ALLELOPATHIC EFFECT OF SELECTED TREE SPECIES ON THE SOIL MICROFLORA AND THEIR ACTIVITIES

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CERTIFICATE

This is to certify that the thesis entitled "**ALLELOPATHIC EFFECT OF SELECTED TREE SPECIES ON THE SOIL MICROFLORA AND THEIR ACTIVITIES**" submitted by **Mr. ABIDALI D. MOKASHI,** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL MICROBIOLOGY** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Introduction

I. INTRODUCTION

In India, trees and agricultural crops have been integrated in various forms to maximize production. Combination of trees with crops are practiced in different parts of India. Agroforestry represents the integration of agriculture and forestry to increase the productivity and sustainability of farming systems and/or to increase farm income. It includes numerous land use system, ranging from planting of trees on agricultural lands to those in which agriculture is practiced on forest lands without deforestation.

Despite the fact that agroforestry gives supplementary returns per unit of land, it has been criticized for adverse effects of trees by dominating the under storey field crops in utilizing the limited resources (nutrients, moisture and light). Added to this, the release of organic compounds with inhibitory effects on other organisms (allelopathy) is considered as an additional factor affecting growth in any plant–plant environment (Rice, 1984). Tree crop interactions which are quite complex in nature are of paramount importance in any agroforestry system to understand clearly (Tripathi *et al.*, 1998).

The research work carried out of late has shown that it is not only the competition for physical growth resources but also interference of allelochemicals released by tree parts determine the performance of associated crops and rhizosphere microflora. This phenomenon of interference (Phytotoxicity) was termed by Molisch in 1937, as allelopathy.

Rice (1984) defined allelopathty as any direct or indirect and harmful or beneficial effect by one plant (including microorganisms) on other through production of chemical compounds that escape into the environment. Phenolic acids and the associated compounds are the most common growth inhibitors produced by living plants or released from decaying plant parts by microbial action or leaching or by volatilization process.

Allelochemicals mostly refer to the secondary metabolites produced by plants and are also byproducts of primary metabolic process which are produced by all kinds of trees and tree parts with leaf being the main source. The plant leachates have an effect on the physical, chemical and biological properties, besides on the plant growth.

Allelopathic effect have been exhibited by many species of perennial (Stachon and Zindahl, 1978) and annual crop plants (Rice, 1978). In field it is released by decomposition (Parker, 1962) or leaching by water from plant canopy and finally inhibits crop growth and yield (Elliot *et al.*, 1978).

Allelopathic effect has been shown to extend from producer plants to various agriculturally important microorganisms besides their activities microbial process. Florence (1986) observed that the accumulation of leaf litter of *Eucalyptus pilularis* under mature tree changed the microflora of surface soil in such a way that seedlings of the same species failed to grow. Root and leaf extract of

Parthenium hysterophorus was similarly shown to inhibit the growth of *Rhizobium phaseoli* (Sukhada and Jayachandra, 1979). Olsen *et al.* (1971) showed that high concentrations of benzoic acid and catechol in leachates of leaves of *Populus tremula* had a strong inhibitory effect on the growth of mycorrhizal fungi.

Hence, in the present investigation three field experiments, one each with eucalyptus, casuarina and teak were undertaken to confirm the existence of allelopathic potential of these species on soil microflora under the rhizosphere of green gram and wheat crops in field condition with the following objectives.

1. Allelopathic effect of eucalyptus, casuarina and teak on the soil microflora and soil enzymes in rhizosphere of field crops.
2. Allelopathic effect on the plant-microbe associations particularly with nodulation and vesicular arbuscular mycorrhizae in associated crops.

Review of Literature

II. REVIEW OF LITERATURE

Allelopathy concerns with the effect of plants on other plants and/or microorganisms through release of chemicals and their break down metabolites (Willis, 1994). Murthy and Ravindra (1975) demonstrated that root and shoot extracts of *Aristida adscensionis* had an inhibitory effect on the growth of *Rhizobium* and its nodulation of *Indigofera cordifolia.* Root and leaf extracts of *Parthenium hysterophorus* was, similarly, shown to inhibit the growth of *Rhizobium phaseoli.* Literature on the allelopathic effects of forest tree species, crop plants, weeds, crop residues on soil microorganisms is reviewed as under.

2.1 Effect of plant and chemicals on the soil microorganisms and their activity

2.1.1 Soil bacteria, fungi and actinomycetes

Leaf extracts of mustard and barley, sterilized either by filtering through a Seitz' s filter or by autoclaving with the medium, considerably stimulated the growth of all the test saprophytic and pathogenic fungi. However, the autoclaved extract was found to be most effective (Singh and Rai, 1981). Further, they reported that *Alternaria brassicae* and *Nigrospora oryzae* exhibited the maximum growth stimulation when treated with both the types of the leaf extracts of mustard and barley respectively.

Florence (1986) observed that the accumulation of leaf litter of matured *Eucalyptus pilularis* on the soil surface resulted in decline of

microbial population. The effect was so severe that seedlings of the same species failed to grow.

Yellappareddy and Sugur (1988) studied the microbial population in soil under three fast growing plant species *viz.*, *Acacia auriculiformis, Casuarina equisetifolia* and *Dendrocalamus strictus* in the western ghat area of Karnataka. They reported the predominance of *Azotobacter* and actinomycetes under *D. strictus* compared to other two plant species. The fungal population was lower in *D. strictus* which they attributed to the higher pH of the plantation. They also reported that total bacterial, actinomycetes and fungal population were higher under *Casuarina equisetifolia.* The occurrence of higher population of microorganisms including *Azotobacter* in casuarina was attributed to an increase in the availability of organic matter and effect of leaf mulch which helps to moderate the soil temperature.

Inderjit and Dakshini (1991) observed that out of 19 fungi found in the soils, the population of *Aspergillus niger, A.fumigatus* and *A.candidus* were decreased while *A.flavus* was increased in the soils with cogon grass (*Imperata cylindrica*).

According to Yun *et al.* (1993) the growth of *Bacillus subtilis, Aspergillus nidulans, Fusarium solani* and *Pleurotus ostreatus* was inhibited severely by the essential oil released by worm wood leaf (*Artemisia princeps* var. *Orientalis,* a medicinal plant). The allelopathic compounds responsible for inhibition were identified as terpinen, cineole and thujone.

Hegazy and Fadl-Allah (1995) were of the opinion that increasing shoot extract concentration of *Cleome droserifolia* was found to suppress the mycelial relative growth rate, sporulation, spore germination and germ tube length of the soil fungi. The allelopathic effect of the root exudates was so severe that the number of fungal species and the total count of fungi in the rhizosphere was less than in the non-rhizosphere soil. They also found that the *Rhizopus stolonifer* was the only species resistant to the allelopathic effect. The water extract of the shoot suppressed *Penicillium chrysogenum* and *P.funuculosum*.

The plant extracts of cork tree, *Phyllodendron amurense* was found to inhibit the growth of bacteria, yeasts and fungi. The allelochemical responsible for the inhibitory activity of these microorganisms was found to be berberine as reported by Park and Choi (1996).

Qishui Zhang (1997) reported that soil extracts from replanted woodlands significantly inhibited soil non-pathogenic fungal growth, reduced soil respiration and soil nitrogen mineralization rates. The soil extracts, however, increased the growth of pathogenic fungi. The combination of soil extracts and pathogenic fungi did not significantly reduce the growth of Chinese-fir seedlings when compared to the soil extracts alone. The combination of soil extracts with pathogenic and non-pathogenic fungi significantly increased the growth of Chinese-fir seedlings when compared to the combination of soil extracts and pathogenic fungi. Further, he reported the presence of allelochemicals in

soil extracts, rather than pathogenic fungi was the key factor in regulating the productivity and nitrogen cycling in repeated plantation woodlands.

2.1.2 Beneficial microorganisms

Parks and Rice (1968) studied the effect of certain plants of old-field succession on growth of blue-green algae and reported that, the cultures from soil obtained near *Aristida oligantha* in the fall had much poorer algal growth than cultures from soil obtained during spring. However, *Helianthus annus* appeared to limit the growth of nitrogen fixing algae which could decreased with an increase in distance from the base of the plant. Decomposing plant material of several plant species, was also found to be inhibitory to the growth of *Lyngbya* and *Anabaena* and leaf leachates from *Rhus glabra* was found to be inhibitory to the growth of both *Lyngbya* and *Anabaena.*

Udo Blum and Rice (1969) reported that the soils from underneath *Euphorbia supine* and *Rhus copallina,* species in abandoned fields contained tannic and gallic acids which were responsible for reduction in the nodulation and leghaemoglobin content in beans.

Ranga Rao *et al.* (1972) studied the inhibition of *Rhizobium in vitro* by non-nodulating legume roots and root extracts. Autoclaved extracts of *Leucaena leucocephala* showed maximum inhibition of *Rhizobium* followed by *Cassia fistula* and *C.occidenalis.* According to them, the water soluble and heat stable phenolic compounds present in

the coloured root tissues and root extracts may be inhibiting the bacterial growth.

Purushothaman and Balaraman (1973) studied the effect of soil phenolics on the growth of *Rhizobium* in a culture medium. The lignite was found to contain highest quantity of phenols than peat, black and red soils. The lignite also contained five different phenolics while in others there were only three types of phenolics. Of the phenols studied P-amino benzoic acid and hydroquinone were more inhibitory than others.

Sukhada and Jayachandra (1979) studied the effect of *Parthenium hysterophorus* on nitrogen fixing bacteria and reported that the root or leaf extract inhibited the growth of *Rhizobium phaseoli* and *Azotobacter vinelandi.* Similar inhibition was caused by parthenin, caffeicacid and anisicacid, the important inhibitors isolated from the weed. Leghaemoglobin content in the root nodules of the bean plants grown in soil mixed with parthenium leaf was reduced significantly.

Water extracts of fresh leaves, buds and leaf litter of *Populus balsamifera* (*Balsam poplar*) were tested at different dilutions for allelopathic effects on the nodulation, nitrogenase activity and growth of nodulated green alder (*Alnus crispa*) seedlings and on growth of unnodulated green alder seedlings, Robert and Thibaoult (1981). All the extracts inhibited shoot growth, root elongation and dry weight increment of nodulated and unnodulated green alder seedlings to some degree during a 2 month experiment. The number of nodules per plant

in seedlings treated with any *Balsam poplar* extract was only 5 per cent that of control plants. Acetylene reduction by seedling treated with bud and leaf litter extracts indicated a decrease of 62 per cent compared to control.

Weston and Putnam (1984) studied the inhibition of growth, nodulation and nitrogen fixation of legumes by quackgrass in which soybean (*Glycine max*) navy beans and snap beans (*Phaseolus vulgaris*) were grown both in green house and field in living or killed quackgrass. Legumes grown in mowed quack grass sod in the green house and in the field exhibited decreased nodule number, nodule fresh weight and nitrogen fixation when compared to legumes grown under similar conditions in screened quack grass soil or the control soil. In many cases, legume nodulation and growth were decreased in glyphosate-treated quack grass sod as compared to quack grass soil or the control soil. Decrease in legume growth and nodulation in the presence of quack grass was attributed to allelochemicals.

Mallik and Tesfai (1988) reported that water extracts of shoot of common lambsquarters (*Chenopodium album*), yellow nutsedge (*Cyperus ulentus*) and sunflower (*Helianthus annus*) at 1 per cent level significantly reduced soybean seed germination. Soybean seedlings inoculated with broth culture of nodule bacterium were grown for 25 days in N-free nutrient solution amended with cold water extracts of weed residues at 1 and 2 per cent levels. Nodulation was generally stimulated by the extracts of five weeds at 1 per cent level except that of lambsquarters. Extract from lambsquarters at 2 per cent level

completely suppressed and at 1 per cent level reduced nodulation by 60 per cent. Extracts from roots of foxtail (*Setaria viridis*), Pennsylvania smart weed (*Polygonium pensylvanium*) and sunflower at 2 per cent level reduced at 1 per cent on the otherhand the extracts enhanced nodulation in soybean.

Duhan *et al.* (1994) reported the allelopathic effect of rhizosphere soils and plant extracts of *Acacia nilotica* on growth, nodulation and nitrogen fixation by cluster bean inoculated with *Rhizobium*. The nodulation in inoculated plants was 10 to 15 per cent lower than uninoculated control. Addition of 10 and 20 per cent allelopathic soil extracts (ASE) was found to inhibit the nodulation by 41 and 54 per cent respectively in plants raised in chillam jar, while with 10 and 20 per cent combined plant extracts (CPE) the inhibition of nodulation was 46 and 65 per cent, respectively. The *in vivo* nitrogenase was also found to be inhibited in the above treatments.

