CHAPTER - 2
REVIEW OF LITERATURE

In this chapter, a thorough reconnaissance of past published research works in the field of forestry, logically relevant with the present study titled ‘Standardisation of cost effective nursery technique with Nitrogen, Phosphorus, Potash and other parameters of Gmelina arborea Linn’ has been carried out, for further improvisation of research achievements on Gmelina arborea nursery. Attempts have been made to compile the available research findings under the following broad heads:

2.1. General outlines of the species diversity.

2.2. Effect of potting media on growth and development of seedlings.

2.3. Effect of containers on growth and development of seedlings.

2.4. Effect of nutrient application on growth and development of seedlings.

2.5. Field performance of seedlings raised under different treatments in nursery.

2.1. General outlines of species diversity.

Gmelina arborea is native to the mixed forests of moist regions of India and is naturally occurring in the forests of North, Eastern, Central, Southern as well as in coastal states. Interestingly, it occurs in eleven out of fifteen agro climatic zones of India. It also occasionally occurs in evergreen as well as in Sal forests. In moist fertile valleys it attains best growth, while in dry sandy and poor soils it shows stunted growth. It is commercially planted in many tropical countries. The natural variability of Gmelina arborea with regard to the climatic adaptability coupled with faster growth and versatility of uses has prompted many researchers world over to initiate the tree improvement work and silviculture of the species.
*Gmelina arborea* is a multipurpose and fast growing tree species; occurs between 5° to 30°N latitude within 50-1300 meter elevation in countries like India, Bangladesh, Nepal, Myanmar, China, Vietnam, Laos, Thailand, Cambodia, Sri Lanka and Pakistan having areas with distinct dry seasons (Plate-2.01). *Gmelina arborea* attains its best development in wild stands growing on deep clay loams and also in areas with optimum precipitation ranging between 1780-2280 mm per annum. It occurs predominantly in semi-deciduous broadleaved forests, often with *Tectona grandis*. *Gmelina arborea* is widely introduced in Brazil, Gambia, Ivory Coast, Malaysia, Malawi, Nigeria, Panama, the Philippines and Sierra Leone (Dvorak 2003).

![Geographic distribution ranges of Gmelina arborea.](Plate-2.01)

Despite its relatively wide natural geographical distribution in Asia, large plantations are seldom established in areas of its natural occurrence because of severe attacks of insects and diseases. Approximately 7,00,000 ha of *Gmelina arborea* have now been established in plantations in West, Central and Eastern Africa, South-East Asia, the south Pacific and Northern Latin America.

*Gmelina arborea* wood is one of the best timbers of the tropics especially desirable as an alternative to teak for manufacturing of doors, particle board,
plywood core stock, pit props, match wood, sawn timber for light construction, furniture, general carpentry and also for packing cases. It finds usage in carriages, carvings, rifle butts, artificial limbs, musical instruments and ornamental works. With pulping properties superior to most hardwood pulps, the millions have planted *Gmelina arborea* in the Rio Jeri region of Brazil to feed a 750 MT/day kraft pulp mill. In Gambia there are dual-purpose plantings, for firewood and for honey. It is often planted as an ornamental avenue shade tree. The wood makes a fairly good charcoal. According to Little (1983) the leaves are harvested for fodder for animals and silkworms; humans once consumed the bittersweet fruits.

In the year 1967, Qureshi and Yadav were the first foresters who realised that fertilisers are useful to cut short the time required to obtain seedlings of transplantable size. Their landmark paper was presented before leading field foresters during “Eleventh Silviculturists' Conference” held during 1967 at the Forest Research Institute, Dehradun (Qureshi and Yadav 1967). According to them, vigorous seedlings overcome the shock of transplanting more quickly and more effectively. In every respect healthy, vigorous and sturdy seedlings are more resistant than the stunted planting material planted on sites deficient in nutrients.

In forestry research in India, Bhatnagar was the first who conducted sand culture experiment to study mineral (nitrogen, phosphorus and potassium) requirements in the plant tissues of teak seedlings. Result indicated that for good growth of teak seedlings, 680 mg/plant of nitrogen and potassium and 450 mg/plant of phosphorus is required (Bhatnagar *et al*. 1969). Chemical analysis further revealed that higher the application of nitrogen and phosphorus (680 mg/plant) greater was absorption of these minerals along with calcium and magnesium by the plant tissues. Higher potassium application (680 mg/plant) has resulted in lower absorption of both calcium and magnesium. In respect of three-element treatment combination data as percentage, indicated that higher potassium application increased ash percentage in plant tissues.
Pot experiments of Sal (*Shorea robusta*) carried out by Singh and Muhammad (1976) in red soils of Chotanagpur (Jharkhand), revealed that all the growth attributes (such as height, girth, branching, dry weight of roots and shoots) increased significantly under loam soils, followed by sandy loam and clay loam after nitrogen application. Increasing doses of nitrogen application were found beneficial for sal saplings. There were more uptakes of nitrogen, phosphorus and potassium from loam soils as compared to sandy loam or clay loam soils.

2.2. Effect of potting media on growth and development of seedlings:

2.2.1. Nursery bed trial:

Negi and Singh (1995) conducted study to determine suitable method and covering medium for the germination of seeds of exotic pines. The results showed that sand being the covering medium and line-sowing method gave higher germination percentage and better growth of seedlings as compared to broadcast sowing and soil medium.

The effect of shade was investigated by Gopikumar and Bindu (1999) on the growth of 3-month-old seedlings of 10 important tropical commercial tree species, planted in polybags and arranged either under full sunlight or 50% shade (in a thatched shed) in a nursery trial at Kerala Agricultural University, India. Growth was monitored periodically over a year and measurements were also made of leaf area, stomata density and chlorophyll content. *Artocarpus hirsutus, Cedrela toona, Diospyros ebenum, Gluta travancorica, Terminalia paniculata* and *Vateria indica* all recorded increased height growth and greater vigor under shade, while *Gmelina arborea, Pterocarpus marsupium* and *Terminalia tomentosa* gave better height growth in the light. *Xylia xylocarpa* showed similar height growth under the two conditions. In the case of girth, most species grew better in the shade, excepting *Cedrela toona* and *Terminalia tomentosa*. The highest leaf area was recorded in *Artocarpus hirsutus* under shade, followed by *Vateria indica, Terminalia tomentosa* recording the least leaf area growth under shade. *Terminalia tomentosa* and *Xylia xylocarpa* gave better leaf area growth in the light, while all the other species gave better leaf
growth under shade. Even though leaf areas were generally higher in the shade, all species except Cedrela toona, Gluta travancorica, Terminalia paniculata and Terminalia tomentosa had more stomata when grown in the open. The shade loving species Gluta travancorica and Terminalia paniculata had more leaf chlorophyll content when grown in the shade, while no pattern was observed for the other species.

2.2.2. Trial with different agricultural and industrial waste:

Tripathi and Bajpai (1984) carried out an experiment to observe influence of various potting media on the growth of Anogeissus pendula seedlings. Four potting media viz., sand, red soil, black soil and saw dust were used in pots of 6”x 9” replicated five times. One hundred seeds were sown in each pot and germination was noticed after six days and completed within 15 days of sowing. After two months, seedlings were uprooted carefully to determine the fresh weight, shoot and root length, number of leaves and secondary roots per seedling. It was observed that growth performance of Kardhai (Anogeissus pendula) in sand was best, while red soil as second best growth medium in the early phase of life of this species. Maximum shoot length (5.08 cm) was recorded in black soil with a gradual decrease in red soil, sand and saw dust respectively. Root length was found best in sand. The maximum dry weight was found in sand while a gradual decrease was observed in red soil, black soil and saw dust. The results lead to the conclusion that the early growth of this species is directly related to the porosity and percolating system of the soil.

Yadan et al. (1982) investigated the growth of root system and dry weight of Tectona grandis in fifteen different potting media. Each media was filled in 25 polythene bags (6”x13”), which were placed in shade and transferred after 4 weeks to sunlight. After six months, results reveled that maximum dry weight of seedling (2.28 gm) was found in pure black natural soil while minimum (0.13 gm) in sand. Maximum root length (35.60 cm) observed in medium having equal amount of black natural soil and sawdust. Shoot length was more (8.75 cm) in pure sawdust than in pure black natural soil (6.0 cm). Combination of sawdust
with black natural soil produced more shoot length (3.75 cm) than with sand (3.5 cm).

Rai et al. (1988) observed germination and nursery technique of four species viz. *Ficus bengalensis*, *Ficus glomerata*, *Ficus mysorensis* and *Ficus religiosa* of different stages of maturation. Seeds were germinated in a media of sand or sand and earth mixture (2:1 ratio) under seven different pre treatments. It was observed that moderately ripe fruits gave the best germination and soaking the seeds for 10 minutes in hot water at 60°C. It was also found that the young seedlings are very delicate for transplanting individually, therefore in the first stage they are transplanted in bunches and there after picked out individually. For both the stages of transplanting shade is essential for one week.

