PART G

EVALUATION OF PLANTING STOCK QUALITY (PROCEEDINGS OF SESSIONS)

In the four final sessions an attempt was made to summarise the main points that had arisen during the workshop on the utility of various techniques for assessing planting stock quality at four stages in the growth and development of the forest crop: in the nursery; between the nursery and the planting site; immediately after planting; and several years after planting. In these final sessions, emphasis was placed on viewing planting stock quality holistically, from the general perspective of the field forester.

PLANTING STOCK QUALITY IN THE NURSERY

Discussion leader — C. Glerum Recorder — D. Lavender

The general discussion briefly covered different cultural phases in the production of planting stock, and the following general procedures were strongly recommended to maximise production of planting stock of the desired quality either for general forest planting or for afforestation research.

Seed

A thorough biography should accompany every seed lot, recording source, collection time, storage, treatment schedule, and periodic evaluations of seed vigour. It is important that the soil organic content of the seedbed should be optimal in order to provide proper soil tilth and to provide substrate for micro-organisms necessary for the healthy growth of seedlings.

Stratification was recognised as providing rapid, even germination of temperate zone seeds, especially with early sowings when seed beds are cold. Rapid germination of early sown seed will not only reduce losses to pre-emergence damping-off but also facilitate the production of larger seedlings than late-sown and allow more flexibility in management of seedling crops. Segregation of seed on the basis of size to try to obtain a more uniform seedling crop was not recommended as it may reduce the gene pool yet may not reduce variation in vigour.

Germinant

The term "germinant" refers to a seedling in that stage of development in which emphasis is on maximum growth rather than on conditioning. This stage may be as short as two months in tropical climates or as long as a year in higher latitudes. Speed of germination and subsequent growth are closely correlated with effectiveness

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of vegetation management. Some herbicides may stimulate seedlings growth. Participants stressed that proper spacing of individual seedlings in the seedbed (as opposed to density, which is commonly the mean of a range of densities) is vital to the production of vigorous seedlings. The proper spacing will vary with species and nursery conditions, but in general wide spacing will favour strong root development and positive response to conditioning regimes such as wrenching, which are applied to stock to increase their tolerance to the stresses in being planted out. Weed and pest control, fertilisation, irrigation, thinning and conditioning regimes are all nursery- and species-specific. The biography of the germinant phase should include previously noted data for seeds, sowing date, germination date, pre- and post-emergence soil amendments, weed control procedures, irrigation schedules, and spacing data.

Seedling

The term "seedling" refers to a forest tree in that stage of stock development when growth is important but when proper conditioning in the seedbed will have maximum impact on subsequent field survival and growth. This stage which may include a transplanting phase in the nursery extends from the "germinant" stage to outplanting. It may extend from two months to five years depending upon the latitude of the nursery and the species grown. Periodic height growth measurements (weekly to monthly) are important to guide conditioning treatments. Irrigation monitoring is important to guide wrenching or root pruning. Techniques for such monitoring include use of pressure chambers, porometers, Bouyoucos blocks, etc. Irrigation schedules are definitely nursery and species specific, but generally, should be designed to produce well-formed buds by late summer for temperate zone species. Both wrenching and root-pruning are species and nursery specific. Seedling moisture content should be monitored during harvest to ensure that plant vigour is not impaired by desiccation during this period.

There was generally agreement that the following techniques may be useful in assessing plant stock quality, but their weaknesses were also noted.

a. Although foliar and soil nutrient analyses demonstrate nutrient imbalances, these analyses are generally too slow to guide fertilisation unless performed between growing seasons. Facilities can however be organised to provide these results within a few hours if necessary.

b. Chlorophyll analyses may provide a rapid indication of the nitrogen status of seedlings, but require calibration for each species and nursery.

c. Although root growth capacity may indicate seedling survival potential it is generally considered too slow to be predictive. In British Columbia, however, results of root growth capacity are obtained over a seven-day period and are used to decide whether or not to plant particular tree stocks. Maximum utility requires that such tests be correlated with weather records.

d. Carbohydrate analyses may be useful in determining storability of seedlings, but this technique requires more research and calibration.

e. Photosynthetic rate, seedling lipid content, and membrane integrity, are easily measured in the laboratory but are probably more useful for specific research than for the guiding of nursery regimes.

f. Impedance measurements may be correlated with frost tolerance or seedling vigour, but require more research to be useful. Seedling biographies should include weather data, growth curves (possibly relative growth data), fertiliser and conditioning treatments, irrigation schedules, date of bud formation, condition of buds and moisture content at harvest.

