tions of seed which are identified through a seed registration system which presently includes a description of stand quality, and eventually genetic background. In this approach seed is treated as a special crop and seed production areas are developed utilizing the better-formed trees and fertilizers to stimulate seed production. Under the long term approach clone and seedling banks are established for holding selected material to be used in the breeding program consisting of inbreds, and intra specific crosses. Seed orchards are being developed using initially seedlings grown from seed collected from selected trees and ultimately seedlings grown from seed produced by the breeding program.

Innovations in Present¹ Nursery Production of Conventional Planting Stock¹

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"Conditioning and treatment of stock may offer worthwhile improvements in performance."

Abstract

Nursery production is likened to a subsystem of the total reforestation system. The inputs to the nursery subsystem are categorized as environment, management, raw material, the production process, research and development and finally, quality control.

The various input fields are considered in some detail for innovations which can lead to improvement in quality and economies in production as well as point the direction for future research effort.

In order to close the loop on the system and provide the necessary feedback of information from planting projects close liaison must be maintained by co-ordinators.

The ultimate criterion for measuring success of the total system is the cost per established tree. The co-ordinators must balance the quality of stock versus production cost interaction in the nurseries against this criterion in order to maintain an efficient total system.

Seeding

With the acquisition of increased quantities of seed, direct seeding will be continued where and when we feel it is technically necessary and feasible, especially on otherwise inaccessible and/or poorer sites where we can, for example, use lodgepole pine seed. Results with direct seeding have in general terms been disappointing. At this time British Columbia cannot afford to waste seed, and as such all conditions must be right and/or there is no other alternative, before this form of artificial regeneration can be applied liberally on an operational scale.

Innovations dans les méthodes de production de plants en pépinière

Résumé

La production de plants en pépinière représente en quelque sorte un sous-système de l'ensemble du système de reboisement. Les intrants au sous-système de la pépinière se classent ainsi: environnement, gestion, matière première, processus de production, recherche et développement et enfin contrôle de la qualité.

Les divers facteurs sont considérés de façon assez détaillée pour des innovations qui pourraient mener à des améliorations de la qualité et à des économies de production de même qu'orienter les travaux de recherche futurs.

De façon à reformer la boucle du système et assurer la réaction nécessaire originant des projets de plantation, les coordonnateurs doivent assurer un contact étroit.

Le critère ultime pour déterminer le succès de l'ensemble du système est le coût par arbre, les coordonnateurs doivent assurer un équilibre entre la qualité des plants et les coûts de production dans les pépinières en fonction de ce critère s'ils

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veulent assurer l'efficacité de l'ensemble du système.

The Reforestation Process Considered as a System

The production of nursery stock should not be considered as a discreet open loop system (15) ending when stock leaves the nursery; rather it should be viewed as a closed loop subsystem of the overall reforestation system. The feedback of information from planting projects then provides the means of assessing the quality of the product.

The Nursery Production Subsystem

This subsystem may be further subdivided into the various sectors which contribute to the production of seedlings and transplants. These are the environment, the management, the raw material, the production process, research and development and finally quality control or the closing of the loop.

The Nursery Environment

There are many factors which go together to make up the nursery environment, such as site and topography, soil, climate, water supply, labour supply, shipping facilities, services and communication media.

The ideal requirements are well documented in the literature; (36) however, the importance of a well drained sandy soil and an adequate supply of water of acceptable quality cannot be overemphasized.

Nursery Management

The man: A good nursery manager or superintendent needs to be a man of many attributes. He should have a working knowledge of farm and other machinery and its limitations, the ability to inspire and handle people and a working knowledge of accounting. In addition, he needs a farmer's feeling for soil and plants and a forester's long range outlook.

Organization: In order for a nursery to function efficiently the manager should have a good pre-organization plan. Supplies must be ordered in time to be on hand when required. Very often weather is a governing factor and plans must provide for taking quick advantage of suitable weather for sowing, etc. Worthwhile fill-in or maintenance jobs should be listed and staff trained to carry on with these whenever other jobs permit or weather forces changes. He should be constantly checking and inspecting all aspects of the process. During the growing season there should be daily tours of inspection, (at least some of which are the nose to ground type). All staff should be trained to report anything unusual or unknown at once.

