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SEEDLING AND CLONAL OPTIONS FOR REFORESTATION IN NEW BRUNSWICK

In recent years, the refinement of rooted cutting procedures and major advances in micropropagation through cell culture have stimulated considerable interest in the potential of clonal propagation to enhance returns from breeding and reforestation programs in New Brunswick. The question facing forest managers in the light of this advancing technology is whether or not clonal propagation offers gains and management benefits that justify the higher cost anticipated for planting stock production. This study was initiated with the help of funding from the Canada/New Brunswick COOPERATION Agreement on Forest Development in order to investigate factors that should be considered in the evaluation of clonal propagation as a possible breeding tool and deployment method for reforestation activities in New Brunswick.

Wind-pollinated seed orchards form by far the most prevalent method of tree improvement in New Brunswick. Pollen contamination is a problem in such orchards, as half of all genetic gain comes from the male parent. In addition to this, trees in wind-pollinated orchards will not produce equal quantities of seed or pollen and mating is rarely random. Although the combined impact of contamination and non-panmictic mating on genetic gain and diversity will be substantially lower than would be predicted under "ideal" conditions for pollination. The only way to overcome these difficulties is to physically control the source of pollen delivered to each tree in the orchard.

Many new approaches to breeding and reforestation make use of clonal technology. This study examines a number of clonal approaches to tree breeding and improvement from a number of different perspectives, so as to evaluate the strengths, weaknesses, and potential benefits to the New Brunswick forest industry.

Genetic gain is of primary importance to any tree improvement program. In this study, genetic gain was approached by simulating the results of various seedling and clonal strategies over time. A computer program was written that allows the user to define genetic and environmental parameters in an initial breeding population. This population is then subjected to selection and testing schemes that generate tested parents for seed orchard parents and clonal deployment. This simulation was used to estimate gains under a variety of genetic variance scenarios for eight breeding strategies. A consistent 28-year breeding cycle was used in all cases and the testing effort was fixed. All of the strategies used sublining (breeding groups) to control inbreeding and positive assortive mating to generate selection material which was based on polycross results for each parent. The results were plotted over a time line and average genetic gain calculated for a 140-year period (five breeding cycles).

In order to be useful, clonal forestry approaches to tree breeding and improvement must satisfy certain stringent requirements for (a) technical and logistical feasibility; (b) biodiversity and risk of failure; and (c) benefits and costs. This study considered the impact of each of these requirements on the feasibility of a number of approaches to clonal forestry practices.

Obviously, the integration of cloning into any breeding or reforestation strategy is pointless unless clonal propagation is both technically possible and can be implemented in an operational setting. Certainly, there have been problems implementing clonal technologies with New Brunswick conifers, but the efforts of propagation specialists have been rewarded with considerable success. The only cloning system that has been used on an operational scale for species indigenous to New Brunswick is based on the rootings of cuttings from very young seedlings, producing stecklings. While large quantities of vigorous steckling stock have been produced from various spruce species, the labor-intensive nature of these operations creates logistical problems when annual production levels rise above a few million. If this method is to be used on a large scale, a high quality nursery labor pool, careful production scheduling, and improvements in mechanizing handling will be required. Newer technologies for vegetative propagation may have a profound impact upon the feasibility of producing large quantities of clonal planting stock. Tissue culture methods for micropropagation, the production of differentiated plant parts in culture for subsequent rooting (or organogenesis), and asexual embryogenesis have all been considered. While organogenesis has not been particularly successful with New Brunswick conifers, the production of plantlets by means of asexual embryogenesis has renewed interest in tissue culture propagation. Many researchers believe that somatic embryogenic systems should reduce the cost of cloning, although there are, as yet, few operational demonstrations to support this claim. More work is required to automate the process. Finally, other questions need to be considered in order to solve certain logistical problems: there may be a requirement to deploy clones in particular mixtures or spatial arrangements (as is now required in some European countries), and maintaining the identity of the clones and producing required mixtures from within the nursery will present difficulties to nursery managers. These difficulties may add to the cost of clone reproduction.