PRESERVATION OF NURSERY STOCK QUALITY THROUGH PACKAGING, STORAGE, TRANSPORT AND PLANTING

Discussion leader — B. Cleary   Recorder — R. Tinus

Although the species grown and the climates under which trees are planted differ greatly around the world, it was remarkable to see how much agreement there was among workshop participants regarding what is necessary to maintain quality in the seeding. Nurseries create quality during growing and conditioning of the seedlings, and that quality must be maintained through the processes of packaging, storage, transportation and planting.

Packaging

The common method of packing in tightly strapped bales or bags is poor, because seedling tissue is unavoidably crushed and bruised. Exposure of inner tissue and release of metabolites promotes development of disease and reduces root growth capacity. Furthermore, close packing of a large volume of respiring tissue maximises the opportunity for damage by heating.

Bags are satisfactory, provided seedlings are packed loosely and the bag is closed without crushing them. Boxes are better than bags, because their rigid form eliminates the need to strap, and they can be stacked without crushing the trees. Bags and boxes maintain seedling moisture better than open bales. Bales are satisfactory for short, but generally not long, term storage. A minority view was that open bales are suitable for long storage, if they include moist sphagnum, or other moisture-holding material, against the roots, and the cold room in which they are stored is maintained at high humidity.

Storage

Problems of storage differ depending on length of storage, and there is a need to develop better methods to monitor the condition of seedlings in storage.

Seedlings should periodically be inspected visually for disease and mechanical damage. At present only the temperature of stored seedlings is routinely measured. The most suitable above freezing air temperature was generally agreed to be $1° \pm 1°C$. Below freezing storage requires more precise control to $\pm 0.5°C$. The reason for using frozen storage is to reduce respiration and the incidence of disease, but freezing places the seedling under high moisture stress, so the temperature should not be any lower than absolutely necessary. Another test which could add valuable information is plant moisture stress measured with a pressure chamber. Survival and growth are expected to correlate with the degree and duration of moisture stress. Several other tests appear useful, but are not yet operational. One is measurement of carbohydrates reserves, which decline steadily during storage. A variety of tests are available that measure different carbohydrate fractions; however, which carbohydrates represent the best index of seedling vigour, and how much is enough, has yet to be determined. It is unlikely that any single test will prove meaningful. For instance, both sugars and starch may have to be measured, because conversion of one to the other is temperature sensitive, and the proportion of each will be affected by the conditions of storage.

A quick test is needed for "level of dormancy". This is a measure of readiness of buds to break and flush, and critically affects long term storability. Seedlings must be fully dormant, but not postdormant, if they are to be stored more than 30 days. At present the best test is to place the seedling under growing conditions and note how promptly they break bud, but that takes too long to be of value to nurserymen.

More research is needed on the effects of different levels of O_2, CO_2 and ethylene in the storage atmosphere. The effect of light under storage conditions is poorly known, but has some interesting possibilities. For instance, it was reported that Douglas fir seedlings stored in open bales benefitted from being given light in the autumn, but by mid-winter they were no longer sensitive to light.

Transporting

As in storage, seedlings in transit must be kept cool using either insulated or refrigerated containers. Likewise, the bags or boxes must be spaced apart so that the refrigerated air can circulate between them; tight packing will result in heating. Throughout their journey from the nursery to the planting site, handling should be minimised to avoid mechanical damage.

Some aspects of transportation remain unclear. What is the effect of vibration on the seedling? Temperature fluctuations during transportation are hard to avoid, and their effect surely varies with duration and the dormancy state of the seedling. But how much fluctuation is too much? How can seedling injury be quickly measured? Determining the pressure-volume relation of expressed sap with a pressure chamber shows promise.

Planting

There was wide agreement that three key factors influence planting success. First, the site must be ready. This means the proper combination of soil moisture and temperature, weather, and site preparation. Second, the planting stock must be matched to the site, that is, the seedlings must be of the right species, seed source, size, balance, and physiological condition to establish and grow rapidly. Since climatic and edaphic situations vary tremendously across the globe, a great variety of sizes, root-to-shoot ratios, and physiological states of seedlings are required to meet worldwide planting needs, and therefore, it is no wonder that the workshop participants were unable to agree on any single standard of seedling quality.

Finally, all operations of seedling care and handling should be performed by people who are motivated to do the job right, and adequately supervised to ensure that the recommended procedures are indeed followed. As much as anything else, good personnel management and attention to detail will go a long way towards making best use of what we know, and ensuring the success of our afforestation efforts.

