BIOLOGICAL AND OPERATIONAL CONSIDERATIONS IN THE DEVELOPMENT OF INTEGRATED HANDLING AND TRANSPORTATION SYSTEMS

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Abstract.--A number of the larger nurseries in Sweden have developed systems and hardware for integrating the handling, packaging and storage of containerized planting stock in the nursery with its delivery and distribution in the field. Biological and operational factors to be considered in the development of integrated handling systems are reviewed and discussed.

Résumé.--Un certain nombre des principales pépinières suédoises ont intégré l'équipement et les systèmes de manipulation, d'emballage et de stockage sur place du matériel de reproduction en mottes emballées puis de son transport et de sa distribution sur le terrain. On étudie les facteurs d'ordre biologique et opérationnel dont il faut tenir compte dans la mise au point des systèmes intégrés, et on présente une discussion sur ce sujet.

INTRODUCTION

The starting point for an integrated containerized system is the seed in the nursery, and the goal, or outcome, is the planted seedling in the field. The seedling should be firmly positioned or planted and should have good prospects for developing into a healthy tree in the future forest. The three important links in the chain--plant production, distribution and planting--should be interrelated and the whole process optimized. An important element in the distribution link that merits special attention is storage.

Various approaches can be used in designing a containerized system. Frequently, the pivotal feature of a system is a specific item such as container design or planting technique. With a little luck and skill, such systems will find specific situations to which they are well suited. An alternative approach is first to identify the basic characteristics of the situation at hand and to specify the demands they make on the production-distribution-planting system. The problem is then one of finding solutions that satisfy these demands.

The likelihood of finding the "right" system for specific situations is probably greater if the latter approach is used. However, it is crucial that the characteristics of a given situation be accurately identified.

ASSESSING THE SITUATION

The setting under which our system is to function must be clearly specified in terms of critical characteristics. For example, the size of the tract to be planted will determine the volume of trees to be transported to the planting site. Smallhold forests in southern Sweden average 1 to 3 ha, whereas industrial tracts in northern Sweden range from 15 to 20 ha. These two extreme cases call for entirely different modes of transportation (types of vehicles, etc.). Similarly, the infrastructure in the form of

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roads and available manpower will influence the types of transport that can be used. The timing and duration of the planting season are a function of manpower supply and climate, and these also have a decisive effect on the length and intensity of the transport season, as well as upon the need for storage facilities.

The scale of operations influences the length of supply lines. A company with vast forest holdings and centralized plant production will have long supply lines. The type of forestry operations also influences the length of supply lines as well as the total area over which the plants have to be distributed. Patterns of ownership (socio-economic structures) also exert considerable influence on the organization of transportation. For a heterogeneous group of forest owners who draw their plants from the same nursery a system of considerable adaptability will be required. A single, flexible system will be more economical than several rigid ones.

Totally integrated systems are most easily achieved when the forest owner is in a position to plan and steer plant production, distribution and planting. Independent plant-producing companies or organizations may put too much priority on plant production. Furthermore, efforts to effect changes in such systems often take a long time. A typical example of this is the situation in Sweden, where practically the entire forest industry, which accounts for roughly 50% of the total forest area, utilizes containerized systems and has developed appropriate and well practised routines. On the other hand, smallhold forest owners in southern Sweden lack systems specially adapted to their conditions. It is unlikely that this group will be able simply to copy industrial systems. The forest industry has been able to analyze its situation and identify its needs; the corresponding process among smallholders started only recently.

VIEWS ON DISTRIBUTION

As suggested earlier, many of the needs in a given system are dictated by field conditions. Therefore, in examining the handling and transport link of the overall system one must start in the field.

Planting concludes the distribution process. It can be achieved in two fundamentally different ways: by inserting the seedling into the soil, or by placing the seedling on the surface of the soil. The latter technique, which is discussed elsewhere in this symposium (Lindstriim and Wigberg 1982), has had only limited application to date. The technique used to fix or anchor the seedling dictates features of container design, container function and handling.