Records: A good system of records is the best tool available to a nursery manager aspiring to increase the efficiency of his operation. First he needs a detailed history of every field or block, including past disease or insect problems, as well as pictorial records and morphological analyses of stock so that he can determine whether size or characteris-

The new Campbell River Nursery. The cost of producing two-years seedlings such as new nurseries, with sandy soil and excellent drainage, is approximately half the cost of that old established nurseries.

tics are changing. Any changes in cultural practices and their effect, if any, on quantity and quality of stock should be recorded. Second, he requires detailed records of man hours, etc., spent daily on each specific nursery task such as weeding, watering, cultivating, etc. He can then assess the effect of changes in method and calculate costs of production for budget preparation.

Seed — the Raw Material

If we consider the nursery as the manufacturing plant in our reforestation system we may look upon seed as the raw material which is put into the production process and subjected to various treatments in order to convert it to a tree with a high survival potential.

Unfortunately for him the nursery manager has little or no control over the quality or quantity of his raw material and there is little he can do to improve it. He must therefore rely on other sections of the reforestation system to provide the improvement in seed quality.

Selection: It is known that there is an interaction between seed source and nursery location. Some sources grow better at one nursery and produce stock with a higher root regeneration potential, and hence survival potential, than they do at another (27). Nurserymen soon get to recognize seed lots from certain stands which produce a high proportion of culls for various reasons. Collections from such stands should be avoided unless it can be shown that performance of that seed lot after planting out offsets the undesirable characteristics encountered in the nursery. Stock is often required for particular problem areas. It has been demonstrated that deer do not browse certain Douglas fir. Identification and collection or breeding these strains would permit the nursery manager to produce stock with a low deer acceptability. Seed from certain localities produces seedlings which respond very vigorously to clipping or pruning and therefore should have a high potential for overcoming the effects of browsing.

Conditioning: "Crop year effect" is a well known phenomenon to nursery men. Certain weather patterns during the growing season can produce undesirable results in the seed crop. Seed from spotty crop years generally is not as good as that from bumper years. Often the most mature and productive seed lots are collected on southerly exposures. Rowe (24) has discussed the possibilities of conditioning. Very uniform stands of good seedlings are produced by seed from thinned and fertilized seed production areas (12). Fertilizing is known to produce larger seed which produces larger first year seedlings. (2)

Negative conditioning, especially of immature seed, may occur during the extraction process and the usual germination tests may not reveal this. It has been demonstrated (5) that carefully collected, sun dried, hand extracted sugar pine seed produced first year seedlings 50 per cent taller than seedlings from normally collected and extracted seed. This effect may be even more pronounced on smaller seeded species with thinner seed coats.

Screening: Sowing studies on collections from single mother trees indicate a wide discrepancy in germination of trees from the same stand. The sowing of such half-sib families for establishing seedling seed orchards in Douglas fir indicate that some families will not germinate under the usual conditions. Other families appear to be able to germinate but not grow beyond the cotyledon stage. Still others, although they grow reasonably well as seedlings suffer very high mortality upon being transplanted.

Tests on seed collections from individual trees in seed production areas would permit identification of those families with poor germination, growth or transplantability characteristics. Removing these from the production area would considerably influence the quantity and quality of trees produced by a nursery using seed from such an area.

There is considerable variation in the characteristic root appearance of seedlings. Different types need to be checked out for survival potential and related to characteristics of the parent so that these types can be avoided. Characteristic root systems, possibly coupled with characteristic appearance of the top, could enable nursery graders to cull out tree types with known low survival potential.

The Production Process

This is the area where the nursery manager has the greatest scope to exercise his own initiative in revising technique and developing practices which will upgrade the efficiency of his operation.

Field Preparation: The practice of ripping or chiseling 14 to 16 inches deep to thoroughly fragment any plow pan is highly desirable prior to working up. The nursery seedbed shaper as designed by Ontario has wide acceptance. In some soils fields can be worked up and shaped in the fall for sowing in the spring. This enables earlier than usual sowing.

