DISCUSSION
CHAPTER V
DISCUSSION

For the present study four different minespoils viz., magnesite, quarry, limestone and lignite minespoils were selected and utilized. The details of the above minespoils are given in table of the chapter III. The vegetation has been very scarce in all the minespoils and mainly composed of herbs and small shrubs in patches. The fauna of this region included some domestic animals such as cattle, sheep and goats, which usually graze on the patches of pasturelands.

The natural soil profile of the study mining areas are shown in Plate 2a to h. Mining has been a semi mechanical process, where drilling, blasting, loading, transport of raw limestone and spoils, collection of ore, sizing, chipping and stacking are done with the help of machines. The respective minespoils were collected from their sites. The physico-chemical properties of these different minespoils are given in Table 18.

Mining is next to agriculture in world's economy. But mining and its allied works have wasted and ravaged the land surface, particularly the loss of topsoil, which is an integral storage and exchange site for nutrients. Nutrient status of the minespoil is with low inherent fertility of spoil material (Smith and Bradshaw, 1972; Bradshaw, 1983). Raman et al. (1993) reported that the magnesite minespoil is in general, poor in available phosphorous. Granite minespoil contains low amount of all major plant nutrients, except calcium and magnesium (Reynolds et al., 1978). Generally microbial activities are lacking in mining and industrial wastes. Wilson (1965) has opined that the lack of suitable microorganisms might be deterrent to the development of vegetation of mine tailing. Minespoils are nutritionally and microbiologically impoverished (Visser et al., 1979). Besides this, the minespoils may contain materials which are potentially unfavourable for
plant growth (Chichester, 1983). Sheltron and Trettin (1984) observed toxicity, low water holding capacities, alkalinity and poor physical conditions in minespoils. Almost all physical, chemical and biological parameters are affected by mining activity. Reclamation and rehabilitation of the minespoil can be made with selection of suitable tree species (Ramprasad, 1988; Dadhwal and Bijendrasingh, 1993) and soil amendment techniques (Intodia et al., 1995; Ravichandra et al., 1996), which include trenching around the plant, mulching with organic materials and cover crops and application of biofertilizers and inorganic fertilizers. Increased growth performance of many plants owing to treatments of minespoils with amendments has been attributed to enhanced nutrient status (Merrill et al., 1980; 1983; Sabey et al., 1990; Balasubramanian and Palaniappan, 1995; Jayanthi Chinnuswamy et al., 1997).

The present study was contemplated to utilise such of these minespoils for raising crops by improving their physical, chemical and biological properties with the application of organic, amendments and biofertilizers, thereby preventing the environmental pollution caused by these minespoils.

1. EFFECT OF DIFFERENT MINESPOILS AND THEIR MANAGEMENT WITH ORGANIC AMENDMENTS ON GERMINATION AND SEEDLING VIGOUR OF NEEM AT 30 DAYS AFTER SOWING

It is obvious from the observations of this study that the different types of minespoils affected the germination (Fig. 1) and seedling vigour in terms of root and shoot length, drymatter production and vigour index (Fig. 2). In the present study, soil fertility could be a major factor which regulates plant growth. Several investigators have reported that N and P are the factors limiting plant growth in minespoils. Day et al. (1979) observed in growth chamber experiments that even with adequate irrigation, but without proper fertilization, plant growth in topsoil and in spoil was extremely poor.
RS : Red Soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS - Lignite minespoil; FYM : Farm yard manure; CCP: Composted coirpith
Among the different minespoils viz., magnesite, quarry, limestone and lignite minespoils, reduction in germination percentage (Fig. 1) and seedling vigour (Fig. 2) was less in magnesite minespoil and it was higher in lignite minespoil. The higher reduction in germination and seedling growth upto 30 days after sowing could be ascribed to poor fertility status particularly the organic carbon, available nitrogen and exchangeable Ca and Mg contents. Similar growth reduction in limestone minespoil has been reported by Dadhwal (1987). Limestone minespoil is slightly alkaline in reaction, high in CaCO$_3$ content and bulk density with low water holding capacity. The present study clearly showed that the plants varied in their responses to different minespoils confirming earlier reports of Dadhwal and Singh (1993) and Manorama (1996). This emphasizes the need for enriching the soil status of different minespoils for better utilization for growing of trees and neem, in particular. The limestone minespoils have a layer of calcium carbonate at a depth of about 9 m below the surface and support very sparse germination and seedling growth.

