

Working Paper

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MULTIPURPOSE TREE NURSERIES FOR RESEARCH

Dennis A.M. Wambuguh and Peter A. Huxley

November 1990

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FOREWORD

There are several major sources of variability in experimental work with woody perennials: variability due to plant raising, planting out, genetic differences, site factors, seasonal changes, management and the effects of the treatments themselves. All sources of unwanted variability need to be contained as far as is feasible, so that the statistical comparisons planned can be carried out at maximum efficiency. This is especially important in agroforestry field trials where the site may often impose limitations on the number of replications possible. In addition, programmes addressing multipurpose tree germplasm improvement require the highest level of control of "environmental" variability in its broadest sense, i.e. including all management inputs.

A long history of research, both in the tropics and in temperate regions, has shown that an important source of unwanted variation during the early stages of field investigations with woody perennials is attributable to variability brought about during the processes of plant raising and planting out. The importance of these early factors tends to diminish as the experiment continues and other sources of variability, such as the effects of pests and diseases, site factors that affect long-term growth and damage due to management errors, begin to assume importance. Genetic differences can influence growth either directly or through the onset at different times of flowering/fruitletting, and this will apply through the life of the tree, with the differences becoming more apparent as time passes.

In experiments on fruit or beverage crops that may last 15-25 years, the relative impact on the interpretation of experimental data of early versus late causes of variability will be less than in those where the trial is to last only a relatively short time (e.g., 5-6 years). Most agroforestry field trials fall in this latter category, so that causes of variability that affect the early stages of growth could be of critical importance. Because tree seedlings can remain in the nursery for longer than most non-woody plants, the nursery techniques applied need to be especially reliable and reproducible.

Under these circumstances, it is clear that attention paid to plant raising and planting out techniques will be well repaid. This Working Paper addresses itself to the first of these. In practical terms, a small amount of extra money spent on this stage of the field experiment is likely to be well recovered in terms of its beneficial effect, and in view of its relatively small cost-increment in relation to the overall cost of the experiment.

There are now a very large number of sophisticated technologies and new materials which are considered commonplace for plant raising for horticultural and forestry applications; advanced commercial glasshouse procedures are probably the culmination of all this technology, but commercial horticultural tree-production units come close. In many tropical regions, there seems to have been a lag in adopting many of the newer advances in plant-raising methods/technologies; perhaps because of cost factors. If, as in agroforestry research, the numbers of young plants needed are comparatively small (most experiments will require only several thousands), and the justification for any extra cost is fully met, then arguments against adapting modern nursery methods cannot be sustained.

In this Working Paper, we give a brief account of some essential factors that must be properly addressed in any advanced nursery which is devoted to raising woody perennial seedlings for research and/or plant-breeding programmes. A second section contains some information about the types and availability of methods and equipment that can be used.

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1. INTRODUCTION

There are some basic principles in raising young plants of any kind. First they have to be propagated. This can be done either from seeds or from vegetative propagules such as cuttings of one kind or another; or plantlets can be produced by micropropagation techniques. Nursery conditions should be designed to carry out the propagation procedures efficiently and provide optimum conditions, initially for the growth of the young plants, and then later to provide a period of gradually increased environmental stress so that the plants are "hardened-off" prior to being planted out. The conditions of propagation will obviously differ depending on whether this is from seeds, or by some form of vegetative propagation. In either case, particular species may have special requirements. Different forms of vegetative propagation also have their own required practices and conditions. Providing details of these is not within the scope of this paper (but see, for example, Garner et al., 1976).

Many nurseries designed to raise woody perennials will need facilities for propagating from both seeds and cuttings. Seeds may not remain viable for long (so-called recalcitrant seeds - Willan, 1985); furthermore, unlike seed from outcrossing plants, those propagated vegetatively are genetically the same unless somatic mutations have occurred (e.g., chimaeras). On the other hand, vegetative propagation perpetuates, and hence spreads, infection by viruses and mycoplasmas. Advanced nurseries will always have facilities for both kinds of propagation.

Micropropagation techniques are usually carried out in even more closely controlled environmental conditions in a suitable laboratory in which heat treatment can be used to eliminate viruses. Plantlets so produced will need to be transferred to a nursery at some stage and, as they are very small, the conditions provided have to be very carefully controlled.

Before seeds of any kind are sown in a nursery, they should always be subjected to appropriate germination tests (International Seed Testing Association, 1976). In practice, this can often be carried out using simple equipment in order to get a useful, practical idea of seed viability. Such tests will be the subject of another Working Paper. Nurseries must always maintain a very high level of pest and disease control, or else they may become centres from which these are spread.

1.1 Basic considerations

The medium in which seeds are to be germinated has to have an ideal physical structure and be free from chemically retarding conditions (e.g., acid, alkaline or saline conditions, and any toxic materials or compounds); the provision of plant nutrients at this stage is not essential. Similarly, the rooting of cuttings requires a coarse, well-aerated and free-draining medium (especially if mist propagation is used); again without plant nutrients.

As seedlings emerge, or cuttings root and begin to sprout, then growth quickly becomes inhibited by lack of nutrients. The required concentration of these can increase as the young plant grows. Furthermore, the balance of essential elements will change with each stage of growth and development of the young plant. A great deal is known about this for many of the important commercial horticultural crops; a tomato grower can obtain a blueprint telling him exactly what to provide for his plants and when, for example. We have nothing of this level of plant nutritional advice for raising multipurpose trees, (MPTs), as yet. Cuttings that are being rooted require a critical balance between being provided with sufficient light for photosynthesis, but not so much that they suffer water stress. They also require increasing concentrations and a changing balance of nutrients as they grow into young plants.

In an ideal situation, each stage of growth for germination or rooting would be given its own precise set of conditions. In practice, commercial nurseries often limit these: seeds may be sown in a seedbed with one kind of medium and then pricked out into containers with another. The containers may be large enough to maintain growth of the young plants until they are to be planted out in the field, or they may be potted on (grown on) one or more times before this (thereby replenishing the nutrient status of the medium). Additional nutrients can, of course, be supplied by top dressings of appropriate fertilizers and/or by foliar feeding nutrients in solution. Using a single container from the pricking-out stage until field planting is very much a compromise between efficiency and cheapness. Placing small seedlings into relatively large containers leaves a lot of the growing medium unexploited by roots and, under the constant watering regime used in nursery work, parts of the medium are liable to become stagnant and inhibitory to root growth.

In nurseries designed to produce plants for field experiments, or MPT germplasm improvement trials, i.e, tree research nurseries (TRNs), the techniques of seed germination or rooting of cuttings will be carried out under carefully controlled conditions with absolute freedom from pests and pathogens (especially damping-off fungi). In such advanced nurseries, emerging seedlings are pricked-out when still young, and then almost always potted on in a succession of larger containers with appropriately formulated media for each stage. The containers will always be large enough to avoid roots becoming pot-bound or growing out of the bottom of the container. Obviously, this requires a lot of resources and skill, and entails continuous and strict control and adjustment of light conditions through shading and, in high-tech situations, even supplementary lighting with special lamps. Also, watering has to be very carefully controlled, often with drip irrigation, capillary beds or other means (described later). Most people wishing to become nursery operators of this level spend one or two years training in nursery-management skills.

Some notes on specific nursery materials and equipment that can facilitate good nursery management are given in Chapter 3, and details of suppliers in Appendix 1. The comments below address some of the essential considerations in regulating the environment of young tree seedlings so as to be able to optimise growth.

1.1.1 *Nursery media (or composts)*

Many different kinds of media can be used that provide the appropriate conditions for one or more of the different stages from propagation to growing-on stage. Extensive research in the 1940s and 50s produced a series of composts from the John Innes Horticultural Research Institute in the UK. These were based on different proportions of coarse sand, shredded peat and composted top soil (best made by stacking grass turves until they have become well rotted, then turning the heap a number of times). These constituents provide drainage, water-holding capacity and a suitable nutrient status, respectively. Such a compost is heat sterilized before use. However, in the tropics, a suitable peat is difficult to obtain.

Another useful type of compost was that researched by the University of California (U.C. composts). This was based mainly on sand/peat mixtures and thus needed additions, initially and at regular intervals, of a balanced fertilizer mixture and minor elements. Some more recent nursery composts have been based on peat only. In some cases vermiculite, an expanded mica, can supply the water-holding capacity needed. For such composts, it is essential to get the right kind of vermiculite. Vermiculite used in building insulation has usually not been neutralized, and it can be highly alkaline. Sand and grit can vary in quality. If sand particles are of mixed sizes, and if they are coated with iron, then the result can be a kind of cement. It is, therefore, usually best to thoroughly wash sand that is to be used for plant raising purposes and grade it when dry, using only the coarser grades.

Why go to all this bother? Why not just take a good topsoil and use it in a container or seedbed? To answer this question, we need to remember what happens to the medium in a nursery. The comparatively small volume of compost in any particular container is being constantly watered, usually more than once a day. Under these conditions, its physical conditions will deteriorate rapidly if the soil is not extremely well structured (i.e., unless it contains a high proportion of organic matter and/or clay particles). Leaching of nutrients will occur and, if the compost does not have (a) a suitable level of nutrients to start with, and be re-supplied as needed or (b) consists of a medium that has a high cation-exchange capacity (organic matter and clay, again), the loss of nutrients will be very rapid indeed under nursery conditions. In addition, the compost has to be free draining. These apparently conflicting needs can be satisfied by making an appropriate mixture, and then by handling the irrigation and nutrient additions skilfully. Hence the need for special nursery composts and equipment that can accurately control the application of water. A watering can with large droplets or a hose controlled just by a thumb can be extremely detrimental!

As long as we understand the principles underlying the physical and chemical nature of a good propagating compost, there are various ways of achieving what is required, as the examples given have shown. In many cases, the careful choice of locally available compost components can provide a satisfactory solution, and local knowledge in this respect should be used wherever possible.

1.1.2 Containers

There are a number of issues relating to the choice of an appropriate kind of container in which to grow plants, in this case tree seedlings. Containers need to be made of durable, non-porous, non-toxic materials. Polythene film was introduced around the world in the 1950s as a suitable material that could be easily made into plant containers.

Black ultra-violet-

inhibited film is now usually used because the pot, being not so easily degraded by sunlight, lasts longer and the soil inside does not heat up and harm the roots in the way that clear polythene does. Polythene sleeves have been used extensively in commercial nurseries because they are cheap. They have several disadvantages for nurseries attempting to produce top quality tree seedlings, however. Their first fault is that watering of a batch of plants in polythene sleeves is invariably uneven. A slight difference in the level of compost in some of the sleeves might allow their edges to fold over causing water to be shed to the outside. Furthermore, in a research nursery, a useful way to avoid locational errors is to move around the plants at regular intervals when watering them. This cannot easily be done with plants in polythene film sleeves. Potting-on is not so easy if plants are grown in polythene film, nor are the pots readily markable on the outside for permanent labelling.

All advanced tree nurseries should use rigid or semi-rigid containers of appropriate sizes (see the Appendix). These are re-usable and can produce plants of considerably better quality, both for the reasons given above and because they can be more readily used with modern, controlled irrigation equipment designed for nurseries. They also facilitate potting on (Wilson, 1986).

Where small batches of seed need to be propagated, this can often best be done by using seed boxes or seed trays. This again has the advantage that the individual boxes can be moved around so as to minimize locational environmental differences. The size of individual seed boxes can be adjusted to suit individual requirements; weight when filled and ease of handling are important factors. They must always be filled to within 0.5 to 1.0 cm from the top, and the germinating medium has to be firmed and made completely level.

Soil blocks require a special kind of compost if they are not to disintegrate with use, or to be so dense that they impede plant growth. Equipment for making them is available (see the Appendix). Although they can be useful with crop plants such as tomatoes, soil blocks are probably of little use for tree seedlings.