Halsall *et al.* (1995) reported that the sterile cold water extracts of a range of residues from pasture legumes and grasses, cereal and weed species exerted allelopathic effect on *Trifolium subterranium, T.repus, T.balanse, T.prutense, Medicago littoralis, M.truncatula, C.niginosa* and *Vicia villosa* resulting in reduced germination, stunted growth and reduced growth of the radicle and nodulation. Roots exposed to the extracts became discoloured and shortened with distorted and scanty root hair formulation ultimately resulting in reduced nodulation. Seedlings exposed to these allelopathic

compounds were smaller, less robust and slower growing than the control seedlings leading to susceptibility to plant pathogens.

Balasubramanian and Ravichandran (1996) studied the allelopathic significance of six agroforestry trees on growth and nodulation of *Casuarina equisetifolia.* They found that *Eucalyptus tereticornis* and *Leucaena leucocephala* had highly deletarious effect on growth and nodulation, moderate effects were found on *Ailanthus excelsa* and *Acacia nilotica* and much lower effects for *Tectona grandis* and *Gliricidia sepium.*

Moura *et al.* (1996) reported the allelopathic effect of *Eucalyptus grandis* in soil grown for 40 years in Brazil. The nodulation of *Leucaena* grown in the eucalyptus soil, under green house, was inhibited. They also reported that the *Rhizobium* strain nodulating *Leucaena* were unable to grow in aqueous extract of eucalyptus leaves. While extract tolerant strains isolated from tree legumes of the Atlantic forest nodulated their hosts in both eucalyptus and forest soils. Rhizobial strains from other parts of the country were more sensitive to the extracts than native strains. The non-specific native bacterial populations not inhibited by the extracts were found only in eucalyptus soils. The tolerance/sensitivity of *Rhizobium* in the extract was attributed to the selective pressure exerted in the environment by the active allelopathic principles of eucalyptus. They also reported that the inhibition of nodulation was not corrected by liming.

Mallik and Watson (1998) observed the stimulation of growth and nodulation of soybean (*Glycine max* L.) by residue of black nightshade (*Solanum nigrum*) incorporated in sand at 2.5, 5.0 and 10.0 mg g^{-1} levels and Silver nightshade (*Solanum elaegnifolium*) residue at 2.5 and 5.0 mg g^{-1}. Whereas pigweed (*Amaranthus retroflexus* L.) residues at 5.0 mg g^{-1} significantly reduced soybean nodulation. Similarly ragweed (*Ambrosia artemisifolia* L.) at 10.0 mg g^{-1} also significantly depressed the growth and nodulation.

Zwain *et al.* (1999) studied the effect of decomposing wheat residues on the growth and biological nitrogen fixation of blue green algae and they found that the decomposing wheat residues although, significantly stimulated the growth of *Anabaena cylindrica* and *Nostoc musicorum* but inhibited the rate of biological nitrogen fixation. They further attributed the reduction in growth of rice due to poor nitrogen fixation of the blue green algae on amendment with wheat residues.

Bioassay of allelopathic activity of leaf and root aqueous extracts of *Dalbergia sissoo* on the germination, growth, nodulation and biochemical changes in cowpea (*Vigna radiata)* was studied by Tripathi *et al* (2000) the leaf and root extracts were found to stimulate the nodulation besides, seed germination and plant growth. Further, the leaf and root extract along with *Rhizobium* had greater benefit on nodulation and accumulation of seed protein as compared to leaf extract with nitrogen treatment. Phenolics and carbohydrates flavanoids and

terpenoids were the main allelochemicals present in the extract which might be responsible for improving nodulation and seed germination.

2.1.3 Mycorrhiza

Robinson (1972) reported that certain tree species such as *Betula pendula* and *Picea abies* failed to develop in association with heather (*Calluna vulgaris*). The affected trees can remain in a state of check for many years, exhibiting no pathological symptoms but making little measurable growth. This lack of growth was characteristics of both roots and shoots and in addition they failed to form any mycorrhizal association. The poor development of uninfected roots was mainly due to the production by heather of an allelochemical toxic to growth of mycorrhizae of *Betula* and *Picea*.

Boufalis and Pellissier (1994) observed that the phenols produced by *vaccinium myrtillus, Atherium felix-femina* and *Picea abies,* (which are the predominant species of spruce forests) found to inhibit the respiration of mycorrhizal fungi *viz.*, *Laccaria laccata* and *Cenococcum graniforme.*

The growth rates of the ectomycorrhizal fungi *Laccaria proxima* and *Rhizopogon luteolus* were negatively affected by the *Pinus sylvestris* needle extracts. The growth rate of *Laccaria bicolor* was enhanced by the needle extracts and the growth rate of *L.proxima, P.involutus* and *R.luteolus* were inhibited by the shoot extracts of *Deschampsia flexuosa* while the growth rate of *L.bicolor* was enhanced by

shoot extracts of *Pinus sylvestris* and *Deschampsia flexuosa* as observed by Baar *et al.* (1994).

Mallik and Zhu (1995) reported that the mycelial growth of ectomycorrhizal isolates NF_4, GB_{45}, GB_{23} and GB_{24} were stimulated in presence of kalmia leaf extract but were found inhibitory to black spruce. Further, they inoculated black spruce seedlings with the four fungal isolates under green house condition in presence of kalmia plants and found that three of the four isolates had better germination compared to the non inoculated control. All the three isolates (NF_4, GB_{45} and GB_{24}) have potential in overcoming growth inhibition in black spruce particularly important is isolate NF_4 which was found more effective and caused two fold increase in seedling biomass compared to the control.

2.1.4 Nitrifying microorganisms

Sahrawat *et al.* (1974) reported that the seeds and bark of karanja possessed nitrification inhibitory property. The alcohol extract of the seeds had maximum effect on retardation of the nitrification followed by the bark extract, where as the leaves showed no inhibitory effect. They also reported that the alcohol extract of the seeds was effective upto 60 days depending upon the concentrations used. The lack of nitrite accumulation in any of the treatments indicated that the material do not inhibit the conversion of nitrite to nitrate and specifically inhibit the ammonia-oxidizing bacteria.

Sukhada and Jayachandra (1979) studied the effect of *Parthenium hysterophorus* on nitrifying bacteria and reported that the *Nitrosomonas* activity was progressively lowered with decreasing distance from the plant and also in leaf or root mixed soil. Leaf and root leachate containing parthenin, anisicacid, vanillic acid and fumaric acid inhibited nitrite production to varying degrees.

Lodhi and Killingbeck (1980) studied the dynamics of ponderosa pine (*Pinus ponderosa*) stands in western north Dakota to determine the influence of plant produced chemicals on nitrification rates. Low levels of nitrate-nitrogen relative to ammonical nitrogen and lower population of both *Nitrosomonas* and *Nitrobacter* in the soil indicated that nitrification rates were low. Chemical inhibitors of nitrification, including caffeicacid chlorogenicacid, quercitin, and condensed tannins were found in extracts from ponderosa pine needles, bark and A horizon soils. These extracts proved to be toxic to soil suspensions of *Nitrosomonas* causing reduction from 68-93 per cent of the control.

Baldwin *et al.* (1983) made an attempt to identify the compounds responsible for the nitrification inhibition by fractionating the aqueous and methanol extracts of the forest floor. Condensed tannins and smaller molecular weight phenolics in the extracts were the most important nitrification inhibiting components of the extract. When all phenolics material was removed from the extract, the remaining solution stimulated the nitrification.

McCarty *et al.* (1991) studied the effects of three phenolic compounds i.e., ferulic acid, caffeic acid and p-coumaric acid produced by the vegetation in certain ecosystem on nitrite production by *Nitrospira, Nitrosomonas* and *Nitrosolobus* grown on medium containing aqueous suspension of soil treated with $(NH_4)_2SO_4$ nutrient solution. They observed that, nitrite production by *Nitrospira* was inhibited by ferulicacid, caffeicacid and p-coumaric acid at the concentration of 10^6 M or 10^5 M. They also found that ferulicacid did not markedly influence nitrite production when the concentration was as high as 10^8M.

Ito and Ichikawa (1994) reported that the nitrification potential of soil samples was generally decreased in samples collected near to *Digitaria ciliaris* plants compared to those furtheraway. This was mainly because the *D.ciliaris* roots release substances that inhibit nitrifying activity in the soil.

2.1.5 Soil enzymes

Pancholy and Rice (1972) studied the soil enzymes in relation to old field successional stages and a climax stand in each of three vegetation types, tall grass prairie, post oak black jack oak forest and oak-pine forest. They reported that the activities of amylase, cellulase and invertase were highest generally in the first successional stage (pioneer weed stage) intermediate in the second stage (an annual grass stage) and lowest in the climax stand. Whereas, dehydrogenase and urease activities were lowest in the first successional stage,

intermediate in the second stage, and highest in the climax stage. These trends were observed in all the three vegetation types throughout the year. No correlation was found between soil enzymatic activity and amount of organic matter or soil pH.

Fernando and Roberts (1976) reported that the polyphenols present in the black tea cake are effective in retarding urea hydrolysis both *in vitro* and by soil urease, thereby reducing the losses due to ammonia volatilization.

Sahrawat (1980) in his review reported that dihydric phenols and quinones inhibited urease. From his study he concluded that the phenols were effective in inhibiting urease after their auto-oxidation to quinone form.

Padhy and Khan (1996) reported inhibitory effect of eucalyptus litter leachates on synthesis of chlorophyll, protein and nucleic acid and certain metabolic enzymes (amylase, catalase, peroxidase, DNAse, RNAse) in addition to the rate of germination and seedling growth.

Material and Methods

III. MATERIAL AND METHODS

The allelopathic effect of perennial tree species on the soil microorganisms and their activities were studied over a period of one year at different locations. The materials used and procedures followed are detailed in following paragraphs.

3.1 Tree crops and locations: The experiments were conducted at three farm locations in Dharwad district during the year 1998-99. The three plant species included in the allelopathy study were *Casuarina equisetifolia* in farm belonging to Shri Milind Deshpande at Amminbhavi, Eucalyptus hybrid (UAS Dairy farm Dharwad) and *Tectona grandis* in the farm belonging to Shri Mahaveer N. Desai at Timmapur. The three tree crop species were planted on bunds of the field at different distances and were at different growth stages. The soil conditions of the three locations also varied. The details of plant species are given in Table 3.1 while that of soil physical and chemical properties are presented in Table 3.2.

3.2 Treatments: In order to study the allelopathic effect of tree species on the soil microbial population, soils were sampled at different distances from the tree rows. The sampling distances were at 3m, 6m, 9m, 12m, 15m and 18m away from the bund planted tree rows. A soil sample was also collected at about 30m away from the bund planted tree species which served as control.

3.3 Replications: The plot under the influence of the tree rows was demarkated horizontally into four blocks measuring 3x18m. which

Table 3.1 Details of the experimental sites

Sl. No.	Particulars	Eucalyptus site		Casuarina site		Teak site	
		I Year	II Year	I Year	II Year	I Year	II Year
1	Number of trees	12	12	19	19	11	11
2	Number of off shoots	31	31	-	-	-	-
3	Age of trees (yrs)	6	7	10	11	17	18
4	GBH (cm)	51.61	53.60	65.10	65.10	103.00	103.50
5	Height (m)	9.50	10.00	12.45	12.45	9.32	9.48
6	Tree spread (m)						
	East-West	2.54	2.60	1.64	1.75	3.30	3.34
	North-South	1.82	1.89	1.47	1.56	3.42	3.45
	Average	2.18	2.24	1.56	1.65	3.36	3.45
7	Direction of bund plantation	East-West		North-South		East-West	
8	Nature of tree	Evergreen		Evergreen		Deciduous	
9	Leaf shedding period	All round the year		During winter		During winter	

GBH - Girth at breast height

Table 3.2 Physico-chemical properties of the soil at experimental sites

Sl. No.	Particulars	Eucalyptus site		Casuarina site		Teak site	
A.	Physical properties						
1.	Particle size distribution (%)						
i.	Coarse sand (%)	26.5		28.0		21.8	
ii.	Fine sand (%)	29.6		22.0		22.2	
iii.	Silt (%)	11.0		21.0		19.0	
iv.	Clay (%)	32.5		39.0		37.0	
2.	Field capacity (%)	18.2		29.0		27.0	
3.	Bulk density (g/cc)	1.5		1.4		1.4	
B.	Chemical properties	pH	EC (ds/m)	pH	EC (ds/m)	pH	EC (ds/m)
i.	3 m	7.5	0.7	8.2	0.2	7.3	0.8
ii.	6 m	7.4	0.7	8.2	0.3	7.2	0.9
iii.	9 m	7.3	0.8	8.2	0.4	7.1	1.0
iv.	12 m	7.2	0.9	8.2	0.4	6.9	1.0
v.	15 m	7.1	1.1	8.0	0.5	6.9	1.1
vi.	18 m	7.1	1.1	8.0	0.5	6.8	1.1

served as replications. Therefore the sampling was restricted to only in the four blocks.

