

NITROGEN AND HERBICIDE TREATMENTS IN
SEMIMATURE JACK PINE FOREST,
CHAPLEAU, ONTARIO: FIFTH-YEAR RESULTS

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ABSTRACT

In May 1970, a 3 x 4 factorial experiment, replicated three times, was established to determine the effects of killing ground vegetation by herbicides, in combination with nitrogen fertilization, on the growth of 45-year-old jack pine (*Pinus banksiana* Lamb.). Two herbicides, singly and in combination, paraquat (1, 1'-dimethyl-4, 4'-bipyridylium) and simazine (2-chloro-4, 6-bis [ethylamino]-s-triazine) were applied to ground vegetation in 0.8 ha square plots. Nitrogen fertilizer treatments using urea at 0, 168, and 336 kg N/ha were applied. The stand, of fire origin, was on a Site Class I sandy site near Chapleau in north-central Ontario. Periodic annual increment on controls was estimated at 4.8 m³/ha. After 5 years the response variables, mean DBH increment, BA increment, percent BA growth, total volume increment, and merchantable volume increment were estimated. The best response, to urea at 336 kg N/ha with no herbicide, was an increase of 9.45 m³/ha of merchantable volume increment over controls over 5 years (1.89 m³/ha/yr). Herbicide was associated with increased growth of jack pine in only one instance: a combination of paraquat and simazine increased mean DBH increment. Nutrient tie-up by ground vegetation does not appear to be an important limiting factor in jack pine tree nutrition.

RÉSUMÉ

Une expérience factorielle 3 x 4, trois fois effectuée (répliques), fut établie en mai 1970 afin de déterminer les effets causés par la destruction de la végétation basse au moyen d'herbicides, concurrente à une fertilisation à l'azote, sur la croissance du Pin gris (*Pinus banksiana* Lamb.) âgé de 45 ans. Deux herbicides, employés seuls ou de concert, soit le paraquat (1, 1'-diméthyl-4, 4'-bipyridylium) et la simazine (2-chloro-4, 6-bis (éthylamino)-s-triazine), furent appliqués à la végétation basse dans des placeaux de 0.8 ha². Le composé azoté était de l'urée appliquée par quantités de 0, 168 et 336 kg N/ha. Le peuplement, survenu après un incendie, se situait dans une station sableuse de classe I, près de Chapleau, dans le centre-nord de l'Ontario. L'accroissement périodique annuel des témoins fut évalué à 4.8 m³/ha. Cinq ans plus tard, on évalua les variables de réponse suivantes: accroissement moyen du d.h.p., accroissement de la ST, pourcentage d'accroissement de la ST, accroissements du volume total et du volume marchand. Le meilleur traitement, 336 kg N/ha, sans herbicide, produisit une augmentation de 9.45 m³/ha de volume marchand, comparative-ment aux témoins sur une période de 5 ans (1.89 m³/ha/an). L'herbicide augmenta la croissance du Pin gris en un seul cas: le paraquat et la simazine ensemble augmentèrent l'accroissement moyen du d.h.p. Il semble que la végétation basse ne soit pas un facteur important d'assimilation des matières nutritives pouvant limiter la nutrition du Pin gris.

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INTRODUCTION

During the 1960s, interest grew in North America in the use of fertilizers to increase forest growth. This interest led to research by the Canadian Forestry Service to assess the effects of fertilizers on northern Ontario pulpwood stands. A series of experiments was established in 1969 in 55-year-old jack pine (*Pinus banksiana* Lamb.) near Dryden, Ontario, the results of which have been previously reported (Morrison et al. 1976a). In 1970 a second series of experiments was established in 45-year-old jack pine near Chapleau, Ontario. Each experiment was designed to test various fertilizer types and levels, alone and in combination with other silvicultural treatments. One of the experiments is reported herein.