1.13 Watering young plants

A regular supply of clean, chemically pure water is always needed for any good plant nursery. Otherwise the growing medium becomes chemically unbalanced and applications of water will leave dried salt patches on the leaves, which can be very inhibiting to growth.

Watering has to be based on a skilful adjustment of amount (per pot) and frequency, depending on (a) the compost being used, (b) the weather, (c) the size of the container and (d) the species and size of the plant. In glasshouse culture, plants are usually watered on an individual basis because overwatering can be as harmful as underwatering. Modern equipment is capable of applying measured amounts of water (or plant nutrient solution) to batches of plants in a regular and controlled manner. Sometimes electronic control equipment is provided in order to do this. If time switches are used, they should be of the electric-driven but, mechanically wound kind so that power failures do not put them out of operation. Some form of high-level misting equipment can also be valuable, both to improve the quality and rate of plant growth, and also provide water when workers do not turn up over weekends and during public holidays. Plants left unwatered for one day may still survive without damage if they have been misted automatically two or three times during the day. In such a system, water supply is pumped under pressure. Irrigation should always be carried out after fertilizers have been applied so as to obviate local high-nutrient concentrations that can be especially toxic to young plants.

Tree seedlings have been successfully grown by nutrient-film techniques. This is where plants are grown, with or without containers, in a constant shallow flow of complete plant nutrient solution contained in troughs (often made of polythene film laid in a shallow trench). The technique requires considerable skill and constant vigilance so that no breakdown occurs. Another method is to use slabs of materials such as Rockwool (a substance made from fused diabase and limestone), and these are now being used extensively in developed countries. We may be able to manufacture something similar from local materials.

1.1.4 *Shading*

Exposure of nursery plants to sunlight has to be adjusted according to the propagation medium/container type/irrigation regime, and according to the requirements of individual species and the particular stage of growth. Less water and more exposure to sunlight are given when "hardening off."

In general, it pays to have both high (3 metres plus) as well as low (1 meter or so) adjustable shading. It goes without saying that, for the precise control of shade that is needed to raise tree seedlings for research purposes, materials that cast a completely even type of shade which is of known light transmission should be used. Why have both high and low shade? In practice, this is useful as the high shade can be of a fairly high transmissivity and also provides a background of light shade against which one can exert very precise control at the lower level. Often, the high shade is fixed, or only adjusted seasonally, and the low shade can often be of the roll-on/roll-off type that allows adjustments through the day and/or according to the weather. There will be special times when plants need to be shaded carefully, for example, after pricking out or repotting, and after pesticides have been sprayed (nearly all pesticides are at least slightly phytotoxic, and their effects are made worse by bright sunlight).

There are numerous other practical aspects of good nursery management that are referred to in the references given at the end of this Working Paper.

2. NURSERY DESIGN CONSIDERATIONS

2.1 Introduction

Any ordinary commercial tree nursery requires a site that is sheltered from wind, must be near an adequate supply of water, is easily accessible for transport and preferably near the final planting-out area. It must also be level, well drained and large enough to provide adequate space for the planned operations (Kwesiga, 1989; Carter, 1987; Das, 1984). Design considerations should allow for rational traffic patterns, adequate work space and storage and enough shelter for the nursery staff. A research-oriented, tree-production nursery requires equal attention to these but, in addition, space should be allocated for nursery experiments *per se*. Germinating or propagation beds and compost bins will be needed as well as sufficient space for moving around and sorting experimental-grade, container-grown seedlings. Some tree nurseries might require special equipment for growing on and "hardening-off" of micropropagated plantlets.

For TRNs the level of control of each stage of tree propagation and tree raising will be much greater than that found in a commercial operation.

2.2 Features of Tree Research Nurseries

Particular attention needs to be given to the following in the establishment and management of tree research nurseries:

- (i) The structural design and arrangement as a whole. This requires the proper integration of modular units/systems, e.g., for propagation, irrigation, soil sterilization, etc;
- (ii) Shelter/shading techniques. These need a high degree of control;
- (iii) Materials used, e.g. floors, benches, containers, etc. These should be kept clean and/or sterilized if necessary;
- (iv) Provision of supplementary equipment, such as misting, soil heating and lighting facilities;
- (v) An exemplary level of pest- and disease-monitoring and control techniques;
- (vi) Detailed recording of germplasm, acquisition information, storage procedures and all nursery activities.

2.3 Layout/design

Area required for the entire nursery (example)

Beds:	14 beds x 150 m ²	=	2100 m ²
Paths:	15% bed area	=	315 m ²
Working area:	24 m x 10 m	=	240 m ²
Media bins:	20 m x 4 m	=	80 m ²
Store:	4 m x 4 m	=	16 m ²
Open area:	24 m x 10 m	=	240 m ²
TOTAL			2991 m ²
			i.e., 3000 m ²

This nursery would be rectangular in shape with internal dimensions of 125 x 24 m and a surrounding hedge, security fence and gate.

2.3.1 Main areas

Clearly, a design for any particular TRN will have to be drawn up according to the precise requirements of any project.

As an example, main areas will usually consist of a loading/mixing area adjacent to nursery media bins, the propagation area, the nursery beds (Fig. 1a) and an open area (both for "hardening-off" of the seedlings and for experimental work).

Water should be piped through the entire area with at least some of it under pressure 200-410 kN/m² (30-60 p.s.i.), with connections for fogging and/or automatic misting (see Section 3.6 and Appendix Section 5.1).

Layouts will depend on design requirements (Fig. 1a), but an important feature is to arrange the nursery beds in east-west direction so that shading over the container-grown plants is as even as possible. For the same reason, the high shade may extend laterally beyond the nursery beds/standing areas so as to operate effectively from, say, 9.30 a.m. to 4.30 p.m.; or it can be brought vertically down the eastern and western sides of the main supporting nursery structure. Lower level shade (actually over the nursery beds)

should always be adequate to maintain an even shading effect for most of the day, and this can best be done by an arrangement whereby the shade is fairly close to the tops of the young plants and can be moved up as they grow.

2.3.2 *Suggested construction and structured materials*

- (i) Perimeter fencing - chainlink wire/steel or treated wooden posts set in concrete.
- (ii) Inner fence with inert windbreak material (see Appendix, Section 2.3).
- (iii) Actual nursery wooden or steel poles/roof wires across entire roof to minimise unaccounted for shade.
- (iv) High shade: fixed at a height of about 2.5 m. The shade should be on a roll-on/roll-off basis and erected on struts (Fig. 1b). The shade netting should preferably be of known light transmission.
- (v) Individual beds for standing containers or, with compost, for direct sowing of seeds treated wood covered with galvanized zinc (or painted with bitumen paint) for side walls of beds, beds and treated wooden poles with wire stretched across for individual low shade. If low shading height is to be adjustable, then an angle, iron-supporting structure with holes and pegs will be necessary.

2.4 Size of **the nursery**

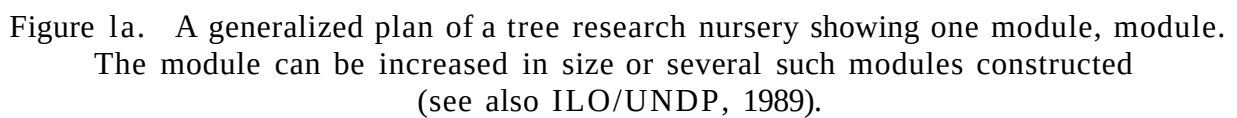
The actual size of the nursery will depend, to a large extent, on the objectives. A hypothetical example is used here to illustrate the point.

Objectives

- (i) To raise approximately 7000 seedlings at a time per season for experimental/research purposes only.
- (ii) To demonstrate the system used for such a TRN where raising extremely uniform, high-quality tree seedlings is the main priority, and to show particular improved nursery techniques, equipment and materials.
- (iii) To demonstrate layouts/methodologies for conducting nursery experiments.

$$\text{Area of beds} = \frac{\text{number of seedlings}}{\text{number of containers per m}^2}$$

Assuming containers each of 15 cm diameter (top) are used to raise 7000 seedlings, we need 10 beds of 10 x 1.5 m (Fig. 1c). Allowing for paths, work area, storage and experimental areas, a gross area of 3000 m² will be adequate. Each bed will hold 650 seedlings. Two beds will be used for propagation purposes before pricking out.



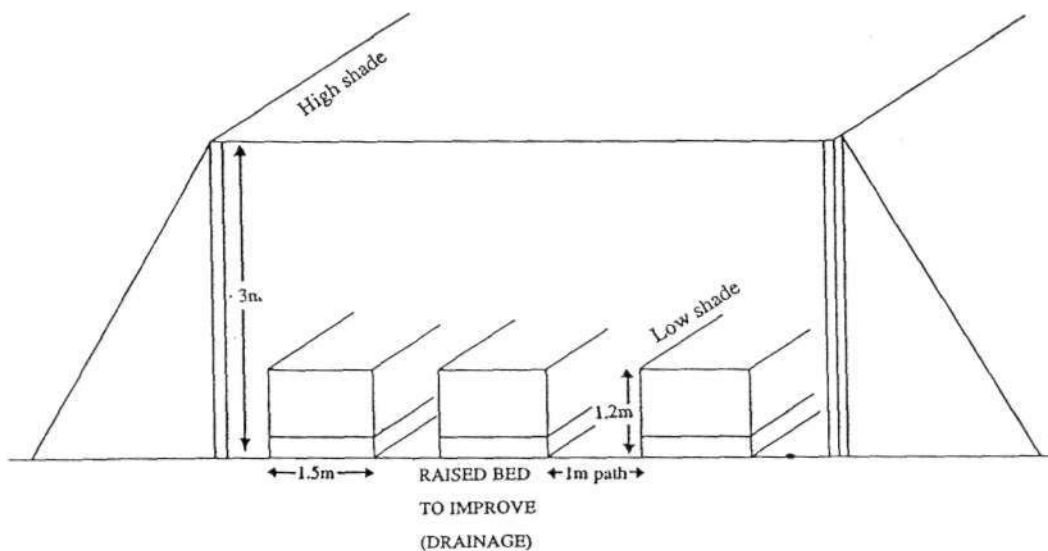


Figure 1b. End view of nursery to show disposition of high and low shade

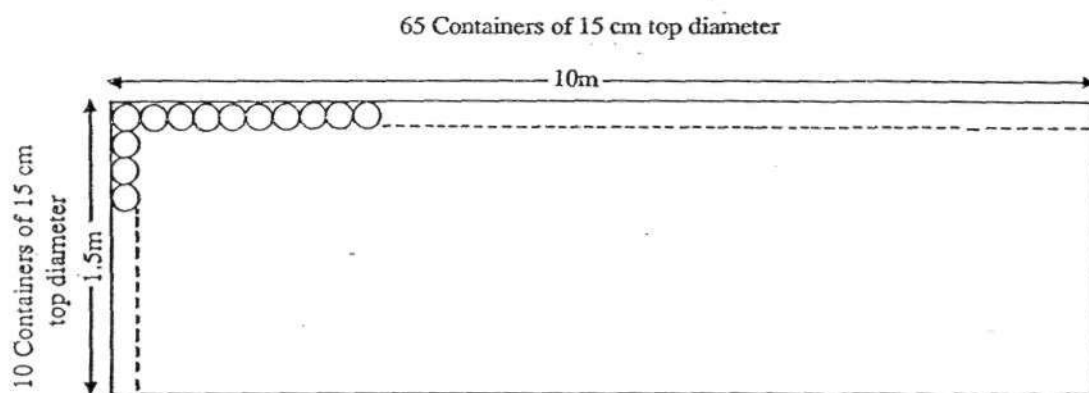


Figure 1c. An example of a single bed with suggested dimensions.

Note: Assuming sufficient containers, to raise approximately 7000 seedlings (and each of 15 cm **top** diameter) we need 10 beds of 10 m x 1.5 m. Each bed will hold 650 seedlings, but there will be a need to have extra beds for propagation purposes before pricking out (say 4 extra beds of similar size).