Beniwal and Dhawan (1991) conducted an experiment to standardize the nursery technique of *Anthocephalus chinensis* at FRI, Dehradun. The experiment was carried out with complete randomized design with four potting media (S$_1$=soil; S$_2$=soil: sand: farmyard manure (1:1:1); S$_3$=soil: sand and S$_4$=sand only) and three watering method (W$_1$=watering with a can, W$_2$=watering with side floating and W$_3$=watering with the help of fine sprayer). The results of the study conducted show that 52% germination was obtained from clean seeds and only 4.85% from pulped seeds. After statistical analysis the best results for germination are obtained by using soil (S$_1$) as medium. Similarly the mean value for the number of seedlings is highest for soil medium (22.23%) followed by soil : sand (19.23%) and soil : sand : farmyard manure (19.18%). Also, maximum height growth after 60 days was observed in case of S$_2$W$_1$ (0.897 cm) and lowest in the S$_4$W$_1$ (0.467 cm).

Bahuguna and Pyarelal (1992) conducted a nursery trial at the Silviculture Division of Forest Research Institute, Dehradun to find out the best combinations of seed sowing and irrigation schedule. The results showed that dibbling method of sowing with twice a-day irrigation gave good results. In another study Bahuguna and Pyarelal (1989) carried out multiple species trials on *Albizia lebbeck*, *Eucalyptus FRI-4*, *Dendrocalamus strictus* and *Acacia*
nilotica to observe their comparative growth performance at nursery stage. Five seedlings of vigorous and healthy growth were selected from each bed of each species of which height; collar diameter and number of branches per plant were measured periodically for one month. They reported that the growth of Albizia species is better than Eucalyptus and other species in nursery stage. Among Albizia species; Acacia nilotica attained to the best height growth.

Nursery trials on Grewia optiva was carried out by Maithani et al. (1992) at Silviculture nursery, FRI, Dehradun. The size of each of the 20 cm raised nursery bed used was 5 m x 1 m and media used was decomposed farmyard manure and river sand laid in a split plot randomised block design. After total germination growth data on height, collar diameter and number of branches were recorded after 90, 120 and 150 days. The results of the experiment indicate that dibbling method of sowing and irrigation twice a day proves to be the best combination for this species. Irrigation is the most essential factor at nursery stage.

Bahuguna and Pyarelal (1994), while introducing the Grevillea pteridifolia in nursery beyond its natural habitat at FRI, Dehradun with a view to find the best combination of potting media, method of sowing and best container for getting healthy and vigorous plantable seedlings, observed that the species may be line sown in nursery beds or in polybags with soil and sand in 2:1 or 1:1 ratio for better results. In another study, Bahuguna and Pyarelal (1993) studied germination and growth behaviour of Acacia caven at nursery stage under Dehradun climatic condition. Experiment was carried out in a nursery bed of the size 6 m x 1 m x 20 cm high. Each bed was divided into six equal parts of size 75 x 75 cm as sub beds with six different media as; soil: sand: farmyard manure (1:1:1) and (2:1:1), soil: sand (2:1) and (1:1) also soil: sand: farmyard manure (2:1:1) and (1:1:1). Seeds were sown at a depth of (1.0 cm, 2.0 cm and 3.0 cm) in split plot design in randomised block design. Nursery trials have brought out that in main plot soil: sand: farmyard manure (1:1:1) and sub plot treatment (1.0 cm) depth gave the better germination. It also concluded that soil: sand: farmyard manure (2:1:1) is the best media for better growth of seedling in polybags.
Wood et al. (1997) carried out study to assess effects of treatments on nursery growth and the subsequent performance in field was also assessed. *Swietenia macrophylla* seedling heights at the end of nursery phase were greatest in pots with soil without added fertiliser. In brewers waste/sawdust and coir potting media with a moderate amount of slow release fertiliser (4 gm/ltr) reduced seedling height. 10 months after planting out in the field, the trees raised in coir in the nursery were significantly greater in height, diameter and volume than trees raised in soil medium. On the other hand, a study was carried out by Gopikumar and Minichandran (2002) to find out the effect of potting media containing waste materials like garbage and coir dust on establishment, growth and vigour of seedlings of *Ailanthus triphysa*. The seedlings raised in thirteen potting media $T_1$ (soil: sand: cow dung in 1:1:1 ratio), $T_2$ (soil: fresh municipal garbage in 1:1 ratio), $T_3$ (soil: 2 weeks decomposed garbage in 1:1 ratio), $T_4$ (soil: 4 weeks decomposed garbage in 1:1 ratio), $T_5$ (soil: fresh municipal garbage: cow dung in 1:1:1 ratio), $T_6$ (soil: 2 weeks decomposed garbage: cow dung in 1:1:1 ratio), $T_7$ (soil: 4 weeks decomposed garbage: cow dung in 1:1:1 ratio), $T_8$ (fresh municipal garbage), $T_9$ (2 weeks decomposed garbage), $T_{10}$ (4 weeks decomposed garbage), $T_{11}$ (soil: coir dust in 1:1 ratio), $T_{12}$ (soil: coir dust: cow dung in 1:1:1 ratio) and $T_{13}$ (coir dust). The experiment was carried out in completely randomised block design for a period of eight months. Results from the study revealed that the initial establishment recorded after one week of planting and final survival after eight months were not significantly different with regard to potting media. However seedlings raised in potting media $T_1$ (soil: sand: cow dung), $T_2$ (soil: fresh garbage), $T_{10}$ (4 weeks decomposed garbage), $T_{11}$ (soil: coir dust) recorded 100 % success with regard to both initial establishment after one week of planting and final survival after eight months. The initial establishment and survival was very poor when fresh garbage alone was used as a potting medium. The seedlings grown in (soil: 4 weeks decomposed garbage), (soil: 2 weeks decomposed garbage: cow dung) and (soil: 4 weeks decomposed garbage) was most promising where the height increment was 14.77 cm, 13.53 cm and 13.46 cm respectively. The plants grown in standard potting media i.e. soil: sand: cow
dung produced a height increment of 11.70 cm. Total increment in girth was found promising in case of (soil: 4 weeks decomposed garbage: cow dung), (soil: sand: cow dung), (soil: 4 weeks decomposed garbage) and (soil: 2 weeks decomposed garbage: cow dung). Growth and vigour was generally found to be less when seedlings were grown in coir dust. There was a gradual increase in biomass production in various potting media. Shoot dry weight were found to be most superior in case of (soil: 2 weeks decomposed garbage: cow dung), (soil: 4-weeks decomposed garbage: cow dung) and (soil: sand: cow dung). The relative growth rate and other physiological attributes were also found to be less for this treatment. Generally, the chlorophyll–A content was found to be slightly higher when compared to chlorophyll-B. Nutrient uptake particularly nitrogen was found to be more when cow dung and partially decomposed garbage were used as components of potting media.

Influence of potting media on shoot length and biomass production of some forest tree species viz., Azadirachta indica, Acacia auriculiformis, Leucaena leucocephala, Tamarindus indica, Aegle marmelos, Acacia nilotica and Bambusa vulgaris in book type of root trainer were studied by Naidu et al. (2000). Species showed more short length and biomass in potting media of red earth, tank silt and compost. In six types of potting media out of total 18 combinations, Azadirachta indica and Tamarindus indica showed similar shoot length and biomass production.

2.2.3. Trial with alkaline soil:

A nursery study was conducted by Ani and Gopikumar (1993) in the college of Forestry, Kerala Agriculture University to find out the effect of different types of media on the growth and vigour of seedlings of Artocarpus hirsutus and Tectona grandis. The various media used were soil alone, equal proportion of soil+sand ; soil+sand+cowdung ; soil+vermiculite+cowdung and soil+vermiculite. The potting media significantly influenced the various parameters like height and number of leaves in Artocarpus hirsutus seedlings, whereas it failed to induce any significant response in the case of Tectona grandis seedlings.
Masilamani *et al.* (2002) conducted experiment with different pH (8.1, 9.0, 10.2 and 10.5) soil and potting media (soil + sand + farmyard manure at 2:1:1 ratio, control and red earth + sand + farmyard manure at 2:1:1 ratio) in a randomised block design with four replications. Germination %, root length (cm), shoots length (cm), number of leaves/seedling, collar diameter (cm), root and shoot dry weight (g), leaf area (cm$^2$) and chemical constituents were estimated. Data revealed that highest germination of 66.1% was recorded with T$_1$ treatment (red earth+ sand+ farmyard manure at 2:1:1 ratio) followed by T$_2$ treatment at 57.0% (soil having pH 8.5). In other study, Garg (1998) used alkali soil mixed with white sand in equal proportions and alkali soil+sand+farmyard manure mixed in equal ratios filled in polythene bag (6 x 6 x 20 cm) and clay earthen pot (15 cm diameter) with four levels of nitrogen (0, 50, 100 and 150 Kg/ha) in factorial combinations with 5 replications. Uniform doses of 20 Kg/ha P$_2$O$_5$ and K$_2$O was applied to each treatment. After five months it was found that the seedlings were about 46% taller in polythene bags and 25% in earthen clay pots in alkali medium mixed with farmyard manure and sand. Root lengths were greater in earthen pot than in polythene bags. In case of shoot dry weight seedlings grown in earthen pot having alkali soil mixed with sand and farmyard manure has given significant response at 50 Kg/ha of nitrogen applied.