By examining the chain of events leading from nursery to planted seedling, we can identify a series of critical points in the transportation process: terminal, roadside depot, edge of the cleared site, strategic placement on the site and the location of

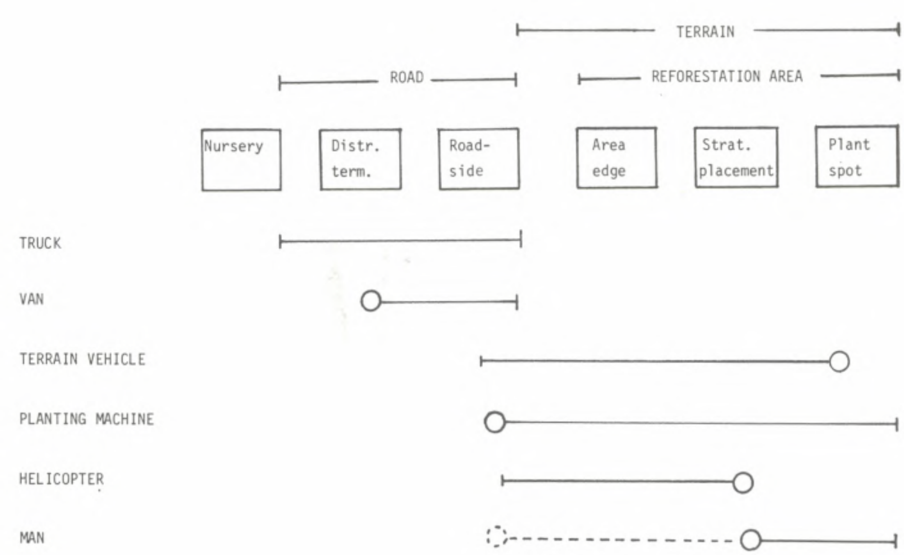

Figure 1. Schematic diagram of stock distribution and various means of transportation.

each individual plant. Various means of transport may be used, depending on the types of roads, volumes of trees and length of the supply line. The application of various types of vehicle to different transportation situations is illustrated in Figure 1.

The transportation of seedlings from the nursery to the planting site may be looked upon as a flow in which the volume to be transported is progressively broken down, ultimately to the individual seedling. Figure 1 indicates the most natural points for such subdivisions. It is important that the weight or volume of the transport unit (e.g., box, pallet, etc.) be matched to the vehicle capacity. In the case of small planting tracts, the strategic placement of seedlings on the site is unnecessary. The only feasible means of transport here, in terms of costs, is to carry the seedlings on foot to the site, so that the transport unit at the edge of the site must break down into units suitable for manual transport.

In the case of hand planting the planter performs the final act of distribution on the site. Volumes and packaging should therefore be adapted to the human body. Such packaging characteristics can be built into the nursery operation, e.g., in the form of tear-away segmented cartons.

In large-scale operations helicopters have proven especially effective vehicles for transportation of seedlings from roadside depots to strategic points on the cleared site. Terrain vehicles can bring the plants in unbroken packages practically to the point at which they are to be planted. Planting machines carry the process through to the point of fixing the seedling in the soil, although the machines' feeding mechanisms generally require that transport packages be broken down when the machine is loaded. Normally, the distance between roadside depot and the edge of the cleared site is short or negligible, especially in large-scale operations where access roads were constructed when the former stand was felled.

Generally, large trucks transport the seedlings from the nursery to the roadside depot. When planting sites are small and widely scattered, it may be appropriate to establish a distribution terminal, where the transport unit can be broken down into cartons which can be transported by hand in smaller vehicles. The successive breakdown of the transport unit after leaving the nursery is illustrated in Figure 2. Packaging should protect the plants against mechanical and biological abuse, such as excessive wind, dehydration and less than optimal temperatures. The package should also be designed so that it can be handled and transported easily through the various distribution links. It may be necessary to establish a buffer storage depot somewhere along the distribution chain. The need for such a depot varies, and will depend on administrative and organizational factors. Transfer points in the chain are the most logical places for buffer storage. The earlier in the chain that storage takes place the easier it will be to monitor and maintain an adequate storage environment because of the greater volumes involved.

