
|---|---|---|---|---|---|---|
| Wynad | 132200 | 5300 | 4.09 | 16900 | 142 | 0.84 |
| Calicut | 4025 | 280 | 6.95 | 1320 | 11 | 0.83 |

Table 5. Effect of VAM and agrochemicals on foot rot disease and yield of black pepper

| Treatment | Mortality of vines (%) VAM | Non. VAM | Mean | Yield vine g/vine VAM | Non. VAM | Mean |
|---|---|---|---|---|---|---|
| Control | 60.9 | 44.4 | 52.7 | 1226.6 | 1323.0 | 1275.0 |
| VAM | 10.8 | 27.7 | 19.7 | 6313.3 | 1828.0 | 4070.6 |
| Copper oxychloride, Bordeaux mixture | 33.8 | 27.6 | 30.4 | 2973.3 | 8920.0 | 2460.0 |
| Metalaxyl 100 ppm (Ridomil mancozeb) | 38.8 | 21.9 | 30.4 | 2821.3 | 456.0 | 1639.0 |
| Potassium phosphonate (Akomin) | 10.8 | 21.9 | 16.4 | 4745.0 | 3633.0 | 4181.1 |
| Mean | 30.95 | 28.74 | 29.8 | 3615.9 | 1037.0 | - |
| LSD 0.05 | NS | NS | 18.12 | 2122.8 | - | 1294.3 |

Source: IISR, 1997 Annual Report 1996-97, Indian Institute of Spices Research, Calicut Kerala.

Table 6. Effect of VAM on root rot of black pepper caused by *P. capsici*

| VAM isolate | Root rot index in black pepper varieties (0-4)* Sreekara | Subhakara | Kottanadan | Panniyur - I | Mean |
|---|---|---|---|---|---|
| *Glomus sp.* | 1.0 | 1.0 | 1.3 | 1.3 | 1.1 |
| *G. gigantea* | 1.5 | 2.5 | 1.5 | 1.0 | 1.6 |
| *Glomus* sp. | 2.3 | 1.3 | 2.8 | 2.8 | 2.1 |
| *G. gigantea* | 0.8 | 0.8 | 1.8 | 1.8 | 1.3 |
| *Glomus* sp. | 2.5 | 2.5 | 1.8 | 1.5 | 2.0 |
| *Glomus* sp. | 2.5 | 1.8 | 1.5 | 1.5 | 1.8 |
| *Glomus* sp. | 2.3 | 2.5 | 1.8 | 1.5 | 2.0 |
| Control | 3.8 | 3.8 | 3.3 | 3.3 | 3.5 |
| Mean | 1.9 | 2.0 | 1.9 | 1.8 | - |

LSD 0.05 VAM isolates - 0.53; VAM isolates x Variety - 1.06

* 0 = Healthy; 1 = 25%; 2 = 50%, 3 = 75%, 4 = > 75% Root rot.

Source : IISR, 1997 Annual Report 1996-97, Indian Institute of Spices Research, Calicut, Kerala

Table 7. Integrated disease Management of Capsule Rot of Cardamom caused by *Phytophthora meadii*

| Treat no. | Frequencies | | | Disease incidence % | DPI * | *Trichoderma* pop. x $10^3$ |
|---|---|---|---|---|---|---|
| T1 | BM | *T.h* | *T.h.* | 0.30 (95.46) e | 7.56 (92.20) d | 18.76d |
| T2 | *T.h* | BM | BM | 0.72 (89.11) i | 2.00 (97.94) a | 17.94e |
| T3 | Ak+*T.h* | Ak+*T.h* | Ak+*T.h* | 0.28 (95.76) f | 16.17 (83.31) g | 29.69a |
| T4 | Ak | Ak | Ak | 0.10 (98.49) b | 15.89 (83.60) f | 3.03g |
| T5 | BM | BM | BM | 0.13 (98.03) c | 4.28 ( 95.58)b | 2.47h |
| T6 | T.h | COC | COC | 0.37 (94.40) g | 15.78 (83.71) e | 15.47f |
| T7 | COC | *T.h* | *T.h* | 0.20 (96.97) d | 21.17 (78.15) h | 27.10c |
| T8 | *T.h* | *T.h* | *T.h* | 0.20 (96.97) d | 34.44 (64.45) i | 28.99b |
| T9 | COC | COC | COC | 0.03 (99.55) a | 5.11 (94.73) c | 2.08i |
| T10 | CONTROL | | | 6.61 (**) | 96.89 (0.00) j | 1.50j |
| | LSD AT 5% LEVEL | | | 2.96 | 32.45 | 9.24 |

* Figures in brackets are % reduction over control, Initial *Trichoderma* population 23 x $10^8$

*DPI : *Phytophthora* population as disease potential index.

