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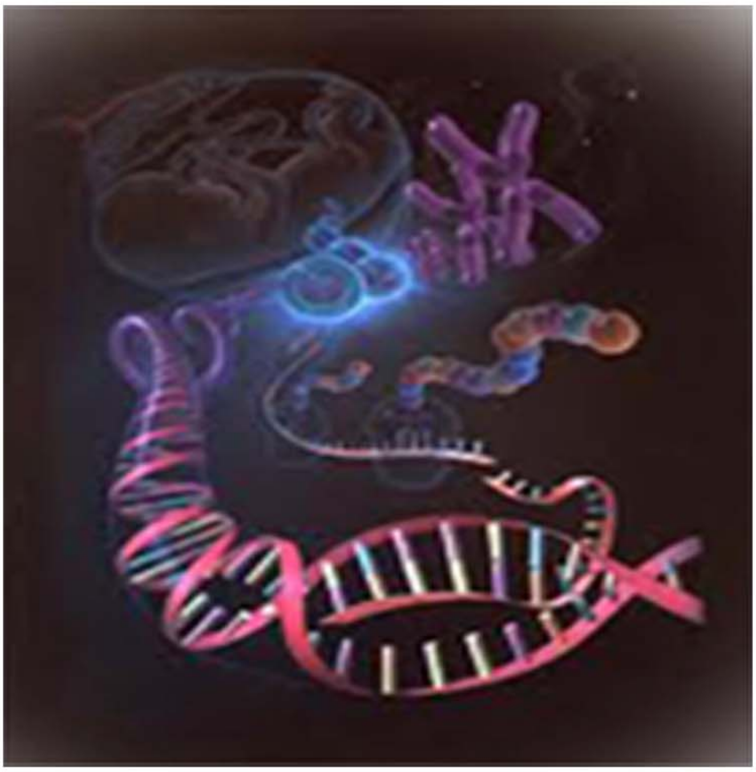

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Research Paper

UPTAKE OF PHOSPHORUS BY ECTOMYCORRHIZAL SEEDLINGS IN DEGRADED JHUM LANDS

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Seedlings of *Pinus insularis* and *Quercus griffithii* with ectomycorrhizae formed by *Suillus bovinus*, *Boletus edulis* and *Scleroderma citrinum* were studied in two different stages of degraded jhum lands. The use of fungal inoculums revealed an increased uptake of phosphorus by the mycorrhizal seedlings as compared to un-inoculated control. The formation of extensive network of fungal mycelium appears to have a positive impact on the increased absorption of nutrients. Ectomycorrhizal fungi assist in the uptake of phosphorus by extending their mycelia beyond the phosphorus depletion zone where the unassociated roots cannot reach. A significant variation ($p<0.01$) in the uptake of phosphorus was observed between the mycorrhizal and non-mycorrhizal seedlings.

Keywords: Ectomycorrhizae, Phosphorus, *Pinus insularis* and *Quercus griffithii* seedlings

INTRODUCTION

The gravity of land degradation and its significance as a problem is a global issue. Shifting cultivation (jhum), an ancient form of agriculture is still dominant in the seven states of north-eastern India, where over 100 tribal communities composed of more than 62,000 families in the region depend on jhum for their livelihood (Ramakrishnan, 1992). In North-East India (with special reference to Nagaland), a major cause of land degradation/forest decline is due to the practice of shifting cultivation. Forest loss due to jhum is believed to have intensified in recent years, mainly because of increasing population, pressures on land, coupled with decreasing fallow cycles (Ramakrishnan, 1992). The high prevalence of this system has affected the ecology of the region resulting in drastic loss of forest wealth, soil fertility, biodiversity and environmental degradation. The loss of soil under shifting agriculture has been reported in the tune of 5 to 83 t/ha depending upon crops grown and slope of the land (Prasad *et al*., 1986). In view of the increasing shortage of plant resources due to population explosion, it has become imperative that all degraded lands are put to use by developing vegetation cover. The appropriate use of ectomycorrhizal inoculants for raising plant seedlings of economic value to local population

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is an important factor taken into account by many forest and agricultural industries to resolve problems of land degradation.