In the present study, in general, addition of organic amendments such as FYM and composted coirpith individually to different minespoils improved the germination and seedling vigour compared to their counterparts. The study also revealed that the addition of composted coirpith to magnesite minespoil improved the germination and seedling growth upto 30 days compared to incorporation of FYM. The germination and seedling growth of neem in limestone minespoil increased with the addition of composted coirpith at this stage, but not commensurate with magnesite minespoil. This could be attributed to lower nutrient status (Wilson, 1965; Toy and Shay, 1987; Manorama, 1996, Wali and Freeman (1973). Severson and Gouch (1983) also explained that the poor growth could also be due to the presence of some toxic elements in the minespoils. Sheltron and Trettin (1984) also confirmed the same.
The addition of biologically active organic N₂ to the minespoil through the incorporation of composted coirpith/FYM may be a possible attributed reason for the better germination and seedling vigour of neem. Similar growth promotion of plants applied with organic wastes and organic manures on reclamation of surface mines have been reported (Jha and Singh, 1993; Manorama, 1996 and Schively, 1979).

2. EFFECT OF DIFFERENT MINESPOILS AND THEIR MANAGEMENT WITH ORGANIC AMENDMENTS ON GROWTH PARAMETERS AT DIFFERENT GROWTH STAGES OF NEEM

The present investigation revealed that the growth parameters viz., root and shoot length, shoot collar diameter, number of leaves, total leaf area, leaf, stem and root dry weight, total dry weight, percentage contribution of leaf, stem and root weight to TDW, chlorophyll 'a', 'b' and total, and soluble protein of neem seedlings grown in minespoils were less when compared to red soil. The performance of the seedling growth in different minespoils are depicted in Plate 4a to e and 4.1a to e.

Among the minespoils, limestone minespoil registered higher values for the above mentioned seedling parameters at 24 months after sowing except for root and shoot length, shoot collar diameter and percentage contribution of root dry weight to TDW, where magnesite minespoil registered the higher values.

The study also revealed that addition of organic amendments proved efficient in improving the various seedling growth parameters at all the growth stages. In general, the addition of composted coirpith to different minespoils registered better seedling growth parameters rather than the addition of FYM, probably due to the proliferation of roots. The pronounced effect of the root growth in foraging the nutrients is mainly because of the favourable action of composted coirpith or FYM in improving the physico-chemical
Plate 4. Neem seedling growth as influenced by minespoils

b) Magnesite minespoil
c) Quarry minespoil

a) Red soil
d) Limestone minespoil
e) Lignite minespoil
Plate 4.1. Neem seedling growth as influenced by minespoils

a) Red soil
b) Magnesite minespoil
c) Quarry minespoil
d) Limestone minespoil
e) Lignite minespoil
and biological characteristics of minespoils as observed in this study (Table 19). The experimental results of Pushpanathan and Veerabadran (1992) confirmed that the application of coirwaste enhanced the length and spread of roots in sorghum plants. Similarly, improvement in root growth of maize was reported by Gajri et al. (1994) by the use of FYM.

The results of this study further showed that the addition of composted coirpith to limestone minespoil might have improved the seedling parameters such as root (Fig. 3) and shoot length (Fig. 4), shoot collar diameter (Fig. 5), number of leaves (Fig. 6) and total leaf area (Fig. 7) compared to its counterpart and other treatments. The addition of composted coirpith to soil brought about favourable changes such as optimum pH, high organic carbon and increase availability of nutrients (Table 19) in seed soil rhizosphere and thereby improved seed germination and seedling growth (Hume, 1949). The results of this study are in conformity with the results of Manshar et al. (1983) in coconut palm. Increased plant height and drymatter production due to addition of composted coirpith was reported by Packiaraj and Venkataraman et al. (1991), Pushpanathan and Veerabadran (1992) and Savithri et al. (1992) in different crops. Increased drymatter production due to the application of FYM was reported by Devarajan et al. (1988). The treatment with coirpith registered taller plants, more number of leaves and more number of bright flowers and in general, the stand of crop was healthy and vigorous as reported by Sabanayagam and Savithri (1995).

Incorporation of composted coirpith to different minespoils improved the root, leaf, stem dry weight (Fig. 8; 9; 10), total dry weight (Fig. 11), percentage contribution of leaf, stem and root dry weight to TDW (Fig. 12; 13; 14), chlorophyll 'a', 'b' and total (Fig. 15; 16; 17) and soluble protein (Fig. 18) compared to their counterparts. This increment could be associated with the growth enhancing properties of organic
**Fig. 3.** Effect of different minespoils and their management with organic amendments on root length of neem at 24 months after sowing