BM : Bordeaux mixture, *T.h* : *T. harzianum*, * : cfu x $10^7$, AK : Akomin, COC : Copper oxychloride

Source : R. Suseela Bhai, 1998, Ph. D Thesis "Studies on 'Azhukal' (Capsule rot) disease of cardamom, University of Calicut, Kerala.

Table 8. Macroscopic and microscopic changes in *Pythium aphanidermatum* due to interaction with *Trichoderma* and *Gliocladium*

| Organism | | Isolate | Macroscopic | | | Microscopic | | |
|---|---|---|---|---|---|---|---|---|
| | | IZ | OA | AFL | GS | HC | L | O |
| *T. viride* | ISO - 1 | | - | - | - | - | - | - |
| | ISO - 2 | - | + | - | + | + | - | - |
| *T. harzianum* | ISO 1 | - | + | - | - | - | - | - |
| | ISO 2 | + | + | + | + | + | + | - |
| *T. hamatum* | ISO 1 | - | + | + | + | - | - | Abnormal granules and Vacoulation |
| | ISO 2 | + | + | + | + | + | - | |
| | ISO 3 | - | + | + | + | + | - | |
| *T. aureoviride* | | - | - | - | - | - | - | Vacoulation |
| *T. psuedokoningii* | | - | - | - | - | - | | |
| *T. koningii* | | - | - | - | - | - | - | Cytoplasmic coagulation |
| *T. polysporum* | - | + | - | - | - | - | + | |
| *T. longibracheatum* | - | - | - | - | - | - | + | |
| *G. virens* | ISO 1 | - | + | - | + | - | - | Cytoplasmic coagulation |
| | ISO 2 | - | + | - | + | - | - | -do- |

IZ - Inhibition zone, OA - Overgrowth of antagonist, AFL - A flattening of test organism, GS - General stunting of pathogen mycelia, HC - Hyphal coiling, LI - Lysis, O - Other abnormal microscopic changes.
Source : Usman *et al.* 1997.

Table 9. Effect of antagonists on rhizome rot of ginger

| Antagonist | Germination | Disease incidence | Disease severity | Yield |
|---|---|---|---|---|
| *Aspergillus niger* | 100. 0A | 0. OC | 0. OC | 331. OA |
| *A. terreus* | 97. 5A | 20.0 BC | 12.0 BC | 233. OB |
| *Penicillium* sp | 100. OB | 25.0 BC | 19.25 BC | 192. 7C |
| *Absidia cylindrospora* | 80. OB | 30.0 BC | 30. OB | 140. 3C |
| Control | 75. OB | 72.5 A | 64.83 A | 43. 5D |

Source :Balakrishnan *et al.* 1997

Table 10. Effect of biocontrol agents on germination, disease incidence and yield of ginger

| Organism | Solarized | | | Non solarized | | |
|---|---|---|---|---|---|---|
| | G% | DI% | Y% | G% | DI% | Y% |
| *T. viride* | 77.69 | 13.70 | 2.846 | 71.52 | 35.25 | 1.225 |
| *T.harzianum* I | 79.61 | 15.80 | 3.552 | 79.43 | 32.07 | 2.673 |
| *T. harzianum* I | 77.87 | 19.38 | 2.910 | 72.91 | 43.61 | 1.439 |
| *T. hamatum* | 75.00 | 16.16 | 2.744 | 73.23 | 39.26 | 1.602 |
| *G. virens* | 74.48 | 18.25 | 2.641 | 74.43 | 36.63 | 1.705 |
| Mancozeb | 79.23 | 36.22 | 2.260 | 73.89 | 46.70 | 0.818 |
| Control | 81.53 | 57.58 | 1.692 | 79.86 | 53.8 | 0.992 |
| Mean | 77.92 | 25.30 | 2.278 | 74.90 | 41.08 | 1.485 |
| CD ( P=0.05) | NS | 6.26 | 0.430 | NS | 6.26 | 0.430 |

Source : Usman *et al.* 1996.