2.2.4. Trial with Soil, Sand and Farmyard manure:

Nursery trials were carried out by Bahuguna *et al.* (1987) on *Acacia albida* under north Indian climatic condition to find out the best combination of soil media, method of sowing and best container for obtaining maximum number of healthy plantable seedlings. Four types of soil media soil: sand: farmyard manure (2:1:1), soil: sand (2:1), soil: sand: farmyard manure (1:1:1) and soil: sand (1:1) were used with four types of containers in split plot design in randomised block design with four replications. On analysis it indicated that the height and collar growth was significantly better in plants grown under sowing in boxes and in polybags. Also seedling grown under treatment of soil: sand: farmyard manure in the ratio of 2:1:1 and soil: sand: farmyard manure 1:1:1 has performed better.
Leucaena leucocephala saplings were raised in polythene bags (15 cm x 7.5 cm) containing a mixture of soil: sand: farmyard manure in the ratio of 6:2:3 (Dadhwal and Singh, 1992). Leucaena leucocephala showed 100% survival in well-tended pots throughout the study period. Highest height and maximum above ground dry matter yield was recorded in normal soil+debris (50:50). Again maximum root biomass was found in normal soil, which was nearly 100% more over debris treatment. It is inferred from this study that with normal soil, roots environment in mine spoil gets improved.

Production of high quality seedlings in large-scale plantation programmes needs a readily available and suitable seedling-growing medium. An experiment by Hossain (1995) using different combinations of forest topsoil and cow dung showed that cow dung mixtures significantly increased the growth of Dalbergia sissoo seedlings in comparison with control and inorganic fertilizer treatments. Harvested seedlings from different soil and cow dung mixtures attained significantly higher root collar diameter, root diameter, nodules per root and oven dry weight of roots, leaves, twigs and stems in comparison with control seedlings. The initial field growth performance of the seedlings raised in soil-cow dung mixtures also showed significantly higher height and collar diameter growth than both control and inorganic fertilizer treatment.

Nautiyal et al. (1995) studied suitable growing medium for Grewia optiva. The investigation was carried out with six growing media made by mixing soil, sand and farmyard manure in different volume proportions such as T₁ (1:1:0), T₂ (1:1:1), T₃ (1:2:1), T₄ (1:2:2), T₅ (1:2:4) and T₆ (1:3:6). Each medium was filled in polythene bags and seedling was sown. After four months observations, the seedlings were removed from polybags while shoot, root and collar diameter were recorded. The seedlings were dried at 72°C for 72 hours to determine dry weight. Results revealed that shoot length was maximum (21.62 cm) in T₅ closely followed by T₆ (20.92 cm). The maximum root length (39.73 cm) was observed in medium T₆ having 1:3:6 proportion of soil, sand and farmyard manure respectively. In case of collar diameter there was no
consistent pattern of increase or decrease under all treatments. However maximum collar diameter was recorded in seedlings grown in the mixture of soil, sand and farmyard manure in 1:3:6 (T₆), which was at per with T₅. In terms of dry weight of shoot, root and total seedling, the mixture of soil, sand and farmyard manure 1:3:6 (T₆) the best. It was concluded that the mixture of soil, sand and farmyard manure in ratio 1:3:6 was found superior followed by treatment T₆.

An experiment was conducted by Sudhakar et al. (1995) to determine effect of seedling, farmyard manure and fertiliser in the rooting medium on growth of containerised *Ceiba pentandra* seedlings. Rooting medium containing sand, soil and farmyard manure in the ratio 1:1:1 was significantly better than rooting medium with sand and soil in the ratio 1:1. Advantage of fertilizer application was negligible. Presence of farmyard manure in rooting medium gave rise to an increase of 152 % in height growth. Height growth due to fertilizer application was higher by 23 % as compared to unfertilised control. Again, supplementing farmyard manure with fertilizer gave rise to 226 % increase in height and 327 % in dry matter. Farmyard manure had a more significant influence on leaf area (to a level of 288 %) than fertilizer (33 % only). Further, large size seeds gave rise to 24 % increase in height compared to other treatments. Generally larger sized seeds produced seedlings with greater number of function leaves. Seed size doesn’t have effect on leaf area.

Performance of four leguminous pot-grown tree species (*Dalbergia sissoo*, *Acacia nilotica*, *Albizia lebbeck* and *Prosopis cineraria*) in 9-different mixtures of sand: farmyard manure: soil was studied by Singh et al. (1997) under greenhouse and nursery conditions. Greenhouse plants performed better compared to nursery plants. An increase in root and shoot weight was recorded with a 1:1:1 ratio of sand: farmyard manure: soil for *Dalbergia sissoo*, *Acacia nilotica* and *Prosopis cineraria* and a higher root: shoot ratio was observed in *Dalbergia sissoo* with a ratio of 1:1:2. However, higher root: shoot ratios were observed in *Acacia lebbeck* and *Prosopis cineraria* with 1:1:1 and 2:1:1 ratios of sand: farmyard manure: soil respectively.
Sharma et al. (1997) studied different soil mixtures on development and quality of *Tectona grandis* seedlings in the nursery at the State Forest Research Institute, Jabalpur and Madhya Pradesh. Growing media consisted of mixtures of soil, sand and farmyard manure in proportions of 1:0:0, 2:1:0.5, 2:1:1 and 1:1:1 using loam soil and proportion 1:0:0, 1:1:1, 2:0:1 and 2:0.5:1 using sandy loam soil. The 1:1:1 mixes gave good results for the loam soil with respect to shoot and root development and biomass production; it also gave maximum seedling drought resistance, quality index and vigour. For sandy loam soil mixture 2:0:1 gave superior results.

Sharma et al. (1998) conducted an experiment to find out the effect of various soils and farmyard manure on the growth and development of *Dalbergia sissoo, Albizia procera, Dendrocalamus strictus* and *Gmelina arborea*. Soil, sand and farmyard manure was mixed in four different proportions $T_0$ (1:0:0); $T_1$ (1:1:1); $T_2$ (1:0.5:0.5) and $T_3$ (1.5:0:0.5) and filled in polythene bags of size 27 x 11 cm. Each treatment contained 40 polybags in 4-replications of 10 plants in a block. After eight months of plant growth, seedlings were taken out and plant shoot length, root length, collar diameter, biomass and root-shoot ratio were recorded. The data indicated that the mixing of sand and farmyard manure in soil could not affect plant growth significantly.

However, *Dalbergia sissoo* and *Albizia procera* preferred sandy soil which gave maximum shoot height and collar diameter in the mixture of 1:1:1 (soil, sand and farmyard manure) in comparisons to other soil mixture. Red soil is best for the growth of *Dendrocalamus strictus* (1:1:1), while *Gmelina arborea* performed best in black soil (1:1:1). In case of root development sandy soil is best for *Dalbergia sissoo* and *Gmelina arborea*, while for *Albizia procera* alluvial soil in 1:1:1 proportion was found superior. Similarly Srivastava et al. (1998) reported that height growth at four month was better with potting mixture of farmyard manure, sand and soil having 2:1:2 ratios.

A study was carried out at Hissar, Haryana by Singh et al. (2000) to observe effect of soil media on germination, shoot and root length and number of nodules in *Acacia nilotica, Prosopis cineraria* and *Dalbergia sissoo*. Seeds
were sown in polythene bags (22.5 x 12.5 cm) filled with nine different mixtures of sand: farmyard manure: soil (1:1:1, 1:1:0, 1:0:0, 1:0:1, 0:1:1, 0:0:1, 2:1:1, 1:2:1 and 1:1:2) as potting media. In all treatments, germination %age was higher in *Dalbergia sissoo* followed by *Prosopis cineraria* and lowest in *Acacia nilotica*. Sand, farmyard manure and soil in equal ratio (1:1:1) showed %age in *Dalbergia sissoo* (91 %). Maximum germination in *Prosopis cineraria*, (90 %) was recorded in 2:1:1 ratio. Sand, farmyard manure and soil (1:1:2) showed maximum shoot and root length in *Acacia nilotica* (39.7 cm and 37.3 cm respectively).

