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EVALUATION OF ALTERNATIVE MATERIALS FOR USE AS CONTAINERS FOR RAISING FOREST PLANTING STOCK

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ABSTRACT

The potential of utilising various materials as containers for raising forest planting stock in Kerala was examined The study found that conventional containers made from locally mailable materials such as bamboo splits, leaves of trees and other forest plants and gunny bags are not suitable for large scale forestry programmes. Higher production cost and poor durability of containers, difficulties in handling and transportation and poor survival of stock in nurseries are some of the major disadvantages. Root trainers, the container system currently popular in many temperate and tropical countries, though require higher initial investment and high intensity management, are superior to polybag in many respects. Low overall cost, better nursery stock having healthy root system, convenience in nursery handling and transportation, and shorter nursery regime are some of their advantages. Besides, large quantities of scarce polyethylene, a petroleumproduct hming differentend uses, required annually for production of polybags, can be saved and consequently the problem of waste disposal of such a large quantity of non-biodegradable material can be moided

However, efficient use of root trainers requires total change in current nurserypractices. Being part of a technology which ismore exacting, success of root trainers largelydependson how effectively different components of this technology, i.e., the root trainers, potting medium, fertilizer and irrigation regimes, raised platformto provide aeration to root trainers, overhead shelter to protect the nursery stock from excessive sunlight and rain, are put to use so as to produce the synergistic effect. Preliminary trials hwe highlighted the need for more research and development efforts for the adaptation of different components of this technology to suit the specfic conditions prevailing in the State. Further studies in this directionarerequired

However till appropriate root trainer technology is developed, the only option auailable is to continue with the polybag containers. In this situation,to enhance the efficiency of the polybag nursery system more attention needs to be paid to the selection of optimal sue of the polybags, provision of adequate number of drainage holes, use of well aerated potting medium (soil),judicious application of fertilizer and irrigation and timely removal of planting stock for outplanting.

1. INTRODUCTION

Raising the planting stock in nurseries is one of the important aspects of a successful forestry plantation programme (Evans, 1992; Shepherd, 1986). In Kerala, at present, except for teak, for which stump is used, the planting stock for almost all other forestry species is prepared by growing them in containers. A perusal of records revealed that during the last decade, the Kerala Forest Department, the main practitioners of forestry in the state, have produced about 900 million containerised seedlings. Taking into consideration the renewed interest in enriching degraded forests, enhancing productivity of plantations, various social forestry and farm forestry programmes, the requirement of tree seedlings for coming years in the forestry sector in the state can be expected to be around 50 million per annum. In the context of such a massive activity. the choice of containers assumes a significant role, not only in deciding the quality of tree crops, but also from several social, economic, ecological and logistic perspectives.

Polythene bags are the currently used containers in the forest nurseries of the State. The State Forest Department has been experiencing difficulties in using them due to increasing price and scarcity of material. They have approached the Kerala Forest Research Institute to explore the possibility of finding out an alternative to polybag. They have suggested alternative materials such as split bamboos, gunny bags, straw, grass and leaves of reeds as potential candidates.

A preliminary survey revealed large number of materials in addition to those suggested by State Forest Department as potential candidates for containers. There were also different types of containers such as paper pots and root trainers popular in many other countries and therefore in a study to find out a viable alternative it was but necessary to include all available ones.

A number of factors were found to influence the choice of containers. These include cost and availability, easiness and familiarity in use, eco-friendliness and physical suitability to grow healthy planting stock. Suitability of the container was also found to be influenced by the planting stock size required for different plant species. planting site and plantation objectives. While selecting the suitable container it became necessary to take into consideration all these factors in totality.

Often these factors were found to exert conflicting demands on container. *So*. the suitable alternative has to be arrived at based on a compromised solution identified by systematically evaluating different container alternatives under a multi- criteria environment as constrained by the various biophysical, socioeconomic. ecological and iogistic factors prevailing in the forestry sector in the State. The large number of factors together with the different container alternatives involved make the problem quite complex rendering conventional approach inefficient in tackling the problem in a holistic perspective.

However, Operations Research (OR), a scientific discipline emerged during Second World War to tackle complex decision making problems, provides powerful tools to deal with such situations in a systematic manner (Ackoff and Sasieni, 1968). Operations Research methods are increasingly being used in studying complex forest management problems having large number of factors and decision alternatives with varying trade offs (Dykstra, 1984; Dress and Field, 1985: Davis and Johnson, 1987).In this study, an attempt was made to look the problem of choice of appropriate container for forest nurseries of Kerala by taking into consideration the various aspects involved in a total perspective using OR techniques.

consonance with the approach adopted in the study, this report is presented in eight sections. In the second section an attempt is made to provide a brief state of art information on past studies regarding the various aspects of containerisation in forest nurseries. The general methodology adopted in this study is described in section three. Details of different container alternatives available and considered for evaluation are given in section four. The studies carried to develop an appropriate suitability criteria **to** enable a balanced evaluation of different containers is provided in section five. The evaluation of containers made using the suitability criteria is described in section six. The general results of the study and a brief discussion of its implications are provided in section seven. The section on conclusion and recommendation summarises the findings of the study.

2. REVIEW OF PAST STUDIES ON CONTAINERS

Early trials with containers in forest nurseries started way back in 1930's with 'Donas' (leaf cups) from India (Mathur. 1951) and Tar paper pots from USA (Strachan, 1974).Since then, a number of materials such as brick pots, containers made from different plant leaves, metal tubes, veneer pots, bamboo tubes and baskets, wood boxes. moss and cylinder tubes were tried as containers (Champion and Seth, 1968;Khanna. 1984; Evans, 1992; Naik 1993; Josaih and Jones, 1992). In 1960'spolybag containers came to the forefront and they replaced almost all other containers in tropical countries (Champion and Seth, 1968; Dwivedi, 1992). In the meantime, considerable amount of studies were also carried out in countries such as USA, Canada, Swedan, Denmark, Norway to develop tree seedling containers capable of producing quality planting stock (Hulten, 1974; Hallman, 1974; Vyse and Ketcheson. 1974).Consequently a variety of containers called root trainers and paper pots have emerged (Tinus *et al.,* 1974; Hoedemaker. 1974; Landis *et al,* 1990; Josaih and Jones, 1992). These containers, by and large, are made of plastic or paper pulp and have better facilities for development of healthy root system, efficient storage and release of nutrients, air, water, temperature and light: physical and mechanical support to the stock; handling and transportation as well as mechanisation of nursery and planting activities.

Extensive studies were also made in the past on aspects such as principles of containerisation (Kinghorn. 1974; 1978; McGuire, 1974; Stein, 1974; Spencer, 1978; Fayle, 1978).the role of containers in effective use of potting media (Tinus and McDonald, 1979).fertilizers, imgation, nursery cultural practices and planting methods and influence of containers on tree root form (Brix and Driessche, 1974:Eerden and Arnot, 1974; Goodwin. 1974; Phipps, 1974; Hahn and Hutchinson, 1978; Leaf *et al.,* 1978; Chavasse, 1979; Stone and Norberg, 1979; Grene, 1979; Hagner, 1979: Landis *et al.,* 1990).Another area which received attention was realisable upper limits of seedling growth and the strategies for achieving this (Larson, 1974).There were also studies for identifying other factors influencing choice of containers such as availability and cost of containers, familiarity and easiness in use. and eco-friendliness.

The spurt in forest plantation activities occurred during 1960's have resulted in more worldwide attention on production of containerised planting stock. In 1986, Wilson published an article on appropriate root trainers for tropical countries (Wilson. 1986). A number of seminars and symposia were organised in this period on containers used in forest nurseries (Tinus *et al.*, 1974; Eerden and Kinghorn. 1978). Currently in US, the association of nursery specialists have been holding annual meetings to discuss different issues on containerised planting production (Landis *et al.*, 1993;1994). Josaih and Jones provides detailed account of root trainers and their role in enhancing productivity of forest plantations in the tropics (Josaih and Jones, 1992). In India, though. various issues related to containers were being discussed in silviculturists' conferences, containerisation is yet to get adequate attention in forest management.

3. GENERAL METHODOLOGY

The identification of a viable container requires a holistic approach taking into consideration the various container alternatives available and lhe different factors involved in their totality. To facilitate this, a systems approach as envisaged in Operations research (Ackoff and Sasieni. 1968) was adopted in this study. This approach attempts to consider the various aspects of the problem under investigation from a systems perspective by looking at it from a multi-disciplinary and trans- disciplinary angle. To enable this, proper definition of the problem, the identification of the various components involved and their interrelationship are made through a system analysis. The components are then subjected to detailed study. The results obtained are then integrated by taking into consideration the inter-relationships among the components to arrive at final conclusions. In such studies, to ensure transparency, objectivity and easiness in analysis and integration of different components, mathematical modelling is used wherever necessary (Taha, 1976).

A system analysis carried out revealed that the problem of finding a viable container alternative to polybag be divided into mutually linked, but at the Same time, independent component problems. They are (1) identification of all important candidate alternatives (2) development of a comprehensive suitability criteria for evaluation of containers under a multi-criteria environment (3)evaluation of different container alternatives identified using the suitability criteria developed and (4) derivation of the results in the form of problems and prospects of different container alternatives along with the most suitable alternative (or set of alternatives) identified based on container evaluation. The following systems diagram will highlight the overall linkage of these four components to the problem under study (Fig. 1). The methodology adopted for individual components is dealt independently in respective sections.

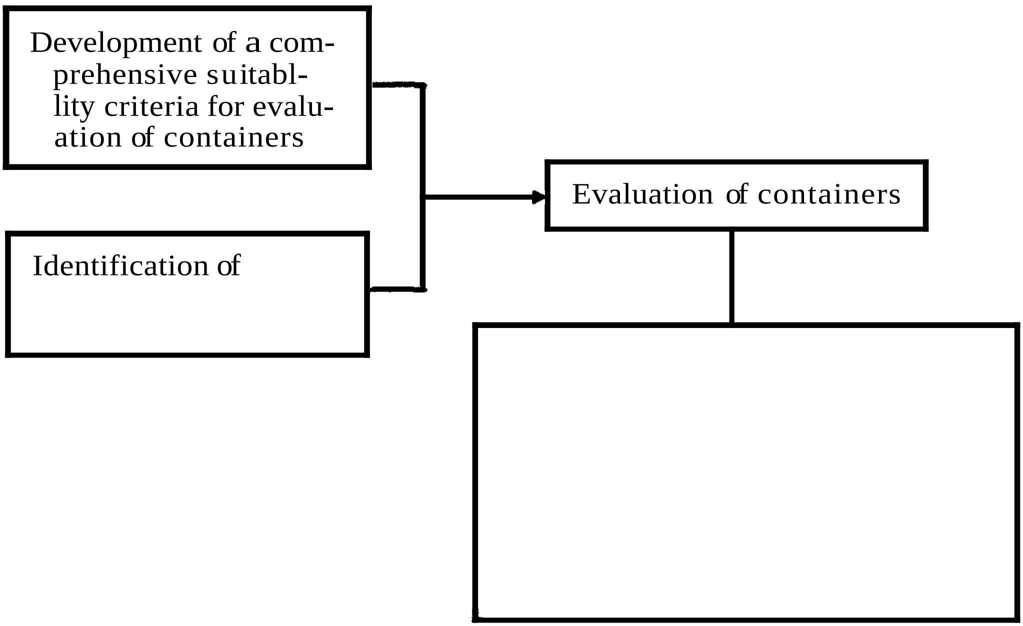

Fig.1 The system diagram indicating overall system components involved in identification of alternative containers

4. CANDIDATE CONTAINERS FOR EVALUATION

An attempt was made to prepare a comprehensive list of candidate containers that can be considered for use in forest nurseries of Kerala.

4.1. METHODS

A list of candidate containers was prepared based on a general survey of probable materials available in Kerala. This list was augmented based on literature survey of all other containers currently used elsewhere in India and abroad.

4.2. RESULTS

The survey revealed large number of locally available materials as potential candidates. Leaves of different plants such as teak, reed, butea, ficus and curcuma. grasses, mosses, bamboo splits, spathe of arecanut palm, cotton waste, waste paper,PVC pipes, earthern pots, used cups, bottles, cans and bags made from metal, plastics or other materials such as thermocol and coconut shells were the locally available candidates (Plate 1 and 2). A literature survey revealed that these materials were being used in India and other countries for raising forestry planting stock (Champion and Seth, 1968; Shepherd, 1986; Evans, 1992 and Vinod Kumar, 1995). Another important category of containers identified as candidates was the root trainers and paper pots. These containers were found to be widely used in many developed countries in temperate and tropical regions (Aycock, 1974; Arnot, 1974; Stein, 1974; Shepherd, 1986; Wilson, 1986; Landis *et al.*, 1990; Anon, 1993). They were also found to gain popularity in many developing countries in the tropics and were replacing conventional containers and polybags (Venator and Munoz, 1974; Walters, 1974; Tinus and McDonald, 1979; Wilson, 1986; Landis *et al.*, 1990; Josaih and Jones, 1992). **A** variety of root trainers of different types and sizes are available (Wilson, 1986; Landis *et al.*, 1990; Josaih and Jones, 1992)(Plate 3, 4, 5 and 6). A list of rcot trainers currently used in US and Canada is given in Appendix 1. These containers need to be evaluated with the polybags. the containers currently used in the State.

