Frontline
Forestry Research Applications
Canadian Forest Service–Ontario
Technical Note No. 68

MIXED GROWTH RESPONSE OF MATURE BLACK SPRUCE TO N, P, AND K FERTILIZERS

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CATEGORY: Stand management
KEY WORDS: Black spruce, fertilization, urea, triplesuperphosphate, muriate of potash, growth response, economics

INTRODUCTION

Today, forecasts of world newsprint demand show a steady increase from a consumption of 32 million tonnes in 1990 to 47 million tonnes by 2010 (Woodbridge, Reed and Associates 1988). During the 1960s and 1970s, in response to raw material shortages predicted for the area's pulp and paper industry over the short to medium terms, interest in the use of fertilizers to promote forest growth increased across eastern Canada. It was argued that extra growth would accrue over relatively short time periods, thereby minimizing investment costs and providing forest managers with flexibility for balancing forest volume/age distributions.

Black spruce (*Picea mariana* [Mill.] B.S.P.), the most abundant conifer in Ontario and the choice of the province's pulp and paper industry, was one of the species studied. It occurs in pure, even- and uneven-aged stands (Fig. 1), and mixed with other species on a variety of site types.

Inconsistent responses to fertilization, however, have been reported for black spruce across eastern Canada (Krause et al. 1982). In Newfoundland, responses exceeding 2.5 m³/ha per yr were reported by Van Nostrand (1979). On the other hand, of the 21 black spruce stands treated across eastern Canada in the Interprovincial Forest Fertilization Program, best gains due to fertilization were less than 1.0 m³/ha per yr (Weetman et al. 1987). In some trials, a suppression of growth occurred.

This note summarizes results of Canadian Forest Service trials in Ontario, provides an economic analysis, and discusses the silvicultural implications of fertilizing mature black spruce.

Figure 1. Views of typical semimature black spruce stands: (A) outside face, and (B) interior.

CANADIAN FOREST SERVICE TRIALS

Growth Response

Results of Canadian Forest Service trials in Ontario have also been sporadic. In a *N x P x K* factorial experiment in a 90-year-old stand on a moist to wet site, results indicated a best growth response of 0.9 m³/ha per yr for only one combination of N and P (Morrison et al. 1976).

In another study, in a 100-year-old stand on an imperfectly drained site with an original volume of 232 m³/ha, net growth

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due to N was 1.1 m³/ha per yr during the initial 5 years, but dropped off rapidly for an average of 0.5 m³/ha per yr in Years 6 to 10 (Foster et al. 1986). Typical 10-year response data in relation to increased N application rate (as urea) are presented in Table 1. Application of N, P, and K to the 100-year-old stand obtained a response of 1.1 m³/ha per yr.

Table 1. Ten-year response to N fertilizer in a 100-year-old upland black spruce stand near Beardmore, Ontario (*from* Foster et al. 1986).

Treatment (kg/ha)	Mean DBH increment (cm)	Gross volume increment (m³/ha)	10-year volume increment to fertilization (m³/ha)
Control	0.09	52.7	–
N112	0.14	58.6	5.9
N224	0.14	60.2	7.5
N336	0.10	53.8	1.1

In a relatively pure, vigorous, 65-year-old upland black spruce stand, with an initial volume of 227 m³/ha, best response to N alone was only 0.86 m³/ha per yr additional volume, while N+P gave a net response of 1.24 m³/ha per yr (Morrison and Foster 1979). Selected 5-year results from this study, illustrating typical response in relation to N and P in combination, are presented in Table 2. At very high rates of N, growth appeared suppressed.

Table 2. Five-year growth response to N and P fertilizers in a 65-year-old upland black spruce stand near Black Sturgeon Lake, Ontario (*from* Morrison and Foster 1979).

Treatment (kg/ha)	Mean DBH increment (cm)	Gross volume increment (m³/ha)	5-year volume increment to fertilization (m³/ha)
Control	0.66	31.4	–
P50	0.74	31.6	0.2
P100	0.71	27.1	less
N150	0.67	35.7	4.3
N150 P50	0.72	32.2	0.8
N150 P100	0.82	33.4	2.0
N300	0.86	34.2	2.8
N300 P50	0.90	37.6	6.2
N300 P100	0.81	33.1	1.7
N450	0.77	33.0	1.6
N450 P50	0.83	35.1	3.7
N450 P100	0.76	31.3	less

A 70-year-old upland black spruce stand in the Kapuskasing area of northern Ontario, with an initial volume of 269 m³/ha, responded to N and K by producing an average growth increase of 4.2 m³/ha per yr during the first 5 years, and 2.8 m³/ha per yr in Years 6 to 10 (Morrison 1991). Selected results from this study are presented in Table 3. In a 70-year-old black spruce stand on a lowland site in the same area (ibid., not included in Table 3), the only treatments that produced significant gains over controls occurred when N was applied as urea at either 112 or 224 kg N/ha with P and K. However, the duration of the response was for the first 5 years, and the response was significant only for mean diameter at breast height (DBH) increment. Also, in a 70-year-old upland mixedwood stand containing black spruce, N with P significantly increased percent basal area growth for the first 5 years.