2.3. **Effect of containers on growth and development of seedlings:**

2.3.1. **Effect of container on seedling quality:**

Bahuguna and Pyarelal (1993) carried out an experiment for finding out the best containers and suitable germination medium for raising seedlings of *Acacia auriculiformis*. The experiment consisted of different types of containers. These are polythene bags (22 x 15 cm-150 gauges), line showing in beds, broadcast sowing and wooden boxes of size 52 cm x 52 cm x 21 cm dimensions. The experiment concluded that *Acacia auriculiformis* seedlings could be raised in nursery through dibbling of seeds either in beds or wooden boxes in a soil media consisting of soil and sand (2:1) ratio. Farmyard manure could be added later on at transplanting stage for better growth of seedlings.

Gera *et al.* (1996) studied the comparative impact of nursery bed raised polybag seedlings with that of polybag seedlings reared without ground contacts, to mitigate the disadvantage of polybag raised seedling *viz.* root coiling and distortion, scanty lateral root development and frequent shifting operation in nursery. They used mounted angle iron beds so as to remove ground contacts. Filled in polybags with bottom perforations are placed on the seedbeds. Observation revealed that polybag seedlings of *Dalbergia sissoo* raised on mounted angle iron beds recorded significantly higher fibrous root biomass (dry wt. 1.78 gm/seedling, number of roots 47/seedling and number of nodules 131/seedling) as compared to 1.31/seedling, 31/seedling and 29/seedling, respectively in nursery bed raised polybag seedlings. However, nursery bed
raised polybag seedlings recorded significantly higher values of root length and primary root biomass of root length 47.2 cm and 3.10 gm dry wt/seedling as compared to 22.5 cm and 2.22 gm/seedling in mounted angle iron beds raised seedlings. No significant difference was observed in case of seedling height, collar diameter, leaf biomass and total biomass. According to them the quality parameters and architecture of Dalbergia sissoo seedlings in fibrosity and nodulation can be improved upon with mounted angle iron beds.

2.3.2. Use of poly bag:

Grewal during 1995 prepared a review article on nursery raising, growth, fertilization, cover crops and water use of Eucalyptus on foothill alluvium near Chandigarh. The paper reviews the results of studies conducted on Eucalyptus since early sixties at the Central Soil and water conservation Research Centre, Chandigarh. These studies concluded that that (1). The polythene bags were better than baskets or pots and white polybags were superior to black for raising nursery. Larger the size of the bag better was the growth. (2). Eucalyptus growth was better on medium as compared to light or heavy soil and on two layered as compared to uniform soil. In another study Adarsh Kumar and Gupta (1990) conducted short duration nursery trial to produce plantable Acacia nilotica seedlings. Germinated seeds from germination box are sown in 3rd week of April and May using 28 x 22 cm and 24 x 18 cm size of polybag. It was revealed that the May sown seeds put forward better growth as against April sown seeds. Heights attained 50 days about 35-40 cm can be found suitable for field plantation in case of Acacia nilotica as against its existing nursery practices of about 120 days more in nursery rearing periods.

2.3.3. Ideal size of poly bag:

Singh (1998) observed the growth of Flemingia macrophylla with two different sizes of polythene bags in nursery stage. Potting mixture was soil, sand and farmyard manure in 2:1:1 filled in perforated polythene bags. Seeds were sown in weekly interval for two months (April to May). Observations were recorded at an interval of 60, 90 and 105 days after sowing and five samples were
collected for destructive sampling. The perusal of data indicated that plant height were better in at all stages under medium size of bags (25 x 15 cm). Further, seed sown on April 27 and subsequent date were statistically at par at 60 and 105 days after sowing in medium size polythene bags whereas in small size it compared with at 105 days after sowing. However, at 90 days after sowing it was at par after 4th May onwards sowing dates in medium size polythene bags and no definite trend was observed at 60 and 90 days after sowing in small size polythene bags. Dry matter accumulations were obtained in medium size of polythene bags than small size. The dry matter accumulation remained unaffected by different date of sowing in both size of bags. This study was earlier substantiated by Maithani et al. (1988) undertook an experiment with different sizes polypots (30 x 15 cm, 23 x 13 cm and 15 x 8 cm) as main treatment and sand, soil and farmyard manure was mixed in four different proportions (1:2:1, 1:3:1, 1:1:1 and forest soil) as sub- treatment in split plot-randomised block design with seven replications. Data revealed that for Acacia nilotica, polypot size 30 x 15 cm and 23 x 13 cm gave best germination % and the value is highest (74.6 cm) in 30 x 15 cm polypot. They recommended polypot size 30 x 15 cm-200 gauge and soil mixture of 1:2:1; sand, soil, farmyard manure for raising the seedlings.

A trial was carried out at Jammu and Kashmir by Gera et al. (1999) to study effect of polybag (23x11, 17x8 and 11x6 cm) and number of performances at the bottom (viz. 0, 2, 4 or 6) on seedling growth and quality of Acacia nilotica seedlings raised on mounted angle iron beds. Polybag were filled with a mixture of soil: sand: farmyard manure in the ratio of 1:1:1 in 3 replications with 25 polybags per treatment. Significances in seedling growth parameters viz. height, collar diameter, root length, shoot biomass and secondary+tertiary root biomass and quality parameters viz. sturdiness, root/shoot ratio and number of nodules per seedling were observed among different treatments. Study revealed that using mounted angle iron beds, seedling growth was best in treatment-T3 (large size polybags with four perforations at bottom) with an average height of 84.33 cm, collar diameter of 0.57 cm, length of tap root of 18.73 cm, shoot
biomass of 8.31 gm and root biomass of 7.10 gm. Whereas treatment $T_{10}$ (small size polybags with two perforations at bottom) recorded increased values for most of the seedling quality parameters viz. sturdiness 151.7, root/shoot ratio 2.03 and ratio of secondary + tertiary root biomass to total root biomass 0.48, when kept on mounted angle iron beds for production of quality planting stock of *Acacia nilotica*.

A nursery experiment was conducted by Patel *et al.* (2001) at the ASPEE College of Horticulture and Forestry, Gujrat to see the effect of different sizes of polythene bag and fertilizers on the growth of *Albizia lebbeck*, *Acacia catechu*, *Delonix regia*, *Samanea saman*. Four levels of NPK (0:0:0, 75:75:25, 100:100:25 and 125:125:25 ppm N, P$_2$O$_5$ and K$_2$O) and four different sizes of polythene bags (10x15 cm, 15x17.5 cm, 12.5x20 cm and 18x24 cm) were used in the study. Seedlings were uprooted 90 days after sowing and observation were recorded on shoot length, root length, number of leaves per seedling, total fresh and dry weight of seedlings. Perusal of data indicated that shoot length, root length and number of leaves per seedling of four tree species was found highest in polythene bags (18x24 cm) whereas smaller size polythene bags were suitable for *Albizia lebbeck*, *Acacia catechu* and *Samanea saman* under $N_{125}P_{125}K_{25}$ treatment and *Delonix regia* responded to $N_{100}P_{100}K_{25}$ treatment in 18x24 cm size of polybag. Root length of the tree species increased with the increase of fertiliser level upto $N_{100}P_{100}K_{25}$ and decreased from $N_{100}P_{100}K_{25}$ to $N_{125}P_{125}K_{25}$ for *Albizia lebbeck* and *Samanea saman*. Data for fresh and dry weight revealed that in all the tree species biomass accumulation increased with an increase of size of bag and level of fertilizer.

**2.3.4. Suitability of root trainer:**

Mishra and Emmanuel (1997) studied effect of root trainer on root formation system in nursery in five multipurpose tree species commonly growing in arid and semi arid parts of India. All the tested species showed well-developed fibrous root system. However, four month old seedlings of *Eucalyptus camaldulensis*, *Prosopis cineraria*, *Azadirachta indica* and *Pongamia pinnata* showed variable deformed root system either in form of
coiled tap root, bifurcated tap root, development of laterals like tap root etc. *Prosopis cineraria* showed highest (64%) deformed root system followed by *Eucalyptus camaldulensis* (47%), *Azadirachta indica* (41%) and *Pongamia pinnata* (24.5%). *Acacia nilotica* had developed well-pruned root system. Results indicate that a cautious approach and more species-specific research work are needed for the use of root trainers in forest nursery particularly in dry parts of the country.

Chadhar *et al.* (1999) conducted study with nine potting mixtures with different ratios of soil, sand and compost using *Eucalyptus tereticornis* and *Pterocarpus marsupium* sown in 150 ml root trainers. Best shoot and root growth for *Eucalyptus tereticornis* was in compost alone medium. The best root quality (straight as opposed to coiled taproot and presence of hairy roots) was in the 1:1:1 soil/sand/compost medium (80% straight taproots, 93.33% hairy roots), followed by the 3:2:1 mixture (86.66% straight taproots and 46.66% hairy roots). For *Pterocarpus marsupium*, there was much less variation in shoot and root growth between the nine growing media. However, incidence of root coiling was greater in this species and a high %age of straight taproots was found only in two medias 3:2:1 soil/sand/compost (86.66%) and compost alone (80%); only the former medium gave hairy roots which overall occurred much less frequently in this species. So this is chosen as the best medium since it also gave acceptable shoot and root growth.