5. SUITABILITY CRITERIA FOR EVALUATION OF CONTAINERS

The containers are used in a nursery, in particular a forest nursery with some objectives and for meeting these objectives, they have to carry out certain functions. To effectively do these functions a container should satisfy some requisites. The suitability criteria developed should facilitate to evaluate the different container alternatives based on their potential to meet these requisites In an integrated manner. It should also help to choose the most suitable container (or set of containers).

5.1. METHODS

The processes involved in the development of a suitability criteria are given in Fig. 2. The details of methods adopted under different components are discussed under respective sections.

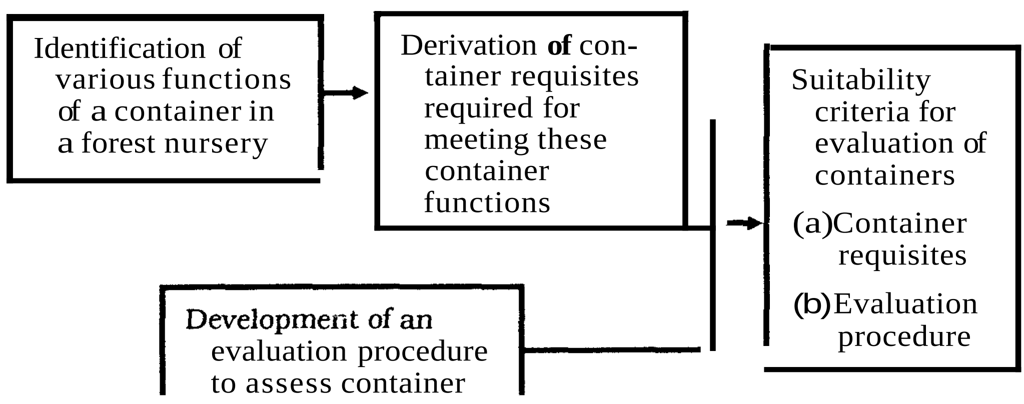

Fig.2. System diagram showing the various processes involved in the development of suitability criteria for evaluation of containers

5.2. THE FUNCTIONS OF A CONTAINER IN FOREST NURSERIES

A clear understanding of the functions that a container has to perform is necessary for identifying its requisites.

5.2.1. Methods

The functions of a container in forest nurseries is a well studied subject (Kinghorn. 1974; Stein, 1974; Tinus and McDonald, 1979; Landis *et al.*, 1990). An effort has been made below to make a compilation of these container functions through a literature review.

5.2.2. Results

The primary function of a container in a nursery is to hold the potting media, nutrients and water required for the plant and also to provide the necessary physical and mechanical support to the planting stock during its life in the nursery and while in transportation to the planting site. The container should also help the potting media to store and release the nutrients. water, air, light and temperature in an optimum manner. It should also provide facilities for producing planting stock with healthy root system. This is essential in ensuring easy establishment, good post planting survival, wind firmness and steady growth for trees. For this, the root system of the planting stock should be free from problems such as root coiling, root strangulation and root deformation and should have a balanced root-shoot ratio and well developed lateral root system with good regeneration potential. In addition to this, a container to be used in large scale forest nurseries should facilitate easy handling of planting stock and also should help in bringing cost effectiveness and eco-friendliness and easiness in nursery and planting practices (Kinghorn, 1974; Stein, 1974: Tinus *et al.,* 1974: Kinghorn. 1978: Persson, 1978).

5.3. REQUISITES OF A CONTAINER

To effectively carry out the functions indicated above, a container has to have certain requisites. A knowledge of these requisites is essential for scientific evaluation of the suitability of a container.

5.3.1. Methods

The required requisites were derived by systematically studying various container functions.

1. Raw material availability and cost

Since raising of forest planting stock is essentially a large scale activity, often large quantity of containers are required every year. To meet these requirements adequate quantity of raw material should be available. While assessing this. the effort and cost involved in its collection, transportation and storage at nursery/container production site before use has to be taken into consideration.

2. Production cost and easiness in large scale manufacture

Taking into consideration the seasonal nature of the nursery work, for timely completion it is essential to get containers of required quantity within the shortest time available. Manufacture of containers in large quantities should be easy to ensure timely availability.

3. Facilities for production of containers of different Sizes in uniform nature

It should be possible to make containers of different size using the material selected. Moreover, there should be uniformity among containers of any particular size category so as to ensure standardisation of nursery practices.

4. Facilities such as strength, durability, lightness in weight and capacityfor resistance to mot shock .

To make handling of containers cost-effective, the containers should be light. They should be strong and durable to hold the plant during its life in the nursery. To resist shocks to the seedlings due to warping or squeezing of containers that may occur while handling in nurseries or during transportation, container wall should be rigid or semi-rigid. While the container should have sufficient size (volume) to carry the potting media and to provide physical and mechanical support to the plant, it should be as small as possible to enable easy handling and to reduce transportation cost. To avoid difficulties in handling the container should not have rough edges.

5. Facilitiesfor regulating

The nursery stock requires specific moisture regime to ensure good growth. The container should have facilities to regulate moisture regime to ensure uniform supply of water to the plant in required quantity. Container features such as wall permeability, volume, size, shape and drainage facility control moisture regime.

6. Facilities for regulating temperature and light

The containers should regulate supply of temperature and light to the plant. In addition to the various mechanisms to regulate moisture, container colour also influences the supply of light and temperature.

7. Facilities for regulating aeration

Good aeration is essential for plant. The container size and shape regulate air supply.

8. Facilities for efficient nutrient storage and supply

The timely and efficient supply of nutrients is one of the essential requisites for plant growth and hence, the container should have facilities for efficient storage and release ofnutrients. This, apart from container material and type is also dependent on the quality of potting media. It is also linked to the facilities available in the container for efficient storage and release of moisture, air and temperature. The container features such as size and shape (height/diameter) influence its potential on these aspects.

9. Biological inertness

To prevent incidence of pests and disease, the container should not act as feeding ground and courtyard for insects and pathogens. To enable this, the container should be biologically inert.

10. Chemical inertness

It should be chemically inert so that it will not release any toxic substance which are harmful to the plant or environmentaly hazardous in nursery or in the planting site.

11. Facilities for development of healthy mot system

The container should promote development of healthy root system. Root coiling, root deformity, root strangulation. improper root shoot ratio,lack of development of lateral roots and consequent inability in post planting root growth potential are some of the ill effects of conventional containerisation in tree seedling nurseries (Wilson, 1986; Dwivedi, 1992; Evans, 1992).These problems affect the growth of stock not only in nursery but also after planting. Poor post planting survival, lack of wind firmness and low productivity of plantations occur due to poor root system (Wilson, 1986: Josaih and Jones, 1992).The container chosen for forest nurseries should have features to minimise these ill-effects.

12. Availability of know how of use of Container

The know-how for use of containers should be readily available. This includes information on suitable type and size of containers required for different species and site conditions. It also includes information on appropriate potting media, fertilizer and imgation schedule and other associated cultural practices.

13. Familiarity and easiness in use of container

The container should be easy to use by the nursery staff and the skill required should be minimum. This is very important especially for third world countries where the workers currently involved in nursery work are mostly unskilled.

14. Facilities for easy filling of potting media

The container should facilitate easy filling of potting media as it will help in reducing cost and labour.

15. Facilities for easy removal of stock from container

At the time of planting, the planting stock is taken out of the container so as to ensure easy contact of the root system with soil. The container should be removable without causing serious shock to the root system. In the case of seedlings which are planted along with container, the container should be easily degradable.

16. Facilities for making nursery and plantation activities easy

Container should help in making nursery management and planting activities easy.

17. Facilities for disposal of used containers

Disposal of container waste should not be a serious problem.

18. Overall cost effectivness

The container should be cost effective. While calculating cost- efficiency of a container, apart from the cost of the container, its contribution at various stages of growth and development of trees from nursery to mature tree in a plantation should also be taken into consideration.

5.4. EVALUATION PROCEDURE

As these requisites make conflicting demands on the container, it is necessary to arrive at a compromise solution taking into consideration the various aspects involved in their totality. The evaluation procedure selected should be able to do this in an objective manner. An attempt was made to develop an evaluation procedure to suit this purpose.

5.4.1. Materials and methods

To facilitate evaluation, the first task is to group the containers into homogeneous categories. This is necessary due to the large number of containers invoked.

The container selected has to satisfy each of these requisites at least to a certain minimum level as otherwise it may not be able to function as a good container. To decide this, the container has to be evaluated in absolute terms with respect to each requisite to ensure that they satisfy the basic needs. Once this is satisfied, the relative potential of different containers needs to be evaluated with respect to each requisite by comparing them. The evaluation procedure chosen should also help in assessing the potential of containers and comparing them in an overall perspective so as to select the most suitable one.

The information regarding the merits and demerits of different containers with respect to each requisite required for evaluation of containers can be obtained by (a)compiling available information through survey of literature and other unpublished information sources and by (b)generating additional information required through field experimentation.

Absolute evaluation of containers can be made by assigning them with scores highly unsuitable, moderately unsuitable, moderately suitable and highly suitable.

To assess the comparative performance, the container categories can be arranged in their relative order of suitability with respect to each requisite.

The next task is to make an integrated analysis of containers taking into consideration all the requisites considered in their totality. For brevity and easiness in comprehension the scores assigned can be replaced with '++', '+', '-', '--', '=' and '>' respectively for highly suitable, moderately suitable, moderately unsuitable. highly unsuitable, same as and more suitable to get a matrix highlighting the scores for different categories of containers for each requisites. Though a number of methods are available to carry out an objective evaluation of alternatives under a multi-criteria environment (Cochran and Zeleny, 1974; Zeleny, 1974; Rao, 1984). taking into consideration the difficulties involved in quantifying the relative importance of different requisites, the method of subjective evaluation is chosen in this study.

5.5. THE SUITABILITY CRITERIA – THE GENERAL RESULTS

Container requisites

1. Raw material availability and cost
2. Production cost and easiness in large scale manufacture
3. Facilities for production of containers of different sizes in uniform nature

4. Facilities such as strength. durability, lightness in weight and capacity for resistance to root shock
5. Facilities for regulating moisture
6. Facilities for regulating temperature and light
7. Facilities for regulating aeration
8. Facilities for efficient nutrient storage and supply
9. Biological inertness
10. Chemical inertness
11. Facilities for development of healthy root system
12. Availability of knowhow of use of container
13. Familiarity and easiness in use of container
14. Facilities for easy filling of potting media
15. Facilities for easy removal of stock
16. Facilities for making nursery and plantation activities easy
17. Facilities for disposal of used containers
18. Overall cost effectiveness

Evaluation procedure

The evaluation procedures of containers involves the following steps.

1. Categorisation of containers into homogeneous categories to facilitate easy evaluation.
2. Evaluation of container categories in absolute term by assigning scores highly suitable, moderately suitable, moderately unsuitable and highly unsuitable based on information gathered through literature survey and field experimentation.
3. Comparative evaluation of container categories using the information obtained under Item 2. Ordering of container categories based on suitability.
4. Development of a matrix containing scores for different categories of containers with respect to each requisites by replacing the scores highly suitable, moderately suitable, moderately unsuitable, highly unsuitable, 'same as' and more suitable with '++', '+', '-', '--', '=' and '>' and integrated evaluation of container categories based on subjective analysis of scores.

6. EVALUATION OF CONTAINERS

In this section an attempt is made to evaluate the various candidate containers identified in section four using the suitability criteria evolved under section five.