3.4 Test crops: Greengram (var. Chinamung) and wheat (var.DWR-162) were grown in the field adjoining bund planted tree crop during *kharif* and *rabi* seasons, respectively. The greengram and wheat were sown at a spacing of 30 cm x 10 cm and 22.5 cm x10 cm, respectively. Planting was made in April 1998 for greengram and November 1998 for wheat.

All agronomic practices with respect of sowing, fertilizer application, weeding, intercultivation were followed as per package and practices. Further a special care was exercised during land preparation to remove stubbles of previous crops.

3.5 Soil sampling: Soil samples were collected at different distances as per the treatments mentioned in 3.2. The sampling was done at three intervals under each crop namely, before sowing, at flowering and at harvest.

Approximately, 100-150 g of samples were collected at each distance from four replications separately. The soil sample away from the tree row as control was also collected in the same manner. The samples from all the four locations within the treatments were pooled and only two replicate samples were used for all the studies. For sampling of rhizosphere soils at flowering and harvest, plants were uprooted and the soils adhering to the roots were collected.

3.6 Observations: From the soil samples collected, observations on the microbial dynamics, mycorrhizal colonization, nodulation, enzyme activities and soil chemical properties were studied.

3.7 Microbiological observations

3.7.1 Enumeration of microbial population

The soils collected at the experimental sites from four replications were pooled and duplicate samples of 10g each were used for estimating microbial population. The populations of microorganisms *viz.*, bacteria, fungi, actinomycetes, nitrogen fixing microorganisms and mineral phosphate solubilizing microorganisms were estimated by following standard serial dilution plate count technique. Soil extract agar (Bunt and Rovira,1955) Martin's Rose Bengal agar(Martin,1950), Kuster's agar(Kuster and Williams,1964) were used as growth medium for bacteria, fungi and actinomycetes respectively. Free living nitrogen fixing microorganisms and mineral phosphate solubilizing microorganisms were enumerated by using Norris N-free agar (Norris,1959) and Pikovskaya's agar(Pikovskaya,1948) respectively. The detailed chemical composition of the media used are appended in Appendix-I.

3.7.2 Mycorrhizal spore count

Extrametrical chlamydospores produced by the VA mycorrhizal fungi were counted by wet sieving and decanting method (Gerdemann and Nicolson, 1963). Fifty grams of soil sample was suspended in sufficient quantity of water and heavy particles were

allowed to settle down for 30 seconds before decanting on to the sieves. The soil suspension was passed through a set of sieves with different mesh size 1000, 300, 250, 125 and 45μm arranged in descending order. The spores recovered on the last two sieves were transferred on to a nylon mesh (mesh size 45 μm). The spore count were made using stereomicroscope and expressed as number of spores per 50 g of soil.

3.7.3 Per cent root colonization

The per cent mycorrhizal colonization of plant roots was determined at the time of peak flowering of green gram and wheat according to the method given by Phillips and Hayman (1970).

The root samples were cut into bits of one cm length and fixed in FAA (Formalin; Acetic acid ; Alcohol ; 5:5:90 v/v/v) for two hours. The roots were then cleared by autoclaving with 10 per cent KOH at 15 lbs/inch^2 pressure for 15 minutes. Samples were allowed to cool. The alkalinity due to KOH was neutralized by adding one per cent HCl for five minutes. The roots were further washed three times with distilled water. To the hydrolyzed root bits, the staining was done with 0.05 per cent trypan blue in lactoglycerol (Appendix-1) for 10 minutes by keeping in the boiling water. The stained root bits (20 nos) were arranged on the slide and observed under projection microscope for mycelia, vesicles and arbuscules. The number of root bits observed for this computation were 50 per sample. The percentage colonization was calculated by the following formula.

$$\text{Per cent root colonization} = \frac{\text{Number of root bits positive for colonization}}{\text{Total number of root bits observed}} \times 100$$

3.7.4 Nodulation

The nodule count of green gram from each of the replicated treatments was done. Five plants from each plot were escavated carefully without damaging root system. The root system was washed and used for counting the number of nodules/plant.

After counting, the nodules were separated carefully. The fresh weight of nodules was recorded.

3.8 Enzyme activities

3.8.1 Dehydrogenase activity

Dehydrogenase activity in the soil samples collected at different distances was determined by following the procedure as described by Casida *et al.* (1964). Ten grams of soil and 0.2g $CaCO_3$ were thoroughly mixed and dispensed in test tubes. To each tube was added with one ml of 1.5 per cent aqueous solution of 2, 3, 5 triphenyl tetrazolium chloride (TTC), one ml of one per cent glucose solution were added, further eight ml of distilled water added to each tube in order to leave a thin film of water above the soil layer. The tubes were stoppered with rubber bungs and incubated at 30°C for 24 hours. At the end of incubation, the contents of the tube were rinsed down into a small beaker and slurry was made by adding 10 ml methanol. The slurry was filtered through Whatman No.1 filter paper. Repeated rinsing of soil with

methanol was continued till the filterate ran free of red colour. The filtrate was made upto 50 ml with methanol in a volumetric flask. The intensity of red colour was measured at 485 nm, against a methanol blank using systronic visible range spectrophotometer (Model 166).

The concentrations of formazan formed in soil samples were determined by using graded concentrations of formazan. The results were expressed as μg of triphenyl formazan (TPF) formed per g of soil per day.

3.8.2 Urease activity

The procedure adopted to determine the urease activity of soil was essentially the same as adopted by Pancholy and Rice (1973), except that the ammonia liberated due to hydrolysis of urea in the reaction mixture was determined by nesslerization as described by Jackson (1973).

Ten grams each of freshly collected soil samples were placed in 100 ml capacity Erlenmeyer flask to which one ml of toluene was added with 20 ml of phosphate buffer (pH 6.7) and 10 ml of 10 per cent urea solution. For blank urea solution was replaced with equal quantity of distilled water. The contents of the flasks were well shaken for five minutes and incubated at 30°C for 24 hours. After incubation, the contents of the flasks were filtered through Whatman No.1 filter paper. The remaining soil in the flask was added with 15 ml of 1 N KCl solution containing 150 ppm $HgCl_2$ shaken for five minutes and filtered. The

volume of the total filtrate was made upto 100 ml in a volumetric flask using distilled water.

The amount of ammonia present in the filtrate was determined by nesslerization. One ml filtrate of each sample was transferred to a 20 ml volumetric flask to which two ml of ten per cent sodium tartarate solution and 0.5 ml of Nessler's reagent were added. The volume was made upto 20 ml with distilled water. The yellow colour developed after 30 minutes was measured at 410 nm using systronic visible range spectrophotometer (Model 166) against the reagent blank.

The results obtained were expressed as µg of ammonia liberated per gram soil (oven dry basis) per day with reference to a standard curve obtained by using graded concentration (0-100 µg/ml) of $(NH_4)_2SO_4$ solution and developing the colour by nesslerization.

3.9 Soil chemical Analysis

3.9.1 Available nitrogen

Available nitrogen in soil was determined by alkaline permanganate method (Subbaih and Asija, 1956).

3.9.2 Available phosphorus

Available phosphorus was extracted using 0.5 N $NaHCO_3$ (Olsen *et al.*, 1954) and phosphorus in solution was determined by chlorostannous reduced molybdophosphoric acid HCl system.

3.9.3 Quantitative estimation of total phenols

Quantitative estimation of total phenolics was done following the method of Bray and Thorpe(1954) using folin-ciocalteau reagent (this observation was taken from the soil samples collected at the end of experiment).

3.10 Statistical analysis

Data recorded on various characters were subjected to Fisher' s method of analysis of variance, as given by Panse and Sukhatme (1967). The level of significance used in 'F' and 'T' tests was p=0.05. Critical difference values were calculated whenever the 'F' test was significant.

Experimental Results

IV. EXPERIMENTAL RESULTS

4.1 Effect of bund planted casuarina tree row on the changes in the microbial population and related parameters

4.1.1 Microbial population

Changes in the population of bacteria, fungi and actinomycete under the influence of casuarina tree row on greengram crop raised during *kharif* are presented in Table 4.1.

In general, the microbial population was higher up to 9 m distance from the tree row but it declined with increasing distance. It was observed that bacterial and fungal population remained almost statistically constant up to 9 m distance from the tree row which was higher than control (far away from the plants) at all the periods of sampling *viz.,* before sowing, flowering and harvest of greengram. From 12 to 18 m distance, however, the population was significantly lower but remained almost constant and was statistically, comparable with control.

The changes in the actinomycete population, although, was similar to bacterial and fungal population but the effect was visible only upto 6 m before sowing and at harvest stage and upto 9 m at flowering stage. From 6m or 9m onwards the actinomycetes remained statistically comparable to control soil.

4.1.2 Beneficial microorganisms

Effect of bund planted casuarina tree row on the changes in the beneficial microorganisms (*viz,* nitrogen fixing bacteria and

Table 4.1 Effect of bund planted Casuarina tree row on the changes in the soil microbial population under greengram during *kharif* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	34.5	66.5	46.5	26.7	57.5	37.5	31.5	48.5	32.7
6	32.5	64.5	45.7	26.2	50.0	36.2	28.0	47.5	31.5
9	30.5	60.5	42.7	25.5	49.0	35.0	23.7	42.5	27.5
12	25.5	53.5	37.5	22.0	40.5	26.2	21.5	39.2	26.7
15	24.5	52.5	36.7	21.0	39.5	25.0	21.0	38.0	26.5
18	23.7	51.7	35.0	20.0	37.5	24.5	20.7	36.2	26.0
Control	23.7	50.0	34.5	20.5	37.0	24.0	20.2	35.0	25.0
S. Em ±	0.74	1.97	1.10	0.66	1.72	0.80	1.10	1.10	0.87
CD 5%	2.21	5.86	3.28	1.96	5.12	2.39	3.28	3.28	2.59

* Control : Soil was sampled from the field approximately 30 meters away from the tree row.

phosphate solubilizing microorganisms) in greengram are presented in Table 4.2.

Similar to the microbial population, nitrogen fixing and phosphate solubilizing microorganisms showed higher population upto 9 m compared with control and other distances. From 12 to 18 m distances, the microorganisms remained statistically constant and were at par with control.

The mycorrhizal spore count were superior upto 9 m at initial and harvest stage and only upto 6 m at flowering stage compared with control. The spore count from 12 to 18 m distance was again at par with control and remained almost constant.

The per cent mycorrhizal root colonization recorded at peak flowering stage was statistically higher upto 6 m distance from the casuarina tree row but with increase in distance the colonization gradually declined upto 9 m and subsequently remained at par with control.

4.1.3 Nodulation in greengram

Effect of bund planted casuarina tree row on the changes in the greengram nodulation is presented in Table 4.3.

In general, the nodule number and nodule fresh weight per plant, recorded at 45 days growth of greengram declined with increase in distance from the casuarina tree row. Upto 6 m distance the nodule count and their weight remained higher than the control plants.

Table 4.2 Effect of bund planted Casuarina tree row on the changes in the beneficial microorganisms in greengram crop during *kharif* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count (per 50 g soil)			Mycorrhizal root colonization* (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	25.0	45.7	31.5	19.7	34.2	24.2	52.0	82.0	61.0	42.1 (45.0)**
6	24.7	44.0	31.0	19.5	34.0	23.2	51.0	81.0	60.7	41.0 (44.7)
9	18.2	38.2	26.2	17.5	32.0	22.0	45.0	75.0	56.0	39.2 (40.0)
12	16.7	36.5	24.5	13.0	26.7	17.5	40.0	64.2	51.0	36.2 (35.0)
15	16.2	35.5	23.7	12.5	26.5	17.0	39.2	66.2	50.7	36.2 (35.2)
18	16.0	35.2	23.5	12.2	25.7	15.7	39.2	66.0	50.2	36.6 (35.7)
Control	15.0	34.7	23.0	12.0	24.0	16.0	38.7	65.5	50.2	35.9 (34.5)
S. Em ±	0.99	1.15	0.72	0.72	1.03	0.67	1.32	3.68	1.70	2.02
CD 5%	2.95	3.41	2.15	2.15	3.08	1.98	3.93	10.94	5.05	5.53

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

Table 4.3 Effect of bund planted Casuarina tree row on nodulation* of greengram

Distance from the tree row (m)	Number of nodules per plant	Nodule fresh weight per plant (mg)
3	37.0	605.0
6	36.5	596.2
9	32.5	501.2
12	25.0	438.7
15	24.1	445.0
18	25.7	450.0
Control	25.7	429.2
S. Em ±	2.52	24.73
C.D 5%	7.51	100.67

* Observations recorded on 45 days crop growth

4.1.4 Enzyme Activity

Effect of bund planted casuarina tree row on the changes in soil enzyme activity under greengram is presented in Table 4.4.

