MINIMAL APPROACHES TO GENETIC IMPROVEMENT OF GROWTH RATES IN WHITE SPRUCE'

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WHAT CAN BE DONE?

Several features of central importance to genetici improvement of white spruce have been demonstrated by tree breeders. First, white spruce is genetically a highly variable species and much of the existent variation can be readily incorporated in planting stock (Jeffers 1969, Hoist and Teich 1969). Second, local seed often is not the best for rapid growth (Nienstaedt 1969). Third, certain stands in southeastern Ontario (Ottawa River Valley) have demonstrated genetic potential for relatively rapid growth over a wide geographic range, including the Lake States (Nienstaedt and Teich 1972). Some of the stands from which genetically superior seed has come are still present and it seems likely that other stands in the Valley will be shown to possess genetic superiority in growth potential. Fourth, the consistently superior growth of certain Ontario seedlots when grown from North Dakota to New Brunswick suggest that one or at most a very few seed orchards could provide improved seed for a geographic region such as the Lake States.

If genetic improvement of white spruce is thus clearly possible, how much improvement might be anticipated? Improvement predictions depend on the improvement methods chosen and on reliable estimates of the complex reactions between trees and their environment. For the simple improvement methods discussed here, namely transfer of seed or sources of seed, research results suggest that seedlings grown from tested southeastern Ontario seed will be 15 percent taller than comparable seedlings from local seed sources in the Lake States (Nienstaedt and Teich 1972). Given that taller trees generally have larger diameters, the potential for increasing wood production is substantial.

HOW TO DO IT

If artificial regeneration of white spruce were a large factor in the Lake States forest economy, a full-scale program of selection and breeding would probably be justified in terms of cost-benefit analysis; then the necessary additional personnel, supplies, etc. could be recommended. The following schemes, however, assume that the improvement program must be carried out as a part of existing nursery operations, but with minimum commitment of effort, supplies, or skills beyond those normally available. Emphasis is placed on minimal approaches due to the uncertain position of white spruce in reforestation efforts in the Lake States and due to the improbability of substantial expansion of tree breeding efforts. A prominent feature of the improvement potential in white spruce is the high probability that such minimal approaches will result in worthwhile yield increases.

In presenting three possible approaches, the following assumptions are made:

	Assumption
Biological:	
Seed harvest	Every fourth year
Plantable seedling yield	135,000/bushel of cones or pound of seed (10 percent inviable, 20 percent nursery cull)
Annual seedling requirements	2,000,000
Commercial cone bearing age:	
Grafts	10 years
Seedlings	30 years

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Economic:	
Labor costs:	
Propagator	$30/day
Laborer	$20/day
Purchase costs:	
Canadian seed	$40/pound
Local seed	$10/pound
Local cones	$8/bushel
Orchard cones	$10/bushel
Orchard seed	$12/pound
Interest on investment	5 percent

The goal of 2 million seedlings annually represents present nursery production in Wisconsin. This goal could be expanded if a regional program was considered or contracted for lesser production needs, although tree improvement efforts beyond direct seed purchase would become financially and administratively unattractive at low levels of nursery production. The biological assumptions are based on published silvical information about white spruce. Cost assumptions represent current wage and price estimates. Compound interest factors were applied to establishment and maintenance costs throughout the life of the orchard. Seed purchase and collection costs were compounded only for the interval between seed acquisition and seedling distribution, a period ranging from 4 to 7 years in each purchase or collection cycle.

Direct Seed Purchase

Seed source experiments have demonstrated improved genetic growth potential in southeastern Ontario white spruce stands. At our present level of knowledge, seed purchase probably should be restricted to tested stands or stands on comparable soil types in the immediate vicinity.

Limited purchase arrangements for source-certified seed seem possible, although none have been successfully completed as far as I know. A Canadian consulting forester last year expressed interest in filling a seed purchase request from the Wisconsin Department of Natural Resources,[2] but the seed crop was too light to warrant commercial collection. This year, spruce budworm attacks have prevented development of a commercial cone crop[3] in the stands of interest.