6.1. METHODS

The systems diagram provided (Fig. 3) will highlight the processes adopted in the evaluation of containers. An assessment of forest nursery scenario in Kerala, with respect to container use was made to have an idea about the

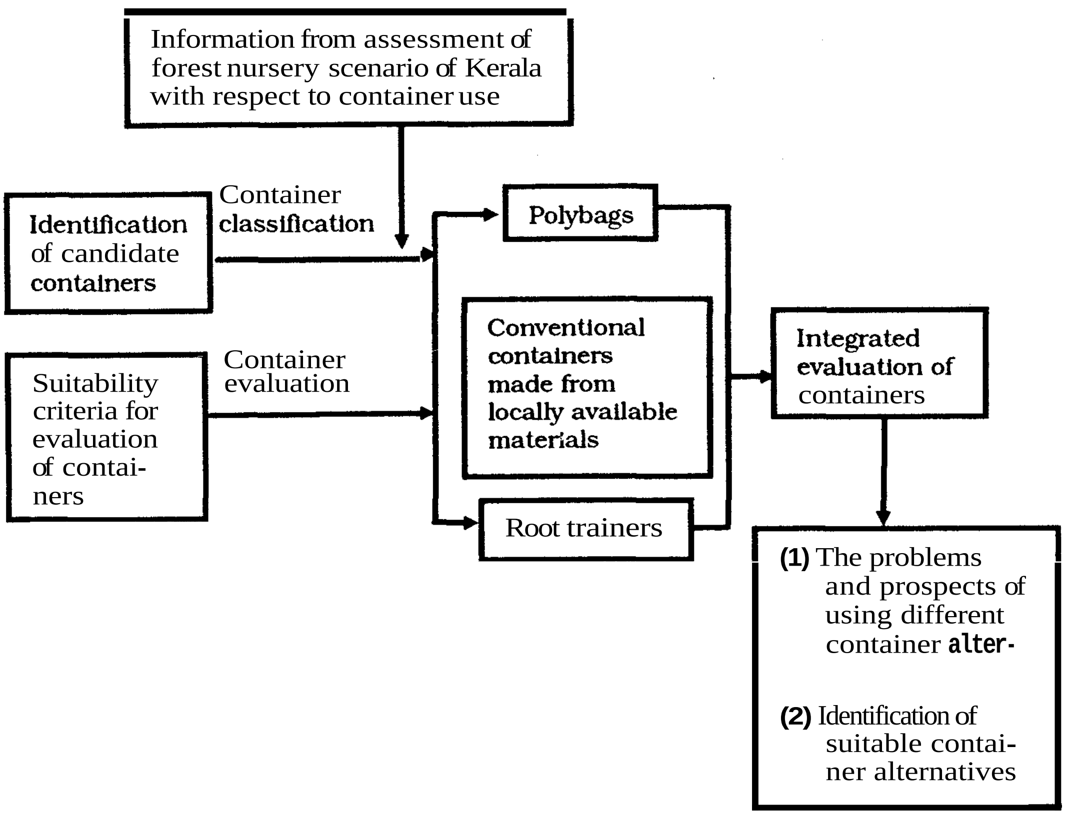

Fig.3. System diagram indicating the processes involved in evaluation of containers

range of values for each of the container requisites required in the State. To minimise the complexity in evaluation, the different candidate containers were classified into three broad categories (a) polybag, the presently used container (b) conventional containers made from locally available materials and (c) root trainers. Each container category was then subjected to separate detailed evaluation, for its absolute potential to meet different individual requisite. The relative potential of container categorfes was also made with respect to each requisite. The information thus obtained was utilised for making an integrated evaluation of containers.

6.2. FOREST NURSERY SCENARIO OF KERALA

The present forest nursery scenario of Kerala is briefly discussed with reference to container use.

6.2.1. Methods

An assessment of forest nursery scenario of Kerala was made with respect to container use and associated nursery practices. Survey of published and unpublished records of State Forest Department. visits to different forest nurseries and discussion with forest officials, etc., were carried out to gather the necessary information.

6.2.2. Results

A perusal of records of State Forest Department revealed a total production of about 900 million seedlings during the last decade under its various programmes. In this 623 million seedlings were produced for supply to farmers (Basha, 1991). About 46,460 ha plantations were raised under Social Forestry. With the termination of first phase of World Bank aided Social Forestry Programme there has been a decrease in production of seedlings for supply to farmers and the current production level is only 15-20 million/annum. Information on actual requirement of planting stock is lacking. However, taking into consideration the renewed interest in tree planting in homesteads, marginal lands, degraded forests and plantations. average total annual requirement can be expected to be over 50 million in the State.

At present, seedlings of four months to two years and having a height ranging from 30 cm to about 2m are used for planting in the State. The age and size used vary depending on species and site requirement (Govindankutty and Alavikutty, 1988; KFD. 1989). The container size recommended for use by Kerala Forest Department varies from 12 cm x 18 cm x 150 gauge to 20 cm x 30 cm x 400 gauge with a container volume ranging from 650 cm^3 to 3010 cm^3, though in some instances containers of smaller size were also used. Before use, the polybag is given with four holes (double punch) to facilitate drainage. The potting medium consists mainly of soil mixed with sand and farmyard manure (or cowdung) in a ratio of 3: 1:1 having an average weight of 1.5kg/1000 cm^3. Seeds are the main source of propagule. Except for species with minute seeds such as Eucalyptus and Casuarina seedlings are grown by direct dibbling in container. In other cases seeds are sown in seed bed nurseries for germination and later transferred to polybags. The polythene bags are shifted in the nurseries at an interval of 2-3 weeks to avoid roots egress through the bag into the soil below.

Watering is normally done on non-rainy days twice daily for the first 30 days, once daily for the next 15 days and once in alternate days for the subsequent 30 days for the seedlings to be planted in the same year. In the arid and semi-arid regions, watering once in a day is extended upto 45 days and that of alternate days increased upto 75 days. In the case of seedlings intended to be planted in the second year, additional watering of once in 3 days is provided for a maximum of 60 days in the second year. The maximum recommended water per plant is 200 cc (Banerjee, 1987; Govidankutty and Alavikutty. 1988; KFD, 1989). As a standard practice no fertilizer is applied and so the seedlings have to depend on the potting medium for nutrients.

The nursery and planting practices are labour intensive and at present there is no mechanisation in the State to carry out these activities. The labour engaged in nursery activities are mostly un-skilled or semi-skilled. Scientific information with regard to the age and size of stock required for planting, the container size, composition of potting media, nutrient and water requirement and other cultural practices are lacking. The practices currently followed are based on thumb rules evolved from general experience and not on the basis of any systematic scientific study.

The seedlings are transported to planting sites through lorries or by head load depending on requirement. The polybags are removed at the time of planting and discarded at the planting site.

A perusal of forest department files indicate that the cost of container constitutes 2-10% of the total plantation cost (upto one year of planting).

6.3. EVALUATION OF POLYTHENE BAGS

As mentioned earlier polythene bags are the currently used containers in most of the forest nurseries of the developing countries, and India in particular. Though bottomless polythene tubes are also used in northern part of India, taking into consideration the difficulties involved in handling and transportation, only closed polythene bags are considered in this study.

6.3.1. Methods

As a container currently used in the State, most of the information required for evaluation is available. This was collected through a survey of published literature, records of forest department and visit to forest nurseries. Based on the information so collected absolute evaluation of containers was made for each requisite.

6.3.2. Results

The results obtained based on evaluation of polybag are given below.

1. Raw material availability and cost

The polybags are made from Low Density Polyethylene (LDPE), a petroleum product and this, to a large extent, needs to be imported from oil exporting countries and so the availability is largely dependent on import facilities from these countries. Assuming an annual requirement of 50 million seedlings, the quantity of polythene required will vary from 76.5 metric tonnes to 555.5 metric tonnes when polybags of 12 cm x 18 cm x 150 gauge and 20 cm x 30 cm x 400 gauge respectively are used. The corresponding costs *vary* from Rs. 4.59 million to Rs. 33.33 million @ Rs. 60/- per kg of raw material. Under normal circumstances there is not much of a problem in meeting this requirement of raw material.

Scope for improvement

There are reports of reuse of polythene bags of higher gauges from Malawi (Evans, 1992). If found possible, this is likely to reduce quantity of raw material required. However, there are problems in removing the root stock without damaging the polybag. There are also problems in the collection of used polybags and their retransportation back to the nursery storehouse for reuse. The use of polybag can be optimised by using polybags of optimum size required for different species and planting site and by ensuring the maximum growth and survival of the existing nursery stock.

Score: Moderately suitable

2. Production cost and easiness in large scale manufacture

There are a quite number of factories manufacturing polybags in the State and it is very easy to produce sufficient quantity of polybag containers within a reasonable time. Production cost at retail price comes to around Rs. 25/- per kg of polybag. (Production cost was calculated by subtracting the cost of lkg of raw material at Trichur, Kerala (Rs. 60/-) from the retail price of lkg of polybag(Rs.85/-).

Score: Highly suitable

3. Facilities for production of containers of different sizes in uniform nature

Being pliable, it is quite easy to make plastic containers of different sizes and shapes. The production is mechanized and *so* it is easy to ensure uniformity in size and shape of container in a desired dimension.

Score: Highly suitable

4. Facilities such as strength, durability, lightness in weight and capacity for resistance to mot shock

Polythene bags are quite light in weight. The containers currently in use weigh only 1.52 g (for 12 cm x 18 cm x 150 gauge) to 11.27 g (for 20 cm x 30 cm x 400 gauge) per container. They are being used to grow seedlingsupto 2m in height and for a period of about two years and so are strong and durable for normal nursery requirement. However, since container walls are not rigid, often the polybag nursery stock is susceptible to shock due to warping, squeezing and jerking which happens during handling in nursery and during transportation to planting site. To minimise this, and to provide adequate physical support to stock, containers of sizes larger than normally required are used. This increases container weight. The weight of container with soil for polybags of currently recommended dimensions comes to lkg to 4.5kg which is much higher than what is normally required when rigid walled containers with specially prepared artificial potting media are used. Many experts are of the opinion that by use of modem containers (withrigid walls) with superior potting medium, a volume of about 150 cm^3 is sufficient for tropical nurseries (Venator *et al.,* 1974: Josaih and Jones, 1992).Even if. a container of double this volume i.e.. 300 cm^3) is assumed to be required, the weight will be only 450gm which is only half that of the smallest polythene bag container currently used (12cm x18cm x 150 gauge). Though container walls are strong enough to hold the potting medium, often the roots of polybag seedling penetrate through the bottom of polybag and strike the ground below causing damage to the stock while being taken out for planting. This necessitates the practice of shifting of polybags in nurseries which adds to the labour cost, though this opportunity is generally used for grading the seedling. The polybag has no rough edges and is easy to handle.

Scope for improvement

Use of containers of optimal size and artificial potting media can reduce container weight.

Score: Moderately unsuitable

5. Facilities for regulating moisture

When soil is used as potting medium, due to the pot bound nature of polybags, often perched water table is formed, with upper portions of the container having periodic drought and heat stress while the bottom half suffering periodic water-logging condition. This is aggravated when the potting medium used is clayey soil and when the drainage facility in terms of number of well spaced holes is inadequate. This results in a very unhealthy condition for the plant. Moreover, because of the large size of container often there is considerable wastage of water due to transpiration loss. This problem was also observed by Wilson (1986).

Scope for impmvement

Careful choice of container dimension (height), provision for sufficient number of holes on polybags, use of potting media with good drainage, careful and regulated watering, taking into consideration the species requirement and nursery conditions can help in regulating moisture.

Score: Moderately unsuitable

6. Facilitiesfor regulating temperature and light

By use of polybags of appropriate colour the light and temperature availability can be controlled to a considerable extent. However, the pot bound nature of polybag causes lack of aeration at bottom and problems of moisture regulation which in turn adversely influence temperature control in polybag containers.

Scope for improvement

Choice of polybags of appropriate colour taking into consideration the requirement of light and temperature for different species and other nursery conditions and various other measures to regulate moisture and aeration will help in minimising the difficulties.

Score: Moderately suitable

7. Facilities for reguIating aeration

Lack of facilities for aeration can often be a problem with polybag containers. The closed bottom of the bag coupled with unaerated soil media and water-logging conditions often create poor aeration.

Scope for improvement

Provision for adequate number of well spaced holes in polybag, use of well aerated potting media and careful watering to prevent water-logging can reduce the problems.

Score: Moderately unsuitable

8. Facilities for efficient storage and supply of nutrients

Since polybag containers of larger sizes than actually required are used, there is wastage of nutrients as they are not fully available to the plant. Moreover, other factors such as regulating moisture, air, light and temperature also adversely affect the efficiency of root system in optimal utilisation of available nutrients. However, since the container is strong enough to prevent leaching, there is not much nutrient loss.

Scope for improvement

Efficient storage and supply of nutrients can be ensured by enhancing the facilities for regulating air, moisture, light and temperature, and by the use of good quality potting media with sufficient quantity of organic matter and sand.

Score: Moderately unsuitable

9. Biological inertness

Polybags are biologically inert and hygienic. This reduces incidence of attack from insect pests and pathogens.

Score: Highly suitable

10. Chemical inertness

Polybags are chemically inert and no report is available with regard to release of any toxic substances harmful to plant or environment.

Score: Highly suitable

11. Facilities for development of healthy root system

Polybag seedlings are found to be highly susceptible to root coiling because of smooth walls. As the container is closed at bottom very often there is root strangulation and root deformities (Plate 7. 8 and 9). The root coiling also prevents development of lateral roots leading to poor root growth potential (Landis, 1990; Josaih and Jones, 1992; Wilson, 1986: Evans, 1992;

1992: Vinodkumar, 1995).There are also problems in regulating storage and supply of nutrients air, water, light and temperature in polybag which in turn adversely affect the development of healthy root system.

Scope for improvement

Use of containers of appropriate size required for the nursery stock (Plate 10. 11, 12, 13. 14 and 15). provision of sufficient number of holes well distributed on the polybag, use of well aerated potting media, careful and regulated watering, timely removal of stock from container for field planting and direct sowing of seeds in container instead of transplanting from seed bed nurseries will reduce the problems for development of healthy root system to a considerable extent (Dwivedi, 1992).

Score: Moderately unsuitable

12. Availability of knowhow of use of container

In the case of polybag containers it is possible to grow seedlings based on thumb rules available, even though the results realisable are far from optimum. The thumb rule for raising seedlings of different species in polybags are already available.

Score: Highly suitable

13. Familiarity and easiness in use of container

Since nursery practices for polybag nurseries are based on simple thumb rules it is fairly easy to use and it does not require much skill.