The use of mobile or static benching could increase the number of seedlings raised by at least 30%. Small benches on wheels can be extremely useful, and can often be constructed locally.

2.5 The need for plastic tunnel houses

The development of film plastic greenhouses began in the mid-1960s in the UK. These structures found favour with outdoor vegetable growers, particularly for increasing production, improving quality and lengthening the production period at low capital cost.

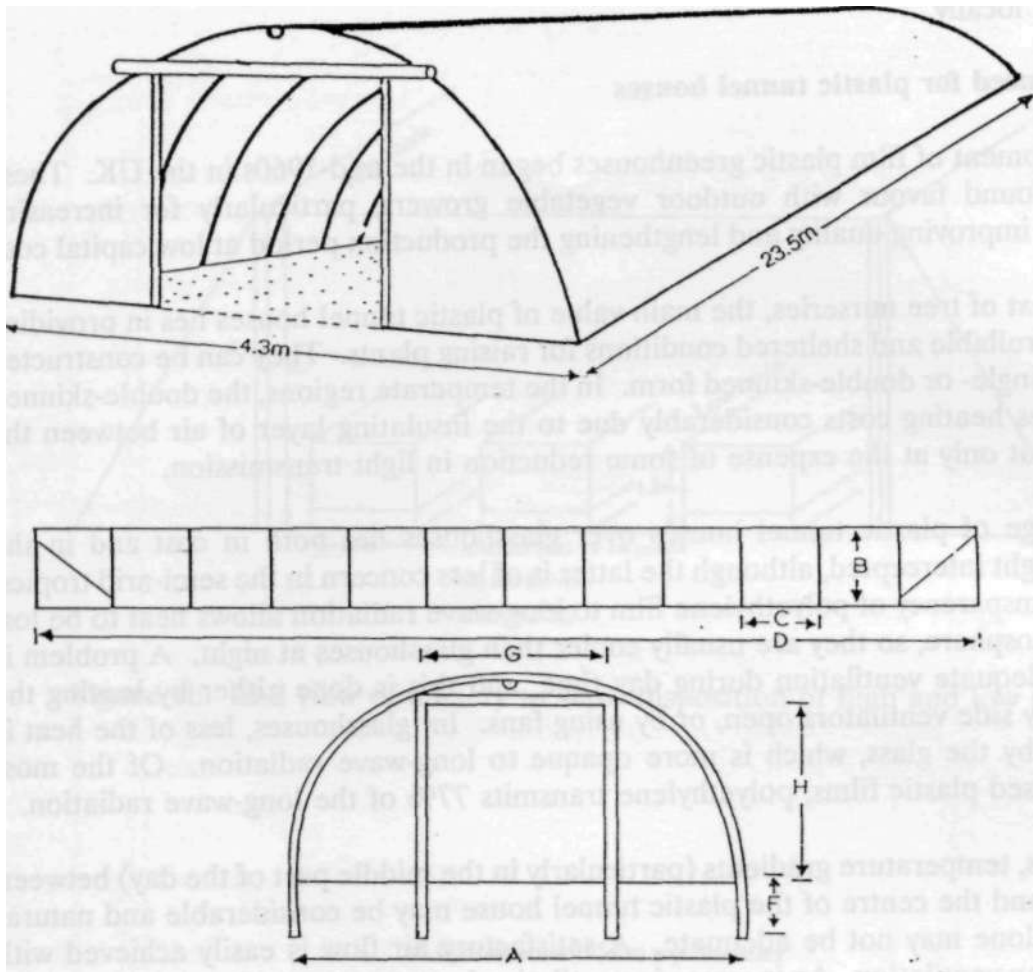
In the context of tree nurseries, the main value of plastic tunnel houses lies in providing readily controllable and sheltered conditions for raising plants. They can be constructed either in a single- or double-skinned form. In the temperate regions, the double-skinned form reduces heating costs considerably due to the insulating layer of air between the two films, but only at the expense of some reduction in light transmission.

An advantage of plastic tunnel houses over glasshouses lies both in cost and in the amount of light intercepted, although the latter is of less concern in the semi-arid tropics. The high transparency of polyethylene film to long-wave radiation allows heat to be lost into the atmosphere, so they are usually cooler than glasshouses at night. A problem is to ensure adequate ventilation during day time, and this is done either by leaving the ends and any side ventilators open, or by using fans. In glasshouses, less of the heat is transmitted by the glass, which is more opaque to long-wave radiation. Of the most commonly used plastic films, polyethylene transmits 77% of the long-wave radiation.

In the tropics, temperature gradients (particularly in the middle part of the day) between the outside and the centre of the plastic tunnel house may be considerable and natural ventilation alone may not be adequate. A satisfactory air flow is easily achieved with end-to-end fan ventilation. An increase in ventilation however means that extra attention has to be given to maintaining a high level of humidity inside the tunnel house at all times, perhaps by additional watering, spraying over or misting.

To avoid overheating, tunnel houses need to be shaded. This can either be done with shade netting or, more cheaply, by using a whitewash spray that is applied evenly on the inside.

The structural construction of plastic tunnel houses is fairly cheap using steel tube hoops covered with a clear polyethylene film. When assembling the plastic film, it is important to paint on a strip where films will touch each hoop (aluminium paint is suitable). This alleviates the damage done to the film when it rests against hot metal for long periods of time. The bottom ends of the sheet are usually just buried in a shallow trench dug around the periphery of the structure.



Dimensions	Imperial	Metric	Dimensions	Imperial	Metric
Width	14'0"	4.3m	A	Length of ground tube	2' 0" 0.6m F
Height to ridge	6'6"	2.0m	B	Width of end frame (Max)	6'0" 1.82m G
Section between hoops	6'0"	1.82m	C	Height of end frame (max)	6'0" 1.82m H
Length From	18'0"	5.5m	D	Width of cladding	73m
To	150'0"	45.7m		Refer to erection instructions for detailed information on site preparation and setting out	
In units of	6'0"	1.82m			
Length of picture is best arranged to economically utilize standard length rolls of polythene i.e.					
25m polythene	66'0"	20.1m		Length of structure	
40m polythene	120'0"	36.5m		Length of structure	
50m polythene	150'0"	45.7m		Length of structure	
Specifications					
Foundation tubes	1 3/8"	35mm	Outside diameter	14 gauge (2mm) steel tubing	
Hoops	r	25mm	Outside diameter	16 gauge (1.6mm) steel tubing	
Ridge	V	19mm	Outside diameter	20 gauge (2mm) steel tubing	
End frame	2"x2"	50x50mm timber, Protim treated for maximum life			
Steel tubing is internally and externally galvanized					
All clamps and finings are plated or coated against corrosion					

Figure 2. A plastic tunnel house with specifications

3. NURSERY MATERIALS AND EQUIPMENT

3.1 Constituents of nursery media (see Section 1.1.1 for discussion)

The constituents of nursery media depend on the type of seedlings or cuttings to be propagated. Forest soil is a common constituent in forestry nurseries, but variable mixtures with graded and washed sand, vermiculite and/or perlite have been tried. Other compounds that have been used are peat, bark, pumice, etc. Local sources or substitutes are recommended. Most of the potting media contain some soil (natural or modified), good quality loam being a common ingredient. Again, local expertise should be sought. Peat is sufficiently fibrous to ensure good aeration, and sufficiently spongy to retain moisture but it suffers from difficulties of re-wetting after drying out and a rather low pH. Chalk or limestone is added to peat to rectify its acidity. In many cases, peat in the tropics is too degraded to be useful. A possible local substitute is the highly fibrous litter sometimes found round the bases of palms (e.g., *Phoenix reclinata*).

Mica, perlite and pumice have been used as inert components in compost but their pH may need to be corrected. For acid-loving plants, sulphur may be incorporated, but not too near to the time of potting.

The John Innes seed (JIS) and the John Innes potting composts (JIP) have different proportions of loam, peat and sand. JIS is composed of two parts steam-sterilized loam, one part peat and one part sand. Chalk is added at approximately 0.5 kg per cubic metre of the mixture. For acid-loving species, chalk is replaced by the same weight of fine sulphur. Additionally, superphosphate may be included in the mixture at the rate of 2 kg per cubic metre. JIP should ideally be composed of 7 parts of steam-sterilized loam, 3 parts of moderately coarse peat and 2 parts coarse sand. U.C. (University of California) soil mixtures are based on moss peat and fine sand in various proportions. In the tropics, it is difficult to produce any of these composts precisely, but we can try to simulate them using local materials.

3.2 Equipment for sterilizing

This refers to *partial* sterilization of nursery media, but, of course, containers, tools, labels, etc. can be treated as well, using chemical sterilants (polyphenol disinfectants) as well as by heat treatment. Soils and other nursery media are usually heat treated. No fertilizer should be added to soil before sterilizing, otherwise toxic substances, including a harmful excess of nitrogen (as ammonia), will be produced. Steam soil sterilization is the usual procedure, and simple equipment can be constructed from old 44-gallon oil drums to accomplish this. Baking in containers, directly over a wood fire, is also a possibility, but this is very hard to control. An electric soil sterilizer should be purchased if any experimental work is to be done with rhizobium or mycorrhizas.

In the propagation of rooted cuttings, there is no benefit in the application of fertilizers in whatever form until the cuttings have rooted. All cuttings are usually rooted in a media containing a high proportion of coarse sand/grit. This is especially important where mist propagators are used.

For seed propagation, particularly where it will be some time before seedlings are transplanted, controlled-release fertilizers can usefully be incorporated in the potting medium.

Controlled-release or slow-release fertilizers have been developed mainly to increase the efficiency of nutrient use by plants (Nair and Sharma, 1979; Prasad et al, 1971). They are especially useful in nursery practices where the young plants in containers experience heavy leaching.

From the viewpoint of nutrient recovery, controlled-release fertilizers offer the following advantages:-

- (i) Reduction in nutrient loss;
- (ii) Reduction in chemical and biological immobilization reactions in soils which cause plant-unavailable forms and;
- (iii) Reduction of rapid nitrification and nitrogen loss through ammonia volatilization and denitrification;
- (iv) The lower immediate availability of salts on application to a growing crop with less likelihood of high concentrations in the soil as well as on plant leaves and shoots (thus lessening the risk of foliar damage).

Controlled-release fertilizers in commercial use include the following:

- (i) Urea-formaldehyde (UF) made by a reaction between urea and formaldehyde. UF has a variable nitrogen content, but the most commonly used has 38% nitrogen content.
- (ii) Isobutylidene diurea (IBDU) is a condensation product of a reaction between isobutyraldehyde and urea in a 1:2 mole ratio. It has a nitrogen content of ca. 32%.
- (iii) Crotonylideneurea (CDU) is prepared by a reaction between acetyldehyde and urea and has ca. 30% nitrogen content.
- (iv) Guanyl urea sulphate (GUS) is a unique product because, unlike the others, it is readily and completely soluble in water but is absorbed on the soil colloid. Because of its poor mineralisation and toxicity problem on aerobic soils, it is good only for flooded rice.

- (v) Magnesium ammonium sulphate.
- (vi) Plastic-coated fertilizer (e.g. Osmocote) - **one** of the few controlled-release fertilizers to make commercial impact. It is a polymeric coated fertilizer, available in a number of nutrient formulations with different release patterns. All commercial formulations contain nitrogen, phosphorous and potassium.
- (vii) Sulphur-coated fertilizer (SCU).
- (viii) Fritted elements are those which have been incorporated into fused particles of glass, usually trace elements.

In addition to incorporating fertilizers into the potting medium, it may be necessary periodically to apply foliar feeds of suitable nutrient solutions. The constituents for these can be bought commercially or made from the appropriate chemicals.