An evaluation of the literature on forest fertilization made prior to 1970 suggested that in slow-growing boreal forests considerable quantities of nutrients were immobilized in various sectors of the ecosystem. For instance, under dense stands, a combination of plant undergrowth, limited sunlight and cool temperatures may result in slow decomposition of organic matter on the soil surface and thereby reduce amounts of nutrients released annually. The literature also suggested that ground vegetation may immobilize nutrients, particularly artificially applied fertilizers, and thus reduce the impact that fertilizers would have on improving tree growth (Gagnon 1965, van Tuil 1967, Weetman 1968). Hence, herbicide application coinciding with or prior to fertilization may be beneficial for increasing tree growth by removing the ground vegetation and increasing the availability of nutrients to the trees. For example, Hagner et al. (1966) used a herbicide (hormoslyr) in a Swedish trial and obtained a small though insignificant response to vegetation kill. In northern Ontario herbicides are used widely in Christmas tree culture but they have not been tested for the use described above. Besides preventing nutrient tie-up by ground vegetation, herbicides may, by enabling additional sunlight to reach the forest floor and thereby raise soil temperatures, increase rates of organic matter breakdown and subsequent release of nutrients.

Consequently, it was decided to test the herbicide-nutrient hypothesis in a field trial established in 1970 at Chapleau, Ontario. Two herbicides, paraquat and simazine, were selected on the basis of their rate and mode of action for single and combined treatments.

Paraquat (1, 1'-dimethyl-4, 4'-bipyridylum) is a fast-acting herbicide that kills plant tissue on contact. It is de-activated on contact with soil and has no residual effect on regrowth (Costen 1968). This herbicide was found to affect a wide variety of ground vegetation occurring in the boreal forest (Winston and Haavisto 1974) of eastern Canada.

Simazine (2-chloro-4, 6-bis [ethylamino]-s-triazine) kills plants by entering the roots, moving to foliage and interfering with photosynthesis. It persists in the upper 2-6 cm of the soil and may remain

effective for several months or more. Simazine kills and prevents regrowth of many species, particularly grasses and broadleaved weeds, especially if application is made prior to foliage emergence or during juvenile growth stages in the spring. Although simazine is toxic to many species at higher dosages, several investigators have reported that it stimulates growth of some species when applied to the soil in very small quantities. Conner and White (1968) observed increases in both growth and foliar nitrogen (N) content of pot-grown slash pine (*Pinus elliottii* Engelm. var. *elliottii*) and loblolly pine (*P. taeda* L.) seedlings following applications of non-toxic levels (0.2-0.8 ppm) of simazine in nutrient solution. Similarly, Ries et al. (1967), Ries and Wert (1972), and Rottman et al. (1974) have reported increased N content and protein level in seedlings of several cereal crops following simazine application. In the study reported herein it was postulated that, in the boreal forest, simazine application to ground vegetation might have the double effect of killing ground vegetation and stimulating the growth of the jack pine trees. However, the manner in which simazine might have acted to bring about the effect indicated was not studied.

STUDY AREA

The study area (lat. 47°38'N; long. 83°15'W) is located in Nimitz Township, Sudbury District, Ontario, approximately 25 km SSE of Chapleau. It is within the Missinaibi-Cabonga Section (B.7) of the Boreal Forest Region (Rowe 1972) and astride the common boundary of Site Regions 3E and 4E of the Ontario Site Region Classification (Hills 1960). The average length of growing season is 161 days (based on a 5.5°C index), extending from May through September (Chapman and Thomas 1968). The soil is a sandy Mini Humo-Ferric Podzol (Anon. 1974), with a 5-10 cm depth of moss and litter, over a 2-6 cm depth of F and H horizon organic material.

The stand, classified as Site Class 1 (Plonski 1974), was a 45-year-old relatively uniform jack pine forest of fire origin. Mean dominant height was 17.0 m, mean diameter at breast height (DBH) 11.2 cm (range 3.0 - 29.5 cm), basal area (BA) 27.2 m²/ha, total standing volume 178.5 m³/ha, merchantable standing volume 138.1 m³/ha, and average number of trees per ha was 2800. The forest floor was occupied by a continuous moss layer (Fig. 1) with *Pleurozium schreberi* (BSG.) Mitt. predominating and *Dicranum polysetum* SW. in lesser abundance. The herb and shrub layer was variable in density; frequently occurring species were *Maianthemum canadense* Desf., *Anemone quinquefolia* L., *Cornus canadensis* L., *Vaccinium angustifolium* Ait., *V. myrtilloides* Michx. and *Oryzopsis asperifolia* Michx. A more detailed listing is given in the Appendix.