Suitability of root trainer for the production of quality seedlings of six important species of southern India, viz. *Acacia mangium, Acacia nilotica, Bambusa arundinacea, Ceiba pentandra, Dalbergia latifolia* and *Eucalyptus camaldulensis* using compost as major ingredient of potting mixture. It has been found in the study by Srivastava *et al.* (2002) that 150 cc root trainers with a potting mixture combination of compost: sand: soil (60:30:10) produce plantable and uniform seedlings within 5 months in all the species under study. The average height attained varied between 13.6 cm in case of *Acacia mangium* to 42.4 cm in *Ceiba pentandra*. The low co-efficient of variance for the parameters study signifies coincided nature of all the seedling population
species under study. The culling %age calculated on the basis of standard deviation for individual species showed that the variation between 8-20 %, when indicated that uniform seedlings could be produced using root trainers for the species under study.

2.3.5. **Suitability of poly tube against root trainer:**

Nanhorya *et al.* (1999) reported use of polytube as an alternative to root trainers, based on a comparative trial in 1998 in which seedlings of *Gmelina arborea* were raised by both techniques in the Madhya Pradesh Forest Department. The results revealed that polytube performance is more or less the same as that of root trainers, while the capital investment costs in a polytube nursery are 6.25 times lower (based on estimates for a nursery of 100,000 plants). On the other hand, Sexena (1997) broadly studied root trainer applicability, its practical utility; long run cost effectively and eases of handling. He opined that a 150 cc root trainer could provide required succour to plants for 90-135 days. Root trainer grown *Gmelina arborea* seedling had several bifurcated anchor roots going in different layers of the soil along with a good network of feeding roots, instead of one-tap roots. According to him there may be possibility of root accumulation upwards, if the artificial fertilisation administered as top dressing. Comparably large size polybag raised seedlings have prominent anchor and feeding roots but the biomass, penetration and spreading were definitely have a marginal difference than root trainer seedlings. According to him, confinement of roots of root trainer seedling to upper soil is a misplaced notion.

2.4. **Effect of nutrient application on growth and development of seedlings:**

2.4.1. **Studies in sand culture and nursery bed:**

Agarwal and Bhatnagar (1984) laid an experiment with four-month-old seedlings of *Pinus caribaea* in sand to observe optimum nitrogen, phosphorus and potassium requirements. Nutritive solution consisted of 100, 200 and 300 mg/plant/application of nitrogen, phosphorus and potassium in different factorial combinations. Plants were given nutrition every 15 days for 12 months.
It was observed that nitrogen and phosphorus each at 200 mg and potassium at 300 mg/plant/application was optimum to produce maximum height, diameter growth and dry matter production.

Totey et al. (1986) conducted a field experiment on a pilot scale in nursery beds to find out effect of nitrogen, phosphorus and potash on teak seedlings. Experiment consisted of 3 level each of nitrogen (0, 150, 300 Kg/ha); phosphorus (0, 75, 150 Kg/ha) and potassium (0, 75, 150 Kg/ha) in randomized block design with two replications. Phosphorus and potassium were added as basal dose while nitrogen was incorporated in split doses (50 % at the time of sowing and balance as top dress). Observations were taken on average length; fresh weight of shoot and root and girth at collar every month. Collected data were subjected to statistical analysis. There was no significance difference in seedling growth in response to fertiliser treatment; probably because nursery soil was already fertile (it had been treated with farmyard manure). Data revealed that teak seedlings became transplantable size with basal diameter 4.75 cm and height 41.84 cm within 4 month’s duration producing 116.72 gm shoot and 42.33 gm root.

Mohan (1992) laid fertilizer trial with *Gmelina arborea* on acidic (pH 5.8) nursery soil in Arunachal Pradesh. Soil was moderately low in available nitrogen and phosphorus and medium in exchangeable potassium. Seeds were sown at 100 sq m plots pretreated with 10 % brominated hydrocarbon and bavistin [carbendazim] at 0.1%. All plots were treated uniformly with 10 Kg farmyard manure and also with different combinations of nitrogen (0, 50, 100 and 150 Kg/ha) and phosphorus (0, 25, 50 and 75 Kg/ha) and a basal dose of potassium (25 Kg/ha). Initially only 40 % nitrogen was added and remaining 60% was added in solution in 2 equal doses 4 and 8 week after 50 % of seeds had germinated. Germination was recorded, survival, diameter and height growth were measured at regular intervals. Biomass production (by component) was measured after 7 months. Germination was greater in N_{150} treatments (39-53%) than in the other nitrogen treatments (24-35%). Maximum height growth was recorded in treatment N_{150}P_{0} (53%) followed by N_{150}P_{75} (48%) treatment. Growth
and biomass production were greatest in the $N_{150}P_{75}$ treatment. According to him nursery soils are depleted of their nutrients due to successive planting of the tree species. Therefore, nutrient application is required to in these soils with optimum dosage of inorganic fertilizer to get the best growth of plants. Further organic manure is applied to improve their physical conditions besides supplementing available nutrient. Mohan (1993) in another experiment provided various doses of nitrogen, phosphorus and potassium fertilizers along with organic manure on *Gmelina arborea* (Gamari). Maximum germination was observed in case of $N_{150}P_0$ treatment followed by $N_{150}P_{75}$ treatment showing their superiority over other treatments. This potential tree species gives maximum growth (height and girth) and biomass (above and below) at 150 Kg/ha nitrogen, 75 Kg/ha phosphorus and 25 Kg/ha of potash as nitrogen, phosphorus and potassium fertilizer doses.

Koul *et al.* (1995) studied combined influence of nitrogen and phosphorus fertilisers on biomass production, nutrient uptake of *Bauhinia variegata* in nursery. Study undertook for 160 days with 4 levels of nitrogen (0, 30, 60, 90 Kg/ha) and 3-levels of phosphorus (0, 40, 80 Kg/ha). Nitrogen application showed significant increase in biomass and was maximum at 60 Kg nitrogen/ha while phosphorus shows influence on leaf and total biomass at a maximum of 40 Kg phosphorus/ha.

### 2.4.2. Studies in pot culture:

Bangesh and Sheikh (1981) while working in Pakistan applied nitrogen (as urea), phosphorus and potash singly and in various combinations to one-year-old *Pinus roxburghii* seedlings in the month of May. After seven months, all combinations except potash alone had significantly increased growth as compared with controls, while nitrogen, phosphorus and potash resulted in best growth. In another study in India, Agrawal *et al.* (1983) determined optimum nitrogen, phosphorus and potassium requirement for *Pinus caribaea* seedlings grown under glasshouse condition using chirpine forest soil of Forest Research Institute, Dehradun. They reported that nitrogen at 336 Kg/ha; phosphorus at 112 Kg/ha and potassium at the rate of 336 Kg/ha produced maximum height,
diameter and biomass production when applied while preparing nursery beds for *Pinus caribaea* seedlings. In Australia, a study was conducted by Fieder and Glowna (1988) to see the effect of the fertilizers sources (urea having nitrogen concentration between 0.15 and 1.2 gm/pot and ammonium nitrate having nitrogen concentration between 0.15 and 0.60 gm/pot) on Australian pine (*Pinus nigra*) revealed that single doses of urea (applied at the beginning of first growing season) resulted in greater growth per unit nitrogen taken up than 2 doses of ammonium nitrate applied at the start of first and second growing season. A trial was carried out at the Mailbot nursery of the Lumle Agricultural Centre, Nepal by Harrison (1989), in cooperation with the Forestry Research Division, to investigate the growth of *Ficus nemoralis* seedlings in nursery polypots containing different proportions of soil and compost (100:0, 90:10, 80:20, 70:30, 60:40). Seeds were sown in the first week of August 1988 and seedlings transplanted to the polypots at the end of September. The pots were laid out in stand beds and reorganized to a wider spacing in April 1989. The seedlings were measured in June 1989, at 10 months old, but 'guard' rows were discarded. Significant differences were found between seedling height growth in the different treatments, with the best growth occurring in the 3-treatments with most compost. Root collar diameter growth was not significantly different between treatments.

In Madhya Pradesh, Totey *et al.* (1989) conducted a polypot experiment in factorial randomised block design with 4-replications to study the effect of nitrogen and phosphorus on the growth and yield of bamboo seedlings. Application of nitrogen at 5.0 gm and 10.0 gm of urea/pot containing 2 Kg soil belonging sub group typic chromousterts, individually as well as in combination with single super phosphate significantly decreased all growth parameters and dry matter yield. However, phosphorus application at 10.0 gm and 20.0 gm single super phosphate /pot individually as well as in combination with nitrogen increased the height of plant, length of rhizome and number of culms after 90 days. After 120 and 150 days total number of culms were found to decrease with increase doses of phosphorus. The average girth of rhizome was increased when
10.0 gm single super phosphate was added per pot with slight decrease on higher doses (i.e. 20.0 gm single super phosphate/pot). Dry matter yield of leaves, roots, culms and rhizomes increased markedly with “phosphorus” application. The correlation coefficients between some growth factors were calculated and were found highly significant. The results of this experiment suggest that with “phosphorus” application better growth of bamboo seedlings may be obtained in short duration and healthy plantation stock could be made available. Besides, further detailed study is needed on this line.