Score: Highly suitable

14. Facilities for easy filling of potting media

It takes time to open and fill polybags. Since the container size required is large, it requires more effort for potting.

Scope for improvement

Introduction of appropriate simple machines to fill polybags will reduce the difficulty and will help to enhance the cost efficiency.

Scope: Moderately suitable

16. Facilities for easy removal of stock

The stock can be easily taken out before planting by vertically cutting the polybag. However, careful handling is essential for preventing root shock. Very often due to the difficulty in tearing the polybag, the labourers neglect to remove them from root stock and this causes problems in post plantation survival and growth.

Scope for improvement

There is not much scope for improvement.

Score: Moderately suitable

16. Facilities for making nursery and plantation activities easy

Under normal circumstances polybags are available in large quantities and can be made, brought and stored in the nursery for use without much difficulty. The containers are light in weight, durable and strong and hence various nursery operations can be carried out easily. Since the container is biologically inert, damage to container and to the nursery stock from insect pests and pathogens is minimised. The familiarity with the technology among nursery workers makes nursery and plantation management simpler.

However since polybag nurseries use larger containers, the potting, nursery handling and transportation are costly. It also lowers the efficient use of available water and nutrients. The large container size required limits the number of nursery stock kept per unit area of nursery and this adds to the supervision and amount of labour required for nursery management. To avoid the roots penetrating into the soil after piercing the container the practice of shiftingofcontainer is necessary which again involves labour cost. The problems of moisture, aeration, temperature variation. etc.. which exist in polybag containers can cause higher incidence of nursery diseases. The poor health of tree root system of the stock leads to root diseases as well as reduction in the general health of plant and slow growth rates which in turn will increase nursery gestation time and mortality rate. Poor survival in plantations is another problem that may occur due to deformed root system.

Scope for improvement

Careful selection of container size, potting media, and judicious application of fertilizer, irrigation and other cultural practices can improve the situation.

Score: Moderately unsuitable

17. Facilities for disposal of used containers

The polybag is non-degradable. Every year the used containers are left in the planting site and this on an average comes to the tune of 76.5 metric tonnes in the State. When accumulated over years this can create problems of waste management.

Scope for improvement

Reduction in consumption of polybags is the only option available. This can be achieved to some extent by using containers of optimum size, and by ensuring maximum survival and growth of available nursery stock.

Score: Moderately unsuitable

18. Overall cost effectiveness

Under normal conditions polybags are easily available and can be manufactured locally in large numbers at a reasonable price (less than Re.1/-). They are easy to make and the technology is simple. However the nursery stock is heavy (1 to 4.5 kg) and bulky (1000 cm^3 to 3010 cm^3). Consequently, almost all nursery practices starting from filling the potting media, watering, manuring, shifting of containers and grading of seedling in nursery, day-to-day maintenance. transportation to planting site, etc., become cumbersome, less efficient and costly. There is also considerable amount of wastage of nutrients and water. The pot bound nature and the smoothness of container poses difficulties in regulating light, temperature and aeration and also leads to problems of root coiling and lack of proper root growth. This in turn results in slow growth of seedlings in nursery, leading to long nursery gestation time, increased costs for pest and disease control and other nursery management practices. The nursery stock with deformed root system affects not only in post planting survival but also in overall growth and development of trees. These trees are often wind prone resulting in increased mortality in plantations. This results in failure to realise the potential productivity and associated returns. Thus overall cost- effectiveness of polybag container is much lower than what is possible by using some of the modern containers. Though quantitative data to substantiate this are very meagre in India, studies conducted in various other countries have proved this (Josaih and Jones, 1992).

Scope for improvement

The above dements of polybag can be minimised to some extent by use of containers of optimum size, use of suitable well aerated and porous artificial potting media, regulated and judicious watering and fertilizer application and timely removal of planting stock for planting. However, there is difficulty in solving problems arising out of the smooth, thin and flexible container walls and pot bound nature of polybag containers.

Score: Moderately unsuitable

6.4. CONVENTIONAL CONTAINERS FROM LOCALLY AVAILABLE MATERLALS

As discussed in section 4, a large number of materials appear as candidates in this category of containers. However, materials such as used cups, tubes, bottles, cans and bags can be deleted at the outset as it will not be possible to get them in sufficient quantities in uniform size as required for a forest nursery. Availability of required quantity of banana leaves at a reasonable price at nursery site will be a problem in Kerala as they are used for many other purposes. The coconut shell will not be suitable as it is too small to raise forestry seedling required under Kerala condition. Earthern pots and PVC pipes are also costlier and cannot be used on a large scale in forest nurseries. Due to the high cost involved in basket making, bamboo baskets are also omitted from the list. Thus the list of promising candidates is reduced to forest plant leaves/grasses. bamboo splits, spathes of arecanut palm and used cement bags and gunny bags.

6.4.1. Field experimentation

Though containers made from these materials were used in the past, no documented information is available with regard to their durability, the production cost of container as applicable to the present condition, and survival of nursery stock, which are quite important in deciding their suitability. To generate this information it was decided to carry out field trials.

In forests, leaves of a large number of plants including trees as well as grasses appear suitable for making containers. However, while conducting field trials, it is necessary to bring down the number. To enable this, it was decided to choose the representative and most potential ones. Teak and reed leaves, being the most commonly available and having all necessary characteristics for making containers were chosen to represent this category.

Thus teak and reed leaves, bamboo splits. spathe of arecanut, used plastic cement bags and gunny bags were considered for field trials. Polythene bags of the largest sizes recommended by Forest Department for use in Social Forestry were used as control. Switenia mahagony a forest tree species which is commonly used for planting in Kerala was chosen as species to be tried.

6.4.1.1. Methods

About 100 containers each of teak leaves, reed leaves, bamboo splits, spathes of arecanut, cement bags and gunny bags were made and were planted with *S. mahagony*, in June 199 1. Polybags of 20 cm x 30 cm x 400 gauge were used as control. For calculation of cost of production of containers, to account for the reduction in cost that may occur when produced in masses, a conservative guestimate was made using the actual production cost for 100 containers.

6.4.1.2. Results

Tables 1, 2, 3 and 4 gives details regarding actual cost of production of different containers, conservative guestimate on production cost of

Table 1. Actual cost of production of different containers (100 numbers)

Container type	Collection charges [labour in man days] (for 100 containers)	Production cost [labour in man days] (for 100 containers)	Total man days (for 100 containers)	Cost per container Rs.**
Teak leaves	0.5	1.5	2.0	1.00*
Red leaves	0.5	1.5	2.0	1.00
Spathes	1.0	2.0	3.0	1.50*
Used gunny bag	-	-	-	2.10
Bamboo splits	2.5	3.0	5.5	2.75*
Plastic cement bag	-	-	-	1.60
Polythene bag (12 cm x 18 cm x 150 gauge)	-	-	-	0.13+
Polythene bag (20 cm x 30 cm x 400 gauge)	-	-	-	0.96+

* No material cost is included. ** A wage rate of Rs. 50/- is assumed for calculating cost (the forest schedule of rate at Peechi in January 1996 rounded to rupees). + The cost/container Rs.85/- per kg.

Table 2. Conservative guestimate on cost of production of different containers when produced in masses

Container type	Collection charges [labour in man days] (for 100 containers)	Production cost [labour in man days] (for 100 containers)	Total man days (for 100 containers)	Cost per container Rs.**
Teak leaves	0.2	0.8	1.0	0.50*
Reed leaves	0.2	0.8	1.0	0.50*
Spathes	0.5	1.5	2.0	1.00*
Used gunny bag	-	-	-	2.10
Bamboo splits	1.0	2.0	3.0	1.50*
Plastic cement bag	-	-	-	1.60
Polythene bag (12 cm x 18 cm x 150 gauge)	-	-	-	0.13+
Polythene bag (20 cm x 30 cm x 400 gauge)	-	-	-	0.96+

* No material cost is included. ** A wage rate of Rs. 50/- is assumed for calculating cost (the farest schedule of rate at Peechi in January 1996 rounded to rupees). + The cost/container Rs.85/- per kg.

Table 3. Percentage degradation in different container types

Container type	1month		2month		3month		4month		5month		6month		9 month		12 month	
	Partial	**Full**	Partial	**Full**	Partial	**Full**	Partial	**Full**	Partial	**Full**	Partial	**Full**	Partial	**Full**	Partial	**Full**
Teak leaves	8	-	12	11	57	43	-	100	-	-	-	-	-	-	-	-
Reed leaves	6	1	17	9	44	56	-	100	-	-	-	-	-	-	-	-
Bamboo splits	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spathe	-	-	-	4	12	8	21	17	36	43	-	100	-	-	-	-
Gunny bag	-	-	-	-	-	-	16	3	19	7	23	19	39	42	-	100
Plastic cement bag	-	-	-	-	-	-	-	-	-	-	-	-	6	-	15	-
Polythene bag	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-

Table 4. Percentage of seedlings survived in different containers

Container type	1 month	2 month	3 month	4 month	5 month	6 month	9 month	12 month
Teak leaves	85	70	54	20	-	-	-	-
Reed leaves	87	75	58	18*	-	-	-	-
Bamboo splits	83	80	78	72	65	60	55	51
Spathe	86	82	80	71	53	22	6*	-
Gunny bag	88	78	75	61	48	36	18	4*
Plastic cement bag	94	92	90	89	86	85	83	80
Polythene bag	98	96	95	93	92	90	88	85

* These seedlings were rooted at soil below the container and so survived even without container.

containers when mass-produced, the durability of different containers and survival of plants in these containers.

6.4.1.3. Discussion.

Table 1 and 2 shows that the cost of production of conventional containers is almost two to four times higher than that for polybags. More than one lakh man days are required just for collection of raw material for making 50 million containers and the required labour charges for this will be around Rs. 5 million. The requirement of labour indicates that it will be quite difficult to get adequate seasonal labour required for making the containers of these materials in large quantities as required for forest nurseries. Table 3, highlights the short durability of these containers, especially plant leaves. Within four months all these containers get degraded indicating that they cannot be used in large scale forest nurseries. The data on survival (Table 4), reveals the high amount of mortality that is likely to occur when these containers are used. This reduction in survival is mainly due to the high incidence of pests and diseases. This occurs as the containers attract insects and microorganisms.

The results vbtained for teak and reed leaves, by and large. can be extended to other forest plant leaves and grasses also.

6.4.2. Evaluation of conventional containers made from locally available materials

The data obtained from above experiment in conjunction with the information gathered from different sources are utilised for evaluation of these containers.

1. Raw material availability and cost

Though leaves of forest plants, trees and grasses are available in adequate quantity in forest areas, the labour and collection charges involved make them highly uneconomical. These materials are easily perishable and so storage of raw materials for more than two or three weeks may create problems. Hence, the collection of these materials has to be made almost at the same time throughout the State. This will require good amount of seasonal labour, the timely availability of which is difficult. In the case of bamboos, though the material is available in forest areas and in some of the homegardens, the demand for other end uses is high. The retail price of good bamboo from homesteads varies from Rs.50/- to more than Rs.l00/-, though at present they are sold from the forest at a much cheaper rate. Moreover, there is a difficulty in meeting the demand for bamboo from the existing industries and so it may not be easy to make them available in large quantities for making containers.

Scope for improvement

Centralised collection and preservative treatment for storage may reduce problems but this needs further investigation.

Score: Moderately suitable

2. Production cost and easiness in large scale

The manufacture of conventional containers from locally available materials such as plant leaves. bamboo splits and spathe is highly labour intensive.

The details of labour requirement for making these containers is provided in Table 1. Taking into consideration the labour required within the short time involved, manufacture of these containers to meet the large scale requirement of forest nurseries in the State will be difficult.

Scope for improvement

. Mechanised production may solve this problem but this needs investigation.

Score: Moderately unsuitable

3. Facilities for production of containers of different sizes in uniform nature

Since these containers are made manually it is very difficult to make containers of uniform size. This can cause inconvenience in standardisation. Also the possibility for making containers of different size and shape is limited.

Scope for improvement

The possibility of producing uniform containers of different size through mechanisation needs investigation.

Score: Moderately unsuitable

4. Facilities such as strength, durability, tightness in weight and capacity for resistance to mot shock

Except bamboo, all the other materials are light in weight. However as these containers are not rigid, to ensure protection of nursery stock from handling damage, containers of bigger size than actually required are needed requiring more potting medium. Thus. in effect the container stock is very bulky and heavy. Durability of containers as indicated in Table 2 is quite short for teak and reed leaves which can be applicable to all forest plant leaves and grasses Due to interaction with water and soil their strength also get deteriorated quickly. These containers cannot be used far more than two to three months. Bamboo is strong and durable but is heavy and inconvenient for handling.

Scope for improvement

Preservative treatment of containers may increase durability but its cost effectiveness needs further investigation.

Score: Highly unsuitable

5. Facilities for regulating moisture

The facilities for regulation of moisture storage and suppIy are very poor in these containers. Often water drains out through the container without any control. Problems of excessive transpiration also exist. In containers made of spathes of arecanut or bamboo splits the situation is often the other way round leading to water-logging.

Scope for improvement

Treating the material used for making containers with preservative treatments and mechanised production may improve the quality of container but this requires more investigation.