Sowing: Sowing in the late fall permits seedlings to take full advantage of the growing season and generally produces significantly larger seedlings.

However, germination in the smaller seeded species is often disappointing. Development of a treatment to protect overwintering seed would increase the yield of plantable trees lifted as 2-0 and lower the cost per tree. In British Columbia all seed for spring sowing is stratified for at least two weeks and treated with Captan or Arasan before sowing. All treatment, stratification and weighing is done at the Seed Centre and delivered to respective nurseries when required. Except for very small lots the advantages of drill seeding are obvious. Uniformity and yield of plantable seedlings per square foot are higher than for hand broadcast seeding. The ability to spray, cultivate and lateral root prune between the rows can mean considerable savings in weeding and lifting costs.

Irrigation: So called "solid-set" irrigation using one and one quarter inch aluminum tubing with thirty by forty foot triangular spacing is standard practice for British Columbia nurseries and fairly widely used elsewhere. Frequent short waterings are used during the germination period. Later first year seedlings are irrigated for at least two hours at mid-day during hot sunny weather. This is a substitute for side boards and shade frames which are only used now on Western hemlock for the first year. The abandonment of lath shade resulted in considerable saving in seedbed preparation.

Older age classes of seedlings and transplants should generally be irrigated at night in order to take advantage of more efficient application of water.

Weed control: Weed control can account for 30 to 50 per cent of the cost of producing 2-0 seedlings, particularly in agricultural areas or nurseries established on old farms. The first year is usually the most troublesome.

Unfortunately the critical period for weed control often coincides with the busiest period in the nursery. Weed control is often delayed until last or until a serious condition is evident. A realistic approach to weed control demands an integrated total control program and a prepared plan with laid down procedures and schedules rigidly adhered to.

An integrated approach requires the use of every conceivable tool for weed control. Some of these are biological control through the use of vertebrates, insects, diseases (11) and others such as irrigation and cultivation of fallow areas, between drill cultivation, use of light oils, chemical herbicides, fumigation and finally hand weeding.

Every nursery manager hopes for the development of a safe overall herbicide. Unfortunately the market potential for forest nursery herbicides is not large and few chemical companies are interested in spending research money in this field. At the nursery level the search for satisfactory herbicides seems rather fragmented and inconclusive. A concerted testing program conducted by people knowledgeable in the field, working in conjunction with chemists with the resources and capability to design herbicides for conifer nurseries, would have many dollars. Although some herbicides such as Simazine are in fairly general use they have done serious damage in some nurseries. A herbicide pro-

gram must therefore be worked out for each individual nursery soil.

Insect Control: Again the objective should be to develop an integrated control program (11) employing as many biological and physical approaches as possible — constant cultivation of fallow can assist in control of nematodes, white grub, etc. Meadow mice can be credited with controlling several forest infestations (23). Domestic fowl might be effective predators also. Other aspects of biological control include nematodes (13) bacteria, viruses, insect predators or parasites, trapping, use of sexual attractants, and use of sterile males. Chemical control should be reserved as a last resort. The chlorinated hydrocarbons have been the mainstay of nursery insect control. There are increased restrictions and a reluctance to use any chemicals with a residual or cumulative effect. A concerted program to test chemicals which can control without having residual effects is required. The carbamates and organophosphates have promising candidates such as Carbaryl, malathion, fenitrothion and sumithion, parathion and Di-syston.

There are possibilities for discouraging insect attacks by manipulating seedling nutrition so as to change proportions of the major elements in the tissue (6). High concentrations of potassium seem to have promise.

The use of organic rather than chemical fertilizers appears to make plants less attractive to pests (19). Thorough investigation should be done to follow this up.

Disease: Diseases of seedlings in the nursery are probably the most frustrating thing to contend with. Damping-off is probably the most troublesome. Weather patterns are often involved. Generally when the symptoms occur it is too late to take any effective action. Again, an integrated control program is needed, with the emphasis on prevention.