The urease activity, expressed as μg NH_4-N per gram soil per day, declined with increasing distance from the casuarina tree row. It remained high upto 9 m distance both before sowing and at harvest of greengram. But, at the flowering, it was superior only upto 6 m distance compared with control. The enzyme activity, subsequently, remained almost constant and was at par with control.

The dehydrogenase activity, expressed as μg TPF per gm soil per day, also showed the similar trend (Table 4.4).

4.1.5 Soil Analysis

The changes in nitrogen and phosphorus (kg/ha) in greengram planted soil from bund of casuarina tree row is presented in Table 4.5.

A close examination of data indicated that the nitrogen content (kg/ha) remained higher compared with control soil upto 9 m distance and thereafter, it was similar to control soil. However at harvest, the nitrogen content was significantly higher upto 12 m distance but at 15 and 18 m distance it was similar to control soil.

The phosphorus content remained significantly higher than the control sample at all the distances from the tree row during initial sampling but at harvest, the phosphorus content was significantly

Table 4.4 Effect of bund planted Casuarina tree row on the changes in the soil enzyme activity in greengram during *kharif* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng $soil^{-1}$ day^{-1})			Dehydrogenase activity (µg TPF g $soil^{-1}day^{-1}$)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	17.53	27.39	23.24	16.55	30.75	23.23
6	17.27	27.20	23.13	18.45	30.58	23.11
9	15.35	24.50	22.34	15.20	29.15	21.75
12	12.80	20.94	18.45	12.32	28.44	18.68
15	12.64	21.90	17.30	12.24	28.33	18.63
18	12.50	21.70	17.27	12.22	28.13	18.62
Control	12.34	21.60	17.12	11.35	28.12	18.60
S. Em ±	0.732	1.039	0.513	0.337	0.516	0.710
CD 5%	2.175	3.084	1.522	1.002	1.533	2.108

Table 4.5 Effect of bund planted Casuarina tree row on the changes in the soil nitrogen and phosphorus (kg/ha) in greengram during *kharif* 1998

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)	
	At sowing	Harvest	At sowing	Harvest
3	388.2	379.9	27.1	30.5
6	386.8	367.9	27.1	29.8
9	385.5	358.3	26.9	28.5
12	384.8	356.3	26.9	27.2
15	384.9	355.5	26.9	26.9
18	385.2	3537	26.8	26.5
Control	384.2	353.5	25.5	26.7
S. Em ±	0.34	0.89	0.38	0.28
CD 5%	1.08	2.62	1.1	0.81

higher upto 9 m compared to control and from 12-18 m it remained at par with control.

4.2 Effect of bund planted eucalyptus tree row on the changes in the microbial population and related parameters in soil

4.2.1 Bacteria, fungi and actinomycete

Effect of bund planted eucalyptus tree row on the changes in total microbial population is presented in Table 4.6.

On the contrary to the casuarina allelopathy, eucalyptus showed the reverse trend with respect of microbial count. In general, the microbial count was low near to the eucalyptus tree row and gradually increased with distance.

The bacterial, fungal and actinomycetes population was drastically reduced at 3 m distance and to little extent upto 9 m distance. There was significant decline upto 9 m distance compared to control in bacteria at all the sampling period.

In fungi however, the population was significantly, lower even at 12 m distance at harvest stage of the crop, compared with control soil.

The actinomycete population was also low compared with control soil upto 6 m at initial soil sampling and upto 9 m at flowering and harvest of greengram crop. The actinomycetes population remained constant statistically at rest of the distances.

Table 4.6 Effect of bund planted Eucalyptus tree row on the changes in the soil microbial population under greengram during *kharif* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	15.2	29.5	25.0	21.5	33.2	24.5	17.5	30.5	21.0
6	19.0	35.5	28.0	29.0	36.7	27.5	21.7	35.7	25.2
9	23.0	42.2	33.7	32.5	41.2	32.2	27.0	40.5	29.0
12	25.2	47.2	34.5	35.0	44.0	34.0	27.2	45.7	30.5
15	25.5	47.0	35.0	36.5	45.0	36.0	27.5	46.0	31.0
18	26.0	46.7	35.5	37.2	45.0	37.0	27.0	46.5	31.5
Control	27.2	47.7	36.0	37.5	46.0	37.5	28.5	46.7	32.7
S. Em ±	1.19	1.86	0.79	0.87	1.05	0.75	0.65	1.51	1.22
CD 5%	3.54	5.54	2.33	2.60	3.11	2.23	1.94	4.51	3.64

4.2.2 Beneficial microorganisms

The changes in the nitrogen fixing bacteria and phosphate solubilizing microorganisms under the influence of eucalyptus tree row in greengram are presented in Table 4.7.

Similar to the general microbial population, the nitrogen fixing bacteria and phosphate solubilizing microorganisms also increased with increase in distance from eucalyptus tree row. Nitrogen fixing bacteria were drastically reduced upto 6 m distance at all the three periods of soil sampling. From 9 to 18 m distance however, there was increase in the population, which was comparable to the soil under control.

The phosphate solubilizing microorganisms were statistically lower than the control soil upto 9 m at the initial sampling and upto 12 m during flowering and harvest stages. In the rest of the cases, *viz.*, from 12 to 18 m, during flowering and harvest, the population remained at par with control soil.

The mycorrhizal spore count upto 9 m was statistically low at all the periods of soil sampling. The spore count was drastically affected particularly at 3 m from eucalyptus row; even at 6 m and 9 m distances the mycorrhizal spore count differed significantly. From 12 m onwards the mycorrhizal spore count did not differ significantly with control soil.

The mycorrhizal root colonization in greengram crop recorded at 45 days of crop growth was significantly low only at 3 m distance subsequently from 9 m onwards it was at par with control soil.

Table 4.7 Effect of bund planted Eucalyptus tree row on the changes in the beneficial microorganisms in greengram crop during *kharif* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count (per 50 g soil)			Mycorrhizal root colonization * (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	24.5	46.0	28.0	8.0	14.0	10.0	28.0	45.0	35.0	26.5 (20.0)**
6	28.0	51.0	32.0	11.5	16.2	12.0	34.2	51.7	42.0	30.6 (26.0)
9	34.0	56.0	36.7	15.7	18.7	14.5	40.5	59.0	48.5	33.2 (30.0)
12	36.0	56.5	37.0	18.0	19.0	15.0	46.7	66.7	56.7	36.2 (35.0)
15	36.2	57.0	38.0	21.0	20.2	16.5	47.0	67.2	57.2	36.2 (35.3)
18	36.5	58.0	38.5	21.5	20.7	17.0	47.5	67.5	57.7	36.5 (35.5)
Control	37.0	59.5	39.0	20.5	21.5	17.7	48.0	68.7	58.0	36.6 (35.7)
S. Em ±	1.02	1.57	1.09	1.00	0.63	0.53	2.04	2.22	2.04	2.23
CD 5%	3.04	4.66	3.23	2.99	1.87	1.59	6.05	6.59	6.06	6.91

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

There was no significant difference between 3 and 6 m distance in mycorrhizal root colonization of greengram.

4.2.3 Nodulation

Number of nodules, nodule fresh weight recorded at 45 days of crop growth in greengram, under the influence of eucalyptus tree row at different distances are presented in Table 4.8.

The nodulation was drastically reduced upto 6 m distance and there onwards it was unaffected compared to control plants.

4.2.4 Enzyme activity

The urease and dehydrogenase activity in the soils sampled at different period in greengram crop under the influence of eucalyptus tree row is presented in Table 4.9.

The urease activity during initial stage was significantly affected to 6 m compared with control, but at flowering and harvest stages the activity was also low compared with control. At rest of the distances the urease activity was unaffected compared with control. Similarly, in dehydrogenase activity, the eucalyptus tree row influence upto 6 m at initial and upto 9 m during flowering and harvest of crop. Rest of the observation did not differ as against control.

4.2.5 Soil Analysis

The nitrogen content (kg/ha) was higher upto 12 m during initial and harvest of the crop compared with control (Table 4.10). The

Table 4.8 Effect of bund planted *Eucalyptus* tree row on nodulation* of greengram

Distance from the tree row (m)	Number of nodules per plant	Nodule fresh weight per plant (mg)
3	15.0	332.5
6	20.0	377.5
9	26.0	451.2
12	30.0	501.2
15	30.5	487.7
18	30.5	497.2
Control	30.7	505.5
S. Em ±	1.9	20.50
C.D 5%	5.93	60.88

* Observations recorded on 45 days crop growth

Table 4.9 Effect of bund planted Eucalyptus tree row on the changes in the enzyme activity in greengram during *kharif* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng $soil^{-1}$ day^{-1})			Dehydrogenase activity (µg TPF g $soil^{-1}day^{-1}$)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	6.5	12.35	8.87	8.20	15.76	10.28
6	9.3	14.24	11.85	11.13	17.77	12.42
9	18.1	17.8	14.17	14.70	20.35	14.40
12	15.8	20.8	15.29	16.23	23.86	16.40
15	15.9	20.8	16.57	16.71	23.89	16.41
18	15.9	21.8	16.77	16.72	23.90	16.42
Control	16.1	22.1	16.81	16.79	23.91	16.44
S. Em ±	0.43	0.47	0.52	0.69	0.62	0.64
CD 5%	1.30	1.41	1.56	2.04	1.84	1.90

Table 4.10 **Effect of bund planted Eucalyptus tree row on the changes in the soil nitrogen and phosphorus (kg/ha) in greengram during *kharif* 1998**

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)	
	At sowing	Harvest	At sowing	Harvest
3	185.5	190.9	11.6	17.6
6	184.6	187.0	11.5	16.6
9	183.2	175.3	11.2	15.7
12	183.0	167.1	11.2	14.6
15	182.6	166.2	10.9	13.9
18	182.3	165.3	11.0	13.9
Control	181.0	163.0	11.2	13.2
S. Em ±	0.54	1.45	0.11	0.7
CD 5%	1.60	4.2	0.3	2.1

phosphorus content of soil was not affected with increasing distance from the eucalyptus tree row.

4.3 Effect of bund planted teak tree row on the changes in the microbial population and related parameters in soil

4.3.1 Bacteria, fungi and actinomycetes

Effect of bund planted teak tree row on changes in total microbial population is presented in Table 4.11.

In general, the microbial count was low nearer to the teak tree row and gradually increased with distance. The bacterial, fungal and actinomycetes population was inhibited at 3 m distance at all the periods. The inhibition was significant upto 9 m distance compared with control soil at all the periods except in flowering stage for fungi, where the fungal population was reduced significantly only upto 6 m distance. Beyond 6 m at flowering stage for the fungi and 12 to 18 m for other microbial population were found comparable with control soil.

4.3.2 Beneficial microorganisms

Effect of bund planted teak tree row on the changes in the beneficial microorganisms (Nitrogen fixing bacteria and phosphate solubilizing microorganisms) in greengram are presented in Table 4.12.

Nitrogen fixing bacterial population were statistically lower than the control soil upto 12 m distance at initial sampling and only upto 6 m during flowering and harvest stage. In the rest of the cases that is from 15 to 18 m distance during initial and from 9 to 18 m distance

Table 4.11 Effect of bund planted teak tree row on the changes in the soil microbial population under greengram during *kharif* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	16.0	24.0	23.0	23.0	34.2	13.0	22.0	29.0	25.0
6	20.7	28.0	26.0	28.0	39.0	16.0	26.0	33.0	29.0
9	23.0	32.0	28.5	29.0	40.2	17.7	29.0	36.0	32.0
12	26.0	34.0	30.0	31.5	44.5	20.5	32.0	39.0	35.0
15	28.5	36.5	31.5	31.7	42.7	22.0	32.2	39.2	35.5
18	28.0	36.7	32.0	32.5	44.0	22.2	32.7	39.0	35.7
Control	29.5	37.0	32.2	33.0	44.5	22.5	33.0	41.2	36.5
S. Em ±	1.22	1.08	0.78	0.99	1.32	0.76	1.11	1.30	1.02
CD 5%	3.64	3.20	2.32	2.93	3.93	2.23	3.31	3.88	3.04

Table 4.12 Effect of bund planted teak tree row on the changes in the beneficial microorganisms in greengram crop during *kharif* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count (per 50 g soil)			Mycorrhizal root colonization * (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	20.2	34.0	25.0	8.0	10.0	35.0	62.0	40.0	40.0	30.0 (25.0)**
6	23.2	38.0	29.7	12.0	13.7	20.0	41.3	67.7	46.2	31.9 (28.0)
9	24.0	41.0	32.0	17.5	17.0	24.7	48.0	73.7	52.7	35.0 (33.0)
12	25.0	43.0	33.0	19.0	20.2	28.0	57.0	78.0	55.0	37.4 (35.0)
15	25.5	43.2	34.5	19.5	20.7	28.2	57.2	78.7	55.2	37.5 (37.2)
18	26.0	43.5	35.0	19.7	20.5	28.7	58.1	77.2	55.7	37.7 (37.5)
Control	27.2	44.0	35.7	20.0	21.7	29.0	60.2	80.5	56.2	37.8 (37.7)
S. Em ±	0.64	1.26	1.28	1.46	1.05	1.20	2.23	1.89	2.09	2.08
CD 5%	1.92	3.74	3.81	4.33	3.12	3.56	6.63	5.61	6.20	6.18

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

during flowering and harvest the nitrogen fixing bacterial population remained at par with control soil.