3.4 Containers

The choice of an appropriate container is probably one of the most important decisions to make with regard to all aspects of ease of handling under a carefully controlled TRN environment. Rigid or semi-rigid containers are by far the best (Beckjard, 1982). The size of the container will depend on the duration over which young plants are to remain in the nursery, whether or not they are to be repotted (unlikely with, for example, leguminous tree seedlings for which root disturbance is detrimental), and the particular species being grown.

A wide range of containers is available including roottrainers, rapid pots, Fyba pots/tubes, jiffy pots, paperpots, vacapots, Soparco pots, etc. Some of these containers have modifications such as square, ribbed or tapered ridges, that reduce root spiralling and subsequent transplanting losses.

3.5 Seed germination equipment

Hassy trays and Fybagrow propagators and seed trays offer a suitable environment for seed germination. Specific modular bedding trays with a button hole allow for root air-pruning (the process by which emerging roots dry off and die).

Plastic germination trays and germination cabinets, in which both temperature and humidity are optimally set, allow for a greater predictability of germination than do mist techniques. Seed-germination cabinets have covers, but seed trays can be covered by single sheets of glass in order to prevent the medium from drying out rapidly.

3.6 Structures for rooting cuttings

Quality rooting structures must ensure the following attributes:

- (i) An atmosphere conducive to low water loss from the cuttings
- (ii) Protection from the elements
- (iii) Ample but not excessive light
- (iv) Proper rooting temperature (usually about 70-75°F)

Such an environment is provided by a controlled, heated propagation bench (see section 3.7).

Bottom heat for rooting cuttings may be supplied within the same structures by lead or plastic-coated electric cables, electric mats, or various hot water circulated systems (Fig. 3). Polyvinyl chloride (PVC) pipes, placed 15 cm apart along the length of a bench and covered with sand or other material to evenly dissipate the heat, may be used also.

In high-altitude areas, or anywhere where night temperatures tend to drop to the point where plant growth is slowed (e.g., around 10-15°C), bottom heating may prove to be advantageous, even in the tropics.

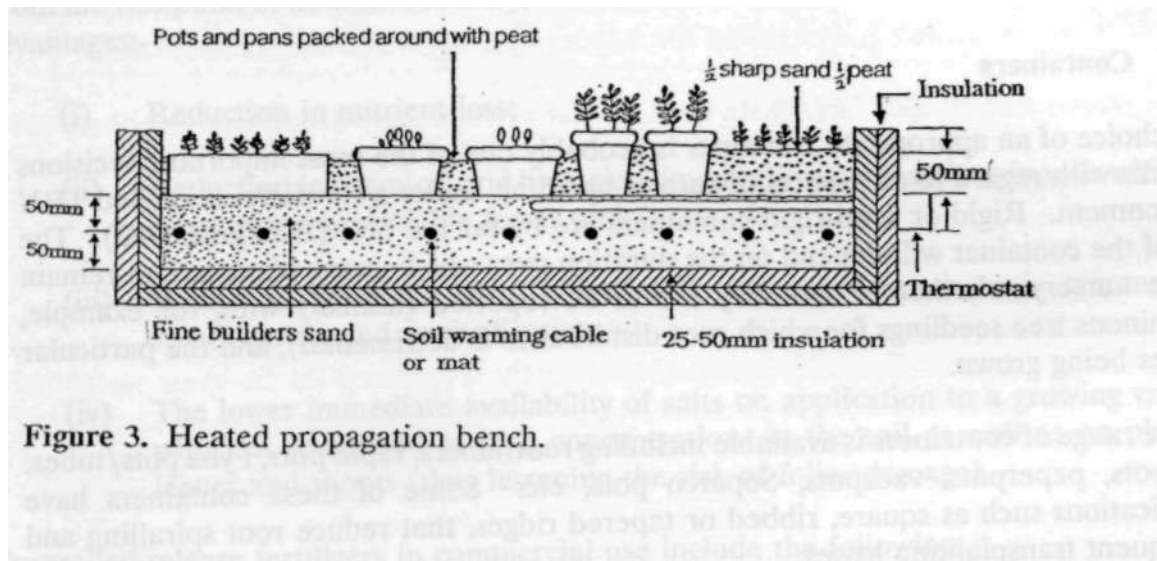


Figure 3. Heated propagation bench.

3.7 Mist propagation systems

Leaves of cuttings wilt and die if they are not kept moist. The mist system provides a film of water over the leaves which lowers leaf temperature, increases humidity and reduces transpiration and respiration. The system has made propagation of many difficult-to-root cuttings feasible. In fact, the two most significant advances in the propagation of cuttings are the use of hormone treatments, e.g., Indole butyric acid (IBA) and Naphthalene acetic acid (NAA), and the development of mist propagation.

A mist-propagation system consists of beds, shading structures, piping and nozzles, an electronic control unit with an electronic leaf (sometimes just a timer) and also a supply of clean water under a constant pressure of 200-400 kN/m³ (30-60 p.s.i.). A heated (or non-heated) propagation bench probably offers the most versatile system in mist propagation systems, particularly for raising seedlings from either seeds or

cuttings for a wide range of species. Care has to be taken to control pests and diseases in this very humid environment, and cuttings that take a long time to root may suffer from having nutrients leached from their leaves. If this is the case, a non-mist propagator can be tried (Fig. 4a and b)

Very free drainage *must* be provided in the form of hard core (stone chips), or similar material to avoid waterlogging. With heated benches, heat loss downwards may be reduced by insulation with polystyrene or styrofoam (25-50 mm thick) immediately below the warmed substrate. Drainage should be provided along the edges. Misting or fogging systems can also be used roughly to control the humidity around standing, container-grown plants.

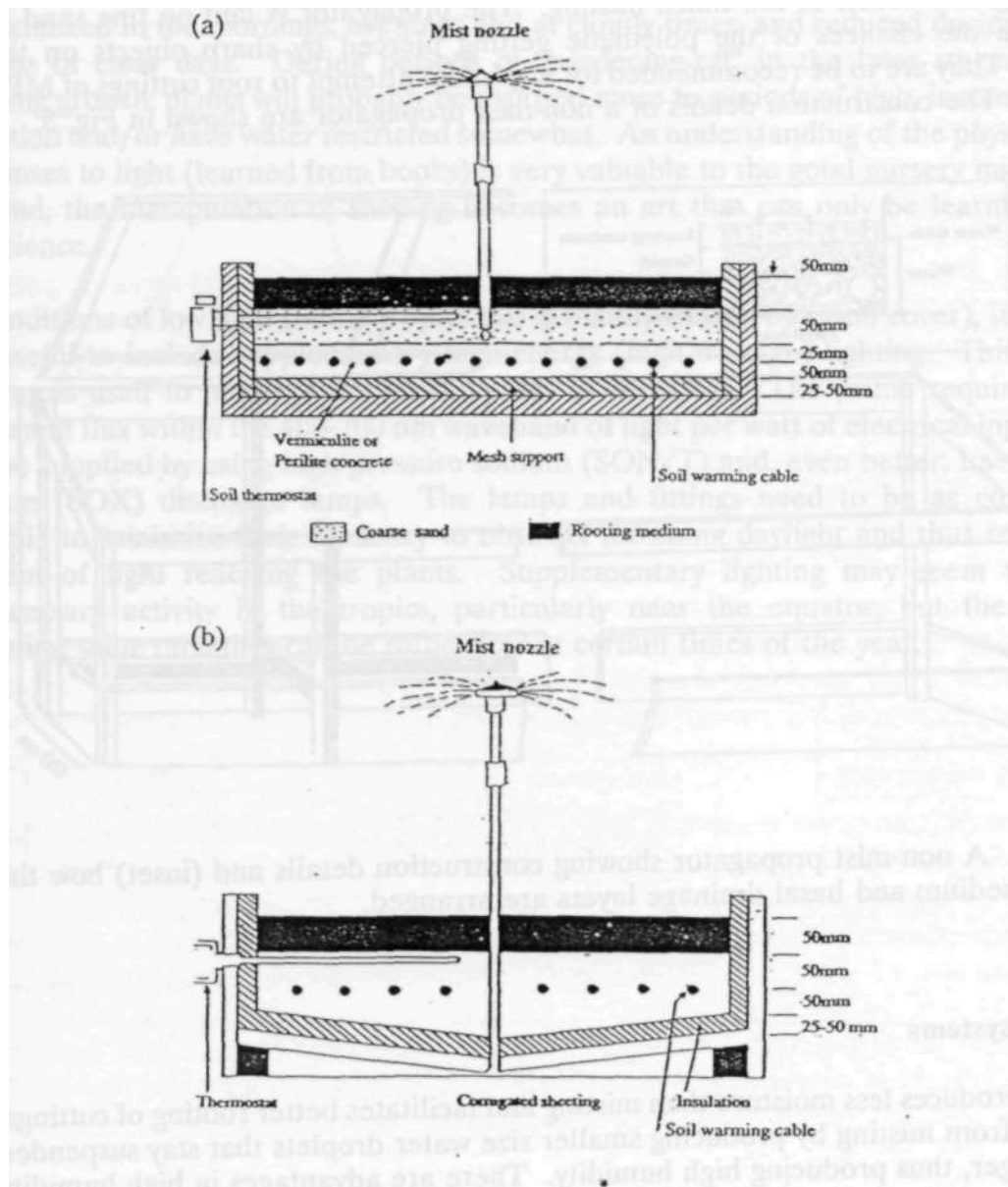


Figure 4. Two forms of bench construction suitable for mist propagation
Source: The Electricity Council, 1987.

3.8 Non-mist systems for rooting cuttings

Non-mist systems are simple, low-technology systems comprising a transparent, water-tight, polythene-covered box (with wood or metal frames) in which layers of stone and gravel are saturated with water and topped with the rooting medium. Electricity and piped water are not necessary since humidity is maintained through constant spraying and by keeping the unit sealed. This is a very versatile unit for rooting cuttings particularly for savannah and dry-zone species which are susceptible to rotting as a result of too much misting. The propagator is laid on fine sand to minimize the chances of the polythene getting pierced by sharp objects on the ground. They are to be recommended for any initial attempt to root cuttings of MPT species. The construction details of a non-mist propagator are shown in Fig. 5.

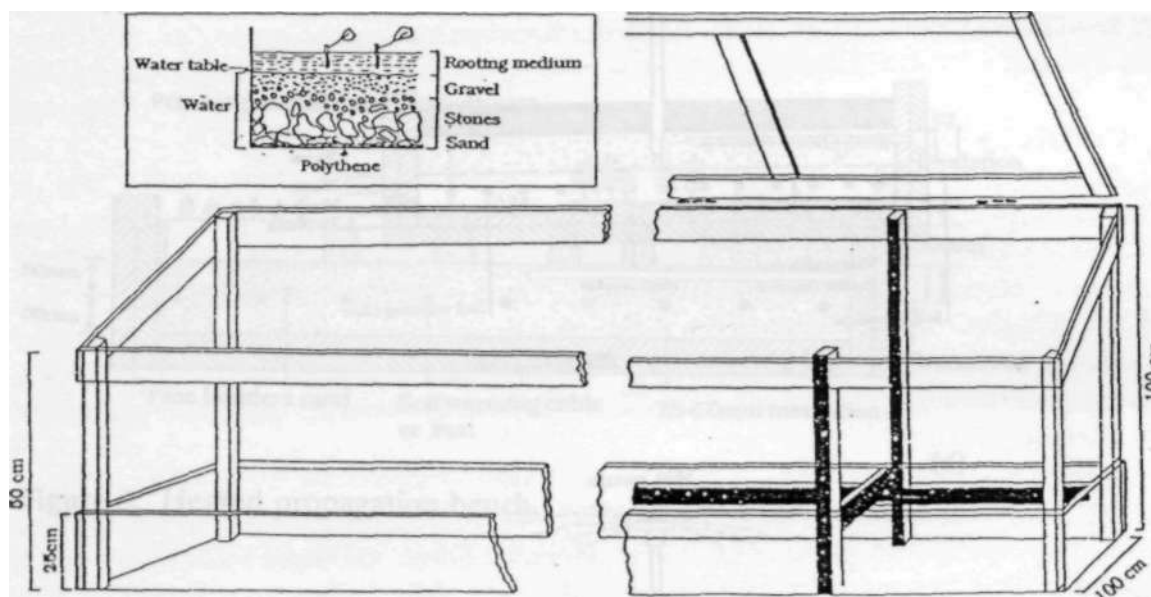


Figure 5. A non-mist propagator showing construction details and (inset) how the rooting medium and basal drainage layers are arranged.