Some possible cultural practices are modification of soil texture and aeration, nutrient balance, organic levels, maintenance of rotations, timing of sowing, mulches such as leaf moulds, measures to encourage the development in the soil of antagonistic organisms, particularly some species of mycorrhizal fungi (18), control of nematodes which may be vectors or participants in root-rot complexes (8) (29), manipulation of micro-nutrients such as copper and zinc, etc.

The possibility of controlling some tree diseases by tissue saprophytes has been suggested (7). Treating tree seed with saprophyte-containing solutions might be worthwhile. The reviving effect of liquid humates or forest duff or litter (36) may have a therapeutic value. Modifying or weakening fungal virulence by heat, chemicals or radiation bears investigation. Identification of individuals or families with a high degree of resistance to a fungal disease or diseases followed by in-depth analysis to isolate the antifungal factor might lead to the synthesis of the resistant factor.

Use of fungicides such as Arasan and Captan as seed coatings have little effect on control of damp-

ing-off. Captan, however, may have desirable side effects when used as an overall spray application to growing seedlings. (14) Pre-sowing soil applications or post-emergence drenches of fungicides have the same disadvantage as soil fumigation. The natural controlling agencies or organisms antagonistic to the disease-causing fungi are also eradicated.

Nutritional Control: A program of routine soil analysis at least once during a rotation coupled with routine tissue analysis is particularly valuable in new nurseries. Indicated modifications in fertilizer schedules (33) can materially increase the quality and quantity of plantable seedlings. Maintaining the soil organic matter at a level of five per cent may be expensive but will pay dividends in size of seedlings. This is important on nurseries with light sandy soils. The introduction and maintenance of mycorrhizae at a high level will produce better stock. The use of slow release fertilizers increases uptake of nutrients (3) and may have beneficial effects on seedling condition.

Conditioning: Most nursery managers begin to reduce soil moisture level in late summer to harden-off their stock. While this may not induce frost hardiness (32) it does harden the stock and put it in better condition for fall lifting. Lateral root pruning and undercutting in late August hasten this process. Fertilization with nitrogen and potassium in late fall also appears to improve winter hardiness. (3)

Lifting and Grading: These two operations can be an expensive phase of nursery production, often approaching one third of the total cost. A recent survey (1) of 129 nurseries in the U.S.A., producing over 700 million plants indicates that only 17 per cent are still sorting in the field.

The vast majority take the trees indoors to sort under controlled climatic conditions. This tends to increase the cost; however, the beneficial effect on seedlings may more than compensate for this. Stone states (28) "Loss of water from evaporative stress at the time of lifting has a greater effect on the physiology of Douglas fir seedlings than does available soil moisture at the planting site when seedlings are planted."

Any process which tends to reduce variation and per cent of cull will save money. Only 67 per cent of the nurseries in the U.S. survey counted seedlings. The need for counting needs critical examination. Some nurseries do not tie bundles. Trees packed without tying probably suffer less from prolonged storage.

Packaging: Superficially it may seem common sense to use the cheapest method of packaging. However, a package which maintains seedlings in essentially the same physiological condition which they were in when lifted will show results in survival and growth. In British Columbia the multi-wall 50 lb. kraft bag with 10 lb. polyethylene liner has proved superior to bales or plain polyethylene bags. For involved shipments, bags in cartons are used.

Storage: Cold storage (34°-36°F) facilities permit lifting stock in deep dormancy and keeping it in this condition until shipped. The use of multiwall

bags eliminates the necessity of humidity control. Stock lifted in the fall should not be placed in cold storage until it is completely dormant as it does not gain frost hardiness in darkness (32). Ideally, nurseries should be able to cold store 50 to 75 per cent of the stock to be lifted during the spring. Portable cold storage units are very useful for difficult to reach locations. Some success has been achieved with freezing planting stock (22).