The soils in degraded lands are generally poor in phosphorus limiting the growth of transplanted seedlings. In soils with low P availability, its uptake by diffusion alone is often exceeded by plant P demand (Marschner, 1995), thereby creating depletion zones in the rhizophere (Junk and Claassen, 1989). Under such conditions, to overcome Pi limitation in the rhizosphere, the formation of symbiotic structures with mycorrhizal fungi is considered as the most widespread response to increase P acquisition by plants (Smith *et al*., 2000; Burleigh *et al*., 2002; Tibett and Sanders, 2002). The beneficial role of mycorrhiza, particularly with respect to the uptake of phosphorus, appears to be related to the nutrient depletion zone. Phosphorus is less soluble and relatively immobile in soil. Mycorrhizal fungi assist in the uptake of phosphorus by extending their mycelia beyond the phosphorus depletion zone where the un-associated roots cannot reach. Another factor can be the capability of the fungal hyphae to absorb P effectively from lower soil concentration; because soil exploitation by mycorrhizal hyphae involves smaller energy expenditure per unit absorbing area than by roots (Kisinyo and Othieno, 2003). The hyphae forms internal polyphosphatase and thus maintain low internal P concentration (Jungk and Claassen, 1989). The production of organic acids and enzymes which increase the availability of phosphorus and the ability of fungi to store and efficiently translocate phosphorus into the host is also been suggested by Grove and LeTacon (1993).

MATERIALS AND METHODS

The study was conducted at two different stages of degraded jhum lands:

- Plot A (a young jhum land: jhum cycle comes once in 6 years) at Yimyu (1080.52 m above msl), in the district of Mokokchung, Nagaland;
- Plot B (an old jhum land: jhum cycle comes once in 9 years) at Lumami (962.25 m above msl), in the district of Zunheboto, Nagaland.

Three dominant ectomycorrhizal fungi, viz., *Suillus bovinus, Boletus edulis* and *Scleroderma citrinum* were isolated and multiplied on Modified Melin Norkran's medium (Marx, 1969). Seedlings of *Q. griffithii.* Hook. f. and *Pinus insularis* Endl. were raised in nursery beds and transplanted in both the plots. One month after transplantation, the selected isolates of fungi were inoculated (5 mm diameter block) near the roots of the seedlings, with each treatment replicated 25 times. For the estimation of total phosphorus in plant tissue the wet tri-acid digestion procedure was followed as suggested by Allen (1974). Phosphorus was analyzed by molybdenum blue method (Jackson, 1973) and was calculated by the following formula:

$$P\ (\%) = \frac{c\ (mg) \times \text{solution volume (ml)}}{10 \times \text{aliquot (ml)} \times \text{sample weight}} \times 100$$

where c = mg P obtained from the graph. The data was processed by analysis of variance (ANOVA).

RESULTS

The result revealed that the P uptake was greatly enhanced in seedlings colonized by ectomycorrhizal fungi. Inoculation of the seedlings with the fungal inoculums resulted in an increase uptake of phosphorus as compared to un-inoculated control seedlings. The inoculated seedlings showed a differential response in the uptake of phosphorus. Among the fungal inoculums tested, higher uptake of phosphorus in *Q. griffithii* seedlings was recorded with *Boletus edulis* and *Scleroderma citrinum* in both the plots. There was no significant difference in the uptake of phosphorus between the two plots (Figure 1)

In contrast to seedlings of *Q. griffithii*, enhanced uptake of phosphorus was recorded in *Pinus insularis* seedlings inoculated with *Suillus bovinus* followed by *Boletus edulis.* Comparatively the uptake of phosphorus was higher in plot B (Figure 2). A significant variation was found in phosphorus content (p< 0.01) between the treated and un-inoculated control (Table 1).