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Root length (cm)</th>
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<tbody>
<tr>
<td>RS</td>
<td>50</td>
</tr>
<tr>
<td>MMS</td>
<td>45</td>
</tr>
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<td>MMS + FYM</td>
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<tr>
<td>QMS</td>
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<tr>
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<td>LMS</td>
<td>15</td>
</tr>
<tr>
<td>LMS + FYM</td>
<td>10</td>
</tr>
<tr>
<td>LMS + CCP</td>
<td>5</td>
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</tbody>
</table>

**Fig. 4.** Effect of different minespoils and their management with organic amendments on shoot length of neem at 24 months after sowing

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shoot length (cm)</th>
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</thead>
<tbody>
<tr>
<td>RS</td>
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<tr>
<td>MMS</td>
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<tr>
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<td>25</td>
</tr>
<tr>
<td>LMS + FYM</td>
<td>20</td>
</tr>
<tr>
<td>LMS + CCP</td>
<td>15</td>
</tr>
</tbody>
</table>

Treatments:
- RS: Red Soil
- MMS: Magnesite minespoil
- QMS: Quarry minespoil
- LSMS: Limestone minespoil
- LMS: Lignite minespoil
- FYM: Farm yard manure
- CCP: Composted coirpith
Fig. 5. Effect of different mine spoils and their management with organic amendments on shoot collar diameter of neem at 24 months after sowing.

Fig. 6. Effect of different mine spoils and their management with organic amendments on number of leaves of neem at 24 months after sowing.

RS: Red Soil; MMS: Magnesite mine spoil; QMS: Quarry mine spoil; LSMS: Limestone mine spoil; LMS: Lignite mine spoil; FYM: Farm yard manure; CCP: Composted coir pith
Fig. 7. Effect of different minespoils and their management with organic amendments on total leaf area of neem at 24 months after sowing.

Fig. 8. Effect of different minespoils and their management with organic amendment on leaf dry weight of neem at 24 months after sowing.

RS: Red Soil; MMS: Magnesite minespoil; QMS: Quarry minespoil; LSMS: Limestone minespoil; LMS: Lignite minespoil; FYM: Farm yard manure; CCP: Composted coirpith.
Fig. 9. Effect of different minespoils and their management with organic amendments on stem dry weight of neem at 24 months after sowing

Fig. 10. Effect of different minespoils and their management with organic amendments on root dry weight of neem at 24 months after sowing

RS: Red Soil; MMS: Magnesite minespoil; QMS: Quarry minespoil; LSMS: Limestone minespoil; LMS: Lignite minespoil; FYM: Farm yard manure; CCP: Composted coirpith
Fig. 11. Effect of different minespoils and their management with organic amendments on total dry weight of neem at 24 months after sowing

Fig. 12. Effect of different minespoils and their management with organic amendment on % contribution of leaf dry weight to TDW of neem at 24 months after sowing

RS : Red Soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; FYM : Farm yard manure; CCP: Composted coirpith
Fig. 13. Effect of different minespoils and their management with organic amendments on % contribution of stem dry weight to TDW of neem at 24 months after sowing

<table>
<thead>
<tr>
<th>Treatments</th>
<th>% contribution of stem dry weight</th>
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</thead>
<tbody>
<tr>
<td>RS</td>
<td></td>
</tr>
<tr>
<td>MMS + FYM + CCP</td>
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</tr>
<tr>
<td>MMS + FYM</td>
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<tr>
<td>QMS + FYM</td>
<td></td>
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<tr>
<td>QMS + CCP</td>
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<tr>
<td>LSMS + FYM + CCP</td>
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<tr>
<td>LSMS + FYM</td>
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<td>LMS + FYM + CCP</td>
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<tr>
<td>LMS + FYM</td>
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<tr>
<td>LMS + CCP</td>
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Fig. 14. Effect of different minespoils and their management with organic amendments on % contribution of root dry weight to TDW of neem at 24 months after sowing

<table>
<thead>
<tr>
<th>Treatments</th>
<th>% contribution of root dry weight</th>
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</thead>
<tbody>
<tr>
<td>RS</td>
<td></td>
</tr>
<tr>
<td>MMS + FYM + CCP</td>
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<tr>
<td>MMS + FYM</td>
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<tr>
<td>QMS + FYM</td>
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<tr>
<td>QMS + CCP</td>
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<td>LSMS + FYM + CCP</td>
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<td>LSMS + FYM</td>
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<td>LMS + FYM + CCP</td>
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<tr>
<td>LMS + FYM</td>
<td></td>
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<tr>
<td>LMS + CCP</td>
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</tr>
</tbody>
</table>

RS : Red Soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS - Lignite minespoil; FYM : Farm yard manure; CCP: Composted coirpith
Fig. 15. Effect of different minespoils and their management with organic amendments on chlorophyll 'a' of neem at 24 months after sowing.