In the case of small, scattered sites, with labor-intensive operations, return transport of packaging materials for reuse in the nursery can prove expensive. In such cases disposable, single-use packaging is preferable, although it may entail special handling (burning, burying, etc.) of the refuse. The decision as to whether or not to assume the cost of return transport will influence the choice of container type.

HANDLING IN THE NURSERY

Containerized nurseries nearly always use stationary facilities, sowing machines and packaging units. The seedlings are transported between these installations and the places of cultivation, storage areas, etc. Transport and handling are thus dominant features in the nursery routines. Cultivation takes place on "surfaces", whereas transportation involves "volumes". Many other nursery activities, such as peat filling, sowing, and packing, also take place on surfaces. Recurrent transportation in the nursery phase thus demands rational internal transport units that can easily be converted to surfaces and back into volumes again, as illustrated in Figure 3.

The smallest unit is the container, numbers of which may be aggregated into a "surface", often into a unit suitable for manual handling (a container set). It is this unit which passes through the peat-filling machine and sowing machine. If these units are stacked in frames which can be used for mechanized distribution and collection in the nursery they may be called "cultivation units". To achieve rational transportation between various locations, these units may be combined into internal transport units (ITU). Use of these various units in the nursery is illustrated in Figure 4.

In situations where the seedlings are packaged, the packing phase marks an important breaking point in the chain of events

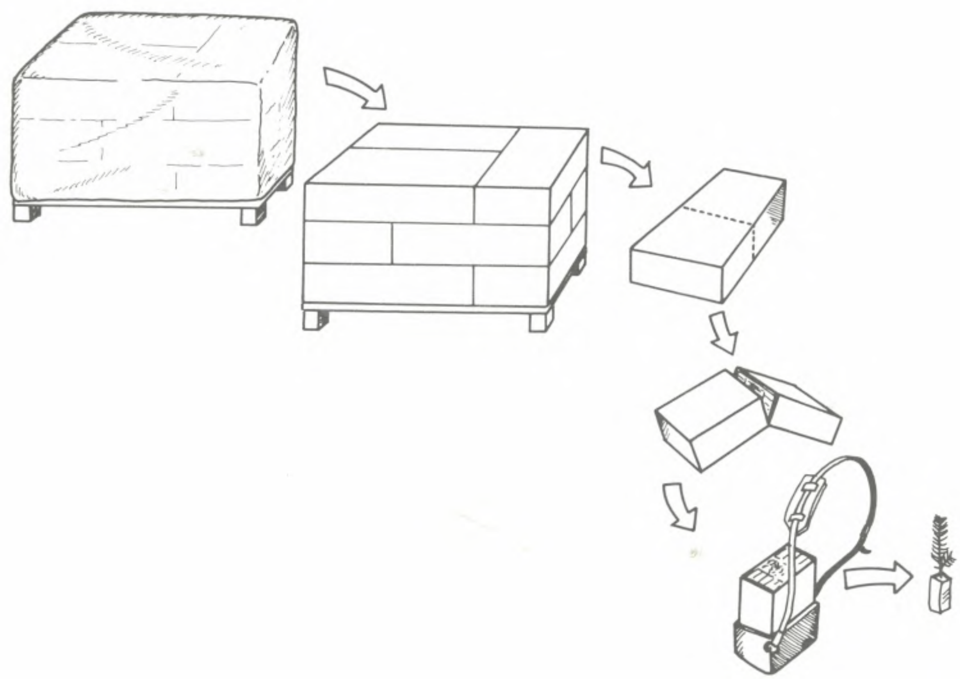

Figure 2. Example of progressive breakdown of an External Transport Unit (ETU).