The phosphate solubilizing microorganisms were significantly reduced upto 6 m at initial stage and upto 9 m distance during flowering and harvest. Subsequently, from 6 m at initial and 12 m at flowering and harvest stages the phosphate solubilizing microorganisms remained constant compared with control soil.

The mycorrhizal spore count upto 9 m was significantly lower at initial and flowering stage and only upto 6 m at harvest. Subsequently, from 9 m onwards at initial and flowering and 6 m at harvest the mycorrhizal spores did not differ significantly compared with control.

The mycorrhizal root colonization in greengram crop recorded at 45 days of crop growth was statistically low only at 3 m distance. Beyond 3 m there was no significant difference and was found at par with control.

4.3.3 Nodulation

Number of nodules, nodule fresh weight in greengram under the influence of teak tree row at different distances are presented in Table 4.13.

The nodulation was drastically reduced upto 6 m distance and there onwards it was unaffected compared with control plants. Nodule fresh weight also reduced upto 9 m significantly compared with control.

Table 4.13 Effect of bund planted teak tree row on nodulation* of greengram

Distance from the tree row (m)	Number of nodules per plant	Nodule fresh weight per plant (mg)
3	22.0	400.0
6	26.0	451.2
9	30.0	501.2
12	35.0	570.0
15	36.5	576.2
18	36.0	583.7
Control	36.2	594.0
S. Em ±	2.27	24.56
C.D 5%	6.76	72.95

* Observations recorded on 45 days crop growth

4.3.4 Enzyme activity

Effect of bund planted teak tree row on the changes in soil enzyme activity under greengram is presented in Table 4.14.

The urease activity during initial stage was significantly affected upto 9 m compared with control but at flowering and harvest stage the inhibition was found at 3 m and 6 m distance respectively. At the rest of the distances the activity was unaffected compared with control. Similarly, the dehydrogenase activity on the teak tree row influence upto 9 m at initial and flowering and upto 6 m distance at harvest stage. Rest of the observation did not differ as against control.

4.3.5 Soil Analysis

The nitrogen content (kg/ha) was higher upto 6 m distance during initial and harvest of the crop compared to control (Table 4.15). The phosphorus content of soil was significantly higher upto 9 m distance at initial and upto 6 m distance during harvest compared with control. Rest of the observation on par with control.

4.4 Effect of bund planted casuarina tree row on the changes in the microbial population and related parameters during *rabi* season.

4.4.1 Microbial population

Changes in the population of bacteria, fungi and actinomycetes under the influence of casuarina tree row on wheat crop during *rabi* are presented in Table 4.16.

Table 4.14 Effect of bund planted teak tree row on the changes in the enzyme activity in greengram during *kharif* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng soil^{-1} day^{-1})			Dehydrogenase activity (µg TPF g soil^{-1}day^{-1})		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	10.34	15.73	10.32	8.86	13.10	9.12
6	13.82	17.84	11.38	10.55	15.54	12.33
9	14.84	17.79	13.36	12.31	18.00	15.66
12	15.54	18.38	14.73	14.52	20.65	17.85
15	15.77	18.25	14.75	14.55	20.66	17.90
18	16.76	18.27	14.78	14.64	20.70	17.94
Control	17.79	18.29	14.85	14.68	20.72	17.96
S. Em ±	0.78	0.63	0.76	0.66	0.78	0.99
CD 5%	2.32	1.89	2.26	1.96	2.32	2.95

Table 4.15 **Effect of bund planted teak tree row on the changes in the soil nitrogen and phosphorus (kg/ha) in greengram during *kharif* 1998**

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)	
	At sowing	Harvest	At sowing	Harvest
3	262.5	284.3	18.3	23.6
6	261.0	281.2	18.0	22.9
9	259.7	279.2	17.7	21.6
12	259.0	278.8	17.1	21.3
15	259.1	278.9	17.1	21.0
18	259.1	279.0	17.6	21.3
Control	258.6	278.5	16.5	21.5
S. Em ±	0.41	0.53	0.25	0.31
CD 5%	1.20	1.57	0.74	0.91

Table 4.16 Effect of bund planted Casuarina tree row on the changes in the soil microbial population in wheat during *rabi* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	29.2	55.0	38.0	27.0	46.2	33.0	31.2	43.0	28.5
6	28.6	54.0	37.2	25.5	45.7	32.7	28.7	41.5	28.0
9	22.4	48.7	35.0	23.0	44.2	31.7	25.0	38.0	25.2
12	21.6	47.2	32.7	20.0	41.0	25.0	23.5	35.0	21.0
15	20.0	46.0	31.0	19.7	41.0	24.7	23.0	34.7	20.2
18	19.2	45.5	31.0	19.5	40.0	23.0	22.5	35.0	19.5
Control	18.7	45.0	30.5	20.2	42.2	22.2	22.0	34.2	20.2
S. Em	1.35	1.18	1.00	0.90	1.05	1.64	1.20	1.115	1.44
CD 5%	4.01	3.50	3.50	2.70	3.14	4.89	3.57	3.42	4.29

* Control : Soil was sampled from the field approximately 30 meters away from the tree row.

In general, the microbial population declined with increasing distance from the casuarina tree row. The bacterial population at the initial stage was found significantly higher at 3 and 6 m over all the treatments. At flowering and harvest stages the bacterial population was superior over control upto 9 m distance from the tree row. Thereafter, there was no significant difference and the population was comparable with the control soil.

The fungal population was higher upto 9 m distance at the initial and harvest stages and upto 6 m distance during flowering stage.

Actinomycetes population at initial stage was significantly higher only upto 6 m compared with the control soil. However, at flowering and harvest stages the actinomycete population was higher significantly upto 9 m distance. However, from 12 to 18 m the actinomycete population was comparable with the control soil.

4.4.2 Beneficial microorganisms

Effect of bund planted casuarina tree row on the changes in the beneficial microorganisms (Nitrogen fixing bacteria and phosphate solubilizing microorganisms) under wheat crop are presented in Table 4.17.

Similar to the microbial population, nitrogen fixing bacteria and phosphate solubilizing microorganisms were significantly higher upto 9 m distance, except in phosphate solubilizing microorganisms at flowering stage, where microorganisms significantly higher only upto 9 m in flowering and harvest. While initial population significantly higher

Table 4.17 Effect of bund planted Casuarina tree row on the changes in the beneficial microorganisms in wheat during *rabi* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count per 50 g soil			Mycorrhizal root colonization * (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	25.5	45.0	32.0	19.5	32.0	23.0	42.0	87.5	65.5	37.4 (37.0)**
6	25.0	44.7	31.7	18.7	31.0	22.7	41.7	87.0	65.0	37.2 (26.7)
9	20.5	40.5	29.0	15.0	30.5	21.0	36.0	80.0	62.0	35.0 (33.0)
12	17.2	38.0	25.0	13.0	27.0	17.5	30.0	74.0	56.0	31.9 (28.0)
15	17.0	37.0	25.7	12.5	27.5	16.5	27.7	73.5	55.5	32.0 (28.2)
18	16.5	36.5	25.5	12.0	26.0	16.7	29.7	73.2	55.2	31.9 (28.0)
Control	16.0	36.0	25.0	11.0	25.2	16.0	29.7	73.0	55.2	31.9 (28.0)
S. Em ±	1.00	0.99	1.05	0.65	1.11	0.87	2.02	1.20	2.05	1.63
CD 5%	2.99	2.96	3.112	1.93	3.32	2.58	6.00	3.58	6.09	4.86

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

upto 12 m distance compared with control. The population at other distances was comparable with control soil.

The mycorrhizal spore count was superior upto 9 m distance at all the periods of sampling compared with control. The spore count from 12 to 18 m distance was again at par with control.

The mycorrhizal root colonization was significantly higher compared with the control soil upto 6 m distance from the casuarina tree row, but with increasing distance the colonization gradually declined upto 18 m and subsequently remained at par with control.

4.4.3 Enzyme activity

Effect of bund planted casuarina tree row on the changes in soil enzyme activity under wheat crop is presented in Table 4.18.

The urease activity before sowing and at harvest was found superior over control upto 9 m distance, beyond which there was no significant difference. Whereas at flowering, highest urease activity only was upto 6 m compared with control. Similarly, in dehydrogenase activity, the casuarina tree row influenced upto 9 m distance at all the periods where the activity was significantly higher upto 9 m distance which was superior over control. At rest of the distances the dehydrogenase activity was comparable with control.

4.4.4 Soil Analysis

The nitrogen content (kg/ha) was higher upto 6 m at sowing and upto 9 m distance at harvest of the crop compared with control

Table 4.18 Effect of bund planted Casuarina tree row on the changes in the soil enzyme activity in wheat during *rabi* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng $soil^{-1}$ day^{-1})			Dehydrogenase activity (µg TPF g $soil^{-1}day^{-1}$)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	15.25	24.35	19.74	13.65	24.85	18.92
6	15.21	24.28	17.66	13.57	24.82	18.87
9	14.81	20.79	17.27	11.73	24.05	16.24
12	12.53	20.54	15.34	9.44	20.55	14.52
15	12.45	20.45	15.22	9.37	20.45	14.49
18	12.40	20.40	15.23	9.33	20.33	14.45
Control	12.37	21.33	15.21	9.27	20.27	14.35
S. Em ±	0.41	0.78	0.39	0.78	0.78	0.61
CD 5%	1.22	2.32	1.17	2.32	2.32	1.81

(Table 4.19). The phosphorus content of soil decreased with distance from the tree row and there was no significant difference upto 18 m distance. At harvest stage, the phosphorus content was significantly higher upto 9 m distance thereafter, there was no significant difference and was comparable with control.

The total phenolic content in the casuarina site was higher nearer to tree row and declined away from the tree row.

4.6 Effect of bund planted eucalyptus tree row on the changes in the microbial population and related parameters in soil.

4.6.1 Bacteria, fungi and actinomycetes

Effect of bund planted eucalyptus tree row on the changes in total microbial population is presented in Table 4.20.

On contrary to the casuarina allelopathy, eucalyptus showed the reverse trend. In general, the microbial count was low near to the *Eucalyptus* tree row and gradually increased with distance.

The bacterial, fungal and actinomycetes population significantly increased upto 9 m distance compared to control at all the sampling periods and remained constant, statistically, in rest of the distances.

Table 4.19 Effect of bund planted casuarinas tree row on the changes in the soil nitrogen and phosphorus (kg/ha) in wheat during *rabi* in 1998

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Total phenols µg/100 g oven dry soil
	At sowing	Harvest	At sowing	Harvest	
3	389.8	385.3	29.0	31.5	21.37
6	389.0	379.5	28.6	30.8	19.70
9	387.1	371.3	28.4	29.5	15.50
12	386.5	365.7	28.1	26.2	14.70
15	387.1	365.7	28.1	28.9	12.55
18	387.0	364.4	28.1	28.9	11.55
Control	386.2	364.5	28.6	28.5	10.81
S. Em ±	0.56	0.68	0.39	0.28	0.85
CD 5%	1.64	2.00	0.66	0.81	2.54

Table 4.20 Effect of bund planted Eucalyptus tree row on the changes in the soil microbial population under wheat during *rabi* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	13.5	24.0	15.7	20.0	31.7	22.0	16.0	29.0	23.6
6	17.0	28.0	19.2	24.5	35.5	35.5	26.0	33.7	26.0
9	20.7	32.0	24.2	29.0	39.5	39.5	29.7	37.0	29.2
12	24.7	37.0	28.2	33.5	43.5	43.5	33.5	40.7	32.2
15	25.2	37.2	28.7	33.7	43.7	43.7	33.7	40.5	32.2
18	25.5	37.5	29.0	34.0	44.0	44.0	34.2	41.7	31.7
Control	26.0	38.0	29.7	34.5	44.7	44.7	34.7	42.0	33.5
S. Em ±	0.94	0.83	1.21	1.44	1.24	1.22	1.22	1.19	0.97
CD 5%	2.80	3.61	3.61	4.29	3.69	3.64	3.64	3.54	2.88

4.6.2 Nitrogen fixing bacteria and phosphate solubilizing microorganisms

The changes in the nitrogen fixing bacteria and phosphate solubilizing microorganisms under the influence of *Eucalyptus* tree row under wheat crop are presented in Table 4.21.