Score: Highly unsuitable

6. Facilities for regulating temperature and light

Facilities for regulation of temperature and light are very poor. Since the container is often not transparent, light supply to the container is cut off. Similarly there is difficulty in regulating temperature also.

Scope for improvement

Treating the material used for making containers with preservative treatments and mechanised production may improve the quality of container but this requires further investigation.

Score: Highly unsuitable

7. Facilities for regulating aeration

The facility available for regulating aeration is often not sufficient in these containers especially in the case of bamboo splits, spathe of arecanut, etc.

Scope for improvement

Treating the material used for making containers with preservative chemicals and mechanised production may improve the quality of container but this requires more investigation.

Score: Highly unsuitable

8. Facilities for efficient nutrient storage and supply

The facilities for storage and supply of nutrients are not adequate as the containers start deteriorating within a month. As the container wall is often not in a position to check leaching there will be nutrients loss.

Scope for improvement

Treating the material used for making containers with preservative treatments and mechanised production may improve the quality of container but this requires more investigation.

Score: Highly unsuitable

9. Biological inertness

These containers in general attract pests and diseases, which in turn attack the nursery stock reducing their survival. The survival rates shown in Table 3 indicate high mortality due to the incidence of pests and diseases.

Scopefor improvement

Application of pesticides and fungicides and other control measures can reduce the loss. but, this will incur additional expenditure.

Score: Highly unsuitable

10. Chemical inertness

All these containers listed for evaluation are chemically inert and there is no report regarding the release of toxic substances.

Score: Highly suitable

11. Facilities for development of healthy root system

The conventional containers made of local material have no specific mechanism to prevent root coiling, root strangulation, root deformation and lack of lateral root development and so the container stock suffers from all these defects as in the case of polybags. This will adversely affect proper development of healthy root system. Very often roots egress through container and get anchored in soil below and this results in considerable damage to root system when taken out for planting. The loss of materials, difficulties in regulation of air, moisture, temperature and light and the high incidence of pests and diseases by using such containers make the root system unhealthy.

Scope for improvement

Treating the material used for making containers with preservative treatments and mechanised production may improve the quality of container but this requires more investigation.

Score: Highly unsuitable

12. Availability of knowhow of use of container

In conventional containers as in the case of polybag, it is easy to grow seedlings based on thumb rules, currently available. Know-how for this is available, though the overall productivity is quite low.

Score: Highly suitable

13. Familiarity and easiness in use of container

These containers are quite easy to use. Not much skill is needed to use the container as the method of growing the stock in these containers are based on simple thumb rules.

Score: Hlghly suitable

14. Facilities for easy filling of potting media

Large container size required to be used demands more labour for filling. However, filling of potting media in these containers is not difficult as it is easy to open the container, unlike the polybag.

Score: Moderately suitable

15. Facilities for easy removal of stock

The planting stock can be removed easily without root shock by opening the container. However increased effort is required because of the large volume of the container used.

Score: Moderately suitable

16. Facilities for making nursery and plantation activities

Since the raw materials for the containers are locally available one need not depend on import. However, the labour required for the collection, transportation and production of these containers can cause difficulties in timely execution of nursery activities. The easily perishable nature of these containers creates problems in storage of containers before use. The containers due to frequent contact with soil and water start deteriorating very fast right from the beginning of use. This is accelerated by the attack of insect pests such as termites. Due to deterioration within a couple of months the potential of the containers to carry out different functions in nursery is seriously affected. This results in problems for handling the containers in nurseries, wastage of water and nutrients and poor survival of plants. The roots of most of the stock pierce through the container and get attached to the soil below causing serious difficulties at the time of removal for planting. As these containers fail to provide the necessary physical support to the nursery stock and potting media, its transportation to planting site also will be quite difficult.

Score: Highly unsuitable

17. Facilities for disposal of used containers

Waste disposal is easy as the containers are biologically degradable.

Score: Highly suitable

18. Overall cost effectiveness

The cost of container is higher than that of polybag. The expenses for potting are high due to the high container volume involved. There is often wastage of water and nutrients. The poor survival of stock results in increased cost per container per survival stock. Since the containers cannot last more than 2 to 3 months. in the case of plant leaves, they cannot be used for raising seedlings. The handling cost make bamboo split containers uneconomical. Moreover, the seedlings which are grown from these containers have also problems such as root coiling, root deformation, improper root-shoot ratio and lack of adequate lateral development of roots. Thus, when taken in the overall perspective conventional containers from locally available material are highly uneconomical for forest nurseries.

Score: Highly unsuitable

6.5. ROOT TRAINERS

All modem containers used for growing forest tree seedlings are included in this category. As such, this category includes paper pots, though they themselves form a separate class as they have no specific mechanisms to shape the root system. However, in this study, thin paper pots are not included because of their limited use in humid climate of Kerala.

A wide variety of root trainers with different characteristics are available. However, as the experience with these containers in India is quite minimal, in this study, they are only considered as a single group for evaluation by taking their general

Though these containers are quite new to Indian conditions, they are being widely used in many other countries and considerable amount of information about their utility is already available. This information was compiled through literature survey for the purpose of evaluation.

6.5.1. Characteristics of root trainers: a literature review

Root trainers are containers specifically designed for growing tree seedlings taking into consideration the various requisites to carry out different container functions in forest nurseries (Landis et al., 1990; Josaih and Jones, 1992).These container systems are, by and large, part of a technology which aims to produce planting stock of superior quality within the shortest possible time by effectively utilising the container volume, potting media, fertilizer, irrigation, different nursery cultural practices, etc., in an optimal manner. Root trainers have got features such as vertical ribs to prevent root coiling: rigid walls to encourage proper shaping of root system as well as to provide mechanical support to nursery stock: opening at bottom with drainage holes to ensure regulation of air, light, temperature and moisture as well as to encourage air pruning. In some cases, they have mechanisms such as coating of cuprous oxide on the inner walls of container to enable chemical pruning and to encourage maximum lateral root growth development with good regeneration potential. In addition to the use of specifically designed containers, root trainer technology also looks into other aspects such as use of artificial potting media much superior to soil, well designed fertilizer and irrigation regime, raised meshed platform to keep the root trainer off the ground so as to provide better hygiene and air pruning facilities and over- roof cover for nursery stock to provide shelter from excessive light, rain and heat.

The container sizes required are, in general, much smaller in volume (often 5 to 8 times smaller than polybagl (Wilson. 1986: Josaih and Jones 1992). This coupled with use of artificial potting media having only half to one third the weight of soil making the container nursery stock very light. This helps in keeping more number of containers/unit area. The cost of filling potting media will also be quite less. Nutrient and water use efficiency is enhanced considerably. The handling and transportation cost are also much less. The smaller volume required, along with facilities available for reusing root trainers helps in reducing the use of plastic. This is further reduced when the plastic is recycled for further use.

As the root system of root trainer grown stock is of high root growth potential, the stock gets established in the planting site at a much faster rate with early subsequent growth. This enhances post planting survival and further growth and development. Since these stocks do not have the ill-effects of unhealthy root system, the trees raised from such stock are more windfirm (Tinus *et al.*, 1974; Tinus *et al.*. 1979; Wilson, 1986: Landis ***et al.***. 1990; Josaih and Jones, 1992).

Since root trainer technology envisages use of containers of smaller volume it is more exacting with regard to potting media, imgation and fertilizer regimes. Various studies conducted in many tropical countries have demonstrated the superiority of different locally available materials such as saw dust, coconut pith, paddy husk and compost as potting media (Josaih and Jones, 1992). However, the combination of potting mixture required varies considerably with respect to species and nursery conditions. This is the same with fertilizers, irrigation regimes and other cultural practices. So to a large extent, the utility of root trainers depends on how best this technology can be adapted to local conditions (Josaih and Jones, 1992).

6.5.2. Trials with root trainers

To explore the possibility of using root trainer technology the following **trials** were conducted.

6.5.2.1. Local manufacture of root trainers

Since root trainers are quite new to India, root trainers of appropriate type are not locally available, though there are some companies which make certain root trainers on a smaller scale. This trial was made to examine the feasibility of making root trainers of different size including cost of production.

Bullet type container, one of the common root trainers was selected as model. Design for **3** sizes were made and moulds were prepared with the help of local manufacturer. About 1000 root trainers of each size were made using these moulds in a local small scale plastic industry.

The details regarding plastic required and manufacturing cost per container for the root trainers tried were given in Table 5. Apart from the variable cost indicated in Table 5, there is a fixed cost for making mould (Rs.5.000/- for one size of blow mould type). There is fairly a good possibility of manufacturing these containers at a reduced price when they are mass produced.

This indicates that the large scale local manufacture of root trainers of desired type at a reasonable cost is possible once the size and type of root trainer required is standardised. In the case of patented models, local production can be obtained through collaboration with those companies.

Table 5. Quantity of plastic required and cost of production of different volume of bullet type root trainer

Container type	Container volume (cm^3)	Weight (gm)	Cost of production (Rs.)
1	78	8.5	0.75
2	105	25.0	2.15
3	260	32.0	2.80

6.5.2.2. Trials for making raised platform

Raised platform is required to keep root trainer stock off the ground. This is to enable airpruning of roots as well as for ensuring better hygienic condition (Plate 16). Attempt was made to explore the possibility of making raised platforms with locally available material. Three types of raised platform were tried. They are (i) steel mesh table top fabricated with angle iron stand, (ii) iron wire mesh table top with bamboo/timber pole stand and (iii) bamboo mesh table top with timber/bamboo stand (Plate 17). While steel mesh table top platform is more or less of permanent nature and will be useful for longer duration, the wire mesh platform and bamboo mesh platform are temporary structures suitable for short term duration. The costs vary depending upon materials used as well as the container size to be used. There is also scope for trying various other designs of platforms using locally available materials.

This indicates that appropriate raised platforms suitable to the container type can be made using locally available materials.

6.5.2.3. Trials with potting media

Trials with potting media have to be made by growing seedlings in different potting media in root trainer. With this objective, a trial was conducted with *Eucalyptus tereticornis* in different potting media made using locally available materials. The following materials were used in different combinations in the trial. They are forest soil. coconut pith, saw dust and paddy husk. In addition to this, potting media such as soil-rite and vermiculite were also included in the combination (Plate 18).

About 50 plants of *Eucalyptus tereticornis* were raised under each combination and their growth performance was evaluated after one month by ranking the seedlings by height growth by visual scoring. The growth performance is given in Table 6.

Table 6. Growth performance of *E.* tereticornis in different potting media after one month (based on visual ranking)

Rank	Potting mix
1	Forest soil
2	Forest soil and vermiculite (1:1)
3	Forest soil and coconut pith (1:l)
4	Forest soil and sand (1:1)
5	Forest soil, sand and paddy husk (1:1:1)
6	Forest soil, coconut pith and vermiculite (1:1:1)
7	Forest soil and paddy husk (1:1)
8	Forest soil, vermiculite, soil rite, paddy husk and sawdust (halfburnt) (1:1:1:1)
9	Forest soil, sand and sawdust (1:1:1)
10	Forest soil, sand, vermiculite, coconut pith and sawdust (1:1:l:1:l)
11	Soil rite, coconut pith, sand and sawdust (1:1:1:1)
12	Forest soil and sawdust (1:1)
13	Forest soil and sawdust (half burnt) (1:1)
14	Forest soil, coconut pith and paddy husk (1:1:1)
15	Soil rite
16	Forest soil, sawdust, paddy husk and sand (1:1:1)
17	Forest soil, sand, coconut pith and paddy husk (1:1:1:1)
18	Forest soil,sawdust and paddy husk (1:1:1)
19	Forest soil, sawdust and soil rite (1:1:1)
20	Forest soil,sand, coconut pith, paddy husk and sawdust

This indicates that the height growth is the best in forest soil, even though various studies conducted elsewhere have clearly demonstrated the superiority of other media used in the combinations (Josaih and Jones, 1992). This might have been due to inadequacy of nutrients, indicating the need for a further study on a comprehensive basis. This also highlights the possible failure that may occur, if we use root trainers, without standardizing other associated components.

6.5.2.4. Trials with irrigation system

Another important aspect while using root trainer is irrigation. Conventional irrigation with rose can is not suitable in this case, due to small container size and higher number of root trainers stored per unit area. Hence the possibility of establishing low cost sprinkler imgation system using PVC pipes and low cost sprinkler nozzle was tried.

This study found that with an amount of Rs.2,400/- (1994 prices), a low cost sprinkler irrigation system capable of providing irrigation to about 20,000 root trainers at a time can be established, provided there is already a pipe water facility. Watering can be done at a much faster rate more efficiently under such system with just one person to supervise the various activities in the nursery.

6.5.2.5. Over roof shelter

A number of locally made over-roof shelter designs can be thought of. A simple over-roof shelter with bamboo/low cost timber frame and thick coloured/white polythene covers which provide shelter for a nursery of 20,000 to 25.000 nursery stock was made at a cost of Rs.3,500/- approximately (1994 prices).