Fig. 16. Effect of different minespoils and their management with organic amendments on chlorophyll 'b' of neem at 24 months after sowing.

**Treatments**
- RS: Red Soil
- MMS: Magnesite minespoil
- QMS: Quarry minespoil
- LSMS: Limestone minespoil
- LMS: Lignite minespoil
- FYM: Farm yard manure
- CCP: Composted coirpith

RS : Red Soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS - Lignite minespoil; FYM : Farm yard manure; CCP: Composted coirpith
Fig. 17. Effect of different minespoils and their management with organic amendments on total chlorophyll of neem at 24 months after sowing

Fig. 18. Effect of different minespoils and their management with organic amendments on soluble protein of neem at 24 months after sowing

RS : Red Soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS - Lignite minespoil; FYM : Farm yard manure; CCP: Composted coirpith
amendments. The result of this investigation is in agreement with Liyanage et al. (1993), who reported that application of coir dust and coconut husk to coconut trees resulted in greater number and weight of roots. This is also in conformity with the results of Kalpana (1998) in blackgram.

The biologically active organic N$_2$ added to the spoil through the farm yard manure /organic waste may be a possible reason for the better growth of tree species. Similar growth promotion of plants applied with organic wastes and organic manures on reclamation of surface mine have been reported by (Schively, 1979; Jha and Singh, 1993). The results are in conformity with the results of Harwort et al. (1966) and Sharma and Dixit (1987).

The possible reason attributed for the improvement in seedling growth and biochemical parameters due to incorporation of FYM / composted coirpith to different minespoils could be due to the increased availability of P from insoluble phosphate (Warren et al., 1965). In addition, FYM increased soil physical properties, released nitrogen slowly and supplied all other macro and micronutrients (Cooke, 1967). Increment in growth response of neem at all stages of growth due to addition of FYM is ascribed to the presence of substantial quantities of organic carbon and organic nitrogen in the present investigation.

Fresquez and Lindemann (1982) also reported that available carbon source is a critical factor to stimulate microflora in minespoils. The results are also in conformity with the results of Rajamannar et al. (1995). Skeffington and Bradshaw (1981) felt that a large pool of organic N and a high rate of ammonification were necessary to sustain vegetation.
Though the addition of composted coirpith to different minespoils was able to improve the dry weight partitioning in different parts such as leaf, stem and root, low partitioning of synthates was discernible in quarry minespoil, by recording higher percentage contribution of leaf (Fig. 12) and root (Fig. 14) dry weight to TDW due to poor translocation of synthates prevailing in this minespoil. While, the limestone minespoil showed its superiority in efficient translocation of synthates as revealed from the higher percentage contribution of stem dry weight to TDW (Fig. 13).

The least percentage contribution of stem dry weight to TDW in quarry minespoil might also be ascribed to lesser availability of nutrients and lower foraging capacity of roots. This impact was felt in the synthesis of chloroplasts, thereby reducing the chlorophyll 'a', 'b' and total contents (Fig. 15; 16; 17) as observed in this investigation. The soluble protein content was also less (Fig 18).

3. EFFECT OF DIFFERENT MINESPOILS AND THEIR MANAGEMENT WITH BIOFERTILIZERS ON GERMINATION AND SEEDLING VIGOUR OF NEEM AT 30 DAYS AFTER SOWING

The study explicitly revealed that all the minespoils registered lower germination (Fig. 19) and seedling vigour (Fig. 20) of neem compared to red soil.

Among the different treatments, inoculation of *Azospirillum* and phosphobacter individually and in combination to different minespoils registered higher germination (Fig. 19) and seedling vigour (Fig. 20) over their counterparts.

Similar findings were reported by Reyndess and Vlessak (1982) and Swaminath and Vadiraj (1988) in *Leucaena leucocephala, Dalbergia sissoo, Acacia nilotica* and
Fig. 19. Effect of different minespoils and their management with biofertilizers on germination of neem at 30 days after sowing

Fig. 20. Effect of different minespoils and their management with biofertilizers on vigour index of neem

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : *Azospirillum*; P : *Phosphobacter*
**Pongamia pinnata**, and Vasudevan and Rangasamy (1995) in legume crops. According to Vanangamudi *et al.* (1993), the enhanced germination and seedling vigour in neem was due to seed pelleting with VAM or phosphobacter or *Azospirillum*.

This enhancement in germination might be attributed to the role of phosphobacter in solubilizing the phosphorus into available form in the soil (Cooper, 1979) and to germinating seed, thereby enhancing the metabolic activity of germinating seed.