Fig. 1. Close-up of ground vegetation, including moss, under a 45-year-old jack pine stand.

METHODS

The experiment was a 3 x 4 factorial with three N fertilizer treatments (0, 168 and 336 kg N/ha with N supplied as commercial-grade prilled urea [46% N]) and four herbicide treatments (control, paraquat at 0.56 kg active ingredient (a.i.)/ha in 135 L of water, simazine at 5.6 kg a.i./ha in 135 L of water, and a combination of paraquat and simazine at levels as above, together dissolved in 135 L of water). Each possible treatment combination was replicated three times for a total of 36 treatment plots arranged in a grid design. Each treatment plot was square, 0.08 ha in area, with a centrally located internal measurement plot 0.04 ha in size. All trees were numbered with metal tags. In late May 1970, weighed amounts of urea were hand broadcast to the soil surface in two or more systematic passes in an attempt to obtain uniform coverage. On the same day, the herbicides were applied by hand sprayer to all herb, shrub, and moss vegetation in the appropriate plots. Each application was sufficient to criss-cross the plot at least twice and a deliberate attempt was made to wet all vegetation to drip point. The DBH of all trees, and height of one randomly selected tree in each

2.5 cm diameter class in each plot, were recorded when the experiment was initiated, and diameters were remeasured 5 years later, in late May 1975. Trees that died during the period 1970-1975 were removed from the record. All measurements were in English units and were subsequently converted to S.I. units.

The following fifth-year response variables were calculated: mean DBH increment, BA increment, percent BA growth, total volume increment, and merchantable volume increment. Mean DBH and BA increment and percent BA growth were calculated in the usual manner. The two volume increments were estimated as follows: a regression of height-on-diameter, derived from pooled measurements on the sample trees (augmented by data from similarly selected trees in nearby experiments), was used to approximate the height of each tree. Total and merchantable volumes, for both 1970 and 1975, were computed on a tree-by-tree basis for each plot, using estimated heights, measured DBHs, and Honer's (1967) volume equations. Total merchantable volume increments were calculated for each plot by subtracting 1970 from 1975 figures. Data were subjected to analyses of variance and Duncan's New Multiple Range Test for the detection of significant differences among means. A second series of analyses of variance was performed on the data omitting the combination herbicide treatment from the factorial design in order to test for a simazine x paraquat herbicide interaction.

RESULTS

Periodic observation of herbicide effect throughout the 1970 and 1971 growing seasons indicated that an almost 100% kill and control of vegetation was achieved with the simazine and the combination treatments during 1970; however, releafing occurred in 1971. Paraquat killed current foliage on shrubs and ground plants but did not prevent releafing in 1970. Examination of the results of analyses of variance (F-ratios) (Table 1) indicates that N alone significantly affected mean DBH increment, BA increment and total and merchantable volume increments. There was no significant effect attributable to herbicides or to the interaction of N and herbicide.

The highest mean DBH increment was associated with the N336 x herbicide control treatment (Table 2). This treatment also produced the highest percent BA growth and volume increments. In general, growth responses increased directly with increased levels of N.

Herbicide treatments to control ground vegetation had little effect on tree growth. In the treatment in which paraquat and simazine were combined (HCOMB) without nitrogen, mean DBH increment increased significantly (Table 2); however, the other parameters showed no increase. Except for the HCOMB treatment, the effects of simazine and paraquat were

identical. The combination of fertilizers with herbicides had no significant positive effect, and with merchantable volume growth over control (Table 3) the response to nitrogen at 336 kg/ha with the combined herbicide treatment indicated a negative interaction although this was not significant. In the supplementary analyses of variance, there were no significant interaction effects attributable to the combination of the herbicides.