3.9 Fog systems

Fogging produces less moisture than misting and facilitates better rooting of cuttings. It differs from misting by producing smaller size water droplets that stay suspended in air longer, thus producing high humidity. There are advantages in high humidity (fog) propagation but care has to be taken that it does not promote pests and diseases. It can be used as insurance against omitting to water container-grown plants if nursery workers fail, to carry out this task during, for example, holiday periods.

4. LIGHT AND PLANT GROWTH

Anyone growing young plants in a nursery needs to understand the ways these plants will respond to light (see Fig. 6). Detailing this is beyond the scope of this Working Paper (but see Duryea and Landis, 1984). The important issues are to understand the photomorphogenetic influences of light (light changing the form of a plant) - in particular that low radiation fluxes (heavy shade) will cause etiolation - e.g., seedlings will be drawn-up. Such seedlings are of little use for planting out. Also, in practice, the rate of photosynthesis is usually best maintained when the level of incoming solar radiation is maximized in the mornings, evenings and at cloudy times, and reduced during midday periods of clear days. During periods of "hardening-off" in the later stages of tree seedling growth, plants will probably be exposed more to periods of high, incoming solar radiation and/or have water restricted somewhat. An understanding of the physiological responses to light (learned from books) is very valuable to the good nursery man but, in the end, the manipulation of shading becomes an art that can only be learnt through experience.

In conditions of low light (in the tropics this is mainly caused by cloud cover), it may still be useful to include supplementary high-energy (high wattage) lighting. This form of lighting is used to increase the growth rates of seedlings. The prime requirement is maximum flux within the 400-700 nm waveband of light per watt of electrical input. This can be supplied by using high-pressure sodium (SON/T) and, even better, low pressure sodium (SOX) discharge lamps. The lamps and fittings need to be as compact as possible to minimize their tendency to obstruct incoming daylight and thus reduce the amount of light reaching the plants. Supplementary lighting may seem to be an unnecessary activity in the tropics, particularly near the equator, but the level of incoming solar radiation can be rather low at certain times of the year.

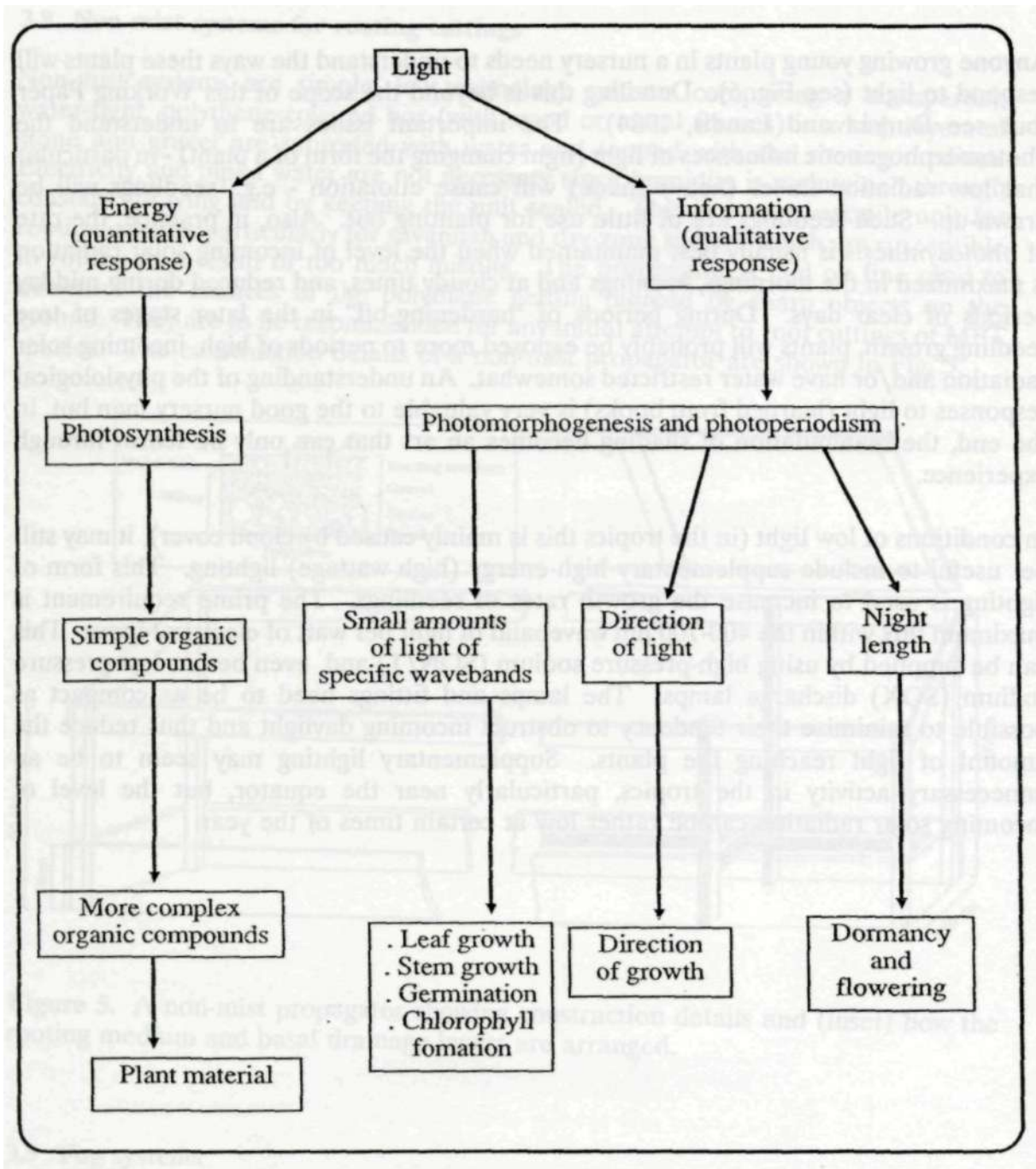


Figure 6. A Summary of plant responses to light.

5. DISEASE, PEST AND WEED MANAGEMENT

Proper nursery management practice calls for integrated disease and pest-management strategies that involve both cultural controls and **the** judicious use of pesticides.

Good sanitation in the nursery is very necessary at all times. This should include sanitizing the equipment and/or used washing containers using appropriate chemical sterilants or heat treatment, monitoring frequently for diseases/pests and taking appropriate control measures by using seed treatments (Captan, Thiram and Benomyl are the common fungicides used), and preventing any part of the nursery from becoming too damp and/or shaded. Removing all plant debris is also essential, as is the scrupulous control of weeds. Pests such as eelworm, crickets, aphids and mealy bugs are especially likely to occur in nurseries. Also, plant pathogens such as damping off and anthracnose fungi could be a problem. All equipment, including re-usable plant containers, should be thoroughly cleaned using a stiff brush and a solution of any appropriate commercial disinfectant (e.g., a phenolic solution).

Damping-off fungi (*Pythium*, *Phytophthora* and *Fusarium*) can be greatly reduced by use of fungicides incorporated in the compost or used as a drench. Aatera W.P. (35% w/w etridiazole) and Repulse, a suspension concentrate containing 500g/l chlorothalonil and 40.2% w/w, are effective control agents for soil-borne fungi.

Control of caterpillars and other foliage pests can be effected by the use of either an insecticide, e.g. Ambush C, a broad spectrum insecticide (E.C. containing 100g/l cypermethrin 10.8% w/w), or Dimilin W.P., containing 25% w/w diflubenzuron.

Successful disease control will ultimately depend on good hygiene, good cultural methods and well-timed fungicide applications. Under the high-humidity regimes in tunnel houses, diseases, e.g., those caused by *Botryti*, could be a problem. Repulse is a useful ally in the control, not only of this fungus, but against mosses and liverworts; it also has activity against mildew and leaf spot diseases.

For control of both grasses and broad-leaved weeds in nursery stock, Surflan, a selective residual herbicide used as a suspension concentrate containing 480g/l oryzalin (41.3% w/w), is a useful spray. Enide 50W, a wettable powder formulation containing 50% w/w diphenamid, is useful in the control of broad-spectrum weeds in nursery stock, both field and container grown.

Gramoxone 100, a liquid contact weed killer containing 200g/l paraquat as dichloride salt (18% w/w), is a good control of grass and broad-leaved weeds, but must be applied before seed emergence, or as a directed spray if spraying in the inter-rows.

6. NURSERY RECORDS

A well-maintained and well-managed nursery should have a complete set of records on sources of seed, any seed pre-treatments, sowing dates, dates of transplanting, weeding, pest/disease control activities, irrigation, application of any soil amendments and all the details concerning the media, containers used, as well as the management treatments applied throughout. The main reason for keeping records is that the exact conditions should be reproducible (if the nursery is successfully produces plants of the right standard for research work). Depending on the scale of operation, nursery records can be kept as a diary, or be computerized.

The following records should be kept:

(i) Seed data

- . species name
- . seedlot number
- . inventory number (and date received)
- . seed source
- . storage details
- . germination test results (and kind of test)
- . comments on pests/diseases and any treatment given to seed lot

(ii) Seed pre-treatment data

- . type of seed pre-treatment (if any) - giving details of procedures and materials used

(iii) Sowing

- . lot number
- . details of sowing depth, etc.
- . date of sowing
- . location or place of sowing
- . management after sowing

(iv) Transplanting (including pricking out - if applicable)

- . lot number
- . time
- . conditions
- . subsequent management (watering/shading, etc.)

- (v) General irrigation regime
 - . frequency and timing
 - . quantity
 - . mode
- (vi) Weeding
 - . type of weeds present (identify)
 - . chemical
 - . hand
 - . mechanical
- (vii) Shading
 - . type used
 - . daily routine
 - . seasonal changes
- (viii) Fertilization
 - . soil
 - . foliar
 - state form of fertilizer/plant nutrient compound used, amounts and conditions under which it was applied.
- (ix) Training
 - . root (vertical, horizontal, air pruning applied?)
 - . top
 - describe (preferably keep photographs)
- (x) Plant protection operations
 - . pesticides applied
 - . biological control (if any)
- (xi) Seedling inventory
 - . lot number
 - . location
 - . number of seedlings and grades
 - total
 - culled (dates, basis of selection, numbers discarded, etc.)
 - loss/death causes

(xii) Final analysis

- . acceptable seedlings for field experiment (by layout in nursery)
- average plant height
- collar diameter
- shoot/root ratio (fresh weight or dry weight basis of sample)
- name of experiment/researcher to whom batch has been consigned

7. DESIGNING NURSERY EXPERIMENTS

7.1 Introduction

An efficient nursery manager/grower is a researcher both by need and inherent nature. He must be keen, observant and inquisitive if he has to continually improve seedling quality and cost-effectiveness of his nursery practice. Of necessity, he has to adapt and, if necessary, change nursery practices. Nursery experiments need to be undertaken with the same scientific rigour as would be applied to field experiments, and the underlying principles are identical. The following notes have, to a large extent, been extracted from Duryea and Landis (1984) with some additional comments.