Table11. Biocontrol of root rot disease of fenugreek at Coimbatore

| Treatments | Root-rot incidence % | | Yield (kg/ha) | |
|---|---|---|---|---|
| | Kharif' 92 | Rabi' 92 | Karif' 92 | Rabi' 92 |
| Seed treatments + Soil drenching with Carbendazim | 14.8 | 10.8 | 422 | 315 |
| Seed treatment with *T. viride* | 4.8 | 4.4 | 384 | 365 |
| *T. viride* 20 days before showing | 26.3 | 20.4 | 288 | 285 |
| Neem cake 150 kg/ha | 3.9 | 3.2 | 427 | 385 |
| T4 + T2 | 3.2 | 3.4 | 424 | 360 |
| T4 + T3 | 5.4 | 12.4 | 288 | 325 |
| T4 + T1 | 12.8 | 14.3 | 345 | 340 |
| Seed treatment with Carbendazim | 27.9 | 24.5 | 294 | 265 |
| Control | 36.2 | 32.8 | 163 | 184 |
| CD (P = 0 .05) | 5.7 | 4.3 | 52.4 | 27 |

Source : All India Coordinated Research Project on Spices . Annual Report 1992-93, p. 61.

Table 12. Effect of seed treatment on wilt incidence in coriander

| Treatments | Wilt incidence % | Yield (kg/ha) |
|---|---|---|
| | Rabi 1992 | Rabi 1992 |
| Seed treatment + Soil drenching with Carbendazim | 11.4 | 307 |
| Seed treatment with *T. viride* | 6.3 | 356 |
| Seed treatment with *T. harzianum* | 12.3 | 300 |
| Seed treatment with *B. subtilis* | 14.8 | 290 |
| Seed treatment with *P. flourescens* | 29.5 | 172 |
| Seed treatment with Carbendazim | 14.2 | 285 |
| Control | 28.9 | 168 |
| CD (P = 0.05) | 5.8 | 26.4 |

Source : All India Coordinated Research Project on Spices . Annual Report 1992-93, p. 47.

Table 13. Population of *Trichoderma harzianum* on different substrates (CFU x $10^6$)

| Treatment Days | 7 | 14 | 21 | 28 | 45 | 60 | 75 | 90 |
|---|---|---|---|---|---|---|---|---|
| Coffee husk | 4.0 | 59.0 | 389.0 | 296.3 | 296.3 | 130.0 | 87.0 | 27.0 |
| Neem cake | 1.3 | 10.6 | 66.6 | 32.3 | 14.3 | 11.3 | 2.0 | 0.6 |
| Tea waste | 192.3 | 307.3 | 1780.0 | 1689.3 | 4602.0 | 1497.0 | 730.6 | 97.3 |
| Cow dung | 6.0 | 17.0 | 94.3 | 75.3 | * | * | * | * |

* Samples not done

Source : Prakash *et al.* 1997.

Table 14. Population of *Gliocladium virens* on different substrates (CFU x $10^5$)

| Treatment | Days 7 | 14 | 21 | 28 | 45 | 60 | 75 | 90 |
|---|---|---|---|---|---|---|---|---|
| Coffee husk | 4.6 | 14.0 | 92.3 | 125.3 | 91.0 | 67.3 | 50.3 | 25.0 |
| Neem cake | 2.3 | 11.3 | 63.0 | 40.6 | 22.3 | 15.6 | 9.6 | 7.3 |
| Tea waste | 239.3 | 490.0 | 502.3 | 829.3 | 792.0 | 555.3 | 380.0 | 277.3 |
| Cow dung | 1.0 | 65.3 | 202.6 | 156.6 | * | * | * | * |

* Samples not done
Source : Prakash *et al.* 1997

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