Rangarajan *et al.* (1987), Srinivas (1987) and Niranjan *et al.* (1990) reported that biofertilizers were able to stimulate growth of forestry crops, enhance the biomass (Huang *et al.*, 1985; Swaminath and Vadiraj, 1988) and increase the uptake of N (Manjunath *et al.*, 1984; Chang *et al.*, 1986), P (Dela Cruz *et al.*, 1988), K (Huang *et al.*, 1985; Merina Prem Kumari, 1991) and other micronutrients (Strullu *et al.*, 1981; Vinayak and Bagyaraj, 1990), which increase the survival rate of planted seedlings.

In the present investigation, conjoint inoculation of *Azospirillum* and phosphobacter to limestone minespoil registered higher germination and seedling vigour compared to its counterparts. The results are in conformity with the results of Rangarajan and Narayanan (1990) in *Rhododendron nilgiricum, Syzygium arnottianum*. According to Sekar *et al.* (1995), combined inoculation of *Azospirillum*, phosphobacter and VAM increased significantly the root and shoot length and dry matter production, besides enhancing the uptake of N, P, K and micronutrients in Shola tree species viz., *Syzygium montanum, S. arnottianum* and *Eleocarpus oblangus*. 

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4. EFFECT OF DIFFERENT MINESPOILS AND THEIR MANAGEMENT WITH BIOFERTILIZERS ON GROWTH PARAMETERS OF NEEM AT DIFFERENT GROWTH STAGES

Combined inoculation of *Azospirillum* and phosphobacter to limestone minespoil registered the better seedling growth in terms of root (Fig. 21) and shoot length (Fig. 22), shoot collar diameter (Fig. 23), number of leaves (Fig. 24), total leaf area (Fig. 25), leaf, stem and root dry weight (Fig. 26; 27; 28), total dry weight (Fig. 29), contribution of leaf, stem and root dry weight to TDW (Fig. 30; 31; 32), chlorophyll 'a', 'b' and total (Fig. 33; 34; 35) and soluble protein (Fig. 36) compared to its counterparts, at 24 months after sowing.

An improvement in root (Fig. 21) and shoot length (Fig. 22) due to combined inoculation of biofertilizers is in agreement with the findings of Merina Prem Kumari (1991) in Tea and coffee and Vijayakumari (1997) in silk cotton, neem and jamun. The increase in plant growth attributes might be due to increased uptake of nutrients by microorganisms associated plants and their synergistic effect (Srinivas, 1987). The microorganisms that are used as biofertilizers stimulate the plant growth by providing necessary nutrients by their colonization at the rhizosphere or by their symbiotic association (Verma and Schve pp, 1995). The association may also regulate the physiological processes in the ecosystems by involving in the decomposition of organic matter, fixation of atmospheric nitrogen, secretion of growth promoting substances, increasing the availability of mineral nutrients and protecting the plants from pathogens. Thus, the rhizosphere effect through microbial activity modifies the plant itself by providing the plant growth substances, and increasing the availability of elements to the root zone (Newman *et al.*, 1992; Jakobsen *et al.*, 1994; Vijayakumari, 1997).
Fig. 21. Effect of different minespoils and their management with biofertilizers on root length of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : *Azospirillum*; P : Phosphobacter

Fig. 22. Effect of different minespoils and their management with biofertilizers on shoot length of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : *Azospirillum*; P : Phosphobacter
Fig. 23. Effect of different minespoils and their management with biofertilizers on shoot collar diameter of neem at 24 months after sowing

Fig. 24. Effect of different minespoils and their management with biofertilizers on number of leaves of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : Azospirillum; P : Phosphobacter
Fig. 25. Effect of different minespoils and their management with biofertilizers on total leaf area of neem at 24 months after sowing

Fig. 26. Effect of different minespoils and their management with biofertilizers on leaf dry weight of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : Azospirillum; P : Phosphobacter
Fig. 27. Effect of different minespoils and their management with biofertilizers on stem dry weight of neem at 24 months after sowing

Fig. 28. Effect of different minespoils and their management with biofertilizers on root dry weight of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : *Azospirillum*; P : *Phsophobacter*
Fig. 29. Effect of different minespoils and their management with biofertilizers on TDW of neem at 24 months after sowing

![Graph showing the effect of different minespoils and their management with biofertilizers on TDW of neem at 24 months after sowing.]

Fig. 30. Effect of different minespoils and their management with biofertilizers on % contribution of leaf dry weight to TDW of neem at 24 months after sowing

![Graph showing the % contribution of leaf dry weight to TDW of neem at 24 months after sowing.]