[2] *Personal correspondence with W. Brenner, Wisconsin Department of Natural Resources.*

[3] *Personal correspondence June 23, 1971, from Dr. E. K. Morgenstern, Canadian Forestry Service.*

An approximate economic analysis of direct seed purchase is shown in table 1. The estimated seed cost is calculated from cone picking costs on standing trees (Pitcher 1965) plus 40 percent (20 percent inflation, 20 percent profit). The seed purchase cost of $2,400 is divided into four amounts of $600 each, representing an annual seed sowing rate of 15 pounds. Interest rates were applied to the period from seed collection to seedling distribution. Each 4-year cycle of direct seed purchase represents an added cost of about 28 cents per thousand plantable seedlings. Administrative simplicity, low cost, and minimum time to produce superior planting stock are the principal positive features of direct seed purchase. Uncertainty of seed availability is the main disadvantage. Seed availability will be subject to major biological uncertainties ; also, increased interest in source-certified seed may require seed collection controls by Federal or Provincial governments in Canada to prevent degradation of an important natural resource. Moreover, several stands of interest are privately owned and maintenance of accessibility or even existence of such stands is uncertain.

Table 1. — Cost analysis of direct seed purchase

Year	Activity	Improved seedlings direct cost	Unimproved seedlings direct cost
		Dollars	Dollars
0	Purchase and sow seeds	600	150
1	Sow seeds	600	150
2	Sow seeds	600	150
3	Distribute seedlings and sow seeds	600	150
4	Distribute seedlings	—	—
5	Distribute seedlings	—	—
6	Last improved seedlings distributed	—	—
	Total cash cost	2,400	600
	Total improved seed cost $2,400 cash plus $600 interest		= $3,000
	Total unimproved seed cost $600 cash plus $150 interest		= 750
	Added cost of improved seed		$2,250
	Seedlings produced = 8,000,000		
	Added cost per thousand = $0.281		

Grafted Seed Orchard

If regular seed purchase in Canada proves inadequate it may be necessary to move the source of seed to the Lake States. A grafted seed orchard will accomplish the move.

The project analysis (table 2) shows a more complicated program in which the part-time employment, training, or assignment of a plant propagator would be necessary. One cost, as indicated by brackets in the table, perhaps might be omitted. As more plant material from southeastern Ontario is collected and brought to the Lake States, scions may be available free of charge. At least two research organizations, the University of Wisconsin and the Institute of Forest Genetics, are starting graft collections of white spruce from southeastern Ontario. Although a grafted seed orchard will remove some of the uncertainties associated with direct seed purchase, comparing table 1 with table 2 shows that the grafted seed orchard will have the disadvantages of increased investment cost, slightly greater cost per thousand seedlings produced, and a doubled time period between initiation of the project and actual production of genetically improved seed.

Table 2. — *Cost analysis of grafted seed orchard*

Year	Activity	Direct cost
		Dollars
0	Scion collection, grafting	(350) + 600
1	Grafting	600
2	Graft maintenance	150
3	Site preparation, field planting of grafts	200
4-9	Orchard maintenance	1/ 240
10	Seed collection (cones picked from standing trees)	720
14	Seed collection (cones picked from standing trees)	720
18	Seed collection (cones picked from orchard thinnings)	720
22	Seed collection (cones picked from orchard thinnings)	720
26	Seed collection (cones picked from topped trees)	720
30	Seed collection (cones picked from topped trees)	720
34	Seed collection (cones picked from topped trees)	720
41	Last improved seedlings distributed	—
	Total cash cost	7,180
	Total grafts 3,000 (15 acres)	
	Total improved seed cost $7,180 cash plus $14,195 interest	= $21,375
	Total unimproved seed cost $4,200 cash plus $1,260 interest	= 5,460
	Added cost of improved seed	$15,915
	Seedlings produced = 56,000,000	
	Added cost per thousand $0.284	

1/ $40 per year.

Seedling Seed Orchard

Establishment of a Canadian seed supply in the Lake States could be achieved in another way. By obtaining as little as an ounce of seed from one of the tested stands, a seedling seed orchard could be established. The principal capital cost would be in weed control to insure survival, rapid growth, and reasonably early flowering (table 3). Total capital costs would be very low and added cost per thousand seedlings would be lowest of the alternatives presented. Added cost would further decline if the orchard were continued beyond 41 years. The main disadvantage to a seedling approach is the time lag between initiation of the project and production of commercial quantities of improved seed. It might be that loss of growth potential in plantations established during the 15 to 25 years of a lag time would far exceed the higher initial costs of quicker methods.