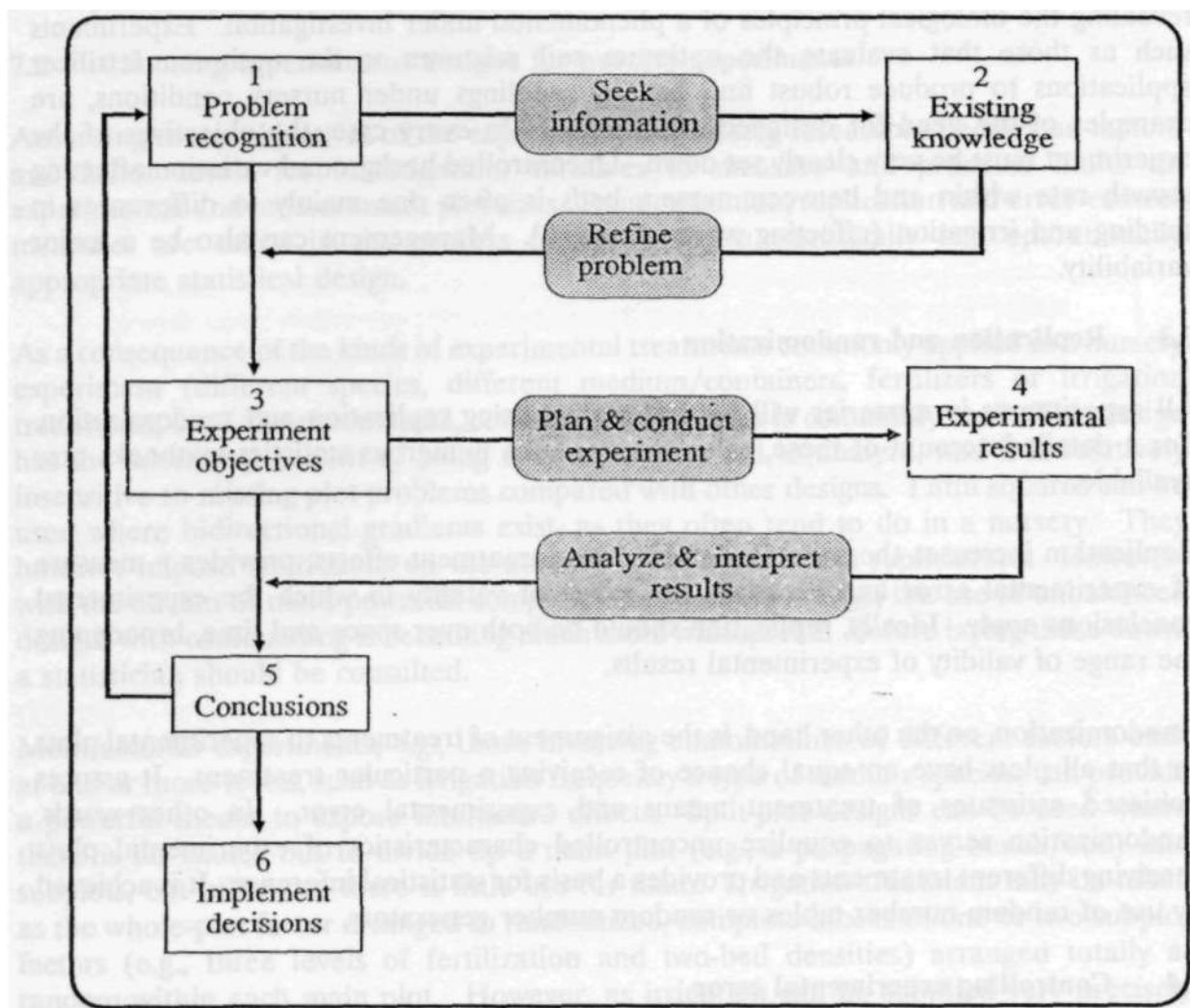


Figure 7. The research process as it might be applied in tree nurseries.
Source: Duryea and Landis (1984).

12 Operational trials *versus* designed experiments

Some nursery problems are appropriately addressed by use of operational trials (preliminary investigations in which each treatment is applied to only one plot). Others must be examined through designed experiments (detailed, critical investigations in which associated measures of uncertainty are required).

Operational trials are mainly used as preliminary investigations and final-phase, large-scale testing, particularly when background variation among experimental plots is *small* relative to expected treatment effects, e.g., the effect of a previously untested seed pretreatment on a new species.

Designed experiments, on the other hand, are useful for detailed investigations, e.g., establishing optimal procedures, investigating interactions among multiple factors or revealing the biological principles of a phenomenon under investigation. Experiments such as those that evaluate the optimum soil mixtures or the optimum fertilizer applications to produce robust and healthy seedlings under nursery conditions, are examples of the need for designed experiments. In every case, the objectives of the experiment must be very clearly set down. Uncontrolled background variation affecting growth rate within and between nursery beds is often due mainly to differences in shading and irrigation (affecting water drainage). Management can also be a major variability.

7.3 Replication and randomization

All experiments in nurseries will be undertaken using replication and randomization. For a detailed account of these, refer to any of the numerous statistics textbooks now available.

Replication increases the precision of estimated treatment effects, provides a measure of experimental error and broadens the range of validity to which the experimental conclusions apply. Ideally, replication should be both over space and time, broadening the range of validity of experimental results.

Randomization, on the other hand, is the assignment of treatments to experimental plots so that all plots have an equal chance of receiving a particular treatment. It assures unbiased estimates of treatment means and experimental error. In other words, randomization serves to equalize uncontrolled characteristics of experimental plots receiving different treatments and provides a basis for statistical inference. It is achieved by use of random-number tables or random-number generators.

7.4 Controlling experimental error

Reducing experimental error can greatly increase the power (or sensitivity) of experiments to expose treatment differences. Methods such as pairing and blocking have been used. Covariates can be used for adjusting current data on the basis of some previous measurement.

The randomized, complete-block design, for example, increases the precision with which treatment effects are estimated by allowing bed (locational) effects to be estimated separately and removed from the comparisons of treatments. This increase in precision is reflected in reduced experimental error. The concept of the block can be extended to more than one dimension through Latin squares and similar designs. However such designs suffer from sensitivity to missing data (e.g., brought about by faulty irrigation or pest attack) and from restrictions on the number of treatments and replications.

One advantage the nursery experimenter has over someone working in the field is that, with tree seedlings being grown in rigid containers, it is possible to re-randomize the set in each block so as to minimize positional, particularly edge, effects. However, care must be taken not to damage the plants when moving them about. Thus the pots need to be spaced well apart. Hence, nursery experiments with plants in containers will invariably take up more space than just a seedling-production unit for the same number of plants.

7.5 Choosing experimental designs for nursery experiments

According to the objectives of the experiment, the nursery researcher decides on factors and factor levels for investigation, variables to measure and practical limits on experimental and measurement plot sizes. Randomization, replication and error-control measures are taken in the process of developing a statistically and operationally appropriate statistical design.

As a consequence of the kinds of experimental treatments commonly applied in a nursery experiment (different species, different medium/containers, fertilizers or irrigation treatments, etc.), the randomized, complete-block design is commonly used. This design has the additional benefit of being easy to lay out and to analyze, and it is relatively insensitive to missing plot problems compared with other designs. Latin squares can be used where bidirectional gradients exist, as they often tend to do in a nursery. They however impose restrictions on the number of treatments and replications. However, with the advent of more powerful computing facilities these days, the use of unbalanced designs with confounding is becoming much more widespread. Before laying these down, a statistician should be consulted.

Multifactorial experiments, e.g., those involving combinations of different factors each at one or more levels, such as irrigation frequency x type of media x species, can provide a powerful means to expose interactive effects. Split-plot designs can be used where there is no choice but to divide up a main plot (e.g., a propagating bench/bed) into subplots, but otherwise there is little use for them. Irrigation treatment may be taken as the whole-plot factor arranged in randomized, complete blocks of one or two subplot factors (e.g., three levels of fertilization and two-bed densities) arranged totally at random within each main plot. However, as irrigation can be supplied very precisely through a drip system individually to each container, a fully factorial arrangement would probably provide much more precise information.

Any experiment should be well documented with notes on the objectives and the experimental plan, including a list of the variables to be investigated and a schematic map of the layout, including its location within the nursery.

7.6 Outlining the analysis

An outline of the format of the data analysis, including the delineation of the sources of variation and degrees of freedom, must always be shown. The tests of significance should be in line with the stated objectives of the experiment, and the biological, practical implications of significance (or otherwise) should be given some thought.

7.7 Interpreting the experimental results

The interpretation of data must follow standard statistical procedures, but if the experiment is properly designed and conducted, the descriptive statistics should be unbiased, precise estimates of population parameters, and the level of uncertainty associated with those estimates and with tests of hypothesis should be low.

When interactions exist, particularly in factorial experiments, it is imperative that particular attention is paid to the type of interaction. Cases of no-factor interaction, scale-effect interaction and rank-change interaction (Figure 8), each has to be interpreted differently.

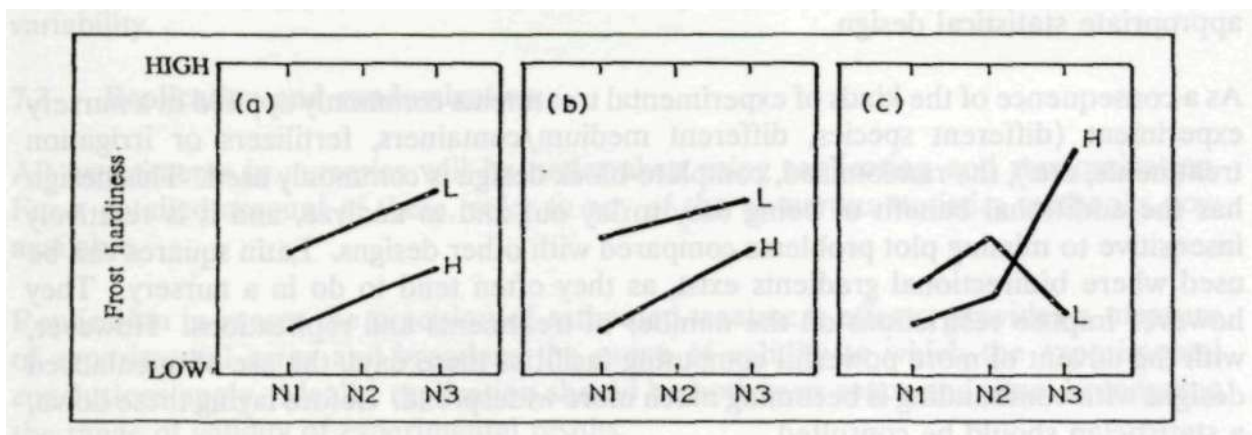


Figure 8. Hypothetical effects of **two** factors, Irrigation level (H = high, L = low) and nitrogen fertilization (N_1 N_2 , N_3) on early-winter frost hardness of Douglas for (a) **no** two-factor interaction, (b) scale-effect interaction, and (c) rank-change interaction.

Source: Duryea and Landis, (1984).

7.8 The scope of nursery experimentation

Research at the nursery level involves all stages ranging from seed storage conditions up to, but not including, the time of planting out. The following areas call for investigation, particularly where several multipurpose species are involved. They may be taken in combination or separately:

- . Storage
 - methods and subsequent viability
 - equipment
- . Studies on pre-germination treatment procedures for different species.
- . Grading
 - for both seeds and seedlings and effects on germination and subsequent growth
- . Containers
 - types, size, etc., and the effects on subsequent growth
- . Potting media
 - a wide area where several components, both local and imported, could be tried out and mixtures standardized.
- . Use of inoculum
 - selection of suitable inocula (both rhizobium and/or mycorrhiza)
- . Modifying the environment
 - e.g., studies on the effect of different levels of shade on growth of seedlings in the nursery, or of different watering regimes and/or nutritional inputs.

This list by no means exhausts the relevant subjects for experimentation with MPTs in the nursery. In general, the kinds of experiments needed for agroforestry nursery investigations will differ a little from those commonly found in commercial forestry or horticulture - unlike the limitation with field experimentation.