6.5.3. Results of root trainer trials

Root trainer trials, in general, indicate that it is possible to use this technology in Kerala. However, being a more exacting technology, standardsation of root trainer type and size,potting media, fertilizer and irrigation regime and other cultural practices is required. Evaluation of root trainers was made based on the available information.

1. Raw material availability and cost

They are made of plastic and so their availability is similar to that of polybag. However, in this case there is an option for reuse as well as use of recycled plastic obtained from damaged containers and so the available material is put to use in an optimal manner, thus minimising the raw material requirement.

Score: Moderately suitable

2. Production cost and easiness in large scale manufacture

Root trainers are amenable for machine manufacturing and so once the container type, size and shape required are standardised, large scale manufacture is not difficult. Taking into consideration the possibilities for reuse the cost of container per seedling is also reasonable.

Score: Highly suitable

3. Facilities for production of containers of different sizes in uniform nature

Root trainers of appropriate sizes and shapes and uniformity can be made as the raw material to be used is plastic or paper pulp which is pliable.

Score: Highly suitable

4. Facilities such as strength, durability, lightness in weight and capacity for resistance to mot shock

The material used for making root trainers is plastic or polythene coated paper pulp and so the containers are light in weight, strong and durable. They have rigid/semirigid walls or have mechanisms to prevent damage to root system due to shock to the container. So the container volume required will be much smaller than polybag or other conventional containers. Moreover, in root trainers artificial potting media having only half or one third the weight of soil are used and so the overall weight is much less. They are durable and often last for more than 5 years.

Score: Highly suitable

5. Facilities for regulating moisture

Features such as opening at bottom of container to facilitate drainage, slightly tapered shape of container, use of appropriate container size, superior potting media having good waterholding capacity makes regulation of moisture easy. The sprinkler type irrigation system used in root trainer nursery and other mechanisms to regulate air, light and temperature also help in regulating moisture. The small size of container helps in avoiding water loss due to evaporation.

Score: Highly suitable

6. Facilities for regulating temperature and light

Use of appropriate container colour and thickness, other features to regulate aeration and moisture, such as opening of container at bottom, drainage holes, use of well aerated potting media, raised platform and special irrigation schedules help to regulate temperature and light.

Score: Highly suitable

7. Facilities for regulating aeration

Root trainers of desired colour and thickness can be made which will help in regulating light and temperature. Features such as raised platform, opening at bottom of container, well aerated potting media and special irrigation schedules can be used effectively in regulating aeration. In addition to this, mechanisms such as container colour and thickness to regulate light and temperature also help in regulating aeration.

Score: Highly suitable

8. Facilities for efficient nutrient storage and supply

The comparatively small container volume, appropriate shape and frequent supply of nutrients in appropriate quantity help in the easy availability of nutrients in quantity required to the plant. This prevents wastage. The superior quality potting medium used also helps in efficient storage and release of nutrients.

Score: Highly suitable

9. Biological inertness

The raw material used are plastic or polythene coated paper pulp which are biologically inert. The potting medium used is also sterile. The projection system helps to maintain better hygiene thus making container resistant to attack from insect pests and pathogens.

Score: Highly suitable

10. Chemical inertness

The material used in making root trainer is plastic or polythene coated paper pulp and no report on release of toxic substance from these material is available.

Score: Highly suitable

11. Facilities for development of healthy root system

Root trainers have special features like vertical ribs to prevent root coiling. They also have better facilities for regulated supply of moisture, air, light, temperature and nutrients. This helps in reducing problems such as root strangulation, root deformation, improper root-shoot ratio and lack of lateral root development.

Score: Highly suitable

12. Availability of knowhow of use of container

The use of root trainers is quite new with respect to the local species and planting conditions. So there is need to standardise the root trainer type and size, potting media, irrigation and fertilizer regimes.

Scope for improvement

This can be solved through research and development efforts. The development of root trainers, potting media, projection system and organic fertilizers from locally available material can be worked out. It is also possible to standardise the various aspects involved.

Score: Highly unsuitable

13. Familiarity and easiness in use of container

Since the root trainer technology is more exacting, its use requires more care and attention. Hence use of root trainers under the current forest nursery set up in the State where people manning the nurseries are often unskilled, is difficult. However, since more number of stocks (5 to 6 times as that of polybags) can be kept in an unit area and various nursery operations can be handled with simple machines, the entire nursery management can be carried out with a small number of skilled staff.

Scope for improvement

As indicated, this difficulty can be completely sorted out through research and development efforts.

Score: Highly unsuitable

14. Facilities for easy filling of potting media

Since the container volume is much smaller, potting is quite easy. The time required for opening the polybags is also not required for root trainers.

Score: Highly suitable

15. Facilities for easy removal of stock

Root trainers help to develop a nursery stock with firm root plug and so the stock can be detached easily (Plate 19). There are also root trainers (book/sleeve container) which can be opened for periodic examination and removal of stock.

Score: Highly suitable

16. Facilities for making nursery and plantation activities easy

The small container volume required will help in reducing effort involved in potting, nursery handling and transportation. As the number of containers that can be kept per unit area is 5-6 times larger than that of polybags. nursery supervision is easy. The optimal container size also helps in utilising nutrients and water more efficiently as they are fully within the root zone of the stock. Other characteristics such as reduced nursery regime and high survival rate enhance efficiency in nursery and planting activities much. Aspects such as use of superior quality potting media and fertilizer and irrigation regime which follows as an integral part of the technology help in enhancing the efficiency of nursery and planting activities.

Score: Highly suitable

17. Facilities for disposal of used containers

Since the root trainer can be subjected to reuse and recycled use waste disposal problem is minimum.

Score: Highly suitable

18. Overall cost effectiveness

Exact cost data require field trials. However, the available information indicates low overall cost. This includes low container cost/stock (due to reuse and recycled use as well as higher survival rate of stock in nursery) low cost for potting, irrigation, nursery handling, transportation and shorter nursery regime help in reducing nursery management cost. There is also a gain due to high post-planting survival and better growth of trees. The trees grown from such stock will be more windfirm (Wilson, 1986; Landis *et al.*, 1990; Josaih and Jones, 1992).

Score: Highly suitable

6.6. EVALUATION OF DIFFERENT CONTAINERS IN RELATIVE TERMS

1. Raw material availability and cost

A comparative study indicates that plastic is available at a cheaper rate than the various locally available materials such as forest plant leaves, spathes of arecanut and bamboo splits, which require high labour charges for collection and transportation to container production site. This coupled with problems of storage of conventional containers before use, make them less preferable to polythenebags or root trainers. Root trainers can last for 5 to 8 years and so can be used repeatedly during its life time. Also once they are damaged, they can be recycled and used again. So the effective quantity of plastic required will be quite less. There is also possibility of utilising many used materials made of plastic, metal or any other suitable material by recycling them. Also there is a possibility of centralised collection and conversion of plant cellulose material into pulp which can be used for making root trainers. This needs further investigation.

Score: Root trainer 'is more suitable than' polybag, which in turn is' more suitable than' conventional container.

2. Production cost and easiness in large scale manufacture

Large scale manufacture of both root trainers and polybags can be made with appropriate machines and so are superior to conventional containers. As the root trainers can be reused, the manufacturing requirement of these containers will reduce significantly and in this respect root trainers have an edge over polybag. This makes cost per planting stock for root trainers comparatively less than others.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

3. Facilities for production of containers of different sizes in uniform nature

In this regard, root trainer will be the most suitable one as it is possible to make containers of desired shape, especially of rigid nature, followed by polybag, which can also be made in different size and gauge. In the case of conventional container it is often not possible to have containers of desired size and shape and also of uniform nature.

Score: Root trainer is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

4. Facilities such as strength, durability, lightness in weight and capacity for resistance to mot shock

Here again root trainers are at the top of the list due to rigid walls, followed by polybag. Conventional containers come last as they do not satisfy this requirement.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

5. Facilities for regulating moisture

Root trainers have better facilities for regulated supply of nutrients followed by polybag because of their size and shape. Conventional containers have least facility as often the container walls do not prevent nutrient loss due to leaching.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

6. Facilities for regulating moisture

Root trainers have better facility for regulating moisture due to container shape, opening at the bottom and drainage holes. Since the container is small, there is no loss due to evaporation. The potting media used in root trainers have more water retention capabilities and effective drainage facilities. Also the irrigation practices followed under root trainer technology is well suited to optimal use of water. In polybags the facilities are better than conventional containers, though they are inferior to root trainers.

Score: Root trainer 'is more suitable than' polybag. which in turn 'is more suitable than' conventional container.

7. Facilities for regulating temperature and light

Root trainers have got better facility for control of temperature and light. Appropriate colour can be used depending on light requirement. Features such as use of raised platform, facilities for moisture and air regulation will also help in modulating light and temperature better. In polythene bags the facilities are inferior and not adequate. The conventional containers have least facilities and are not suitable.

Score: Root trainer 'is more suitable than' polybag. which in turn 'is more suitable than' conventional container.

8. Facilities for regulating aeration

Root trainers have got better facilities due to its shape, opening at bottom, better potting media and projection system. In polybag facilities are not sufficient. In conventional containers the facility for aeration is the least.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

9. Biological inertness

As they are made of plastic, root trainers are biologically inert. The raised platform used helps to avoid direct contact with soil below. The potting medium used is more sterile. Polybag which is also biologically inert comes next, and the conventional containers which harbour insect pests and pathogens come last.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

10. Chemical inertness

Here, all three categories of containers are similar and there is no report regarding the release of toxic substances from any of these container categories.

Score: Root trainer 'is same as' polybag, which in turn 'is same as' conventional container.

11. Facilities for development of healthy mot system

The most ideal containers for healthy root growth are the root trainer as it has got all the mechanisms for the development of healthy root system. Both polybag and conventional containers do not satisfy these requisites. In conventional containers the root system will be worst affected as explained earlier.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

12. Availability of knowhow of use of container

Polybag are the most familiar and currently used container followed by conventional containers. Root trainer technology is quite new and considerable effort is required to adapt them to local conditions as it requires total change in existing nursery practices.

Scope for improvement

The appropriate root trainer technology can be developed through research and development efforts.

Score: Polybag 'is more suitable than' conventional container, which in turn 'is more suitable than' root trainer.

13. Familiarity and easiness in use of container

Root trainer technology is more exacting and requires more care on container size, irrigation and fertilizer application and other cultural practices. It requires more intensive management. However, the number of root trainer stock that can be handled by skilled labour is much higher than that in the case of polybag. Polybag is the most familiar and easy to handle. It is followed by conventional containers.

Score: Polybag 'is more suitable than' conventional container, which in turn 'is more suitable than' root trainer.

14. Facilities for easy filling of potting media

Root trainers provide better facilities for potting. Quantity of potting medium required is quite less. No time is required for opening the container. Automation is also possible. In polybag, the facilities for automation are limited and more time is required for opening the container. In conventional containers, filling facilities are moderate.

Score: Root trainer 'is more suitable than' conventional container, which in turn 'is more suitable than' polybag.

15. Facilities for easy removal of stock

Root trainers are superior as the stock forms a firm root plug, followed by conventional containers which can be easily opened to take out the stock.

Score: Root trainer 'is more suitable than' conventional container, which in turn 'is more suitable than' polybag.

16. Facilities for making nursery and plantation activities easy

Root trainers are the best because of their easiness in nursery handling and transportation followed by polythene bag. They also help in growing better stock having good post-planting survival and tree growth. In polybag the facilities available are inadequate. Conventional containers are not suited.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

17. Facilities for disposal of used containers

Root trainers are the best as waste is practically minimum followed by conventional containers which are biologically degradable. Polybag, which is non-degradable, takes the last position as large scale use can pose waste disposal problems.

Score: Root trainer 'is more suitable than' conventional container, which in turn 'is more suitable than' polybag.

18. Overall cost effectiveness

OveralI cost effectiveness in root trainers is much higher than that with polybag due to reuse and recycled use of the same, low nursery handling and transportation cost, better nursery stock, shorter nursery regime, better post planting survival and tree growth, and windfirmness of tree. Polybag containers are less efficient. Conventional containers are highly inefficient.

Score: Root trainer 'is more suitable than' polybag, which in turn 'is more suitable than' conventional container.

6.7. INTEGRATED EVALUATION OF CONTAINERS

In this section an attempt is made to carry out an integrated evaluation of containers taking into consideration all the container requisites in totality. To enable this, the results obtained from previous sections have been summarised in Table 7.The number of requisites falling under each category of scores in Table 7 are again summarised in Table 8.