A pot culture study carried out by Singh et al. (1989) at Tamilnadu to observe the biomass production of Acacia nilotica seedlings with different doses of nitrogen, phosphorus and potassium with soils of varying textures revealed that in medium textured soils (sandy loam, loam and sandy clay-loam) nitrogen responses was more whereas response to phosphorus was poor on heavy textured soils like clay and clay loam). Acacia nilotica seedlings in general responded more to nitrogen and phosphorus than potassium. Nitrogen in the form of calcium ammonium nitrate gave more promising results at 30 ppm while P\textsubscript{2}O\textsubscript{5} at the level of 10 ppm in the form of single super phosphate and diammonium phosphate increased the dry matter to a great extent. It was also observed that the use of potassium was not significant in any soil type except in loam and sandy clay-loam soils with 10 ppm of K\textsubscript{2}O.

At Coimbatore, Tamilnadu Mohan et al. (1990) studied effect of soil texture (sandy, loamy and clayey) and nutrient application (50 ppm each of nitrogen, phosphorus and potassium) in different tree species. They observed higher biomass production in Albizia lebbeck, Peltophorum pterocarpum and Eucalyptus tereticornis in clayey type of soil. But in case of Albizia amara, it responded better in sandy soils. Acacia lenticularis, Acacia planifrons, Albizia amara, Azadirachta indica and Tamarindus indica showed a decrease in biomass production due to nutrient application. He observed that Albizia lebbeck, Peltophorum pterocarpum and Eucalyptus tereticornis are highly responsive to clay texture and nutrient application. Albizia amara produced
higher biomass in sandy soil while other trial species produced higher upper and lower ground biomass in clay soil.

The green house experiment carried out by Prasad and Rawat (1991) to observe the response of nitrogen, phosphorus and potassium fertilisation by *Acacia nilotica* responded to nitrogen applied alone or in combination with phosphorus and potassium. Application of phosphorus and potassium applied alone or in combination, decreased the growth. The treatment consisting of 100 ppm nitrogen, 100 ppm P$_2$O$_5$ and 25 ppm K$_2$O was observed best in respect of all growth parameters (height attainment, leaf number, fresh biomass, dry biomass and fertiliser use efficacy). In another study, Prasad and Rawat (1992) at the Forest Research Institute, Dehradun studied fertiliser use efficacy of tree species in a greenhouse study with regard to nitrogen, phosphorus and potassium nutrients. *Eucalyptus camaldulensis*, *Eucalyptus citriodora* and *Acacia nilotica* responded to the application of nitrogen, phosphorus and potassium, whereas *Acacia catechu*, *Eucalyptus grandis*, *Eucalyptus tereticornis* var-FRI-5 and *Prosopis juliflora* responded to only nitrogen and phosphorus application and *Albizia lebbeck*, *Leucaena leucocephala* and *Eucalyptus tereticornis* var-FRI-4 responded to nitrogen and potassium only.

Sehgal *et al.* (1992) carried out an experiment to see the effect of nitrogen fertilisation on the growth behaviour of *Enterolobium timbouva* Mart. The potting media was soil: sand: farmyard manure (2:1:1) and phosphorus and potassium at the rate of 80 and 40 Kg/ha were also mixed with soil prior to pot (25 cm diameter) filling. The pots were divided into six groups and kept under glasshouse conditions. Nitrogen was applied at the rate of 0, 20, 40, 60, 80 and 100 Kg per hectare. The samplings were taken out 85, 100, 115, 130 and 145 days after sowing and the various morphological parameters like shoot length and girth, root length and number of secondary roots, fresh and dry weights of different plant parts were recorded. The results showed that an increase in the stem and girth was observed with the increasing dose of nitrogen in all samples taken between 85 and 145 days. In most of the cases maximum values were recorded in control and N$_{100}$ treatments respectively. Similarly, fresh and dry
weight was also increased with the increase of nitrogen doses. The minimum and maximum values for fresh weight (3.07 gm and 37.10 gm) and dry weight (0.81 gm and 12.22 gm) were observed in N₀ and N₁₀₀.

In a pot culture study of Tectona grandis seedlings, Shanavas et al. (1993) reported that phosphorus had a significant effect on height growth of seedlings. Application of phosphorus and potassium at the rate of 60 Kg/ha each increased the taproot length significantly. Further, applications of nitrogen and potassium have shown significant effect on the absorption of phosphorus by the seedlings. While studying the effect of fertiliser (nitrogen, phosphorus and potassium) and micronutrients (B, Mo, Cu, Mn, Fe, Zn) on Eucalyptus tereticornis and Eucalyptus camaldulensis micronutrient does not seem to have any significant effect on the growth of seedlings in nursery.

Singh et al. (1994) carried out study to know the effect of compost and fertilizers on nutrient accumulation in different plant parts of Albizia procera as well as biomass production in coalmine overburden of Talcher, Orissa. Two experiments, one consisting of different combinations of dump material and compost, another with different nitrogenous fertilizers (ammonium sulphate, ammonium chloride and urea) @ 150 ppm nitrogen, phosphorus @ 25 ppm P₂O₅ and potassium @ 100 ppm K₂O with control. Potting mixture consisted of four treatments viz; 1:0, 1:0.5, 1:1 and 1:2 (v/v) filled in earthen pots and replicated five times. Maximum amounts of nutrients were accumulated when ammonium sulphate was applied followed by ammonium chloride and urea. In overburden compost mixture, nutrient accumulation was highest in 1:2 overburden-compost followed by 1:1 and 1:0.5. Compost served a better medium when mixed in higher proportion for growth, development and nutrient availability of plants.

Nath and Das (1995) conducted experiments with uniform 60-day-old seedlings of Leucaena leucocephala and Gmelina arborea were grown in pots of lateritic soil using six treatments: (1) control; (2) NPK fertilizer (urea+super phosphate+muriate of potash); (3) NPK+lime; (4) inoculation with Azotobacter (for Gmelina arborea) or Rhizobium (for Leucaena leucocephala) cultures; (5)
NPK+ inoculation and (6) NPK+ lime+ inoculation. Stem length and total biomass were measured after 1 and 6 months. All treatments enhanced seedling growth in comparison with the control. Maximum growth of *Leucaena leucocephala* was obtained with treatment (5). The increase in total biomass for seedlings inoculated with rhizobium (1654%) was comparable for that of seedlings treated with NPK (2128%). For *Gmelina arborea*, treatment (6) produced the greatest shoot length, but inoculation with azotobacter alone produced the greatest total biomass.

Singh et al. (1995) studied the effect of soil, compost and different sources of nitrogen on growth of *Albizia procera* in coal-mined areas of Orissa. The results indicated that nitrogenous fertilisers when applied @ 150 ppm as basal dose, 25 ppm P2O5 and 100 ppm K2O, the species showed better response to (NH4)2SO4 as compared to control. Number of nodules found maximum in ammonium chloride while length of root was longest in control. The treatment (1:2) soil-compost mixture (V/V) followed by 1:1 and 1:0.5 soil-compost mixture and control registered again best growth performance.

A pot experiment was conducted by Robert Orhue Ehi (1997) for 18 months at the experimental farm of the University of Benin, Nigeria. Fertilizer applied influenced the growth of seedlings. Fertilizer throughout the period compared to control enhanced plant height, number of leaves, and leaf area significantly. The application of 100 Kg/ha was, however, not significantly different from 50 Kg/ha except at 12 and 18 weeks for number of nodes, but it was significantly different from the control. In the case of collar girth, 100 Kg/ha was not significantly different from 50 Kg/ha except at 14 weeks, which may have been attributed to external environment and/or growth rate at the specified period. Throughout the period of study, the seedlings never showed branching or nodule formation in the treated plants or controls. The fertilizer also influenced the dry matter accumulation. The different levels of the fertilizer differ significantly from one another for stem, root, leaf and total dry weight, with higher values in 100 Kg/ha compared to 50 Kg/ha and control. From the
results, it was concluded that N-P-K-Mg compound fertilizer aided the early growth and development of the *Dialium guineense* seedlings.