Treatments:
- RS: Red soil
- MMS: Magnesite minespoil
- QMS: Quarry minespoil
- LSMS: Limestone minespoil
- LMS: Lignite minespoil
- A: Azospirillum
- P: Phosphate bacter

Total dry weight (g seedling⁻¹)

% contribution of leaf dry weight
Fig. 31. Effect of different minespoils and their management with biofertilizers on % contribution of stem dry weight to TDW of neem at 24 months after sowing

Fig. 32. Effect of different minespoils and their management with biofertilizers on % contribution of root dry weight to TDW of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : Azospirillum; P : Phsophobacter
Fig. 33. Effect of different minespoils and their management with biofertilizers on chlorophyll 'a' of neem at 24 months after sowing

Fig. 34. Effect of different minespoils and their management with biofertilizers on chlorophyll 'b' of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : Azospirillum; P : Phosphobacter
Fig. 35. Effect of different minespoils and their management with biofertilizers on total chlorophyll of neem at 24 months after sowing

Fig. 36. Effect of different minespoils and their management with biofertilizers on soluble protein of neem at 24 months after sowing

RS : Red soil; MMS : Magnesite minespoil; QMS : Quarry minespoil; LSMS : Limestone minespoil; LMS : Lignite minespoil; A : Azospirillum; P : Phosphate bacter
Highly significant differences were evidenced for the shoot collar diameter, number of leaves and total leaf area due to inoculation of biofertilizers to minespoils at all the stages of neem seedling growth compared to their counterparts. According to Saravanan (1991) the inoculation of phosphobacter improved the shoot collar diameter in *Acaica mellifera* and *Acacia farnesiana*. Similar results were also reported by Young (1990) in legume tree crops and Vanangamudi *et al.*, (1993) in neem.

The leaf, stem, root and total dry weight increased significantly due to combined inoculation of *Azospirillum* and phosphobacter to different minespoils compared to their respective counterparts. The results of earlier studies demonstrating an increase in dry weight due to combined application of biofertilizers (Huang *et al.*, 1985; Narayanan *et al.*, 1990) support the observations of the present investigation. The increase in seedling biomass might be strongly correlated with higher accumulation of 'N' due to *Azospirillum* and 'P' due to phosphobacter inoculation (Sanders, *et al.*, 1975; Naryana Bhat, 1991; Swaminath and Vadiraj, 1988; Saravanan, 1991).

The results on percentage of leaf (Fig. 30), stem (Fig. 31) and root (Fig. 32) dry weight to TDW showed that the quarry minespoil with or without biofertilizer inoculation recorded higher values for percentage contribution of leaf and root dry weight to TDW at 24 months after sowing. On the contrary, the percentage contribution of stem dry weight to TDW was more in limestone minespoil inoculated with *Azospirillum*. This indicates that the translocation of assimilates from leaf to stem was higher in limestone minespoil compared to quarry minespoil.

Significant differences due to inoculation of biofertilizers to different minespoils at all stages of growth have been observed in respect of chlorophyll 'a', 'b' as well as total chlorophyll.
The contents of these were very high at 24 months after sowing in the seedlings obtained from limestone minespoil. Chlorophyll 'a' was high in lignite minespoil inoculated with *Azospirillum* and phosphobacter (Fig. 33), whereas chlorophyll 'b' was high in limestone minespoils inoculated with phosphobacter (Fig. 34). However, total chlorophyll was high in limestone minespoil inoculated with *Azospirillum* compared to its counterparts (Fig. 35). This could be attributed to more chlorophyll synthesis due to inoculation of biofertilizers. Similar observations were reported by Narayanan *et al.* (1990) and Saravanan (1991). Vijayakumari (1997) also reported an increase in chlorophyll due to combined inoculation of *Azospirillum*, phosphobacter and VA mycorrhizae. Mahatim Singh *et al.* (1983) also observed the beneficial effects of biofertilizer inoculation and reported an increase in chlorophyll content, ascribable supply of higher amounts of nitrogen to the growing tissues.

The results of the present study revealed that conjoint inoculation of *Azospirillum* and phosphobacter to limestone minespoil registered higher soluble protein (Fig. 36) compared to its counterpart. The higher amount of soluble protein due to biofertilizer inoculation is associated with higher uptake of N, P and K and other micronutrients. The present findings corroborated with the results of Niranjan *et al.* (1990), who reported positive changes in total protein content due to inoculation of VAM and *Rhizobium* to *Dalbergia sissoo* seedlings.

