INTRODUCTION

Numerous tree plantation programmes have been undertaken, in our country, with multiple objectives of providing sufficient biomass energy, reclamation of deforested and waste-land areas, and restoration of several disturbed ecosystems. Tree plantation on abandoned agricultural sites has assumed a very profitable proposition for the entrepreneurs and land users, by far the most important considerations of these plantation programmes are the energy and environmental crises that are being faced by our enormous population.

Firstly, considering the need for promotion and development of New Renewable Sources of Energy, the Government of India set up a commission for additional Sources of Energy (CASE) in 1981. Later, in 1982, a separate department of Non-Conventional Energy Sources had been established under the Ministry of Energy. Now a separate Ministry of Non-Conventional Energy Sources has been created. One of the major objectives of this ministry is to implement programmes of energy forestry on large scales in addition for the other sources of the Non-Conventional energy.
India has a total forest area of about 75 million hectares which forms only 22.8% of the total geographical area of the country. Besides, it has been estimated by the National Commission on Agriculture that nearly 43.6 million hectares of the abandoned cultivable land are available in the country which is distributed in 5,67,000 villages. There is a possibility to produce around 6200 dry tons of utilizable biomass per hectare, in a 4-5 year cycle, on waste land in many parts of the country despite the prevailing adverse edaphic and climatic conditions of the sites available for such plantations.

In rural India 80 percent of energy requirement is met from traditional sources mostly the fuelwood. It is, therefore, necessary to find ways and means to increase forest biomass production per unit time and space. This require selection and use of tree species that grow very fast during the first few years and can produce fuelwood at intervals of less than five years. The most suitable crops are those which have capacity to coppice profusely, resulting in considerable saving in the cost of replanting.

Studies on energy plantation in India are still in a formative stage, though the department of forests throughout the country have raised energy plantations, also called as fuel wood plantation or high density energy plantations (HDEP) under social forestry programmes.

Secondly, degradation in the quality of forest and a significant reduction in its total area makes the mass propagation of trees as an asset for the energy proposition. Such plantations have to be carried out without much cost input for
irrigation and fertilizers etc. Our wastelands are of poor soils in respect of vital nutrients viz., N, P, K and water holding capacity. With these conditions plantation programmes will depend much on practicable and viable nursery packages, which must include aspects of seed quality, clonal propagation, and association of the rhizosphere and root microsymbionts. Ensuring this at the nursery stage will be an immensely beneficial development for achieving plantation productivity targets, with cost effectiveness.

Microbial symbiosis involving tree species of importance in forestry have been recognised in four major symbiotic associations viz., leguminous trees - rhizobia; actinorhizal plants - *frankiae*; ectomycorrhizal fungi - host trees; endomycorrhizal fungi - host trees.

The role of legumes in enriching the fertility of soil by contributing nitrogen through symbiotic nitrogen fixation by rhizobial genetic system is well established. Nodule development by soil bacteria of the genera *Rhizobium*, *Bradyrhizobium* and *Azorhizobium* on roots of leguminous plants is a highly specific plant-microbe interaction (Spaink, 1994). At the early stage of symbiosis, the host specificity is regulated by multiple signal exchanges between rhizobia and their host plants (Spaink, 1994; Downie, 1994). The flavonoid signal molecules exuded by the host plant roots induce the expression of nodulation (*nod, nol*) genes in *Rhizobium* in conjunction with the bacterial activator Nod D protein (Long, 1989; Denarari et al. 1992). The products of several of the rhizobial nodulation genes synthesize the lipo-
oligosaccharide Nod factor which induce root hair deformation, cortical cell division, induction of early nodulin genes and nodule formation on the legume roots (Sindhu et al., 1995; Stacey et al., 1995).

The increasing demand for protein and high cost of producing nitrogen fertilizer pose problems that could be solved in part by extensive use of biological nitrogen fixation.

Legume inoculants as commercial products were in vogue in USA and UK even 100 years ago (Brockwell and Bottomley, 1995) and a wealth of understanding on biological nitrogen fixation (BNF) process has been developed through research starting from early 1930’s. Over the past decade or two Rhizobium or Bradyrhizobium inoculation of forest trees, especially for use in developing countries, has been pursued vigorously by scientists at the university of Hawaii under the NifTAL project supported by the USAID since 1974. In collaboration with the Nitrogen-Fixing Trees Association (NFTA) microbiologists have focussed on isolating, culturing, and testing Rhizobium and Bradyrhizobium strains for use in inoculating 11 important leguminous tree genera, viz. Acacia, Albizia, Cassia, Dalbergia, Erythrina, Gliricidia, Inga, Leucaena, Parkia, Prosopis and Sesbania.