Deswal *et al.* (2001) carried out an experiment to find out response of nitrogen and phosphorus to kikar (*Acacia nilotica*) in farmyard manure treated sandy soil during initial phase of growth. Potting mixture (sand soil farmyard manure in 1:1:1 ratio) mixed uniformly was filled in polythene lined earthen pots (22 cm diameter). Treatments consist of 4 levels of nitrogen (0, 10, 20 and 40 mg nitrogen/Kg soil as urea) and 4 levels of phosphorus (0, 5, 10 and 20 mg phosphorus/Kg soil as KH$_2$PO$_4$), replicated thrice in randomised block design and kept in a glass house at temperature 32°C. After one year seedlings were uprooted and growth parameters (shoot length, root length, collar diameter, number of branches and nodules) of each plant were recorded and statistical variance was carried out. Results indicated that shoot length increase (18.0 %) over control at 5 ppm phosphorus, whereas increase due to 10, 20 and 40 ppm nitrogen were 46.0, 89.4 and 117.0 per cent respectively. Study showed that influence of nitrogen on plant height was more conspicuous than phosphorus. Interaction of nitrogen and phosphorus fertilisers was significantly better on increasing plant height than applied separately. Root length was relatively higher with nitrogen application in comparison to phosphorus levels. Increase in root length in nitrogen applied alone at 10, 20 and 40 ppm was 1.66, 2.00 and 2.15 time higher than control respectively. While, addition of 5, 10 and 20 ppm phosphorus alone increased root length by 1.20, 1.37 and 1.47 times respectively. Increasing level of nitrogen as well as phosphorus increased collar diameter per plant of one-year-old *Acacia nilotica*. There was a continuous significant increase in branch number due to increasing nitrogen levels than in control at low phosphorus level (5 ppm), whereas at 10 and 20-ppm phosphorus level a significant increase was observed in presence of 20 ppm nitrogen level.

Results of the pot culture experiment on early growth performance of *Sesbania grandiflora* at different levels of phosphorus and VAM inoculation revealed that mycorrhizal inoculation had significantly influenced nodulation
characteristics (Desai et al. (2003). According to them mycorrhizal inoculation was much pronounced at 60 Kg P₂O₅/ha application.

2.4.3. Poly bag study:

Raina et al. (1988) laid out a factorial experiment comprising three levels each of nitrogen (0, 50 and 100 ppm), P₂O₅ (0, 50 and 100 ppm) and seven application dates on Bambusa tulda. They reported that for all growth parameters (height, number of tillers, leaf numbers, collar diameter and biomass production), application of nitrogen was superior to phosphorus application but their combined applications were always better than individual application. Among the treatments N₁₀₀P₅₀ was found superior. Further split application of nutrients 4, 6 and 8 weeks after germination gave best results. In another set of experiment Raina et al. (1990) conducted an experiment to determine the response of nitrogen, phosphorus and zinc which was applied alone or combination to get healthy seedlings in shortest time. For this experiment potting mixture was soil: sand (1:1) and basal doses of 70 ppm nitrogen as urea, 70 ppm P₂O₅ as super phosphate and 35 ppm potash as muriate of potash was filled in perforated polythene bags. Each treatment consisted of 25 bags in completely randomised design and replicated four times. Observation on germination, survival and growth parameters was recorded at regular intervals. Basal dose of chemical fertilizers decreased seed germination and survival. It was observed that application of 10 ml solution per poly-potted seedlings of 0.2 % each of urea and super phosphate applied 10th and 13th week and 10 ml of 0.02 % zinc sulphate solution after 15 week of seed sowing increased height and biomass growth of Acacia catechu seedlings.

Ngulube (1989) conducted an experiment at Forest Research Institute of Malawi (FRIM) to evaluate the effect of two polythene tube sizes on the nursery and field survival and growth of Eucalyptus camaldulensis, Eucalyptus pellite, and Eucalyptus tereticornis seedlings. Nursery raised seedlings were transplanted into two types of polythene tube sizes: 15 cm circumference (7.5 cm ‘layflat’) by 10 cm long and 20 cm circumference (10 cm ‘layflat’) by 15 cm long. Application of nitrogen, phosphorus and potassium fertilizer was done
three weeks after picking out at the rate of 0.6 gm per plant. Height and root collar diameter measurements were taken weekly for 9-week starting fourth week after picking out. After nine week, ten seedlings from each treatment were randomly selected and cut near the soil surface. Shoot and root systems were separated and the dry weights recorded. Seedlings were used for a field study with a randomised split-plot design. The survival of all the species exceeded 90% in all cases regardless of tube size. Growth of *Eucalyptus camaldulensis* seedlings in larger tubes was significantly better than in small tubes. Tube sizes, however had no significant effect on height and collar growth of *Eucalyptus pellite, Eucalyptus tereticornis*, but biomass production was significantly better with larger tubes in both cases. Root : shoot dry weight ratio was not significantly different between species and tube sizes, although smaller tubes had slightly higher ratios for *Eucalyptus camaldulensis* (0.33) and *Eucalyptus tereticornis* (0.34). Nursery growth differences however had no significant influence on field performance of the three *Eucalyptus*. Small tubes are cheaper and easier to handle and should therefore be used for raising *Eucalyptus* seedlings instead of the large tubes.

Sundararaju *et al.* (1991) conducted a nursery experiment with *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* in polythene bags of size 13 x 25 cm filled with red soil. The trial was laid out in strip plot design with six fertiliser levels, urea (0.0, 0.1, 0.2, 0.4, 0.6 and 0.8 gm); super phosphate (0.0, 0.5, 0.5, 1.0, 1.5, 2.0 gm); muriate of potash (0.0, 0.15, 0.15, 0.30, 0.45 and 0.60 gm/plant) and three micro nutrient level, borax (0, 0.5, 1.0 mg/plant); sodium molybdate (0, 0.5, 1.0 mg/plant); copper sulphate (0, 2.5, 5.0 mg); manganese sulphate (0, 2.5, 5.0 mg); ferrous sulphate (0, 5.0, 10.0 mg); zinc sulphate (0, 5.0, 10.0 mg). Basal dose of super phosphate was applied before pricking out. Urea and potash were applied in split dose of 0.2 gm and 0.15 gm at monthly interval. The height measurement were recorded on 45th, 72nd, 106th and 139th day after pricking out in case of *Eucalyptus tereticornis* and on 21st, 64th, 97th and 113th day for *Eucalyptus camaldulensis*. Statistical analyses of the height measurements indicate that only fertiliser has significant effect on the growth of
Eucalyptus species. For boosting the growth and reducing the nursery period by about a month time it was recommended to adopt A₄ (0.4 gm urea; 1 gm super phosphate and 0.3 gm muriate of potash) for Eucalyptus tereticornis and A₅ (0.6 gm urea, 1.5 gm super phosphate and 0.45 gm muriate of potash) for Eucalyptus camaldulensis. Cost of fertiliser worked out to Rs. 4 for 1000 container seedlings for A₄ treatment, there was a saving of Rs. 18 for Eucalyptus tereticornis. In the case of Eucalyptus camaldulensis the cost of fertiliser per 1000 seedlings for A₅ works out to Rs. 6 as such the maintenance cost reduced by Rs. 16.

A polybag experiment with degraded waste land from Jabalpur, Madhya Pradesh deficient in nitrogen and phosphorus was conducted by Singh et al. (1997) with four levels of added nitrogen (0, 25, 50 and 100 ppm as urea) and P₂O₅ (0, 10, 25 and 50 ppm as single super phosphate) and a basal dose of potash (25 ppm) using Pithecellobium dulce as test species, sown directly in the soil. Growth measurements after four months showed maximum values of all parameters (height above ground biomass, root biomass, root surface area and nodule weight) in the treatment receiving 100-ppm nitrogen and 50 ppm P₂O₅. It was recommended that 100-ppm nitrogen and 50 ppm P₂O₅ may be used for raising good-sized seedlings on site for afforestation of degraded soil, thus reducing the cost of maintenance and seedling transportation from establishment nurseries.

Savio et al. (1998) raised seedlings of Casuarina equisetifolia (from a single tree) in 300 ml root trainers in standard nursery medium (sand/soil/farmyard manure 2:1:1) and in 3 types of test media (sand+pressmud or mushroom waste or composted coir pith at ratios of 1:1, 1:2 and 2:1) for 150 days after transplanting. Various growth parameters (17) and mortality were then assessed. The media had different effects on different growth parameters, but a statistical test of performance based on all those parameters significantly affected, showed that the best overall medium was sand/mushroom waste at 2:1. The growing medium routinely used in the nursery has been changed to this, with the addition of Azospirillum and Frankia (based on earlier findings).
Prasad, Pankaj and Nautiyal (1998) investigated influence of two commonly used fertilizers i.e. urea and diammonium phosphate (DAP) on early growth and nodulation in two important multipurpose tree legumes Albizia procera and Ougeinia dalbergioides. The seeds were sown in polybags of 1 Kg capacity filled with well-sieved garden soil mixed with different doses of fertilizers. The fertilizer dosages used were urea low level (60 mg/Kg soil) and high level (180 mg/Kg soil), diammonium phosphate low level (48 mg/Kg soil) and di-ammonium phosphate high level (144 mg/Kg soil) with control. For each treatment thirty polybags were maintained in a glasshouse. After six months of growth, ten seedlings from each treatment were analysed for their shoot and root length, dry weights of leaves, stem and root, nodule number and their dry weight. The data reveals that the two species responded differently to both types as well as dosages of fertilizer but in general fertilizer treatment resulted in increased growth and dry matter of the seedlings to varying extent. Conversely, fertilization to the seedlings reduced nodule number, which was highly significant in Ougeinia dalbergioides than in Albizia procera. The fertilization also affected per cent distribution of dry matter in various organs of seedlings that was more pronounced in Ougeinia dalbergioides than in Albizia procera. The overall results indicated that Albizia procera responded more significantly in the present fertilizer treatments and it seems to be efficient user of fertilizers given for its growth at nursery level when compared to Ougeinia dalbergioides.