Research and Development

Pilot Studies: Most nursery managers like to start small pilot scale trials to find ways of improving practices and techniques. However, the follow-up is often interfered with by pressure of routine production. Indications from these trials should result in formal research delegated to trained researchers. Continuity is always a problem in such studies and field testing is often neglected. To overcome this drawback in British Columbia, foresters with considerable research and planting experience are given the responsibility of co-ordinating several nurseries and/or areas e.g. Vancouver Island. In addition to administrative duties they have the responsibility of providing continuity in research and particularly in insuring field testing of nursery trials.

Equipment Development: Equipment operators occasionally suggest worthwhile improvements. In British Columbia an experienced, practical nursery specialist is charged with responsibility of checking out suggestions and incorporating them, if practical, into nursery procedures. In addition he has the responsibility of developing specific items of equipment.

One third of the cost of nursery stock is due to lifting and packaging. Machine lifting should result in substantial savings. Such machines are under development in North America and have been in use in some European nurseries for ten years. (21)

Special Measures

Special treatments to improve the survival potential of the stock may not reduce nursery production costs, but they may reduce the cost per established tree. Root dips of such moisture retaining substances as alginates with or without growth regulators have promise and are standard practice at at least one Canadian nursery (17). Foliage applications of anti-transpirants have given inconclusive results. However, other approaches such as antitranspirants which operate as metabolic inhibitors and regulate stomatal opening without completely inhibiting photosynthesis may have promise (16). Other materials which affect water permeability of root membranes may induce drought hardiness and are worthy of attention. (16)

A more direct approach to the treatment of nursery stock to improve survival is the mudpack treatment developed by Pelton Reforestation Limited of Haney, B.C. (31). Roots of individual seedlings are encased in a capsule of clay-peat moss "mud" and dried sufficiently to permit handling. The main impact of this method on nursery costs is that smaller stock, much of which might be culled, is used as

well as one-year seedlings grown specifically for mudpacking. Rates can be so increased, especially where an incentive system is used that the net result is a reduction in total planting cost per tree. This system is certainly worthy of much more experimentation than it has received.

New Techniques: With the imminent availability of very costly genetically improved seed, new systems of production, which ensure a plantable tree from practically every seed, are required. Hydroponic culture can produce seedlings of plantable size in one season. (31) Plastic greenhouse techniques as extensively employed in Scandinavia, particularly in Finland, can produce plantable stock in a very short time. Ideally, such types of stock should be transplanted for a season to harden up. Container grown stock may also be transplanted for a season where sturdy stock is required.

Quality Control — Closing the Loop

Placing the blame

The nursery is always a convenient scapegoat when a plantation fails, but usually the planting stock will only be part of the story. The nursery administrative foresters, thoroughly familiar with the stock being produced by nurseries under their control are charged with pinpointing the weak points in the artificial regeneration system and offering suggestions for improvement.

Balance Between Grade and Survival

The nursery superintendent is prone to believe that his reputation as an efficient manager rests solely on the cost per thousand trees produced. There is always a temptation to drop the cull line a little in order to produce more trees per square foot and reduce the cost. Again the nursery administrative forester, measuring overall success of the system by the cost per established tree, must step in when he thinks the standard is slipping at the expense of field survival and growth.

Since the cost of planting is four to five times the cost of nursery stock, a slight drop in quality of stock, although it may result in a nursery saving of perhaps 0.2 cents per tree, may result in a 10 per cent drop in survival and increase the cost per established tree by one cent.

The close liaison between nursery and planting project closes the loop in the system and provides the necessary direct playback of information which is a prerequisite to maintaining adequate quality control of the nursery product.

In summary we might suggest that starting with well chosen nursery sites, dedicated managers can upgrade the performance of their product by using quality seed preconditioned for specific purposes. An integrated approach to pest control and particularly the development of safe overall post-emergent herbicides together with the maximum of mechanization can contribute materially, not only to savings in cost, but also to condition of the

stock. Conditioning and treatment of stock may offer worthwhile improvements in performance after outplanting. Close liaison to ensure continuity and follow-up of nursery research by field tests, toge-

ther with a feedback of information on stock performance on regular planting projects, should ensure an efficient operation with worthwhile savings in the cost per established tree.

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