EVALUATION OF STOCK AFTER PLANTING

Discussion leader — P. Willén Recorder — R. Sutton

The session opened with an attempt to define "planting stock quality", a term used constantly but not defined during the workshop until now. The following working definition was accepted: "*The quality of planting stock is the degree to which that stock realises the objectives of management (to the end of the rotation or achievement of specified sought benefits) at minimum cost. Quality is fitness for purpose.*"

In general, if a batch of planting stock achieves the purpose for which it is grown, then its quality is 100%. The extent to which a batch of planting stock falls short of achieving the objectives of management, however defined, is the deficiency in quality of that batch of planting stock. Provided that planting stock with certain characteristics achieves the objectives of management, then the more cheaply that stock can be produced the better.

The objectives of management are thus critical in determining quality. They must be realistic, and they must take account of site factors, cultural practices (including site preparation and planting methods), and species characteristics.

Another general consideration that was discussed related to the introduction of new techniques into an ongoing establishment system of full scale operation plantings. Ideally this should begin with an analysis of the problem and then be followed by a sequence of overlapping steps, each of which feeds back information (shown by arrows in Fig. 1) to all previous steps.

These various steps, which will generally require different time scales, represent a progression of decreasing control over environmental variability. The early steps might consist of parts or components leading to an integrated system which would be considered as a whole in the later steps. To attempt to short-cut the procedure by omitting steps is, in most cases, to invite disaster. Understanding must be sought to permit wide application of the results. It was agreed also that economic evaluation is necessary at all stages.

Evaluation of stock after planting is necessary for two different, but related, reasons. First, the scientist needs to ascertain the performance of plantations and to determine the relative importance of the controlling factors in order to guide the search for improvements. Second, the forest manager needs to ascertain what, if any, further operational measures are called for. The timing of evaluations must be such that the necessary information is (a) obtainable and (b) timely. Species and site strongly affect the schedules of evaluation.

Emphasis was laid on the need to understand the physiological processes determining quality and performance. Many of the problems experienced with soil and foliar analyses, for instance, arise from deficiencies in understanding the basic processes involved in tree nutrition and how they affect planting stock quality.

Generally recognised was the importance of making all relevant data available to the forest manager as soon as possible. The forest manager, often under pressure to act, needs whatever data he can get. Incomplete data are better than none. Communication between research workers and forest managers is essential for efficiency in both research and management.

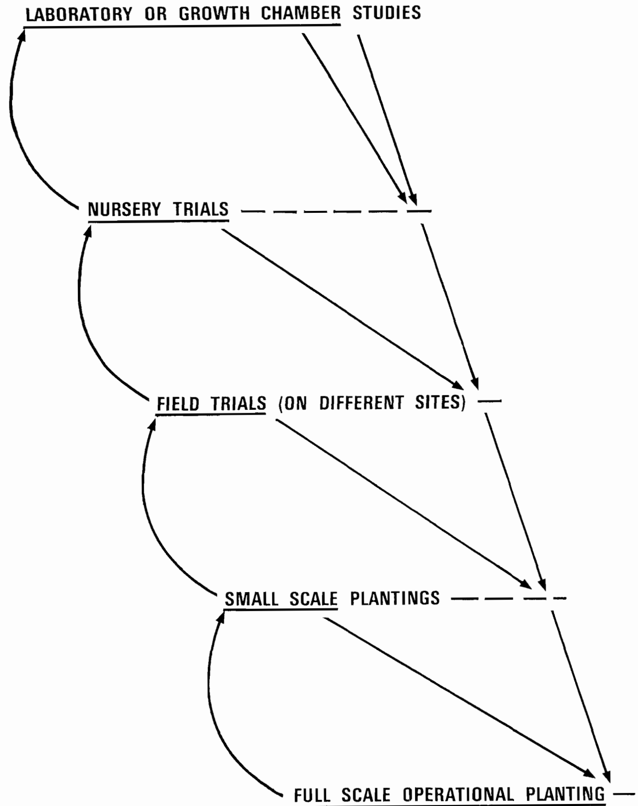

FIG. 1—Ideal sequence of steps for developing new techniques and new systems and introducing them into, and thereby improving, existing operational planting systems.