Nitrogen fixing bacteria and phosphate solubilizing microorganisms were significantly reduced upto 9 m distance at all the sampling periods compared with control. In the rest of the cases *viz.*, from 12 to 18 m distance, population remained at par with control soil. Further, it may also be noted that the allelopathic effect was severe at 3 m distance with respect of the above microorganisms

The mycorrhizal spore count upto 9 m was statistically low at all the periods of soil sampling. The spore count was drastically affected, particularly, at 3 m from *Eucalyptus* tree row. Even at 6 and 9 m distance the mycorrhizal spore count differed significantly. From 12 m onwards the mycorrhizal spore count did not differ significantly with control soil.

The mycorrhizal root colonization in wheat crop recorded at 45 days of crop growth was significantly low only at 6 m distance. Subsequently, from 9 m onwards it was at par with control soil. There was no significant difference, between 3 and 6 m distance, in mycorrhizal root colonization of wheat.

Table 4.21 Effect of bund planted Eucalyptus tree row on the changes in the beneficial microorganisms under wheat during *rabi* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count (per 50 g soil)			Mycorrhizal root colonization * (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	22.0	37.0	28.0	8.0	12.0	17.0	24.0	44.0	33.0	25.1 (18.0)**
6	27.2	42.0	32.0	12.0	15.0	20.0	30.0	49.2	37.0	28.0 (23.0)
9	32.0	47.0	36.0	16.0	18.0	23.0	36.2	55.0	43.0	31.0 (27.0)
12	37.0	52.0	40.0	19.7	21.0	26.0	42.0	60.0	47.0	34.4 (32.0)
15	37.5	52.5	40.5	20.2	21.2	26.2	42.5	60.5	47.2	34.5 (32.2)
18	37.5	53.0	41.0	20.5	21.5	26.7	44.2	60.2	47.2	34.5 (32.2)
Control	38.0	54.0	43.0	21.5	22.5	27.5	44.7	60.7	47.5	34.8 (32.7)
S. Em	1.64	1.43	1.30	1.07	0.97	0.57	1.99	1.78	1.08	2.01
CD 5%	4.87	4.25	3.86	3.20	2.90	1.70	5.92	5.31	3.21	5.98

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

4.6.3 Enzyme activity

The urease and dehydrogenase activity in the soil sampled at different period with wheat crop which was under the influence of *Eucalyptus* tree row is presented in Table 4.22.

The urease activity was significantly affected upto 9 m distance compared with control at sowing, flowering and harvest stages. At rest of the distances the urease activity was unaffected compared with control. Similarly, was the effect on the dehydrogenase activity with the *Eucalyptus* tree row influence upto 9 m distance at initial and flowering stage and upto 6 m distance at harvest stage. Rest of the observations did not differ as against control. Further, the effect was very seveare at 3 m distance and gradually declined with increase in distance.

4.6.4 Soil Analysis

The nitrogen content (kg/ha) was higher upto 9 m distance during initial and upto 12 m during harvest of the crop compared with control (Table 4.23). The phosphorus content of soil was inhibited only upto 3 m at initial and up to 9 m during harvest. Rest of the distances were comparable with control soil.

The total phenolic content was also higher nearer eucalyptus tree row and gradually declined away from the tree row.

Table 4.22 Effect of bund planted Eucalyptus tree row on the changes in the enzyme activity under wheat during *rabi* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng soil^{-1} day^{-1})			Dehydrogenase activity (µg TPF g soil^{-1}day^{-1})		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	6.77	13.68	9.14	1.52	15.35	10.5
6	8.16	15.22	11.45	11.65	18.35	12.63
9	10.18	17.59	13.42	13.36	20.60	14.81
12	12.33	19.85	15.94	16.37	22.80	16.44
15	12.84	19.86	15.96	16.40	22.83	16.48
18	12.88	19.87	15.97	16.46	22.85	16.48
Control	12.91	19.88	15.98	16.53	22.88	16.48
S. Em ±	0.38	0.63	0.40	0.63	0.71	0.65
CD 5%	1.14	1.87	1.19	1.89	2.12	1.94

Table 4.23 Effect of bund planted Eucalyptus tree row on the changes in the soil nitrogen and phosphorus (kg/ha) under wheat during *rabi* 1998

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Total phenols g/100 µg oven dry soil
	At sowing	Harvest	At sowing	Harvest	
3	193.0	194.9	12.5	19.1	42.30
6	187.2	189.5	12.3	18.6	37.10
9	186.0	181.5	12.2	17.5	27.50
12	182.2	173.0	12.1	17.1	25.00
15	184.7	170.2	12.1	16.9	20.85
18	184.5	169.9	12.2	16.7	16.00
Control	184.7	168.5	12.1	16.5	15.75
S. Em ±	0.39	1.21	0.08	0.3	0.84
CD 5%	1.1	3.56	0.2	1.0	2.51

4.7 Effect of bund planted teak tree row on the changes in the microbial population and related parameters in soil.

4.7.1 Bacteria, fungi and actinomycetes

Effect of bund planted teak tree row on changes of total microbial population is presented in Table 4.24.

In general, the microbial count was low near to the teak tree row and gradually increased with distance.

The bacterial population, before sowing of wheat crop, was found to be significantly reduced upto 12 m as compared to control. At flowering, the inhibition was upto 9 m. Subsequently, in rest of the distances were comparable with control. Whereas, at harvest, inhibition was upto 15 m. The bacterial population at 18 m distance was at par with control.

With fungi, the population was reduced upto 6 m distance which reduced to significantly lowest level compared with control. The population from 9 to 18 m distance did not differ significantly and remained at par with control.

The actinomycetes population at initial sampling reduced significantly upto 9 m distance and only upto 6 m distance at flowering and harvest stage.

4.7.2 Beneficial microorganisms

Effect of bund planted teak tree row on the changes in the beneficial microorganisms (Nitrogen fixing bacteria and phosphate

Table 4.24 Effect of bund planted teak tree row on the changes in the soil microbial population under wheat during *rabi* 1998

Distance from the tree row (m)	Bacteria (CFU x 10^6 /g soil)			Fungi (CFU x 10^4 /g soil)			Actinomycetes (CFU x 10^4/g soil)		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	13.5	33.5	18.7	21.0	35.0	17.0	16.0	25.0	19.0
6	16.0	38.7	21.7	25.0	39.2	20.7	19.0	28.0	22.0
9	18.5	43.0	24.7	30.0	45.0	24.0	22.0	31.0	24.5
12	19.2	44.0	25.7	32.0	45.2	26.0	22.5	31.5	25.0
15	20.2	45.7	26.2	32.5	45.7	26.2	22.7	31.0	25.5
18	21.0	46.5	27.5	33.2	46.2	26.5	23.0	32.0	26.0
Control	22.0	46.7	28.7	33.7	47.0	26.7	23.5	33.0	26.0
S. Em ±	0.13	0.95	0.73	1.29	1.47	1.21	0.48	0.82	0.76
CD 5%	2.19	2.84	2.17	3.84	4.38	3.59	1.44	2.45	2.27

Table 4.25 Effect of bund planted teak tree row on the changes in the beneficial microorganisms under wheat during *rabi* 1998

Distance from the tree row (m)	Nitrogen fixing bacteria (CFU x 10^2/g soil)			Phosphate solubilizing microorganisms (CFU x 10^2/g soil)			Mycorrhizal spore count (per 50 g soil)			Mycorrhizal root colonization * (%)
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest	
3	17.0	26.0	20.0	7.0	14.0	9.0	30.0	55.2	35.0	27.2 (21.0)**
6	19.7	28.5	23.0	10.5	19.0	13.0	36.0	62.0	41.0	30.0 (25.0)
9	23.0	33.0	26.0	13.7	20.0	16.7	42.0	68.5	48.0	31.9 (28.0)
12	26.0	35.2	29.0	17.0	23.0	20.2	48.0	74.7	55.0	34.8 (32.7)
15	25.5	35.5	30.0	17.2	23.2	20.7	48.2	74.2	55.2	35.0 (33.0)
18	26.5	36.0	30.7	17.7	23.5	21.0	48.2	74.7	55.5	35.1 (33.2)
Control	27.0	37.0	31.7	18.0	23.7	21.5	48.5	75.2	55.7	35.0 (33.0)
S. Em	1.00	0.82	1.00	1.01	0.95	1.13	1.08	2.07	2.42	1.62
CD 5%	2.99	2.43	2.98	3.01	2.84	3.37	3.23	6.17	7.20	4.81

* Observation taken at 45 days of crop growth.

** Figure in paranthesis shows arcsine values.

solubilizing microorganisms) with wheat crop are presented in Table 4.25.

Nitrogen fixing bacteria and phosphate solubilizing microorganisms also increased with increase in distance. The inhibition was significant upto 9 m at all the sampling periods. From 9 to 18 m distance however, there was increase in the population which was comparable to the soil under control.

The mycorrhizal spore count, before sowing of wheat, was significantly low only at 3 m distance compared to control. Subsequently, from 6 m onwards it was at par with control soil. At flowering and harvest stage, mycorrhizal spore count reduced significantly upto 9 m distance compared with control soil.

The mycorrhizal root colonization in wheat crop was significantly low upto 6 m distance. Subsequently, from 9 m onwards it was at par with control soil. From 12 to 18 m distance there was no significant difference and was comparable with control soil.

4.7.3 Enzyme activity

Effect of bund planted teak tree row on the changes in soil enzyme activity under wheat is presented in Table 4.26.

The urease activity during initial and harvest stage was significantly affected up to 6 m compared with control. But at flowering stage, the activity was low only at 3 m distance compared with control. At rest of the distances the urease activity was unaffected compared with

Table 4.26 Effect of bund planted teak tree row on the changes in the enzyme activity under wheat during *rabi* 1998

Distance from the tree row (m)	Urease activity (µg NH_4-Ng soil^{-1} day^{-1})			Dehydrogenase activity (µg TPF g soil^{-1}day^{-1})		
	At sowing	Flowering	Harvest	At sowing	Flowering	Harvest
3	10.34	15.73	10.32	12.75	16.35	13.25
6	13.82	17.84	12.38	15.13	18.37	15.38
9	14.84	17.79	13.36	17.25	20.43	17.45
12	15.54	18.38	14.73	20.34	22.75	19.48
15	15.77	18.25	14.75	20.36	22.78	19.87
18	15.70	18.21	14.78	20.45	22.93	19.89
Control	15.79	18.29	14.85	20.44	22.71	19.90
S. Em ±	0.78	0.63	0.76	0.64	0.58	0.51
CD 5%	2.32	1.89	2.26	1.91	1.74	1.53

control. Similarly, was the effect on the dehydrogenase activity, with teak tree row influence upto 9 m distance at initial and flowering and only upto 3 m distance at harvest stage, rest of the observations did not differ as against control.

4.7.4 Soil Analysis

The nitrogen content (kg/ha) was higher upto 18 m during initial and upto 15 m at harvest stage compared with control (Table 4.27).

The phosphorus content of soil was higher upto 9 m distance which was significantly superior over control at both before sowing and harvest, thereafter, from 12 to 18 m there was no significant difference compared with control.

The total phenolic content in teak site was also higher nearer to tree row.

Table 4.27 Effect of bund planted teak tree row on the changes in the soil nitrogen and phosphorus (kg/ha)

Distance from the tree row (m)	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Total phenols µg/100 g oven dry soil
	At sowing	Harvest	At sowing	Harvest	
3	268.8	279.8	18.7	27.2	35.00
6	267.7	275.2	18.4	25.6	31.70
9	267.2	267.9	17.9	24.7	28.50
12	266.9	265.5	17.5	24.4	25.00
15	267.0	266.4	17.3	24.1	21.37
18	266.8	263.6	17.1	24.1	19.00
Control	265.7	262.7	17.1	23.9	18.78
S. Em ±	0.30	0.32	0.16	6.22	1.32
CD 5%	0.89	0.92	0.49	0.65	3.67

Discussion

V. DISCUSSION

Putnam (1983) expressed allelopathy as a chemical warfare between plants in the field. Allelochemicals mostly refer to the secondary metabolites produced by plants or byproducts of primary metabolic processess which are produced by all kinds of trees particularly their leaves and roots. The plant leachates have an effect on the physical, chemical and biological properties of soil besides on the plant growth. These chemicals escape into the environment (soil) through exudation, leaching, volatilization and decaying, decomposition which again depends on climatic conditions and soil factors. The presence of trees in crop lands can have profound effects on the microclimatic environment that can either promote or inhibit growth and yield of the crop. Somani and Bhandari (1989) reported that components of root exudates exert a selective action on growth of soil microflora either by stimulation or inhibition. They also reported that crop species varietal differences and age of the plant affect the root exudate secretions. Many workers have conducted bioassays and field studies. However, field experiments under natural conditions are very scanty and literature/information is very meager. The experiments at field levels on the dynamics of microbial population and soil properties and enzyme assay in the soils under the influence of row planted eucalyptus, casuarina and teak was carried out. The results obtained are discussed in the following paragraphs.