Singh and Thind (1999) carried out nursery trials with nitrogen, phosphorus, potassium and three levels of farmyard manure (1:0, 4:1, 2:1; soil : farmyard manure ratio by volume) to find out growth and biomass accumulation in Eucalyptus. A factorial experiment with nitrogen (0, 100, 200 Kg nitrogen ha$^{-1}$, nitrogen spray two foliar sprays of 2 per cent urea), two levels of phosphorus plus potassium (0, 50 Kg of P$_2$O$_5$ and K$_2$O ha$^{-1}$) in a polythene bags (15 x 22 cm). Perusal of data revealed that after 120 days addition of phosphorus plus potassium alone or in combination with farmyard manure and nitrogen failed to influence growth of Eucalyptus significantly. Addition of farmyard manure and nitrogen failed to affect collar diameter. Application of
nitrogen in the form of two foliar sprays of 2% urea significantly reduced number of leaves. Application of nitrogen alone at the rate of 100 Kg nitrogen ha\(^{-1}\) increased dry matter significantly, however when nitrogen increased to 200 Kg ha\(^{-1}\), it failed to cause further increased in dry matter. Foliar spray alone did not affect shoot dry matter but it increased root dry matter significantly.

*Jha et al.* (2000) carried out a nursery experiment to observe effect of nitrogen levels on growth and biomass production of *Dalbergia sissoo*. The experiment was laid out using factorial design in sandy loam soil with nitrogen @ 0, 25, 50, 75 and 100 ppm, phosphorus @ 25 ppm and potassium @ 25 ppm in polythene bags (size; 25x15 cm) with five replications. After one year five randomly selected seedlings from each treatment were removed from polybags, height and diameter were measured and leaves stem, twig and roots were separated and dried for constant weight. Data revealed that rate of height and diameter increment after one year have shown increasing trend with increase in nitrogen levels. Height varied from 6.27 cm in control to 8.33 cm/month in 100 ppm nitrogen and diameter from 0.70 in control to 0.96 cm/month in 100 ppm nitrogen. Biomass increment showed a similar trend and varied between 1.59 to 4.13 g/month/plant. Also, root system becomes healthier and sturdy with increase in nitrogen levels. Study suggested that application of 100-ppm nitrogen to enhance growth and biomass production for growing *Dalbergia sissoo* seedling in the nursery having similar soils in polythene bags.

### 2.5. Field performance of seedlings raised with different treatments in the nursery:

*Sundararaju and Chinnathurai* (1990) conducted nursery trial in polythene bag of size 13 x 25 cm filled with protected shola soils. Basal dose of super phosphate and potash were applied before pricking out and urea was applied in split doses of 0.2 gm at monthly interval. For each treatment 25 seedlings were taken up in polybags and replicated five times. Latin square design was adopted in the experiment. Periodical height measurements were recorded on 44\(^{th}\), 84\(^{th}\), 140\(^{th}\) and 258\(^{th}\) day after pricking out in polythene bags. After statistical analysis, it revealed that application of urea 0.4 gm; 1 gm of
super phosphate and 0.3 gm of muriate of potash per bag to *Eucalyptus globulus* seedling produced 28 cm height in 128 days while a normal period of 258 days is required under natural condition in the nursery. Cost of fertiliser applied for 1000 container seedlings worked out to Rs.3 per poly bag whereas the maintenance cost is reduced by 18%.

Iputu (1991) observed survival (1 month) and growth (2 yr) of *Gmelina arborea* seedling raised in Hiko root trainers (150 ml capacity) and polypots (358 ml capacity) in the field. Seedlings were planted as balled stock or bare rooted stock (treated or not with alginate). Best survival and growth after 2 yr were observed with polypot balled stock and polypot bare root stock dipped with alginate, followed by Hiko balled stock. Survival of stump seedlings was superior but their growth was retarded.

Khedkar and Subramanian (1997) used block type root trainers (150 cm$^3$) filled with sun dried, pulverised, sieved sand, soil and farmyard manure in 1:2:2 ratios at Makhmalabad and 1:1:3 at Lohara. Basal dose of deoiled neem cake (10 Kg), prorate insecticide (0.25 Kg), Indofil M-45 fungicide (0.25 Kg) and single super phosphate of (4.5 Kg) were mixed with one cubic meter potting media. Seedling height was recorded after 30 days. The trial scale root trainer seedlings raised in root trainers have given better development of biologically desirable lateral roots. Comparative growth performance of 75 days old root trainer raised *Tectona grandis* seedlings planted in the field has given better collar diameter, sturdier and healthier plant. According to them, teak planting stock in root trainers up to 90 days may be preferred over seedlings raised in bed for a period of one complete year. They reported that root trainer plants are sturdier, healthier and the collar growth is better in comparison to stump origin plants.

A nursery experiment was carried out by Chinnathurai *et al.* (1997) in polythene bags of size 13 x 25 cm with urea (0, 0.1, 0.2, 0.4, 0.6 and 0.8 gm), single super phosphate (0, 0.5, 0.5, 1.0, 1.5 and 2.0 gm), muriate of potash (0, 0.15, 0.15, 0.30, 0.45 and 0.60 gm) and micro nutrient (B, Mo, Cu, Mn, Fe and Zn)
on *Acacia nilotica*, *Acacia leucophloea*, *Acacia planifrons*, *Albizia lebbeck* and *Pongamia pinnata*. The results revealed that *Acacia nilotica* attains a growth of 33 cm in 141 days in control whereas the same height attains after 121 days with treatment $A_4$ (urea 0.4, single super phosphate 1.0 and muriate of potash 0.30 gm) In case of *Acacia leucophloea* the fertilizer application $A_2$ (urea 0.1 gm, single super phosphate 0.5 gm and muriate of potash 0.15 gm) recorded maximum growth and biomass. The optimum dose for *Acacia planifrons* is $A_5$ (urea 0.4 gm, single super phosphate 1.5 gm and muriate of potash 0.45 gm) in which seedlings attained a height 23.5 cm in 142 days. In case of *Albizia lebbeck* the recommended optimum dose is $A_2B_3$ (urea 0.1 gm, single super phosphate 0.5 gm and muriate of potash 0.15 gm and B-1.0, Mo-1.0, Cu-5.0, Mn-5.0, Fe-10.0 and Zn-10.0 gm respectively) and was superior to other treatment. They concluded that application of fertilizer and micronutrient reduces nursery period as well as cost of maintenance.

Maritime pine (*Pinus pinaster*) containerised seedlings were raised outdoors in a commercial nursery by Fraysse and Cremiere (1998) in SW France using different nitrogen-, phosphorus and-potash fertilizer regimes, with varying sowing dates (January, May, June and July) and culture durations (in which planting season was related to container type for one sowing date), in order to assess nursery factors influencing first-year growth (to November 1995) in the field after out planting 1-yr old stock on a sandy site near the nursery. Seedling biomass and nitrogen, phosphorus and potassium content before out planting were affected by the different cultural regimes tested but one year field growth was more related to nitrogen concentration than to morphological traits.

Container grown *Eucalyptus citriodora* and *Gmelina arborea* seedlings with *Pisolithus tinctorius* or no ectomycorrhizae (control) were planted on a reforestation site at Tansa Hills, Dhabalgiri, Orissa by Poi and Kumar (2000) Three years after planting, seedlings initially colonized with *Pisolithus tinctorius* had greater survival, height and root collar diameter than the control seedlings. Results suggest that container grown *Eucalyptus citriodora* and
Gmelina arborea seedlings planted without ectomycorrhizal association had low survival and poor growth.

Ginwal et al. (2001) used multivariate approach to find out the ideal size/volume and type of root trainer for raising Dalbergia sissoo seedlings. Root trainers consisted of Hiko trays (90 cc, 150 cc and 300 cc), book type (200 cc) and single cell bullet (290 cc) were tried for 3 months in the nursery for 2-consecutive years. Seedlings so raised were planted in the field conditions. Performance of 150 cc Hiko trays was adjudged the best container to raise seedling for planting in field conditions while 300 cc Hiko trays performed well in nursery. According to them larger quantity media and bigger container is not necessarily a catalytic factor for better performance of seedlings in field conditions.