Figure 1: Phosphorus Content (%) in *Quercus griffithii* Seedlings

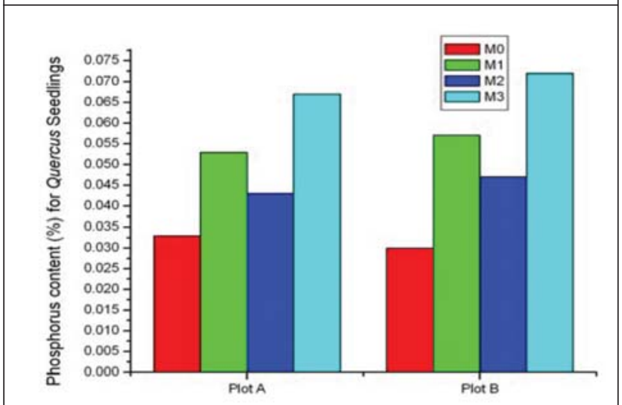
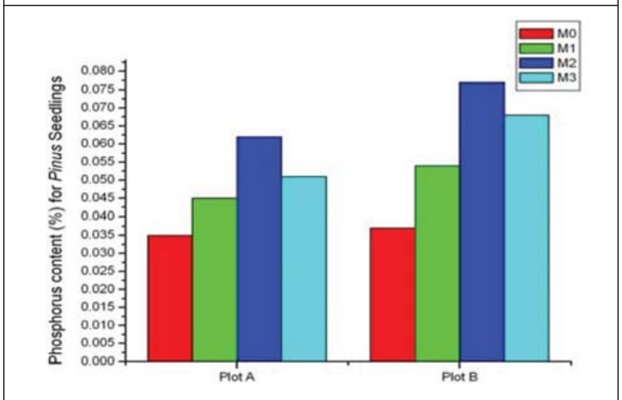


Figure 2: Phosphorus Content in *Pinus insularis* Seddlings



Note: M_0 = *Control*; M_1 = *Scleroderma citrinum*; M_2 = *Suillus bovinus* M_3 = *Boletus edulis*

Table 1: Analysis of Variance (F) Values of Mycorrhizal and Non-mycorrhizal with Various Parameters

	Source of Variance	Variation Between Mycorrhizal and Non-mycorrhizal
Quercus griffithii	Phosphorus	29.8**
Pinus insularis		18.0**

Note: **Significant at p<0.001 level.

DISCUSSION

Extensive mycorrhizal root system has positive impact on the growth performance of the host plant (Ajungla *et al*., 2010). With increased mycelium, more soil is penetrated and the uptake volume of the integraded root fungus system becomes larger. The ectomycorrhizal fungal hyphae by growing away from the roots may detect zones of higher phosphorus availability and hasten root proliferation in these zones (Harley and Smith, 1983; Christophe *et al*., 2006). The development of extra radical mycelium is of great importance for the interaction between the fungus and the fine roots. Fungal cells (hyphae) emanate from the outer mantle as extra radical mycelium and grow into the surrounding soil where they reach micropore areas and absorb nutrients that may otherwise be inaccessible, both physically and biochemically (i.e., enzymatic processes of organic compounds) to roots (Perez-Moreno and Read, 2000).

The results showed that the uptake of phosphorus was higher in ectomycorrhizal seedlings of *Pinus insularis* in plot B. This could be due to the longer duration of jhum cycle in addition to the extensive network of fungal mycelium colonizing the soil for exploitation of minerals. The differential response of the host plants to different fungal species can be attributed to the differences in their physiological functions (Allen *et al*., 1995); the efficiency of mycobionts to improve the growth of host under varied ecological conditions (Browning and Whitney, 1993). The results are in agreement with the statement that ectomycorrhizal associations in tree seedlings is far better than no such associations at all and; some species of ectomycorrhizal fungi have proven to be more beneficial to trees under certain environmental conditions than others (Agarwal and Sah, 2009).

CONCLUSION

The symbiotic relationship of fungi and plant roots is advantageous and even obligatory for the establishment and growth of the plant seedlings. The experimental use of fungal inoculums revealed that the seedlings with more quantity of ectomycorrhizae were able to regenerate numerous lateral roots of greater lengths. The root system of ectomycorrhizal seedlings were capable of increased absorption of phosphorus which could be only due to the formation and network of fungal mycelium. The variation in the efficiency of mycorrhizae for the uptake of phosphorus may depend on the specific mycorrhizal fungi.

Ectomycorrhizal fungi like *B. edulis* and *S. citrinum* facilitated the uptake of phosphorus in *Quercus griffithii* seedlings. The symbiotic association of *S. bovinus* and seedlings of *P. insularis* proved most efficient in the uptake of phosphorus followed by *B. edulis*. The use of fungal inoculums with suitable plant seedlings can be profitably introduced with the existing reforestation programs, for better nutrient utilization and effective use of degraded jhum lands.

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