Lastly, in the endomycorrhizal legume plants symbiotic nitrogen fixation decreases in P-deficient soils (Mosse et al. 1975). Under such conditions applications of VA-mycorrhizal fungi capable of uptaking phosphorus away from the phosphorus depleted zones enhances symbiotic nitrogen fixation as has been seen in the case of several agricultural crops (Gupta et al., 1987; Bhandal et al., 1989).
Vesicular-arbuscular mycorrhizal fungal associations are the most widespread in plant kingdom irrespective of the geoclimatic distribution of plants from the tropics to the arctic regions. The common mycorrhizal association in most of the plants is the VA-type occurring in the majority of agricultural crops, most shrubs, most tropical tree species and some temperate tree species. These fungi are obligate symbionts and have not been cultured on nutrient media so far. VA-endophytes are though not considered as host specific, evidence is now growing that certain endophytes may form preferential association with certain host plants (Mosse, 1977).

Phosphorus is the second most important of the key elements for the plant metabolism and growth. Mycorrhizal fungi have the property of increasing the uptake of immobile ions of phosphate. It is regarded that besides the P, VAM mediate enhanced uptake of zinc, copper and sulphur in such plants. In addition, some mycorrhizal fungi increase the plant resistance to drought conditions, protect against soil borne diseases, improve plant establishment and have a positive effect on soil aggregation, thus contributing to erosion control.

The importance of fungal symbiosis to host plants depends on the structure of the root system and availability of water and nutrients in the soil. The greatest importance of mycorrhizae to the host plants lies in the extension of the penetration zone of the root-fungus system into the soil, facilitating an increased efficiency of water and nutrient uptake. The interconnected network of external and absorbing
surface in the soil beyond the depletion zone that would otherwise remain inaccessible to the plant roots. In tropics, the major importance of mycorrhizal symbiosis will be in its role in the phosphorus nutrition of plants, especially because (i) tropical soils are invariably poor in available phosphorus, (ii) many tropical soil are phosphorus fixing, and (iii) phosphatic fertilizers are expensive. In legumes, particularly, the triple symbiosis between legumes, mycorrhizal fungi and rhizobia deserves special attention because legumes are very important sources of protein, and phosphorus is necessary for symbiotic nitrogen fixation. In phosphorus deficient soils, the leguminous host plants obtain phosphorus mainly through VA-mycorrhizal association.

Crush (1974) observed that VAM strongly stimulated nodulation of a number of legumes grown in a phosphorus deficient soils. Mycorrhizal and nodulated plants have usually lower root/shoot ratios than plants inoculated with either symbiont alone (Hayman and Mosse, 1972; Daft & El Giahmi, 1974; Asimi et al., 1980; Smith, 1980, 1982; Hardie & Leyton, 1981). Selection of efficient VAM fungal species, which can help in enhancing the phosphorus supply and the choice of genotype which can get maximum benefits of the VAM association are the two vital factors to improve the existing VAM plant association. The present position of VAM research pointed out that more investigations are needed on the biological interactions between VAM fungi and beneficial soil organisms, and their effect on plant growth (Linderman, 1988).

Most of the studies on VAM-Rhizobium interaction suggest that colonization with efficient endophytes significantly improve
P nutrition and consequently nodulation and nitrogen fixation (Hayman, 1986). While the principal effect of mycorrhiza on nodulation is undoubtedly phosphate mediated, mycorrhiza may have other secondary effects. Such potentially limiting factors may include supply of photosynthate, trace elements and plant hormones. Recent field studies have shown great advantages of dual inoculation by the two symbionts. The method of application of inoculum would also pose a problem as most of the grain and forage legumes are directly sown in the field. Perhaps an immediate application could be in forestry as some leguminous tree species like Acacia, Robinia, Albizzia, Leucaena, Dalbergia and many others could be preinoculated with selected rhizobia and mycorrhiza in the nursery to produce nodulated mycorrhizal seedlings before planting them out in the field during the afforestation programmes.

It is regrettable that awareness of the importance of these symbiotic associations for forest trees worldwide is so low. Serious efforts are needed to educate horticulturists, foresters, and plant scientists in general on the subject. A major opportunity to prime this aspect was lost, for example, in a recent publication entitled Managing Global Genetic Resources: Forest Trees (National Research Council 1991), which failed totally to mention microbial symbioses with forest trees as an important relationship.

The present study was planned and carried out to obtain scientific results, of preinoculation of the tree seedlings in nursery with suitable inoculants of Rhizobium and VAM fungi, on
the possible benefits accruing to the indigenous tree species being used in social and farm forestry in Chhattisgarh region of Madhya Pradesh.