Biodiversity is widely regarded as an important strategy to decrease the susceptibility of forest stands to all manner of injurious agents and to lower the risk of failure. All of our important reforestation species are outbreeders and have evolved to maintain genetically diverse populations in nature. This genetic diversity minimizes the susceptibility of a species to particular pathogens, pests, or environmental stress factors. If the deployment of only one genotype is generally accepted as hazardous, then we must determine what planting mixture has a sufficient level of diversity to be regarded as "safe". While we must ensure adequate genetic diversity, we must at the same time try to maximize the genetic gain from mixtures. Research has shown that the decision to use clones does not require acceptance of decreased diversity. In fact, the effective population size of clone mixtures can be controlled with some precision and this could be used effectively to maintain or even increase the diversity over that found in natural stands.

Cost estimates for tree breeding, the production of control-pollinated orchard seed, and various types of clonal propagation were reviewed. In addition to this, a financial analysis procedure that extends standard discounted present value techniques to incorporate allowable-cut effects and changes in stumpage value due to genetic improvement was developed. The calculations are performed within a computer spreadsheet which allows the user to conduct analysis for any scenario of site quality, genetic gain, and economic parameters.

Clonal approaches to tree improvement and breeding can be conveniently broken down into three major categories: clonal replication of genotypes in test plantations, which may be used to enhance testing efficiency; vegetative multiplication of planting stock, which may be used to amplify the number of plantable trees from a limited quantity of seed; and clonal selection, which may be combined with vegetative multiplication to deploy operational planting stock originating from tested individual clones or from clonal mixtures.

The simulations performed in this study found that clonal replication of genotypes in genetic tests can have a major impact on the efficiency of breeding programs, even when clones are not actually used for deployment of operational planting stock. Clonal replication will increase test efficiency over a broad range of genetic variance scenarios, but is particularly effective when most of the genetic variance is additive and/or heritability is moderately low (*i.e.*, less than 0.3). In these situations, the extra gain resulting over time from the use of clonal replicates should be from 7 to 11% higher than that achieved when tests are established as seedlings.

Vegetative multiplication may be used to amplify the number of plantable trees from control-pollinated orchards and selected full-sib crosses when insufficient seed is available to fill the planting requirement. Seed produced in control-pollinated orchards will produce gains from 20 to 30% higher than those predicted for an "ideal" wind-pollinated orchard. As wind pollination is frequently far from ideal, controlled pollination should achieve gains that are at least 50% higher and perhaps even double those actually achieved in conventional wind-pollinated orchards. Although other approaches may be used to deploy control-pollinated materials, the economic analysis suggests that cloning is an economically viable method when allowable-cut effects are available, even at high rates of interest. Without allowable-cut effects, vegetative multiplication will be worthwhile at low to moderate real interest rates. The uncertainty regarding the gain and economic assumptions used in the analysis is perhaps the greatest deterrent to selecting vegetative multiplication as a deployment option.

The simulations suggest that clonal selection (the deployment of tested clones) will only be attractive when there is a substantial component of nonadditive genetic variance. Data from young genetic tests in spruce and jack pine indicate that most of the genetic variance is additive, although limited data now available from older tests and the few existing clonal tests suggest that the nonadditive component may account for as much as one third of the total genetic variance. Under this scenario, the economic analysis suggests that clonal forestry will be worth pursuing if allowable-cut effects are at low to moderate effective rates of real interest. The high degree of uncertainty with respect to actual genetic gains and costs of propagation makes it unlikely that clonal forestry will be attractive until additional data are available to confirm assumptions made in the analysis.

This study identified several areas where additional work is required, including a) the development of practical field experience with clonal material; b) the incorporation of clonal replication in genetic testing; c) the testing of critical assumptions regarding clonal performance; d) storage protocols for clonal materials during the time required for field testing; e) enhancements to the simulation technique and application to other breeding problems; and f) quantitative tools for optimized strategic planning of silviculture.

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