The general microbial population was enumerated in the field condition under the casuarina tree row planted on the bunds with

greengram in *kharif* and wheat in *rabi* season. The bacterial, fungal and actinomycetes population was very high nearer to the casuarina tree row and remained statistically constant almost upto 6 to 9 m under greengram and wheat, sampled three times during growth phases of each crop (Table 4.1 and 4.16). The stimulation of microorganisms in the soil under *Casuarina equisetifolia* was also reported by Yellappareddy and Sugur (1998). Further the microbial population declined gradually from 9 m onwards. The observed increase in the microbial population could be ascribed to the root exudation and leaf fall of casuarina tree row. Being a nitrogen fixing plant, leaf litter may add organic matter with richer source of nitrogen influencing the rapid rate of decomposition. The decomposition of leaf litter may have encouraged microbial population in the near vicinity of the tree row. Similarly, higher populations of nitrogen fixing and phosphate solubilizing microorganisms were observed under the influence of casuarina tree row (Table 4.2 and 4.17). Yellappareddy and Sugur (1998) also observed increase in *Azotobacter* population in soil under *Dalbergia sissoo*.

During *kharif* season, greengram planted under the casuarina tree row also possessed the higher nodulation (nodule number and nodule fresh weight) on 45 days growth (Table 4.3 and 4.18). The nodulation in greengram further declined with increase in distance in casuarina.

The encouragement of nodulation under the influence of casuarina once again could be ascribed due to higher rhizobial

population in the soil nearer to the plantation. Mallik and Tesfai (1988) reported that residues of green foxtail incorporated in soil stimulated the growth and nodulation of soybean. Encouragement of nodulation in legumes due to higher organic matter content in soil has been reported by several workers (Subbarao 1993, Nutman 1976, Stewart 1966).

The mycorrhizal spore count and the mycorrhizal root colonization in both wheat and greengram, also were found to be higher in soils nearer to the casuarina tree row. The mycorrhizal symbiosis declined with increase in distance from the tree row. The encouraging mycorrhizal symbiosis could be due to prolifaration of microflora including nitrogen fixing and phosphate solublizing microorganisms as a result of root and leaf residues of casuarina. Mallik and Zhu (1995) reported that leaf extract of kalmia plant stimulating the growth of ectomycorrhizal isolates.

The urease activity and dehydrogenase activity declined with increasing distance from the casuarina tree row both under greengram and wheat crops (Table 4.4 and 4.19).

The observed spurt in the activity of urease and dehydrogenase could be ascribed to higher organic matter content and higher microbial population near casuarina tree row. Dick (1984) reported that the enzyme activities were found to be significantly correlated with organic matter content. According to Conrad, (1942) and Skujins, (1967), urease activity in soil appeared to correlate, in general, with the number of microbes and was very high in the rhizosphere.

Dehydrogenase activity is a good measure of the total microbiological activity of soil according to Stevenson (1959).

The total nitrogen and available phosphorus content also showed similar trend as that of microbial population throughout the period of observations (Table 4.5 and 4.20). Tripathi (1998) and Itnal (1987) also reported higher nitrogen and phosphorus nearer to the tree line than the soil away from tree plants. Addition of organic matter from the natural leaf fall of casuarina and also the dead or sloughed off roots might add to the fertility of the soil. The resulting increase in the nitrogen and phosphorus content of the soil nearer to the tree rows can be ascribed to minerilization by the microbial activity.

Eucalyptus tree row:

On contrary to casuarina allelopathy, the eucalyptus followed the reverse trend where the microbial population was suppressed near eucalyptus tree row and the effect was declined away from the tree row.

The bacterial, fungal and actinomycete population (Table 4.6 and 4.20) were suppressed nearer to the eucalyptus tree row in both greengram and wheat at all the periods of sampling (*viz*, before sowing, flowering and at harvest) the inhibition was mostly upto 6 or 9 m distance there after there was no significant difference compared with the control. Shivagurunathan *et al* (1997) reported the phenol content in the leachates of tree species of eucalyptus. The leachates contained caffeic, catechol, fumeric, ferulic, hydroxy benzoic acid and vanillic acids. These phenols released into the soil could be the reason to

suppress the microbial activity in the soil. George (1979) also reported that eucalyptus leaf litter also released hydroxy benzoic, syringic and vanillic acid and catechol. The heavy deposition of leaves nearer to the tree rows might also have contributed to the total phenols in the soil there by influencing the suppression of microbial activity. Although variety of phenols produced in the eucalyptus was not studied in the present study, the total quantity of phenols produced near to the eucalyptus support the view of the other workers. The reduced or suppressed bacterial, fungal and actinomycete population nearer to the eucalyptus tree row may thus be due to the result of interference of allelo-chemicals produced by leaf litter of eucalyptus and also through root exudation.

Similarly, nitrogen fixing bacteria and phosphate solubilizing microorganisms (Table 4.7 and 4.21) also were reduced nearer to the eucalyptus tree row. Sukhada and Jayachandra (1979) reported the inhibition of *Rhizoblium phaseoli* and *Azotobacter vinelandii* by the root and leaf extract of *Parthenium hysterophorus* Yun *et al* (1993) also reported the inhibition of *Bacillus Subtilis, Aspergillus nidulans, Fusarium solani* and *pleurotus ostreatus* by the allelopathic compounds produced by worm wood var. *Orientalis*.

The total number of nodules in greengram crop and their biomass (Table 4.8) were also immensely affected in the viscinity of eucalyptus tree row. Purushothaman and Balaraman (1973) reported the suppression of *Rhizobium* due to soil phenolics. Moura *et al* (1996) also

reported the inhibition of nodulation by *Leucaena* in the soils collected from the fields of *Eucalyptus grandis*. Weston and Putnam (1984) also reported the inhibition of nodulation and nitrogenase activity of soybean, navy bean and snap bean due to allelopathic effect of quackgrass. The inhibition of nodulation under the influence of eucalyptus once again could be ascribed due to lower rhizobial population in the soil and/ or inhibiton of nodulation nearer to the tree row.

The mycorrhizal spore count and the mycorrhizal root colonization in both wheat and greengram (Table 4.7 and 4.21) also were found to be lower in soils nearer to the eucalyptus tree row. Boufalis and Pellissier (1994) reported the inhibition of *Laccaria laccata* and *Cenoccoum graniforme*, the ectomycorrhizal fungi, by the phenols produced in *Vaccinium myrtillus*, *Atherium felix fermina* and *Picea abies*. Baar *et al* (1994) also reported the inhibition of growth rates of *Laccaria proxima* and *Rhizopogon luteolus* by the *Pinus sylvestris* needle extracts.

The observed reduction in mycorrhizal symbiosis in greengram and wheat could be ascribed to the root and leaf residues near to the eucalyptus tree row.

The urease and dehydrogenase activity in both greengram and wheat (Table 4.9 and 4.22) under the influence of eucalyptus tree were reduced near tree line, which could be ascribed to the lower microbial population near to the tree row.

The total nitrogen and available phosphorus content (Table 4.10 and 4.23) was higher nearer to the eucalyptus tree row. Addition of

organic matter from the natural leaf fall of eucalyptus might add to the higher nutrient status. Tripathi (1998) and Itnal (1987) also reported higher nitrogen and phosphorus nearer to the eucalyptus tree line.

The total phenol content was assessed only once during the season which showed higher phenols nearer to the tree row (9m) and declined with increasing distance from the tree row. This observation goes to indicate that the phenols produced by the plants might be reason for observed declining microbial activities near the tree row.

Teak tree row:

Similar trend as observed under eucalyptus, was also visible in teak tree row where the microbial population was suppressed near the tree row and gradually increased with distance.

The bacterial, fungal and actinomycete population (Table 4.11 and 4.24) were suppressed at 3, 6 and 9m distances during all the samplings in both greengram and wheat crops. Beyond 9 m however, there was no significant difference up to 18 m distance and was found on par with control. Park and Choi (1996) reported the inhibition of bacteria, fungi and yeasts by the extract of cork tree *Phyllodendron amurense* and they attributed it to allelochemicals. Hegazy and Fadl-allah (1995) also reported the inhibition of *Penicillium chrysogenum* and *P. funuculosum* by the water extract of *Cleome droserifolia.*

Nitrogen fixing bacteria and phosphate solubilising microorganisms under the influence of teak tree in greengram (Table 4.12) and wheat crops (Table 4.25) also suppressed near tree row and

the population gradually increased away from the tree row. Similar inhibition of *Rhizobium phaseoli* and *Azotobacter vinelandii* by the root and leaf extract of *Parthenium hysterophorus* was reported by Sukhada and Jayachandra, (1979) Yun *et al.* (1993) also reported the inhibition of *Bacillus subtilis, A nidulans, Fusarium solani and Pleurotus ostreatus* by the allelopathic compounds produced by worm wood var. orientalis.

Suppression of nodulation in greengram was severe nearer to the teak tree row. Duhan *et al* (1994) observed the inhibition of nodulation and nitrogen fixation in cluster bean by *Acacia nilotica* tree rhizosphere soils in pots. They attributed it to the allelopathy. Balasubramanian and Ravichandran (1996) also reported the inhibition of *Casuarina equisetifolia* nodualtion and nitrogen fixation by *Eucalyptus tereticornis, Leucaena leucocephala, Tectona grandis, Alianthus excelsa* and *Acacia nilotica.* The inhibition of nodulation under the influence of teak once again could be ascribed due to lower rhizobial population in the soil nearer to the tree row.

The mycorrhizal spore count and the mycorrhizal root colonization with both (Table 4.12 and 4.25), greengram and wheat crops also were found to be lower in soils nearer to the teak tree row. Baar (1994) reported the inhibition of growth rates of *Laccaria proxima* and *Rhizopogon luteolus* by the *pinus sylvestris* needle extracts. Boufalis and Pellissier (1994) also reported the inhibiton of respiration of *Laccaria laccata* and *Cenococcum graniforme* by the phenols produced by *Vaccinium myrtillus,* Atherium felix-fomina and *picea abies.* This

observation on reduced mycorrhizal symbiosis could be ascribed to the allelochemicals leached from the litter and root of teak tree row and addition to the rhizosphere soil.

The urease and dehydrogenase activity in both greengram and wheat rhizosphere (Table 4.14 and 4.27) under the influence of teak tree was reduced nearer to tree line. The lower activity near teak tree row could be ascribed to the lower microbial population near to the tree row.

The available nitrogen and available phosphorus content was found to be higher near eucalyptus tree row. Addition of organic matter from the natural leaf fall of teak might add to the higher nutrient status.

As observed in the eucalyptus the phenols in soil under teak plantation was higher upto 9 m distance. Thus the observed decline in the microbial number and their activities could be ascribed to phenolic content in the soils under the influence of teak.

From the above observations it could be concluded that allelochemicals produced from the tree rows could influence the total microbial activity in the soil (Fig. 1). While the nitrogen fixing casuarina tree row could influence higher microbial activity nearer to the tree row the eucalyptus and teak showed the contrasting effect on microbial activity. The nitrogen fixing ability of casuarina and the addition of organic residue through nitrogenous organic matter must have influenced the microbial load, symbiotic activities of *Rhizobium* and mycorrhizal fungi and the enzymes. The possibility of phenols produced by eucalyptus and teak must have suppressed the microorganisms and

influenced the soil fertility. Of the two inhibiting tree rows, eucalyptus was found to be more severe than the teak. Obviously, the eucalyptus is known to exude various phenolic substances and leaf litter that also add to soil high phenolics. Thus the allelochemicals produced by the trees are bound to influence not only the crop growth but also the microbial activity in the surrounding soil. Although detailed study on the allelochemicals produced, pattern of production and their detailed effect on microorganisms could not be determined this study indicated the possible role of allelochemicals in encouraging (casuarina) or suppression (eucalyptus and teak) of the soil microorganisms. This calls for detailed study as to how the allelochemicals produced by tree crops could be reduced by ammending soils with organic manures which might neutralize the effect of allelochemicals produced by eucalyptus and teak rows.