5. **INFLUENCE OF INDUSTRIAL EFFLUENTS ON SEED GERMINATION AND SEEDLING VIGOUR UNDER LABORATORY AND NURSERY CONDITIONS**

The sites which had been once productive, are made unproductive due to the inflow of effluents and also dumping of the industrial wastes. This leads to undesirable changes in the physical, chemical and biological characteristics of the environment, in
general and land and water, in particular. The chances of growing annual crops in such polluted and degraded lands is very remote, and according to the land capability classification, they are only suitable for raising tree crops. The possibilities of growing neem using the industrial effluents are investigated in this study.

The effluents of all the industries used for the study were ranging from acidic to alkaline and contained varying amounts of heavy metals such as Cr, Pb, Mn, B, Fe, Cu and plant nutrients namely N, P, K, Ca and Mg. In addition, TSS, TDS, BOD and COD were also higher. The raw effluents altered the physico-chemical properties of the treated soil which were responsible for reduction in the rate of germination of seeds and subsequent development (Somashekar et al., 1984).

Germination, root length, shoot length, drymatter production and vigour index were inhibited in the seedling grown in the sand and irrigated with raw effluents. Comparing the different industrial effluents used, the reduction in percentage germination was minimal in tannin and rayon pulp effluents, whereas textile dyeing and automobile effluents registered the least by recording zero germination. The trend was similar for seedling growth parameters studied at different stages of growth under nursery conditions (Plate 5a to g).

Among the different effluent concentrations, the effluents diluted to 10 per cent level produced higher germination and improved plant growth attributes both in laboratory (Plate 5a to g) and nursery conditions (Plate 6a to f) compared to the effluents diluted to 50 per cent concentration, probably the raw effluents alter the shoot and root growth significantly with considerable reduction in seedling growth, attributable to the toxic effect of effluents such as the presence of heavy metals, excess or deficit levels of micronutrients and other waste products of decomposition leading to a decline in soil porosity.
Plate 5. Neem seedling growth as influenced by industrial effluents under laboratory conditions

a) A general view
Plate 5. Contd...

b) Tannin effluent

c) Textile dyeing effluent

d) Tannery effluent
Plate 5. Contd...

e) Cement effluent

f) Rayon pulp effluent

g) Automobile effluent
Plate 6. Neem seedling growth as influenced by industrial effluents at 14 DAS under nursery conditions

a) Tannin effluent

b) Textile dyeing effluent
Plate 6. Contd ...

c) Tannery effluent
d) Cement effluent
Plate 6 . Contd ...
e) Rayon pulp effluent
f) Automobile effluent
and aeration. Similar observations were reported by Somashekar et al. (1984) and Jayaprakash (1997).

The raw effluents inhibited the seed germination and seedling growth of neem such as root length, shoot length, drymatter production and vigour index whereas, the diluted effluents (10 to 50% v/v) enhanced the growth, indicating the possibility of recycling of these effluents for agricultural production with suitable crops. Similar reduction in germination and seedling growth parameters was reported by Rajannan and Oblisami (1992), Gomathi and Oblisami (1992), when paper mill effluent was used without dilution for irrigating tree crops. Further, Karunyal et al. (1994) stated that seed germination of Acacia holosericea and Leucaena leucocephala was inhibited by 25 and 50% tannery effluent, while zero per cent germination was reported by them for 75 and 100% effluent, besides a decline in chlorophyll and protein content. Aggarwal et al. (1994) opined that, highly sodic textile effluents can be used for growing tree species and its deleterious effect on soil can be mitigated by addition of gypsum in soil.

In this study, the germination and seedling growth were drastically inhibited by the tannery effluent, which might be due to high BOD and COD as well as higher amount of heavy metals especially Cr and alkaline pH because of high content of Na, besides the presence of phenolic substances. High pH and total soluble salt content at 98 per cent in tannery effluent might inhibit germination, according to Khan and Raman (1972). Khan and Reuben (1986) reported that the inhibitory trend in germination with increase in tannery effluent concentration be attributed to lack of hydrolysis of seed protein under stress of alkalinity and salinity caused by tannery waste.
To summarise, the early seedling growth of neem was not affected by different industrial effluents when applied raw as well as diluted. Subsequently with the continuous irrigation of raw effluents upto 60 days after sowing, a severe seedling damage was discernible (Plate 7a to f). The details of seedling damage are furnished below.