Economic Analysis

A telephone survey of 1994 prices put the cost of prilled urea (the most common form of N fertilizer) at \$330/tonne (\$0.33/kg) and of aerial application at \$0.22–0.32/kg. Using these figures, an application providing 112 kg/ha of N would cost from \$113.91 to \$158.26 per hectare.

SSK Inc. (1993), in a comprehensive survey of costs and prices in the forest sector in Ontario, determined logging costs (separate from transportation costs) to be \$20.89/m³ in 1991. Logging costs per m³ generally decrease as tree diameters increase. In fact, in similar stands in eastern Canada, Gingras (1988) indicated an approximate 10% change in logging costs per 1-cm difference in diameter. Using Tucker's (1974) method, logging cost reductions discounted to present value (assuming a 5% interest rate for 10 years) were calculated for several examples from Tables 1 and 3 and compared with treatment costs (Table 4). The reductions (Column 4) were encouraging (from \$18.63 to \$74.91/ha), though in none of the examples cited could fertilization be justified on the basis of logging cost reduction alone.

Direction '90s, the basic policy document of the Ontario Ministry of Natural Resources, notes that "Prices charged for resources ought to reflect...[among other things]...the extent of benefits received..." (Ont. Min. Nat. Resour. 1992). Subtracting the costs of production (mill processing, transporting wood to the mill, harvesting) and an allowance for profit and risk from the value of the products produced, leaves an amount that is attributable entirely to the wood. This is the residual timber value (RTV). It is a measure of the maximum potential financial price that an existing processor could pay for standing timber. The pulp, as well as the other product sectors, will likely see the introduction of some form of this valuation in Ontario.

Based on 1986–1991 estimated values of standing timber harvested in Ontario, an average RTV of \$117.20/m³ for groundwood pulp was determined (SSK Inc. 1993). A minimum RTV of \$43.10/m³ and a maximum of \$158.52/m³ were also given. The most important variable affecting the timber value of pulpwood was found to be product price. Increasing product price, decreasing manufacturing costs, decreasing distance to the mill, easy ground conditions for harvesting, and larger trees all increase the value of standing timber.

Table 3. Five- and 10-year growth responses to N, P, and K fertilizers in a 70-year-old upland black spruce stand near Kapuskasing, Ontario (*from* Morrison 1991).

Treatment (kg/ha)	Mean DBH increment 10 years (cm)	Gross volume increment 5 years (m^3/ha)	Gross volume increment 10 years (m^3/ha)	Volume increment to fertilization 5 years (m^3/ha)	Volume increment to fertilization 10 years (m^3/ha)
Control	1.14	27.9	41.4	–	–
N112	1.24	38.5	61.3	10.6	19.9
N112 P74	1.29	36.9	54.7	9.0	13.3
N112 K93	1.27	48.6	76.0	20.7	34.6
N112 P74 K93	1.15	30.1	46.4	2.2	5.0
N224	1.32	35.6	55.5	7.7	14.1
N224 P74	1.19	36.2	54.8	8.3	13.4
N224 K93	1.36	38.1	52.4	10.2	11.0
N224 P74 K93	1.25	39.6	52.2	11.7	10.8

Table 4. Net present worth 10 years after fertilization in terms of logging cost savings at a 5% interest rate.

Treatment (kg/ha)	10-year response: Volume difference (m^3)	10-year response: DBH difference (cm)	Treatment cost ($/ha)	Present value logging cost reduction ($/ha)	Present value of fertilized wood ($/ha)	Net present worth ($/ha)
Beardmore N112	5.9	0.05	158.26	18.63	156.11	16.48
Beardmore N224	7.5	0.05	316.52	18.74	198.45	-99.33
Kapuskasing N112	19.9	0.10	158.26	42.35	526.54	410.63
Kapuskasing N224	14.1	0.18	316.52	74.91	373.08	131.47

Using the minimum RTV, the present value of additional wood, assuming the added volume is treated as a lump sum payment after 10 years at 5%, was calculated for the same treatment (Table 4). Net present worth (logging cost saving plus value of the wood less treatment cost) is given in the last column. For three of the four examples cited, the results are positive.