Table 3. — *Cost analysis of seedling seed orchard*

Year	Activity	Direct cost
		Dollars
0	Seed purchase and sowing	20
3	Site preparation and planting	140
5-10	Plantation maintenance	1/ 240
30	Seed collection (cones picked from orchard thinning)	720
34	Seed collection (cones picked from orchard thinning)	720
41	Last improved seedlings delivered	--
	Total cash cost	1,840
	Total seed trees = 3,000 (15 acres)	
	Total improved seed cost $1,840 cash plus $2,328 interest	= $4,168
	Total unimproved seed cost $1,200 cash plus $360 interest	= $1,560
	Added cost of improved seed	$2,608
	Seedlings produced 16,000,000	
	Added cost per thousand $0.163	

1/ $40

COST-BENEFIT ANALYSIS

The economic implications of estimated added seedling cost for genetic improvement are summarized in table 4. Assuming a planting rate of 1,000 trees per acre, a rotation age of 75 years, and required investment return of 5 percent, added costs for the three improvement approaches range from $6.32 per acre for a seedling seed orchard to $11.01 per acre for the grafted seed orchard. A pulpwood productivity of 35 cords per acre (Wilde *et al.* 1965) and a current stumpage price of $7.50 per cord (Peterson 1970) produce a projected market value of $262.50 per acre. Added

Table 4. — *Cost benefit analysis of improvement costs at rotation age*

Improvement method	Estimated added improvement cost per acre	Estimated value of unimproved wood per acre	Growth improvement required
	Dollars	Dollars	Percent
Direct seed purchase	10.90	262.50	4.2
Grafted seed orchard	11.01	262.50	4.2
Seedling seed orchard	6.32	262.50	2.4

costs for genetic improvement thus range from 2.4 percent to 4.2 percent of estimated wood value.- The anticipated benefits of a volume growth increase in excess of 15 percent compare very favorably with estimated costs of achieving the growth increase.

WHAT HAPPENS NEXT?

In the case of white spruce, tree breeders have accomplished exactly what is expected of them. The pattern of geographic variation has been determined, at least in rough outline, And sources of potentially superior seed have been identified. Genetic improvement of white spruce is clearly biologically feasible and techniques for achieving the improvement are well developed. In addition, simple cost-benefit analyses indicate the economic feasibility of producing genetically improved white spruce planting stock.

With feasibility studies accomplished, the decision to produce genetically improved seedlings rests largely on how one views the future of planted white spruce in the forest economy of the Lake States. The Federal government obviously views planted white spruce as an important element, and is proceeding with an intensive tree improvement effort. [4] The views of State governments and private industry are less clear. State forest nursery production seems to have stabilized after a period of rapid decline following changes in federally supported land management programs. An annual production of at least 5 million white spruce seedlings in the Lake States seems reasonable for the next several years: 1 million in Michigan,[5] and 2 million each in Minnesotan and Wisconsin (Wisconsin Department of Natural Resources 1970). Distribution of State nursery stock varies between States with about 60 percent of the Minnesota productions and about 30 percent of the Wisconsin production going to State and county lands (Wisconsin Department of Natural Resources 1970). States thus have an important stake in white spruce improvement. Most of the remaining trees produced by State forest nurseries go to private owners of small acreages. It is doubtful that genetic improvement in growth rate has much significance for the latter group. Forest industry similarly would seem to have little direct need for improved white spruce in view of the relatively small planting programs of most companies.

Exploitation of research findings on white spruce by State governments in the Lake States seems to be proceeding only in Wisconsin, where initial attempts for direct seed purchase, plus plans for a grafted seed orchard with production objective of 2 million seedlings annually are in progress. A joint improvement effort among the States would seem feasible. It has been estimated that a program for direct purchase of source-certified seed could be organized at a level of 5 to 10 million seeds in good seed years.[2] A program at this level would meet about 30 percent of annual State nursery production in the Lake States. A grafted seed orchard program designed to meet a regional demand of 5 million seedlings annually would require about 8,000 grafts and 40 acres of land. Within 5 years a program of this size could be established.

POSTSCRIPT

Discussion following presentation of this paper brought out two points of further importance. First, the choice of 5 percent as a compound interest rate may be low for industrial cost-benefit analysis, though not necessarily low for public land management. The results of cost-benefit analysis for the proposed methods show such wide margins for benefit that substantial changes in direct cost or interest rate could be accom-

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Personal correspondence in August 1971 with R. Miller, Region 9, USDA Forest Service.

Personal correspondence in August 1971 with J. Hodge, Michigan Department of Natural Resources.

Personal correspondence in June 1971 with E Kurki, Minnesota Department of Natural Resources modated without altering the conclusion that genetic improvement in white spruce is economically attractive. Second, not all white spruce seedlings planted in the Lake States need to be from gentically superior seed. Seed needs could be met more cheaply if genetically superior seed was mixed with local seed. Most of the merchantable crop will be in the genetically superior trees, while inferior material will be removed by mortality through suppression, early thinnings, or Christmas tree harvest.

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