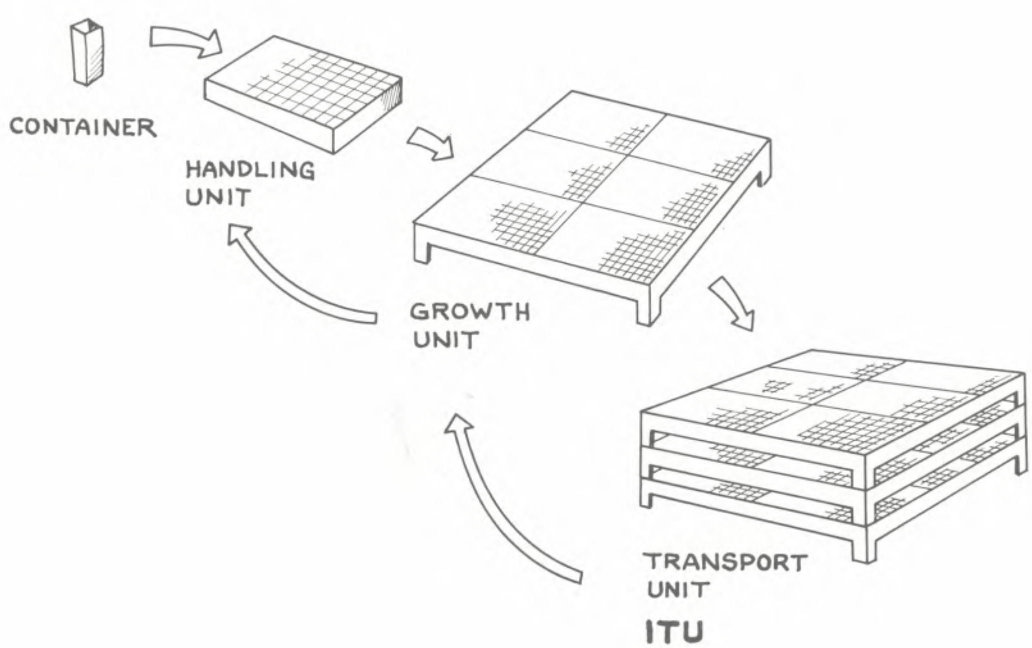

Figure 3. Examples of different handling levels in the nursery.

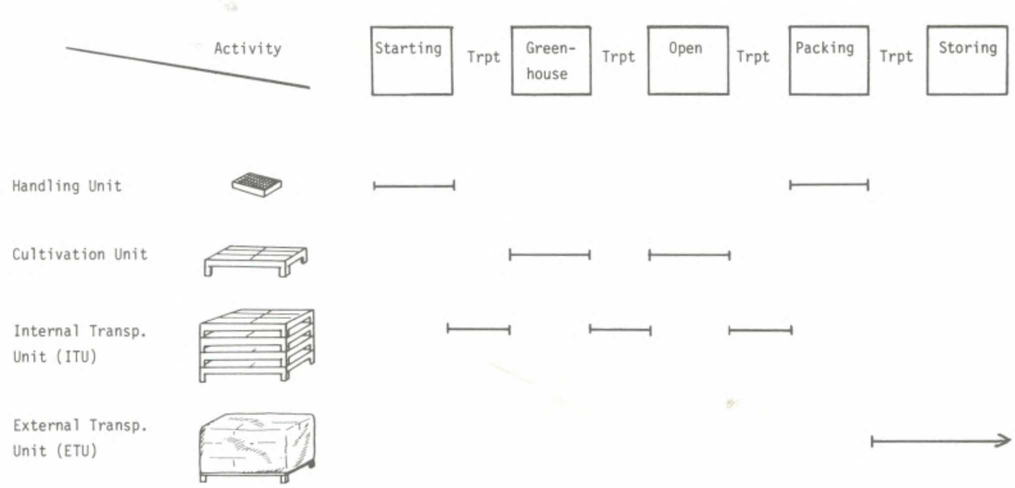

Figure 4. Handling in the nursery.