Table 7. The scores obtained for different container categories for various container requisites

Sl. No.	Requisites/Container type	Poly-bag	Con-ven-tional	Root trai-ner	Relative
1.	Raw material avaflabflity and cost	+	+	+	Root trainer > polybag > conventional container
2.	Production cost and easiness in large scale manufacture	+		+	Root trainer > polybag > conventional container
3.	Facilities for production of containers of different sizes in uniform nature	+		+	Root trainer > polybag > conventional container
4.	Facilities such as strength, durability, lightness in weight and capacity for resistance to root shock	-	- -	+	Root trainer > polybag > conventional container
5.	Facilities for regulating moisture	-	- -	+	Root trainer > polybag > conventional container
6.	Facilitles for regulatingtemperature and light	-	- -	+	Root trainer > polybag > conventional container
7.	Facilities for regulating aeration	-	- -	+	Root trainer > polybag > conventional container
8.	Facilities for efficient nutrient storage and supply	-	- -	+	Root trainer > polybag > conventional container
9.	Biological Inertness	+	- -	+	Root trainer > polybag > conventional

Table 7 contd. to next page

Sl. No.	Requisites/Container type	Poly-bag	Con-ven-tional	Root trai-ner	Relative
10.	Chemical inertness	+	+	+	Root trainer = polybag = conventional container
11.	Facilities for development of healthy root system	-	-	+	Root trainer > plybag > conventional 'container
12.	Availability of knowhow of use of container	+	+	- -	Polybag > conventlonal container > root trainer
13.	Familiarity and easiness in use of container	+	+	- -	Polybag > conventional container > root trainer
14.	Facilities for easy filling of potting media	+	+	+	Root trainer > conventional container > polybag
15.	Facilities for easy removal of stock	+	+	+	Root trainer > conventional container > polybag
16.	Facilities for making nursery and plantation activities easy	-	- -	+	Root trainer > polybag > conventional container
17.	Facilities for disposal of used containers	-	+	+	Root trainer > conventional container > polybag
18.	Overall cost effectiveness	-	- -	+	Root trainer > polybag > Conventional container

* ++ = Highly suitable; + = Moderately suitable; - = Moderately unsuitable: - - = Highly unsuitable:> = More suitable: = Same as

Table 8. The details regarding the number of requisites having different scores for different container categories

	Polybags	Conventional containers	Root trainer
'- -'	-	9	2
6 .	7	2	-
'+'	5	3	1
'++'	6	4	15
I rank	3	1	16
II rank	13	5	-
III rank	3	12	2

A perusal of Table 8 will reveal that, out of the 18 requisites considered in evaluation of containers for polythene bags, none has scored '--', i.e., 'highly unsuitable' indicating that they can be used as container in forest nurseries. However, in 7 requisites polybags have got score of moderately negative indicating that, with respect to these requisites polybag can be considered only when no other options are available. In the case of conventional containers, score obtained for 9 requisites (about half of the total) are '- -'. i.e., 'highly unsuitable' and so, these containers are unsuitable with respect to these requisites. In the case of root trainers 15 out of 18 requisites have secured a score of '++', i.e., 'highly suitable' and so they are most suitable with respect to these requisites. However, with respect to 2 requisites, they are unsuitable. Lack of sufficient know-how in the use of root trainers under local condition and the lack of familiarity and easiness are the constraints and therefore root trainer technology can be adopted only when these constraints are solved. So at present the only option available is to use polythene bag, even though for about 7 requisites they are moderately unsuitable.

The results obtained from relative evaluation of containers also stress the above finding. As far as the conventional containers are concerned, for none of the requisites, they have superiority over both the container types, indicating that they can be considered only when polybags and root trainers are not available. Root trainers are superior to polybag except in requisites such as availability of know-how and familiarity and easiness in use. However, in spite of the advantages of root trainers, they could not be used now as they could not satisfy the minimum requirement for 2 requisites and so for the time being it is necessary to continue with the polybag nurseries.

An examination of the scope for improvement available revealed that, to minimise the ill-effects of polybag nurseries attention for use of containers of optimal size, provision for sufficient number of well spaced drainage holes, use of well aerated organic potting medium with sufficient quantity of sand, careful watering and fertilizer application and avoidance of overgrown nursery stock is required.

Taking into consideration usefulness of root trainers, it is necessary to devote the research and development effort to sort out the deficiencies in two requisites i.e., lack of know-how for use and lack of familiarity and easiness in use. Integrated efforts are needed to standardise appropriate root trainer type and size, potting media, fertilizers, their application regimes, other associated aspects such as projection system, over-roof shelter and low cost sprinkler irrigation system, taking into consideration the species, planting site and planting objectives.

7. GENERAL RESULTS AND DISCUSSION

An attempt was made to evaluate the potential of different container alternatives available for raising forest planting stock in Kerala. To facilitate this, a list of potential candidates (Section 4.2) that can be used as containers was prepared and was evaluated using a suitability criteria designed for the purpose (Section 5). About 18 requisites were identified as important for choice of container (Section 5.5) and were included in the suitability criteria. A brief survey of forest nursery scenario of Kerala was made to decide suitability range in the State for different requisites while evaluating container alternatives (Section 6.2). Various containers were evaluated based on their potential in absolute and relative terms with respect to these requisites individually and on a collective basis (Section 6.3. 6.4 and 6.5).To facilitate easy evaluation, the containers were classified into 3 broad categories - polybags. the currently used one; the conventional container made from locally available material; and root trainers to include all modern containers. While evaluating the container categories, as far as possible, available information was utilised. In certain cases wherever needed, the required information was generated through field experiments. While evaluating the containers, the scope for improvement with respect to each requisite was also considered.

An evaluation of containers made from locally available materials indicate that they are inferior to polythene bag containers for large scale use in forest nurseries. High production cost due to the labour charges required for collection and manufacture and difficulties in large scale production (Table 1 and 2). short durability (Table 3). poor survival of nursery stock (Table 4). and problems in ensuring regulated supply of air, water, light, temperature and nutrient due to difficulties in providing the required physical and mechanical support to the nursery stock and difficulties in handling and transportation make them totally unsuitable for large scale forest nursery programmes (Section 6.4). An independent study conducted by Kerala Forest Department also has found the unsuitability of these materials (Ravindran, 1992; personal communication).

Evaluation of polythene bags, the currently used containers, revealed that though they do not have any constraint which makes them totally unsuitable, they have got serious limitations when used in forest nurseries. The flexible, smooth, thin walls of these containers necessitate the use of containers of larger size to ensure necessary mechanical and physical support to plant from possible shocks that may happen while handling. This makes potting costly, the container bulky and heavy leading to difficulties in handling and transportation. Again, the pot bound nature of the polybag coupled with soil potting media makes problems in regulated supply of moisture, air, light, temperature and nutrients to the plants. It also results in root coiling root strangulation, root deformities, improper root shoot ratio, inadequate lateral root development and in turn unhealthy root system or poor growth resulting in longer nursery regimes, low post-planting survival and growth, poor resistance to wind and ultimately higher cost (Wilson, 1986: Josaih and Jones, 1992). Huge recurring requirement of Low Density Polyethylene, the imported raw material having many other end uses, and problems of waste disposal are other disadvantages. These disadvantages overshadow the various advantages of polybag containers such as low cost/container, lightness in weight, strength and durability, and biological inertness.

Evaluation of properties of root trainers reveal that they are superior to polythene bag in many respects. Because of the rigid nature of containers, the container volume required is 4 to 6 times less than that of polythene bag. This reduces cost of potting considerably. It also reduces the weight of the root trainer stock and in turn the handling and transportation cost. As more containers can be kept/unit area than polythene bag, nursery management is more efficient and cost effective. The nursery regime required to produce seedling of desired size is often 3 to 4 times less than that of polybag reducing the overall cost involved. Also as the root trainers can be used for many times (5-8 yrs) the container costs/seedlings are much low (Landis *et al.* 1992; Josaih and Jones, 1992).The raw material requirement is also quite less due to the possibility of reuse and recycled use of root trainers. This is the similar in the case of waste disposal also. However, for effective use, root trainers require total change in the current forest nursery practices in the State. Since the container volume used is quite small, to ensure suitable conditions for sufficient appropriate growth, the potting medium having better moisture retension capacity and drainage facilities than soil is required to be used. Root trainers are more exacting in the case of irrigation and fertilizer regimes also (Wilson, 1986; Josaih and Jones, 1992).This specification often varies with respect to species and nursery conditions. The study at KFRI has demonstrated the chances of failure when root trainers are used under conventional nursery practices (Plate 20). This possibility was also reported by Josaih and Jones, 1992 after reviewing experience of root trainers in different tropical countries (Josaih and Jones, 1992).There is also need for appropriate raised platform to keep root trainers, Over roof shading and sprinkler irrigation system. Preliminary trials made at KFRI highlighted the possibility of making root trainers, potting media, raised platforms and over roof shelter in a cost effective manner in local conditions, though there is a need for further work in this direction. More studies from a multi perspective are needed to standardise appropriate root trainer type, root trainer size, potting media, irrigation and fertilizer regime to suit local species and conditions. As it requires more care and skill in the use root trainers, the field staff need to be trained adequately before large scale use of the technology.

In the meantime, the only option available is to continue the use of polybag till appropriate root trainer technology is developed. An examination of the status of polybag seedlings in forest nurseries will reveal that very often the seedlings are kept for a longer period than originally intended, thus making the seedlings overgrown, which in turn aggravate the problems of root coiling and other root deformities resulting in considerable wastage. Careful planning with regard to the quantity of seedlings required, their size and age depending on species and planting site conditions: choice of container size in accordance with the planting stock size required; provision of adequate number of well spaced holes in the container to ensure adequate drainage: use of well aerated pottingmedium with sufficient quantity of organic matter, improved fertilizer and irrigation application are likely to help in rhinimising the problems of polybag nurseries.

8. CONCLUSIONS AND RECOMMENDATIONS

1. Conventional containers made from locally available materials such as forest plant leaves, split bamboos, grass, gunny bags, etc., are not suitable for large scale forest nurseries. Main problems with these containers are higher production cost, short durability, low survival of nursery stock, and difficulties in handling in nursery and during transportation.
2. Polythene bags, the currently used containers, though have several advantages, have serious limitations when used in forest nurseries. The thin, flexible container walls necessitate use of containers of larger size to ensure adequate physical and mechanical support to the plant. This results in high handling cost and inconveniences in nurseries and during transport to planting sites. The smooth wall and pot bound nature of container together with the soil potting medium lead to problems such as root coiling, root strangulation, improper root-shoot ratio and lack of adequate lateral root growth development. Thus the root system produced is comparatively unhealthy. Consequently plant growth is much less than the potential. Also the post planting survival, general growth and health of trees as well as their resistance to wind are below par.
3. Though root trainers are much superior to polythene bag containers in many respects, they are more exacting and require total change in the existing nursery practices in the State. It requires superior potting media and improved fertilizer and irrigation regimes and the specification vary depending on species and nursery conditions and nursery stock size required and very often the thumb rules currently followed in polybag containers are not adequate for root trainers. The technology currently used needs to be suitably adapted to local conditions before large scale use. This requires considerable amount of research and development efforts covering various aspects involved.
4. So, for the time being, the only option available is to use polythene bags till appropriate root trainer technology is developed. Use of containers of optimal size taking into consideration the requirement of species and nursery stock size required for planting, provision of adequate number of drainage holes in polybags: use of well aerated potting medium with sufficient quantity of organic matter; judicious application of fertilizer and irrigation and timely removal of nursery stock for outplanting to avoid retension of overgrown seedlings can help in minimising problems of polybag nurseries.

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APPENDIX 1

List of a few common root trainers including paper pots used in USA and Canada (Landis *et al.* 1990)

	Construction material	Manufacturers/suppliers
CONTAINERS PLANTED WITH SEEDLING		
Paper containers		
Paperpot	Specially treated paper	Hakmet Ltd., PO Box 248 Dorion, PQ CANADA J7V 755 Lannen, Inc., 880 Calle Plano. I PO Box 3383, Camarillo, CA 93011
Stretch-A-Pot	Specially treated Paper	Pan Agro, 2084 North, 1200 East North Logan, UT 84321
Wood fiber containers		
Jiffypot Forestry pellet	Molded peat moss Molded peat moss in plastic mesh	Jiffy products of America 1400 Harvester Road PO Box 338, West Chicago, IL 60185 Jiffy Products Ltd., PO Box 360 Shippagan. NB CANADAEOB 2PO
Fiber pot	Molded wood pulp	Western Pulp Products Co. Box 968, Corvallls, OR 97339

	Construction material	Manufacturers/suppliers
CONTAINERS REMOVED BEFORE OUTPLANTING		
Individual cells in trays		
Ray Leach Single Cell System	Low-density polyethylene cell, with high-impact polystyrene tray	Stuewe and Sons, Inc., 2290 SE Kiger Island Drive, Corvallis. OR 97333
Stuewe Super Cell	Low-density polyethylene	Stuewe and Sons, lnc.. 2290 SE Kiger Island Drive Corvallis, OR 97333
Hawaii dibble tube	High-density polyethylene cell, with Ngh-impact polystyrene tray	Firewheel Manufacturing Co. Ltd.. PO Box 72-41 Taipei, Taiwan, Republic of China
Colorado container	High-impact polystyrene cell, with an expanded polystyrene tray	Colorado Hydro, Inc. 5555 Ute Highway Longmont, CO 80501
Deepot	High-density polyethylene cell and tray	J.M. McConkey & Co.. Inc. PO Box 1690, Sumner WA 98390 Stuewe and Sons, Inc., 2290 SE Kiger Island Drive Corvallis, OR 97333
Book or sleeve containers		
Spencer-Lemaire Rootrainer	PET (polyethylene terephthalate) or ABS (acrylonitrilebutadienestyrene)	Spencer- Lemaire Industries, Ltd., 11413 120 Street Edmonton, Al3 CANADA T5G 2Y3 A.H. Hummert Seed Co.. 2746 Choteau Avenue Louis. MO 63103