As to what variables should be measured to evaluate performance in the field, there was agreement that both growth and survival are important. Root growth is especially important and especially difficult to measure. Evaluations, or at least examinations, should be done often enough to detect any significant development (including the identification of any agency causing disease or damage) affecting the condition of the plantation. In some species, e.g., Douglas fir, the vigour of stock after planting may be indicated by needle length on new foliage. Plant moisture stress as determined by the pressure chamber technique is perhaps the most promising general index of plant condition and potential performance. Chlorophyll content cannot be used as a universal index of plant condition, but for research purposes the strong relationship between chlorophyll and nitrogen contents may be useful. Plot volume index (number of trees $\times$ d^2h), or cumulative height $\times$ survival, may be useful in comparing one plantation's performance with another. Often, perhaps usually, the condition of a tree or stand cannot be represented adequately on the basis of one or two variables. In stands, stem distribution is also very important. The system of mechanically located lines with random offsets, as used in Oregon (see "Regenerating Oregon's Forests." Oregon State

University Extension Service) detects gaps as small as 27 ft in diameter that contain less than 150 trees per acre.

The session closed by emphasising several critical points. The important thing in regard to research studies is understanding what really happens to produce an end result rather than the end result itself; the effects of variation in the weather year by year need to be evaluated more precisely; trade-offs between seedling quality and site preparation should be taken more into account; the greater the variability among planting stock used in trials, the greater will be the difficulty in detecting effects of treatment; the variability within and between sites of course increases the size and number of trials needed; and field trials must be of sound design and they must be continued long enough to permit the detection of significant effects in the medium and long-terms.

EVALUATION OF PLANTING STOCK QUALITY SEVERAL YEARS AFTER PLANTING

Discussion leader — G. Fry Recorder — B. Poole

It was suggested that any growth gains achieved through improved nursery stock would be permanent and must be large enough to be measurable although some exceptions to this general proposition, e.g., where "improved" stock leads to a greater propensity for windthrow or toppling, were accepted. The subsequent discussion concentrated on three aspects of this topic, namely the time when full benefits of improved stock can be assessed, economic implications of improved forest establishment practices, and difficulties in assessing operational results.

The point in the rotation when the full benefits from improved nursery stock can be assessed

There was general agreement that improvement of nursery stock was one factor that would allow full expression of site potential. Improved growth would result in new interactions between the planted tree, the site, and the weed competition. The effect could compound until canopy closure after which growth rates between the "improved" and the "routine" would be comparable. Canopy closure therefore represented a convenient point at which the benefits from improved nursery stock quality could be conveniently measured. As the gain usually represents an advance along an existing growth curve, the gain might be conveniently measured in terms of time, i.e., a shortening of the rotation. Toppling and windthrow were noted as exceptions to the appropriateness of this measurement point. Nursery stock could be manipulated to render them more resistant to wind damage, but these benefits might not become evident until after canopy closure. Attention was also drawn to instances where the site potential was being raised by fertilisers, or other cultural practices, and advancement along the new growth curve was being obtained through improved stock quality. In these cases there was still no difficulty, at an experimental level, in isolating the effects of improved stock quality from the other factors involved in forest establishment.

The economic implications of applying improved practices

Participants at the workshop represented countries covering the whole range from scarcity to abundance in timber resources. Those from countries deficient in these resources, yet capable of growing forest crops under short rotations, were those best able to justify their improved techniques on classical economic grounds. Those concerned with longer rotations argued that forestry should be a special case for cheap money or that sociological factors, e.g., guaranteeing a wood flow to an existing enterprise and community, are a sufficient argument for improved nursery practice. The foresters dealing with short rotations emphasised that nursery improvement was also only one facet of establishment practice. In many cases establishment could bear increased costs for land, cultivation, weed control, and improvement in nursery stock, provided criteria for production including such factors as site topography and distance from markets, were met.

The difficulties of assessing operational results as distinct from experimental treatments

The speakers in this session dealt in some detail with the difficulties of estimating accurately the returns from improved performance of nursery stock at the level of full scale operational plantings. Unfortunately no good solutions of how to overcome these difficulties were offered. It was disappointing to find that organsations were using nothing more sophisticated than a stocking assessment to measure operational success. Field assessments involving volume measurements were not being widely used nor were remote sensing techniques (including cameras). Sophisticated remote sensing techniques are claimed to be capable of such measurement, but they may be expensive and are not readily available. Although the value of, say, a 3% increase in wood volume, or decrease in rotation length, over a large area was recognised, the difficulties of detection were regarded as formidable against the general background variation caused by carrying out these operations over a considerable period of time and over various and varying site conditions and with different personnel. Yield improvement techniques generally appear to be based on the confident extrapolation of experimental results. Reduction factors to the experimental results have been quite arbitrarily applied. This session of the workshop ended with the plea for devising techniques for evaluating changes in operational practices.