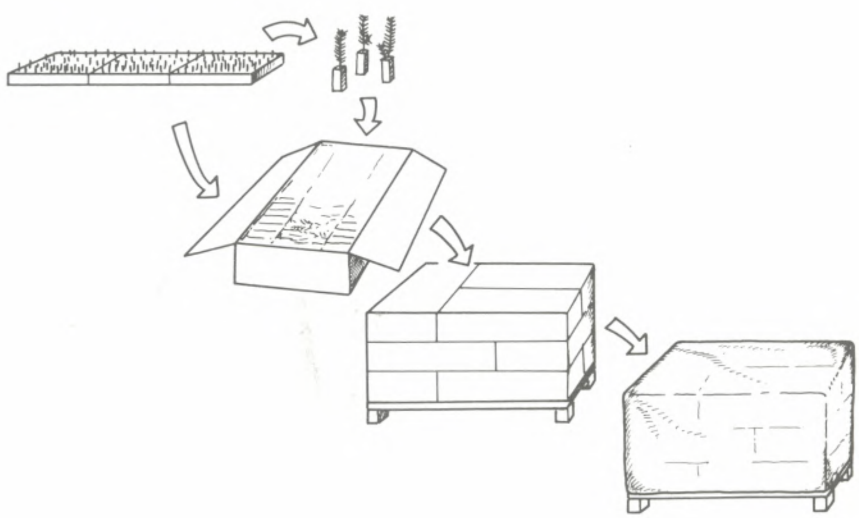

Figure 5. Composition of an External Transport Unit (ETU).

from seed to planted seedling. Demands on handling and transport in the nursery may be more easily satisfied if the nurseryman is free to ignore all the demands posed in the subsequent distribution phase outside the nursery, and vice versa. In the simplest case, ITUs will be broken down into units that may be packed by hand in cartons to constitute the elementary units in external transport units (ETU). If the container is removed in the packing process (as in the case of plug seedlings), the container set will be broken down into individual seedlings. Handling is thus intimately associated with container characteristics and the mode of aggregation. The situation is somewhat simpler when the container stays with the plant (as in the case of paperpots), leaving only the handling tray behind.

Figure 5 illustrates the composition of an ETU. Properly designed, an ETU will accommodate many plants per cubic metre and is therefore well suited to refrigerated storage, provided that the packaging material shields the plants against dehydration.

Other functions besides handling may also be accommodated in the cultivation unit, including air pruning of the roots. This generally works well during the growing season, but is risky for winter storage at the cultivation site--especially on elevated racks--even for such hardy species as Scots pine *(Pinus sylvestris* L.) and Norway spruce *(Picea abies* Karst.).

Where there is no packaging of seedlings, but the ITU is identical with the ETU, the requirements of the distribution process must be completed in the nursery phase. Long-term refrigerated storage is made more difficult, but certain advantages are gained in the event of buffer storage in the field inasmuch as the plants can be set out in a single layer to resume growth. However, this entails special care and attention. Such a system is relatively simple, with few components, but it is a typical return transport system.

CRITICAL POINTS IN HANDLING

The need for culling and sorting of seedlings in the nursery is well known from bare-root production. This need probably cannot be neglected much longer in containerized stock production. This requirement necessarily implies individual handling, which is a key problem that requires the development of fully automated technical solutions. First of all, empty containers must be discarded. This is not too great a problem, but more difficult is the removal and discarding of substandard plants. Intensive research and development efforts are required to solve this problem.

Thinning to make sure that each container contains only one plant, and replacing empty cavities, are problems familiar to all of us which call for a radical solution. Thinning is extremely hard to mechanize. One way of getting around the problem is to sow in preliminary containers (precontainers) and then transfer the seedlings to the final container. This would also solve the problem of refilling empty cavities, since all the containers would be filled at time of transplanting. This is a potentially interesting line of development, which may also afford opportunities to sort or segregate seedling populations without sacrificing the benefits of surface or belt aggregation when planting stock is delivered to the planting machine.

STANDARDIZATION

Finally, a word about standardization is in order. It is essential to adopt generally accepted standard measures in all phases of production. Standardization will facilitate adaptation to existing technology and equipment, particularly in the realm of handling and transportation. Tailor-made is luxury indeed.

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