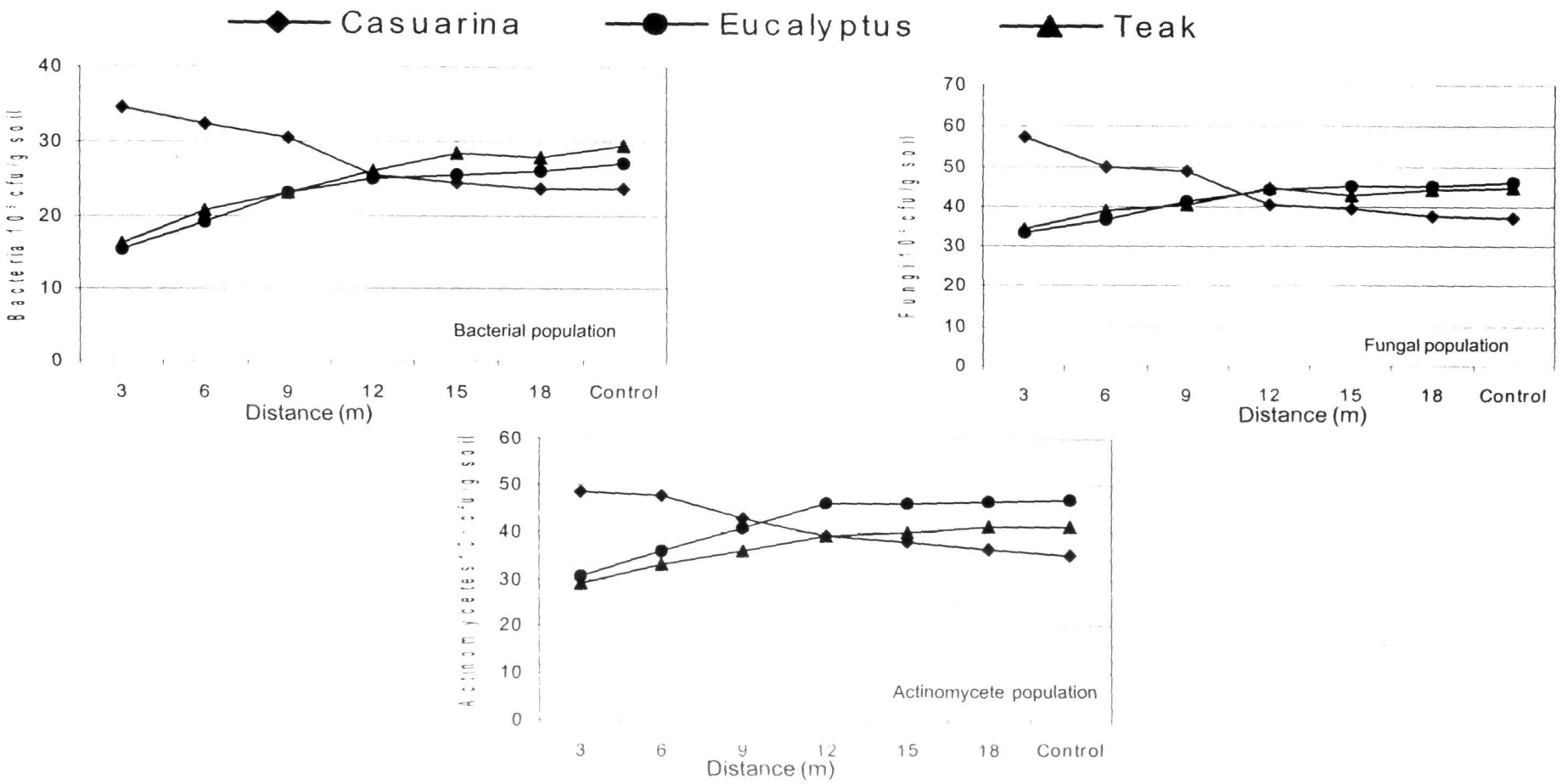

Fig. 1a. Effect of casuarina, eucalyptus and teak trees on microbial population

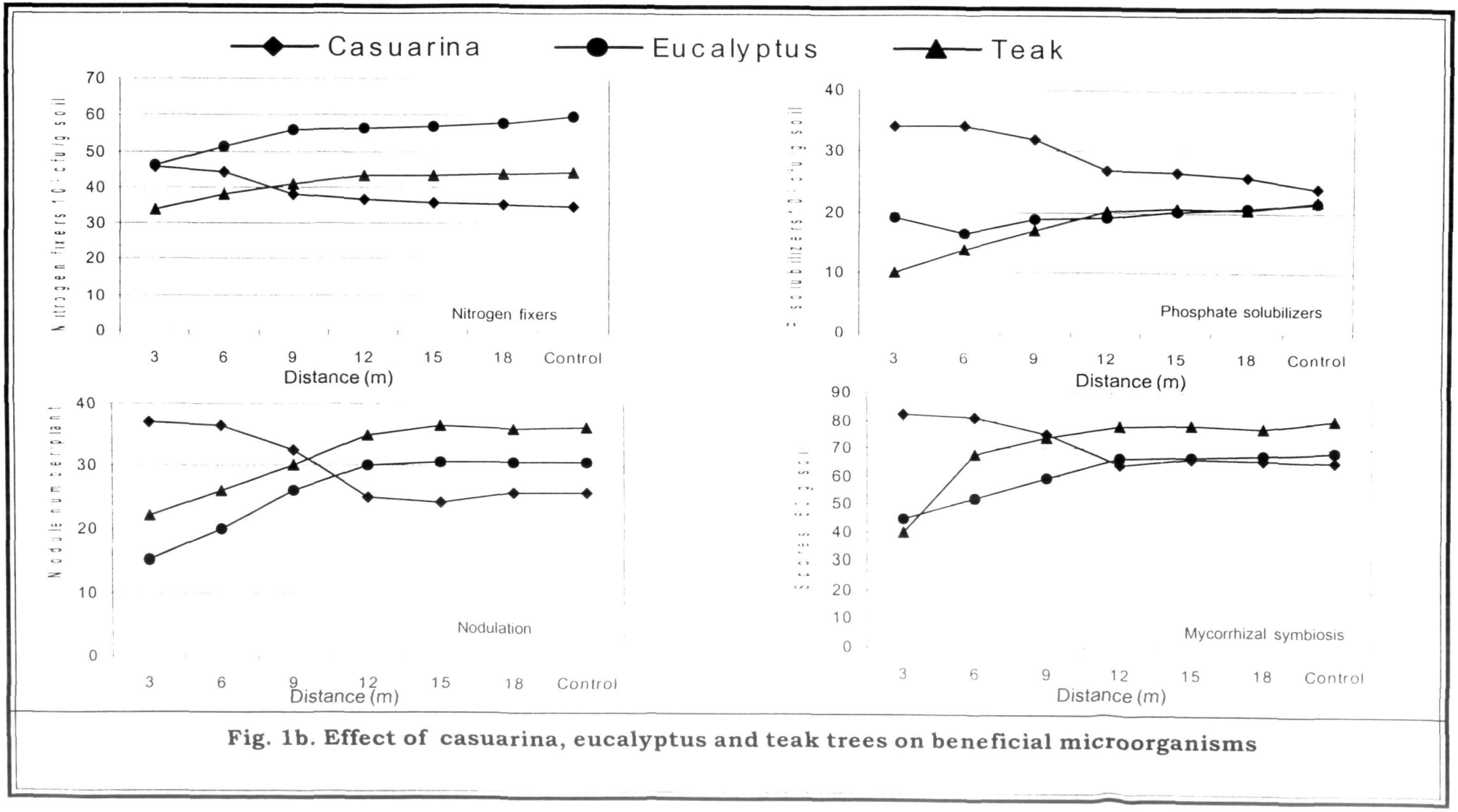

Fig. 1b. Effect of casuarina, eucalyptus and teak trees on beneficial microorganisms

Bacteria 10^n cfu/g soil

Summary

VI. SUMMARY

The microbial population namely bacteria, fungi and actinomycetes and their activities were greatly influenced by the allelopathy of casuarina, eucalyptus and teak trees. Summary of the results obtained is presented here under.

1) The bacterial, fungal and actinomycete population under the influence of casuarina were found to be high nearer to the bund planted tree row. While these organisms were greatly suppressed nearer to the tree row of eucalyptus and teak. The population density however, was reduced under casuarina and increased under eucalyptus and teak with increasing distance.

2) Similarly, the nitrogen fixing microorganisms and phosphate solubilizing microorganisms were stimulated near casuarina tree row. While in eucalyptus and teak tree rows these beneficial microorganisms were highly suppressed.

3) The symbiotic interaction of microorganisms and crop plants namely, nodulation and mycorrhizal symbiosis in greengram were stimulated under casuarina tree row while under eucalyptus and teak they were greatly affected.

4) The urease and dehydrogenase activity, which are indicators of microbial dynamics in soil which once again were stimulated under casuarina but with eucalyptus and teak trees the enzyme activities were suppressed.

5) The available nitrogen and phosphorus content in soil were higher nearer to the casuarina, eucalyptus and teak tree rows.

6) The phenolic content also was found to be higher nearer to the casuarina eucalyptus and teak tree rows.

7) The concentration of phenols in the visinity of the tree rows were found to be in the declining order of eucalyptus > teak > casuarina, which indicates severity of the allelopathic effect on microorganisims in eucalyptus and teak.

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Appendix

APPENDIX - I

COMPOSITION OF MEDIA USED

Soil extract agar (Bunt and Rovira, 1955)

K_2HPO_4	0.4 g
$(HN_4)_2SO_4$	0.5 g
$MgSO_4$-$7H_2O$	0.05 g
$MgCl_2$-$6H_2O$	0.1 g
$FeCl_3$	0.01 g
$CaCl_2$	0.1 g
Peptone	1.0 g
Yeast extract	1.0 g
Soil extract	250 ml
Distilled water	750 ml
pH	7.2 to 7.4

Preparation of soil extract

One kg of soil was suspended in one litre of water, autoclaved at 1.5 kg/cm^2 pressure for 30 minutes, allowed to stand overnight and filtered through Whatman No.1 filter paper. The volume of the filtrate was made upto one litre with water and used.

Martins rose-bengal agar (Martin, 1950)

Glucose	10.0 g
Peptone	5.0 g
$MgSO_4$-$7H_2O$	0.5 g
Rose Bengal	0.33 g
Distilled water	1000 ml
Streptomycin sulphate	3 ml of 1% aqueous solution
Agar	20.0 g
pH	6.0

Three ml of one per cent aqueous solution of streptomycin sulphate was added to the medium just before pouring into the petriplates.

Kuster's agar (Kuster and Williams, 1964)

Starch	10.0 g
Casein	0.3 g
KNO_3	2.0 g
NaCl	2.0 g
K_2HPO_4	2.0 g
$MgSO_4$-$7H_2O$	0.5 g
$CaCO_3$	2.0 g
$FeSO_4$	0.01 g
Agar	20.0 g
Distilled water	1000 ml
pH	7.0

Norris N-free agar (Norris, 1959)

K_2HPO_4	1.0 g
$MgSO_4$-$7H_2O$	0.2 g
$CaCO_3$	1.0 g
NaCl	0.2 g
Glucose	10.0 g
Agar	20.0 g
Distilled water	1000 ml
pH	7.2

Pikovskaya' s (Pikovskaya, 1948)

Glucose	10.0 g
$Ca_3(PO_4)_2$	5.0 g
$(NH_4)_2SO_4$	0.5 g
Yeast extract	0.5 g
$MgSO_4$-$7H_2O$	0.2 g
NaCl	0.1 g
Kcl	0.2 g
$MnSO_4$	Trace
$FeSO_4$	Trace
Distilled water	1000 ml
Agar	20.0 g
pH	7.0

Lactoglycerol

Lacticacid 400 ml : Glycerol 500 ml : Distilled water 100 ml.

ALLELOPATHIC EFFECT OF SELECTED TREE SPECIES ON THE SOIL MICROFLORA AND THEIR ACTIVITIES

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ABSTRACT

Experiments to study the allelopathic effect on the rhizosphere microflora of greengram and wheat of the established bund planted eucalyptus, casuarina and teak were examined for a period of one year. The allelopathic effect was assessed from the tree rows from 1-18 m at an interval of 3 m. A composite soil sample, 30 m away from the bund planted tree rows served as a control. Soil sampling was done to study the microbial activity three times each under greengram during *kharif* and wheat during *rabi* seasons.

Microbial population under rhizosphere of greengram and wheat varied with increasing distance indicating the allelopathic effect of tree rows on the soil microflora. The nitrogen fixing casuarina tree row could influence higher microbial activity nearer to the tree row, but the eucalyptus and teak showed the inhibitory effect on microbial activity. The nitrogen fixing ability of casuarina and the addition of organic residue through nitrogenous organic matter may be the reason for influencing the microbial load, symbiotic activities of *Rhizobium* and mycorrhizal fungi and also the enzymes. The phenols produced by eucalyptus and teak could have possibly suppressed microorganisms. Of the two inhibiting tree rows, eucalyptus was found to be more severe than the teak. Obviously, the eucalyptus is known to exude various phenolic substances and leaf litter that also add to soil high phenolics. Thus the allelochemicals produced by the trees are bound to influence not only the crop growth but also the microbial activity underground.