<table>
<thead>
<tr>
<th>Industrial effluents</th>
<th>Nature of seedling damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Normal growth (Plate 8a)</td>
</tr>
<tr>
<td>Tannin</td>
<td>Stem with premature leaf fall and blend shoot tips (Plate 8b)</td>
</tr>
<tr>
<td>Textile dyeing</td>
<td>Yellowing and marginal scorching of young and old leaves and complete drying of seedling from top to bottom, leading to death (Plate 8c)</td>
</tr>
<tr>
<td>Tannery</td>
<td>Scorching of seedling tips and yellowing of older leaves and outward curling, with ultimate death of seedling (Plate 8d)</td>
</tr>
<tr>
<td>Cement</td>
<td>Yellowing of entire leaves leading to complete chlorosis of the seedling with conspicuous tip drying at later stages (Plate 8e)</td>
</tr>
<tr>
<td>Rayon pulp</td>
<td>Premature drying and leaf fall with blend shoot tips (Plate 8f)</td>
</tr>
<tr>
<td>Automobile</td>
<td>Chlorotic and complete bleaching with drooping of leaves, stunted growth leading to death (Plate 8g)</td>
</tr>
</tbody>
</table>

The severe damages noticed in the seedlings irrigated with different industrial effluents might be attributed to the accumulation of heavy metals and their toxicity to the seedlings. Similar observations were made by Sengar *et al.* (1998), who reported severe shrinkage in biodiversity caused by harmful effects of the effluents. The major
Plate 7. Neem seedling growth as influenced by industrial effluents at 60 DAS under nursery conditions

a) Tannin effluent

b) Textile dyeing effluent

c) Tannery effluent
Plate 7. Contd ...

d) Cement effluent

e) Rayon pulp effluent

f) Automobile effluent
Plate 8. Nature of damage as inflicted by industrial effluents

b) Tannin effluent

c) Textile dyeing effluent

d) Tannery effluent
Plate 8. Contd ...

- a) Control
- e) Cement effluent
- f) Rayon effluent
- g) Automobile effluent
reason attributed by them was the presence of heavy metal toxicity, particularly zinc, the effect of which is enhanced by the presence of other heavy metals like lead, chromium, cadmium etc.

6. INFLUENCE OF WATER HOLDING CAPACITY ON GERMINATION AND SEEDLING VIGOUR IN NEEM UNDER LABORATORY AND NURSERY CONDITIONS

In the present investigation, it was observed that, higher germination was observed with 50% water holding capacity. The germination declined below and above 50% water hold capacity, indicating 50% water holding capacity was optimum for better seed germination (Fig. 37) and seedling growth of neem (Fig. 38). Very high water holding capacities of 90 and 100 per cent proved detrimental. Similar trend was followed for root (Fig. 39), shoot (Fig. 40) and drymatter production (Fig. 41) at different stages of seedling growth in the nursery condition. Reports of Robert et al. (1990) and Selvaraju (1992) in sorghum and Jerlin (1998) in pungam were corroborated with present findings. However, in contrast Bharathi (1999) reported that 60 per cent water holding capacity was optimum for better germination and seedling vigour of neem. According to them, low water potential of soil reduced water absorption of seeds and delayed the emergence of radicle and coleoptile.

The seedling growth attributes in terms of root length, shoot length and drymatter production decreased due to moisture stress at low water holding capacities and excess moisture at high water holding capacities (Plate 9a to i), since the moisture plays a major role in maintaining cell turgor and water potential, the optimum moisture is necessary for nutrients uptake and their translocation.
Fig. 37. Influence of water holding capacity on germination of neem under laboratory conditions

Fig. 38. Influence of water holding capacity on vigour index of neem under laboratory conditions
Fig. 39. Influence of water holding capacity on root length of neem under nursery conditions at 90 days after sowing

Fig. 40. Influence of water holding capacity on shoot length of neem under nursery conditions at 90 days after sowing
Plate 9. Effect of water holding capacities on Seedling growth of neem

a) A General view
Plate 9. Contd ...

b) 20% WHC compared with 50% WHC

c) 30% WHC compared with 50% WHC
Plate 9. Contd …

d) 40% WHC compared with 50% WHC

e) 60% WHC compared with 50% WHC
Plate 9. Contd …

f) 70% WHC compared with 50% WHC

g) 80% WHC compared with 50% WHC
Plate 9. Contd …

h) 90% WHC compared with 50% WHC

i) 100% WHC compared with 50% WHC
According to Zahner (1968) and Steinberg et al. (1989), water deficit inhibits both leaf growth and internode expansions, besides reducing leaf area. Even the chlorophyll synthesis was affected, according Bourque and Naylor (1971). The high water holding capacity leads to stunted growth and premature leaf fall (Plate 9f to i), attributable to the lack of oxygen at rhizosphere level for root respiration and imbalance of nutrient absorption and this corroborates with the findings of Viets (1972) and Beadle and Jarvis (1977).