	Construction material	Manufacturers/suppliers
Tubepack	Polystyrene	Porter-Walton Wholesale Nursery, 262 West, 400 South Centerville, UT 84014
Block containers		
Styroblock	Expanded polystyrene	Silvaseed Company PO Box 118, Roy, WA 98580 Beaver Plastics, Ltd. 12150 160 St., Edmonton, AB CANADA T5V 1H5
First Choice bloc	Expanded polystyrene	First Choice Manufacturing 19402, 56th Avenue Surrey, BC CANADA V3S 6K4 Stuewe and Sons, Inc. 2290 SE Kiger Island Drive Corvallis, OR 97333
Styrofoam block	Expanded polystyrene	Plant-A-Plug Systems PO Box 1953. Pine Bluff AK 71613
Colorado Styrofoam block	Expanded polystyrene	Colorado State Forest Nursery Foothills Campus Colorado State University Ft. Collins, CO 80523
Ropak Multi-pot seedling tray	High-density polyethylene	Sauze Technical Products *Corp.* 345 Cornelia Street Plattsburgh, NY 12901 Stuewe and Sons, Inc. 2290 SE Kiger Island Drive Corvallis. OR 97333 Ropak Can-Am Ltd. PO Box 340 Springhill, N S CANADA BOM IXO

	Construction material	Manufacturers/suppliers
Hiko System Containerset	High-density polyethylene	International Forest Seed Co. PO Box 290, Odenville AL 35120
Deep Groove Tube Tray	polyethylene	Growing Systems, Inc. 2950 North Weil Street Milwaukee, WI 53212
Capilano seedling tray	High-density polyethylene	Capilano Plastics Co., Ltd. 1081 Cliveden Avenue Annacis Island New Westminster. BC CANADA V3M 5V1 Stuewe and Sons; Inc. 2290 SE Kiger Island Drive Corvallis, OR 97333
Todd planter flat	Expanded polystyrene	Speedling Inc., Old Highway 41 South, PO Box 7238 Sun City, FL 33586
Seedling tray	Expanded polystyrene	Castle and Cooke Techniculture, Inc. PO Box 1759, Salinas, CA 93902 Grow-Tech, Inc. 56 Peckham Road Watsonville, CA 95076
Ecopot	Plastic-laminated	Hakmet, Ltd., PO Box 248 Dorion, PQ, CANADA J7V7J5 Lannen. Inc. 880 Calle Plano. 1 PO Box 3383 Camarillo CA 93011
Stretch-A-Pot	Polyethylene film	Pan Agro, 2084 North, 1200 East North Logan UT84321

	Construction material	Manufacturers/suppliers
Separate containers		
Treepot	High-density polyethylene	Stuewe and Sons, Inc. 2290 SE Kiger Island Drive Corvallis. OR 97333 J.M. McConkey & Co. Inc. PO Box 1690 Sumner WA 98390
Rootrainer One Cell	PET (polythylene terephthalate)	Spencer-Lemaire Industries, Ltd. 11413 120 Street Edmonton, AB CANADA T5G 2YE A.H. Hummert Seed Co. 2746 Choteau Avenue St. Louis, MO 63103
Miniature containers		
Techniculture plug system	Expanded polystyrene	Castle and Cooke Techniculture, Inc. PO Box 1759 Salinas CA 93902
Miniblock 448	Expanded polystyrene	Same as Styroblock distributors
First Choice Hahn 408	Expanded polystyrene	Same as First Choice block distributors

PLATES

Plate 1. Containers made of locally available materials

Plate 2. Seedling grown in plastic bag used for packing cement

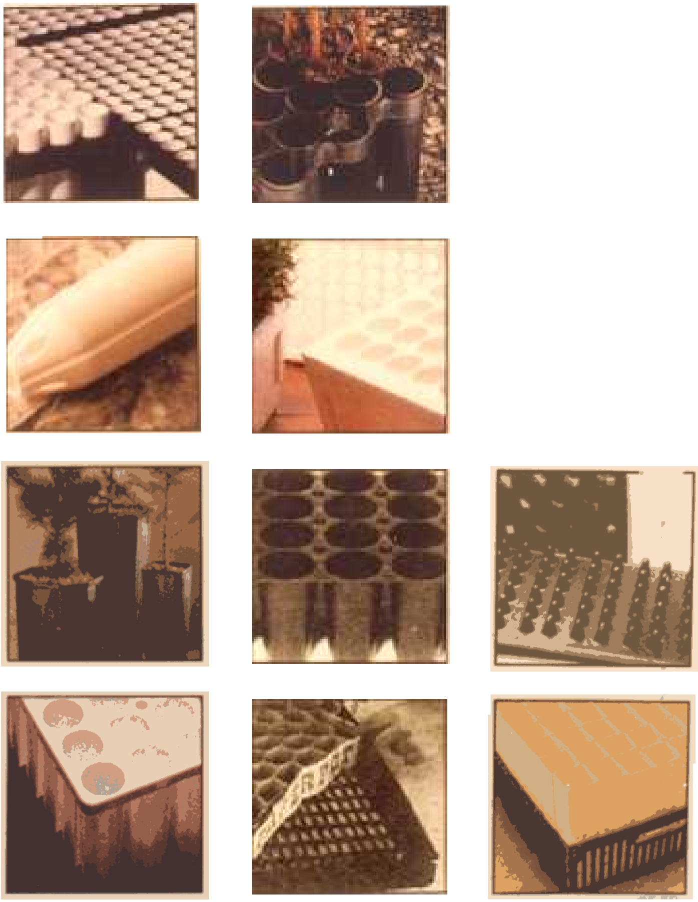

Plate 3 **Different types of root trainers (a) Ray Leach Conetainers (b) Economy Super Cell and Groove Tube™ Trays (c) Treepots™ (d) Ropak Multipots™ (e) Deepots (f) First Choice Blocks™ (g) Hiko™ Trays (h) Lannen Paperpots™ (i) Grower Supplies (j) Zipset™ Plant Bands (Courtesy: Stuewe and Sons 1995-96 Catalog)**

Plate 4. Different types of root trainers (k) Solid Bullet Type Containers (l) Rigid Plastic Book/Sleeve Container (m) Vickpots

Plate 5. Seedlings grown in Treepots (Courtesy: Stuewe and Sons 1995-96 Catalog)

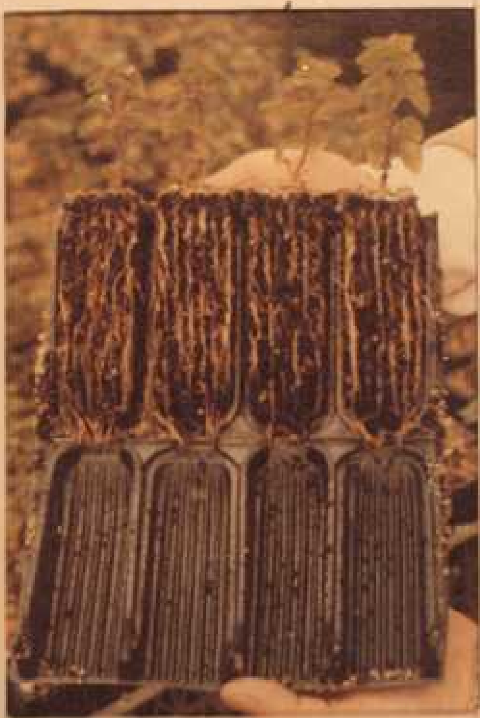

Plate 6. Seedlings grown in Sleeve/Book container (Courtesy: Landis *et al.*, 1990)

Plate 7. Coiling of roots: a common phenomena in polythene bag seedlings which adversely affect growth and stability of trees

Plate 8. Roots egressing through polythene bags and get rooted below. These roots break while taken out for planting which may subsequently result in poor establishment and growth

Plate 9. **Over-grown nursery seedling: a common scene in forest nurseries**

Plate 10. **Root systems of seedlings of different forest species (a)** ***Casuarina equisetifolia*** **(b)** ***Calamus thwaitesii*** **(c)** ***Garcinia indica*** **(d)** ***Asparagus racemosus*** **(e)** ***Artocarpus hirsuta***

Plate 11. Can we not choose better container for this species? Seedlings of *Casuarina equisetifolia*
Careful selection of container dimension taking into consideration the root characteristics can help in improving quality of planting stock, reducing nursery maintenance and transportation cost and optimising use of polythene

Plate 12. **Can we not choose better container for this species? Seedlings of *Calamus thwaitesii*.**
Careful selection of container dimension taking into consideration the root characteristics can help in improving quality of planting stock, reducing nursery maintenance and transportation cost and optimising use of polythene

Plate 13. **Can we not choose better container for this species? Seedlings of *Garcinia indica*.**

Careful selection of container dimension taking into consideration the root characteristics can help in improving quality of planting stock, reducing nursery maintenance and transportation cost and optimising use of polythene.

Plate 14. Can we not choose better container for this species? Seedlings of *Asparagus racemosus*.
Careful selection of container dimension taking into consideration the root characteristics can help in improving quality of planting stock, reducing nursery maintenance and transportation cost and optimising use of polythene

Plate 15. **Can we not choose better container for this species? Seedlings of *Artocarpus hirsuta***
Careful selection of container dimension taking into consideration the root characteristics can help in improving quality of planting stock, reducing nursery maintenance and transportation cost and optimising use of polythene

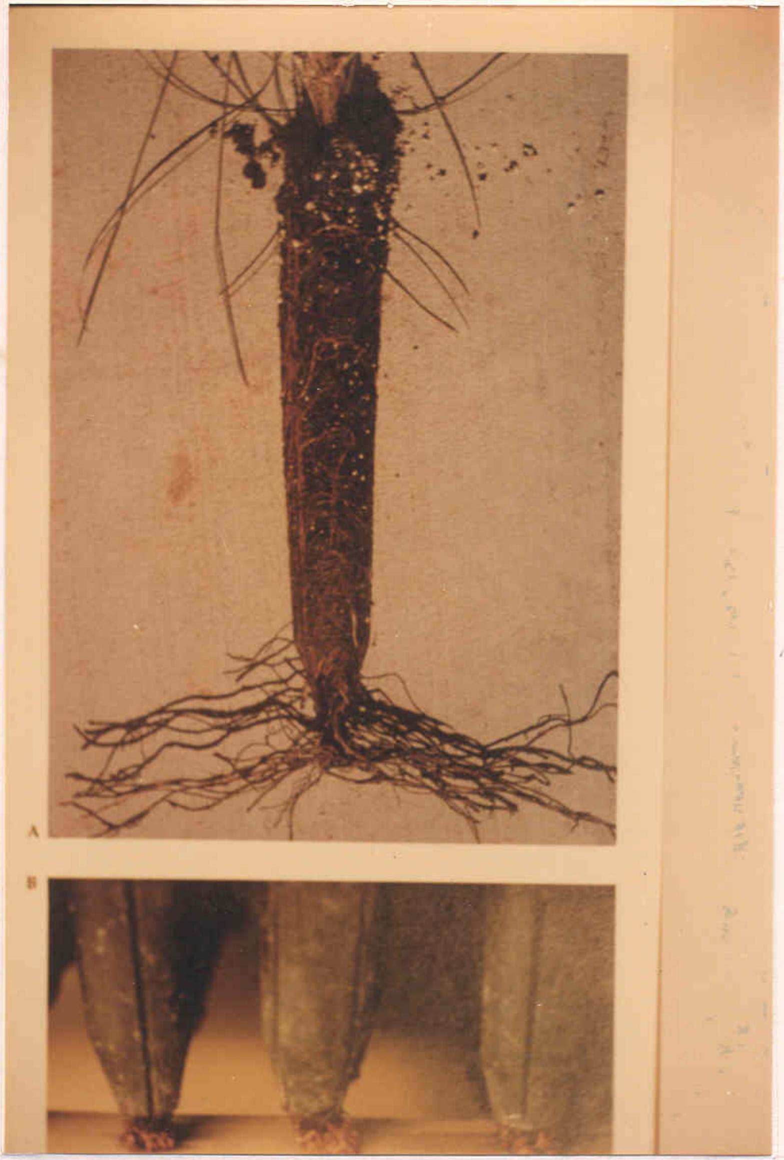

Plate 16. Root trainer grown seedlings (a) not airpruned (b) airpruned by keeping on a raised platform (Courtesy: Landis *et al.*, 1990)

Plate 17. **Support structures for root trainer nurseries: raised platform - possible local adaptation (a) Portable Aluminium Bench Table Top (b) Steel Mesh Table Top (c) Bamboo Mesh Table Top**

Plate 18. **Potential candidate potting media (a) Sawdust (b) Paddy husk (c) Soil rite (d) Coconut pith (e) Paddy husk (half burned) (f) Vermiculate (g) Soil**

Plate 19. A root trainer grown seedling with firm root plug (Courtesy: Landis *et al.*, 1990)

Plate 20. Ficus seedlings grown in root trainer and polybag, using conventional polythene bag nursery approach. The poor growth in root trainer seedlings suggest the need for appropriate adaptation in nursery practices