APPENDIX: INFORMATION ON MATERIALS AND EQUIPMENT¹

DISCLAIMER

The mention or use of trade name(s) of product(s) is for information only and does not imply endorsement or recommendation (by the authors) over others not mentioned or used. This applies also to products previously mentioned in the text. The information contained in this section may be useful directly, and it may provide ideas for utilizing local materials/products.

1. Containers, growing materials and equipment

Ordinary commercial nurseries use plastic film pots or sleeves (polybags) for transplants and wooden/plastic boxes for the germination/propagation of seeds/cuttings. A main disadvantage of plastic plots is root coiling/spiralling, particularly for seedlings that overstay in the nursery. Transparent plastic films also encouraged algal growth. Polybags tend to be less well drained than most rigid pots, are difficult to water evenly, fall over and cannot be moved about readily. For weak-rooted subjects, they are definitely unsuitable. With open-ended sleeves, an acute problem is the tendency for seedlings to root into the ground with subsequent damage when they are moved.

To improve uniformity, the nurserymen may use the following:

- 1.1 The Emport Handling System - a complete pot-handling system for all seedling stages from planting to marketing. It includes lightweight, but tough, propylene pots (rapid pots) with a wide range of dimensions, and Rapidex container pots.

The Emport Handling System consists of pot carriers, grow 'n' show carriers, bulk storage carriers, spacers for use with bulk-storage carriers and carrying handles.

Address

Rapidex Products Ltd
March Hares Hall Lane
Mobberley Cheshire, WA16 7AD
England

Note: A substantial portion of the information was synthesized from technical bulletins supplied by numerous manufacturers.

The grow 'n' show carriers are designed ostensibly to:

- (i) **Eliminate the tedium of large container movement;**
- (ii) **Keep plants upright under adverse ground and weather conditions;**
- (iii) Save on transport loading time.

1.2 Fyba Whalehide Pots and Growingpots/Growtubes

In this range are the long-life pots that last for 8-10 months depending on growing conditions and the short-life pots that last for 10-12 weeks. Both are biodegradable, and roots penetrate through the side wall obviating the need for removing from the container at transplanting and thus reducing root damage and check to growth! They are made from organic material from wood pulp, recycled paper, peat and textile fibres saturated with bitumen. In essence, they have good moisture- and heat-retention properties ensuring strong and rapid root growth. Greytrainers and rosetrainers are made from the same material but last for two seasons in the nursery. A fungicide and a waterproofing substance prolong the life of the pot. The only difference is that rosetrainers are deep compared to top diameter to accommodate the deep roots of roses. Green carripots have a plastic lining on the inside and cannot, therefore, be planted with the seedling. They last for at least 2 years in the nursery.

Address

The Fyba Pot Company Ltd
Malvern Road, Knottingley
West Yorkshire, WF11 8EG
England

1.3 Capogro Cubes. Blocks and Slabs

Although designed for hydroponic systems, these inert and sterile products can be used as propagation and growing media. They are made from the fibrization of molten basalt and other minerals. Since there is no nutrition in rockwool, nutrient feed would have to be provided to the seedlings from sowing to planting.

Where the porosity of peat-based composts and heavy soils is required, water-repellent Capogro wool may be used. Conversely, water-absorbent Capogro wool is used to increase water or liquid retention, particularly where rapid drying and nutrient retention is a problem.

The complete range of Capogro rockwool products include:

- propagation tubes
- growing blocks and slabs for hydroponics
- Capogro wool for use as a soil or compost conditioner available in four granule sizes and in water-repellent and water-absorbent forms.

These products reduce the long-term risks arising from pot settlement, compost compaction, waterlogging and other dangers associated with **anaerobic conditions. An addition of 15-20% by volume of water-repellent Capogro wool gives a hardy nursery stock compost with an open, fibrous texture.**

Address

Pilkington Insulation Ltd
P.O. Box 10, St. Helens
Merseyside, WA10 3NS
England

14 Jiffy Pots

Jiffy products include a whole range of pots and pallets (moveable platforms on which containerized plants can be transported) designed to be used on capillary and ordinary watering systems. These are designed to give increased wet strength and increased life.

Address

Jiffy Products (UK) Ltd
14/16 Commercial Road
March, Cambridgeshire, PE15 8QP
England

15 Hassy Trays/Paperpot System

The Paperpot system of nursery products is biodegradable and has the following grades:

- B, 4-6 weeks propagation
- V, 7-9 weeks propagation
- F, 3-12 months propagation

They come complete with heavy-duty, plastic trays for ease of handling. A new Ecopot system, made from plastic laminated paper, is most suitable for forest seedlings which have to remain in the nursery for one or more growing seasons.

Address

Planter Systems Ltd
Unit F1 Coedcae Lane Industrial Estate
Llantrisant
Mid Glamorgan, CF7 9EW
England

1.6 Vacapaks. Seed Trays and Vacapots

These products are easily divisible units of 1000. Two drainage levels cater for overhead or sub-irrigation. There is a range for all products.

Address

H. Smith Plastics Ltd
The Mayphil Industrial Area, Battlesbridge
Wickford
Essex, S11 7RJ
England

1.7 Universal Drainage Products

Whichever watering system is used, the finished plant's quality is dependent, to a high degree, on the efficiency of the container's drainage, as regards quick discharge of excessive water, and the satisfactory aeration of the potting media so as to ensure healthy root development.

The universal drainage products range includes: deep, narrow models; mini pots for mini cultures and herbs; G-pots for greenhouse; low, wide models; all-round containers and square pots (and accessories), all with universal drainage.

Address

O.S. Plastic (U.K) Ltd
Parkside, Duke Street
Ipswich, IP3 OAF
England

1.8 Grodan Rockwool Products

The Grodan range includes high-performance growing slabs, blocks and granulates in both the water-absorbent and non-water-absorbent forms to improve the soil/compost properties (Sonneveld, 1989; de Boot, 1979).

Grodan rockwool is produced from a special volcanic rock (Diabas) melted at a temperature of 1600°C. The liquid lava runs onto a fast-revolving wheel into a chamber where the fine rockwool fibres are formed. The fibres are then fixed with a special binder resulting in a very stable, structured, uniform and porous product.

Address

Avoncrop Ltd

Northfield, Nye Road, Sandford
Bristol, BS19 9QE
England

1.9 Soparco Container Pots

Manufactured from polypropylene, Soparco pots and polypots are tough, resistant to weather and have high-impact strength. The polypots, manufactured with a touching gusset, have the advantage of sitting exactly square on the ground thus providing excellent stability.

Address

Lows of Dundee Ltd
6 South Ward Road
Dundee, DD1 1PN
Scotland

1.10 Roottrainers

Commercial forestry nurseries, particularly in the tropics, use plastic pots for nursery seedlings before transplanting. Root spiralling may result, particularly for seedlings that overstay in the nursery. Plastic bags have to be quite large in order to accommodate a tree of plantable size without resultant problems of transportation. The roottrainer system uses open, easily drained soil in a small volume. The roots get into the grooves of roottrainers and are directed to the drainage hole at the bottom. The grooves train roots to go to the outside of the container and hence prevent root spiralling.

Address

Roottrainers Corporation Ltd
11413 - 120 Street
Edmonton, Alberta
Canada T5G 2Y3.

1.11 Ronaash Roottrainers

These come complete with space-saving trays. They are deep and open up reducing disturbance. Parallel grooves encourage roots to grow downwards, preventing root spiralling. Natural air pruning helps increase lateral roots, resulting in a better root-to-shoot ratio.

Address

Ronaash Ltd
Kersquarter Kelso
Roxburghshire, TD5 8HH
England

1.12 The Vefi Potting System

This system ostensibly enables one man to do the job of three by allowing the carrying out of several operations at the same time instead of doing them one at a time.

Fifty four pots in a system tray are set up with one single movement of the hand. Using special equipment, filling, spacing, selecting and packing can be done at one go. With the use of a magazine and a roller, one man can fill 10,000 pots with soil in an hour. The roller makes the soil in each pot have the required degree of firmness.

A transport trolley with shelves makes internal transport of system trays very easy. This system is a revolution in nursery management.

Addresses

O.S. Plastic (U.K.) Ltd
Parkside, Duke Street
Ipswich, IP3 OAF
England

Jiffy Products (ILK.) Ltd
14/16 Commercial Road
March
Cambridgeshire, PE15 8QP
England

2. Shading, Windbreaks, Protection Nettings

Controlled shade and shelter are very necessary in proper nursery management.

2.1 Fordingbridge Engineering Products

This range includes screen systems that are air/water porous, have variable shade value and are energy saving. These come complete with wire or rope-driven systems.

A wide range of Netlon high-density polyethylene is available for windbreaks.

Address

Fordingbridge Growers Supplies
Arundel Road, Fontwell, Arundel
West Sussex, BN18 OSD
England

2.2 Polytherm Tunnel Films

It is well known that there is usually a trade-off between heat retention and light transmission. There is roughly a 1% crop yield loss for every 1% light loss.

Materials that have high light transmission and heat retention properties aid growth in a nursery. The range of polytherm AF tunnel films provides materials with such qualities.

Address

Visqueen
Yarm Road
Stockton-on-Tees
Cleveland
TS18 3RD
England

2.3 Windbreaks/Predator Control Nettings

Windbreak materials have to have great strength and permeable meshes to reduce eddy effects. Wind reduction lessens the risk of physical damage to nursery seedlings, reduces excessive evapotranspiration and generally creates a stable environment for the growth of seedlings.

Address

Bridport-Gundry Netting Ltd
The Court, Bridport
Dorset
DT6 3QU
England

2.4 Nicofence Products

The Nicofence product range includes windbreaks and shade netting with variable shade values. The Visqueen range of shade netting is also available.

Address

Clovis Lande Associates Ltd
104 Branbridges Road
East Peckham
Tonbridge
Kent
TN12 5HH
England

2.5 Rokolene Protection Netting

Rokolene nettings are made from 100% high-density polyethylene, giving shade values from 25% to 70%. They come in standard green colour but other colours are available. The protection netting is ultra-violet stabilized to ensure a long life.

Address

Strella Group
Strella House
385 Alfreton Road
Nottingham
NG7 5NW
England

2.6 Lows of Dundee Products

This range covers a wide selection of shade netting and wind protection materials. The materials are ultra-violet stabilized for long life.

2.7 Bird Protection Netting

Protection nettings include bird-protection netting for which there are various mesh sizes. The Netlon protection net is manufactured from ultraviolet stabilized, black polypropylene and is dual purpose, offering protection both from birds and butterflies. It is non-toxic, rotproof and completely unaffected by chemical sprays. It is available in 15 mm diamond and 19 mm square mesh forms. It comes in widths of 2 and 4 m and lengths of 100, 200 and 300 m.

Address

Lows of Dundee Ltd
6 South Ward Road
Dundee
DD1 1PN
Scotland

2.8 Tildenet Products

Tildenet products provide shade, windbreak **and** predator/insect **control** or barriers.

Address

Longbrook House
Ashton Vale Road
Bristol
BS3 2HA
England

3. **Plant Nutrition, Growing Media, Conditioners**

One of the problems of nursery management is the supply of nutrients at the required time for the duration that the seedlings are in the nursery. The danger from excessive leaching due to constant watering is real.

Commercial forest nurseries use soil mixtures containing variable types and amounts of compost and/or virgin forest soil in a bid to improve plant nutrition. The onset of controlled-release fertilizers has alleviated the problem of nutrient depletion in the propagation media.

3.1 The Osmocote Range

The Osmocote range of products includes many brand names and in variable formulations, some in tablet form. They have a duration varying from 2 to 24 months. In addition to supplying nitrogen, phosphorus and potassium, some of the products in the range also supply Magnesium oxide (Mgo) and traces.