SILVICULTURAL IMPLICATIONS

Some opportunities to fertilize do exist; the chief response variables are DBH increment (which, depending on the harvesting system, may reduce logging costs) and additional volume produced.

Treatment expense combines the cost of the fertilizer and its application. In order to minimize handling, fertilizers of high element content are favored.

Responses to N have generally been seen following applications in the range of 100–300 kg N/ha, requiring 222–666 kg urea or 303–909 kg ammonium nitrate per hectare. Responses to phosphorous have generally been to applications of 50–100 kg P/ha; potassium responses have been to applications of 50–100 kg K/ha.

There is no convincing evidence of differential response to fertilizers on different site types; there is, however, some suggestion of slightly better responses by slower growing black spruce stands or black spruce stands on poorer sites.

Similarly, no convincing evidence has been presented of differential response related to stand age. Regardless of any rationale that might be advanced for fertilizing stands at a particular stage of growth, the stand age question is overshadowed to a large degree by the necessity to fertilize just prior to harvest in order to minimize treatment carrying charges and to ensure that the extra growth goes into crop trees only.

While there have been no definitive studies of stand response in relation to time of year, fertilizer application in May or early June is recommended to permit maximum opportunity for uptake and to minimize carrying charges on investment. Application on snow is inadvisable because of possible stream contamination during the spring runoff. The nitrate anion of ammonium nitrate is mobile, and excessive application may in some situations lead to groundwater contamination.

Economic evaluations must be done on a case-by-case basis. In exceptional cases, fertilization of black spruce for pulpwood can be profitable. However, the generally extreme variability of response dictates a need for caution.

REFERENCES AND FURTHER READING

Foster, N.W.; Morrison, I.K.; Swan, H.S.D. 1986. Growth response of a boreal forest black spruce stand to fertilizer treatments. North. J. Appl. Forest. 3(4):142–144.

Gingras, J.-F. 1988. The effect of site and stand factors on feller-buncher performance. Forest Eng. Res. Inst. Can., Pointe Claire, PQ. Tech. Rep. No. TR-84. 18 p.

Krause, H.H.; Weetman, G.F.; Koller, E.; Veilleux, J.-M. 1982. Interprovincial forest fertilization program. Results of five-year growth remeasurements. Can. For. Serv., Ottawa, ON. Inf. Rep. DPC–X–12. 38 p. + appendices.

Morrison, I.K. 1991. Ten-year growth response to fertilizers by semimature black spruce and spruce-poplar mixedwoods near Kapuskasing, Ontario. For. Chron. 67(1):27–32.

Morrison, I.K.; Foster, N.W. 1979. Five-year growth in two nitrogen-phosphorus fertilization experiments in spruce and spruce-fir upland forest in northern Ontario. Can. For. Serv., Sault Ste. Marie, ON. Inf. Rep. O–X–299. 15 p.

Morrison, I.K.; Swan, H.S.D.; Foster, N.W.; Winston, D.A. 1976. Ten-year growth response to fertilizer of a 90-year-old black spruce stand in northwestern Ontario. For. Chron. 52(5):233–236.

Ontario Ministry of Natural Resources. 1992. Direction '90s. Queen's Printer, Toronto, ON. 14 p.

SSK Inc. 1993. Quantification of residual timber values - northern model. Queen's Printer, Toronto, ON. 148 p.

Tucker, T.L. 1974. What is it worth? An economic evaluation of fertilizer trials in jack pine at Dryden, Ontario. p. 39–47 *in* F. Hegyi, chairman. Proceedings of a Workshop on Forest Fertilization in Canada. 8–10 January 1974, Sault Ste. Marie, Ontario. Can. For. Serv., Sault Ste. Marie, ON. Tech. Rep. 5. 127 p.

Van Nostrand, R.S. 1979. Growth response of black spruce in Newfoundland to N, P and K fertilization. For. Chron. 55:189–193.

Weetman, G.F.; Krause, H.H.; Koller, E.; Veilleux, J.-M. 1987. Interprovincial forest fertilization trials 5- and 10-year results. For. Chron. 52(6):184–192.

Woodbridge, Reed and Associates. 1988. Canada's forest industry. The next twenty years: Prospects & priorities. III. Pulp and paper. Vancouver, BC. 355 p.

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The preparation of this note was funded under the Northern Ontario Development Agreement's Northern Forestry Program.

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Catalogue No. Fo 29–29/68E
ISBN 0–662–22763–8
ISSN 1183–2762

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