Address

Sierra UK Ltd
116A Melton Road
West Bridgeford
Nottingham
NG2 6EP
England

3.2 Ficote Composts

This product range includes a wide array of composts and the Ficote controlled-release fertilizer. Used with Ficote composts, the fertilizer ensures unrestricted growth of vigorous species without risk of toxicity in phosphate-sensitive subjects.

The Ficote composts come in variable pH ranges and grade options. It is recommended that composts containing Ficote should be used within 21 days from despatch as extended storage can result in an unacceptable rise in water-soluble nutrient levels. Ficote composts can be used as a top or base dressing.

Address

Fisons plc
Horticulture Division
Paper Mill Lane
Bramford
Ipswich
Suffolk
IP8 4BZ
England

3.3 Capogro Wool as a Growing Medium and a Soil/Compost Conditioner

Capogro wool is used by leading nurseries for controlled germination of certain species, prior to growing on Capogro cubes. It has successfully been used for striking cuttings. The addition of water-repellent grades of Capogro wool to peat-based composts improves their porosity and, hence, aeration. This allows for more even distribution of nutrients, water and air while root damage/death is minimized. It also allows for faster root development, a reduction in pot settlement and improved bacterial activity. The incorporation of water-absorbent Capogro wool grades in dry, sandy soils has remarkable effect on the water or nutrient solution holding capacity of the soil.

Address

Pilkington Insulation Ltd
P.O. Box 10, St. Helens
Merseyside
WA10 3NS
England

4. Irrigation and Fogging Equipment

Fybamat Capillary Matting - a material made from high-quality, non-woven polyester fibre - is strong, rot proof and shrink resistant. The material has a high absorption rate and an excellent liquid retention capacity. The system is an efficient method for water and nutrient distribution on benches or level ground. It is reputed to retain moisture during the unirrigated periods, and its reflective nature helps reflect light on the plant thus improving growth. In a nutshell, the system allows constant delivery of water and nutrients to potted plants on trays, thus reducing the amount of water used. Fybamat comes in lengths of 50 m with a range of widths 460 mm, 915 mm and 1830 mm, and a thickness of 3-4 mm.

As most of nursery stock is grown in containers, an efficient irrigation system giving even precipitation, is essential. The containers, laid out in beds or rows, can be irrigated using overhead sprinklers, low-level spray lines or drip systems each of which can easily be automated.

Addresses

Geerings of Ashford Ltd
Cobbs Wood House
Chart Road
Ashford, Kent
TN23 1EP
England

Streeta Group
385 Alfreton Road
Nottingham
NG4 5NW
England

4.1 Fogging"

A supply of compressed air combines with water supply at the nozzle to produce fog. Fogging cools and humidifies the plant environment and can be used to raise and maintain any required relative humidity up to 98% when controlled by a humidistat. Fogging is an essential follow up to tissue culture. It is also used in growing rooms and for cooling structures such as tunnels/glasshouses.

MacPenny or Sonicore nozzles are recommended.

Address

E.J. Woolard Ltd
Fieldings Road, Cheshunt
Waltham Cross
Hertfordshire EN8 9TY
England

4.2 Micron 5 Fog

This advanced fogging equipment comes complete with a 2 HP pump, controller, an aspirated wet-dry humidistat controller and accessories. The Micron 5 Fog gives a very fine spray, creating up to 100% humidity. The spray minimises transpiration losses leading to improved rooting quality (cuttings) without the risk of overwetting either the growing medium or the plants. The fog blanket also acts as a sunbarrier, reducing the scorching effects of the sun.

Address

Fordingbridge Growers Supplies
Arundel Road, Foatwell, Arundel
West Sussex
BN18 OSD
England

5. Propagation and Germination Equipment

Included in this range are Hotbox propagators, soil warming cables for heating beds (and associated thermostats) and mist propagators.

5.1 Mist Propagation

Mist propagation maintains a film of moisture over the leaf surface of cuttings. MacPenny control units and electronic leaves positioned on the mist bench and wired into the mist control unit do the trick. When the leaf is dry, it signals the absence of moisture on its surface to the controller, which opens a Solenoid valve. The duration of the mist burst is adjustable from 3 to 10 seconds; the presence of moisture on the electronic leaf closes the Solenoid valve. The control unit has a manual override if required.

A weaner and crossover unit allows for variation in the misting frequencies in different benches. The mist jets suit benches of widths from 0.5 m to 1.5 m and are mounted on 1-metre risers spaced at 1-metre intervals.

Addresses

E J. Wollard Ltd
Fieldings Road, Chestnut
Waltham Cross
Hertfordshire EN8 9TY
England
or

Fordingbridge Growers Supplies
Arundel Road
Fontwell, Arundel
West Sussex
BN18 OSD
England

or

Even Products Ltd
Evesham
Worcestershire
WR11 4TS
England

5.2 The Hotbox Propagator

The Hotbox propagator incorporates a Melborne frame cover with a ventilation system that reduces condensation. It also retains most of the heat given off by the bench, and thereby provides a warmer environment for the seedlings, promoting growth of healthier and stronger plants. A foil-heating element, earthed for safety and thermostatically controlled, gives the right temperature for perfect seed germination or propagation of cuttings.

Address

Hotbox Heaters Ltd
Unit 7, Gordleton Ind. Park
Sway Road
Lymington
Hants
SO41 8JD
England

5.3 Soil-Warming Cables

Soil-warming cables provide ideal base heating for propagation and misting beds. The inclusion of thermostats allows for accurate temperature control.

Address

Fordinbridge Growers Supplies
Arundel Road, Fontwell, Arundel
West Sussex
BN18 OSD
England

5.4 Hotbox Heatwave

These are made-to-measure, bench-heating panels. The heating element is laminated between sheets of foil which spread the heat evenly, giving excellent seed germination and a high striking rate for the propagation of cuttings. The whole foil panel is earthed for safety. Thermostats can be fitted on the heating panels.

Addresses

Heating Appliance Manufacturers
Unit 7, Gordleton Industrial Park
Sway Road, Lymington
Hampshire
S041 8JD
England

and

Clovis Lande Associates Ltd
Branbridges Road
East Peckham
Kent
TN12 5HH
England

5.5 Germination Cabinets/Rooms

The use of a germination cabinet saves nursery space while at the same time showing a greater order of predictability than when using mist techniques for the production of seedlings. The unit consists of a small, thermally insulated cabinet held at relative humidity approaching 100% and air temperature between 20 and 30°C. It does not have a humidifier, but depends on its air tightness for maintaining the high relative humidity required. For seeds requiring light for germination, a bulkhead fitting with a 60W GLS lamp is satisfactory. In a large germination room, the atmospheric humidity is regulated by a humidifying device - a water spray system producing particles of moisture small enough to be vaporized.

5.6 Seed Trays

Fybamat Products include Fybagrow propagators and seed trays.

Address

The Fyba Pot Co. Ltd
Malvern Road, Knottingley
West Yorkshire
WF11 8EG
England

5.7 Hassy Trays

A wide range of trays is available for propagated species, whether they are seed or cuttings. The cells made from rigid plastic have smooth, tapering walls to allow for easy manual extraction of seedlings.

In addition, specific modular bedding trays with a bottom hole allow for air root pruning.

6. General Equipment

6.1 Advanced Sprayer Technology

For spraying equipment, we have the Fox Motori range or Powered Knapsack, portable or trailed sprayer and Attila hand-held CDA sprayers.

Address

Microcide Ltd
Shepherds Grove
Stanton
Bury St. Edmunds
Suffolk
IP31 2AR
England

6.2 Soil Warming

Soil-warming cable in beds (hot beds).

Address

The Electricity Council
Farm-electric Centre
National Agriculture Centre
Stoneleigh, Kenilworth
Warwickshire
CV8 2LS
England

The temperature of soil or other growing medium is a major factor affecting plant growth. Seed germination, root formation/development and root function are particularly dependent on the temperature of the rooting medium. It has erroneously been assumed that the root-zone temperature will closely follow air temperature, but, in practice, the root-zone temperature generally remains significantly below that of the air.

A highly effective method of warming the growing medium is by using electrically controlled warming systems. These offer very even distribution of heat, precise control, versatility and low initial capital cost.

Heating systems can either be in cable form or flexible mats. The use of electronic thermostats allows accurate control of the bed temperatures since the thermistor sensor is small and can be connected by means of a flexible cable into the rooting medium itself.

Artificial lighting from high-efficiency lamps, e.g., high-pressure mercury or sodium-discharge types, can be used to supplement daylight to provide maximum photosynthetic energy or to extend the daylength.

For growth response, the prime requirement is maximum radiant flux within the 400-700 nm waveband of light per watt of electrical input. The most efficient lamps in this sense are the high-pressure sodium (SON/T and SOX) discharge lamps. These might be used on small batches of seedlings in agroforestry research nurseries to bring on those that were sown later than the others.

Address

The Electricity Council
Farm-electric Centre
National Agriculture Centre
Stoneleigh, Kenilworth
Warwickshire
CV8 2LS
England

6.4 Ventilation Fans

There are two types of ventilation - natural and artificial. In artificial ventilation, a number of extractor fans are arranged to draw air through the glasshouses from air inlets. The design will depend on the type, size, speed throughput and number of ventilating fans, the size and configuration of the inlet ventilator and some knowledge of the air-speed and air-flow pattern likely to be encountered within the nursery structure.

Address

The Electricity Council
Farm-electric Centre
National Agriculture Centre
Stoneleigh, Kenilworth
Warwickshire
CV8 2LS
England

6.5 Soil Sterilization

Heat treatment is a highly effective and safe means of sterilizing soil. A common set up is an electric soil sterilizer consisting of a metal box mounted on legs raising it to about

40 cm from the ground. The box, fitted with six 1.5 kW vertical heaters, can hold 200 kg of moist loam soil. The sterilizing operation takes about 90 minutes during which time the soil temperature is raised to 82°C and approximately 11 kWh of electricity is used. At this temperature, harmful bacteria and weed seeds are destroyed while a high proportion of bacteria beneficial to plant growth survive. A time switch can be fitted to switch off the sterilizer after the prescribed heating time (to avoid overheating). The limit of 82°C minimises the release of nitrogen.

Address

The Electricity Council
Farm-electric Centre
Stoneleigh, Kenilworth
Warwickshire
CV8 2LS
England

6.6 Hot-water Treatment

Plant material may require treatment to rid it of tissue-borne pathogens such as eel worms. The hot-water treatment consists of a large, hot-water bath into which quantities of plant material are immersed for a period of time sufficient to kill the pathogens without harming the plant tissue. There is a very narrow margin between the lethal temperature for the pathogens and that for the plant material and therefore, the right water temperature is critical.

6.7 Sprayers and Spray Technology

A whole range of spraying equipment - knapsack, pneumatic and motorized sprayers with related accessories - is available.

Address

Cooper, Pegler and Co. Ltd
2 Victoria Gardens
Burgess Hill
Sussex
RH15 9LA
England

Codacide oil is a new product that uses a plant oil instead of water as the primary means of carrying pesticide chemical from the spray tank to the biologic target. The resulting controlled emulsion dramatically improves the physical and biological aspects of spray application. Its triglyceride base allows it to penetrate both the waxy cuticle of the leaf and the water-resistant shells of insects, grubs and larvae, which are triglyceride based too.

In addition, a wide range of sprayers is available, including the Attila atomizer, Cobra, Wasp and Solo sprayers - in both the manual and electronic versions.

Address

Microcide Ltd
Shepherd's Grove
Stanton, Bury St. Edmunds
Suffolk
IP331 2AR
England

6.8 Aluminium Benching

The PG Aluminium benching is strong yet light, has a long life and is maintenance free. The bench-top sides are available in 3 heights: 50 mm, 90 mm and 120 mm.

Address

P.G. Horticulture Ltd
Street Farm
Tornham Magna, Eye
Suffolk
IP23 9HB
England

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