Table 1. Analysis of variance: summary of F-ratios

Treatment	Response variables				
	Mean DBH increment	Basal area increment	Basal area growth (%)	Total volume increment	Merchantable volume increment
F-ratio					
N	4.71*	4.28*	5.63**	5.06*	4.07*
HERB	.31	.94	.25	.89	.89
NHERB	1.54	.57	.57	.67	.56

* Significant, $P = .05$

** Significant, $P = .01$

N = nitrogen

HERB = herbicide

NHERB - nitrogen and herbicide interaction

Table 2. Five-year growth response of 45-year-old jack pine to increasing levels of nitrogen and to different herbicide treatments applied to ground vegetation

Treatment	Response parameters				
	Mean DBH increment (cm)	Basal area increment (m ² /ha)	Basal area growth (%)	Total volume increment (m ³ /ha)	Merchantable volume increment (m ³ /ha)
CONTROL	.57 ^{c*}	3.15 ^a	11.3 ^b	24.07 ^b	24.04 ^a
HPAR ¹	.63 ^{bc}	3.12 ^a	11.4 ^b	23.94 ^b	24.21 ^a
HSIM ²	.73 ^{abc}	3.46 ^a	12.3 ^{ab}	27.19 ^{ab}	27.22 ^a
HCOMB ³	.80 ^{ab}	3.25 ^a	12.8 ^{ab}	25.02 ^{ab}	24.92 ^a
N168	.77 ^{abc}	3.54 ^a	13.8 ^{ab}	27.20 ^{ab}	27.27 ^a
N168 HPAR	.80 ^{ab}	3.83 ^a	14.0 ^{ab}	29.82 ^{ab}	29.71 ^a
N168 HSIM	.67 ^{bc}	3.60 ^a	13.1 ^{ab}	28.05 ^{ab}	28.02 ^a
N168 HCOMB	.77 ^{abc}	3.36 ^a	12.5 ^{ab}	26.89 ^{ab}	26.75 ^a
N336	.90 ^a	4.37 ^a	16.2 ^a	34.20 ^a	33.51 ^a
N336 HPAR	.80 ^{ab}	4.06 ^a	15.6 ^{ab}	31.36 ^{ab}	30.82 ^a
N336 HSIM	.83 ^{ab}	4.34 ^a	14.5 ^{ab}	34.03 ^a	33.97 ^a
N336 HCOMB	.80 ^{ab}	3.33 ^a	13.6 ^{ab}	26.14 ^{ab}	25.91 ^a

Note: Common letters within columns indicate treatments not significantly different at the 5% level, Duncan's New Multiple Range Test.

¹HPAR = paraquat .56 kg/ha

²HSIM = simazine 5.6 kg/ha

³HCOMB = paraquat .56 kg/ha + simazine 5.6 kg/ha

Table 3. Merchantable volume increment growth over control (m^3/ha) for the 5-year response period, by fertilizer and herbicide treatment

Nitrogen (kg/ha)	Herbicide (m^3/ha)			
	HO	HPAR	HSIM	HCOMB
0	0	0.2	3.2	0.9
168	3.3	5.7	4.0	2.8
336	9.5	6.8	10.0	1.9

DISCUSSION

The response (merchantable volume increment) to N fertilizer (N336 HO) is in the order of $33.5 \text{ m}^3/\text{ha}$ or $6.7 \text{ m}^3/\text{ha/yr}$ and is similar to the $7.3 \text{ m}^3/\text{ha/yr}$ reported by Morrison et al. (1976b) for an N application of 224 kg/ha to jack pine in a stand adjacent to the one described in this report. The study again supports the previous research indicating that nitrogen fertilization can increase tree growth substantially.

The application of herbicides to ground vegetation, as an alternative or additional silvicultural treatment, had neither a positive nor a negative effect on tree growth that was statistically significant. In one instance, DBH increment was increased significantly by the herbicide combination (HCOMB) treatment. This effect could be a result of either vegetation control or growth stimulation by the low level simazine stimulation effect. The vegetation control theory is most likely, though unconfirmed, since the tree roots tend to be located deeper than the 2-6 cm soil depth zone of simazine penetration.

The volume response to simazine alone (HSIM) was virtually identical to the response to N168 (Table 3) and the volume response to paraquat plus simazine (HCOMB) was much less (though not significantly less) than to simazine alone (HSIM). The simazine response may be a further indication of a slight nutrient release.

The general lack of response to the herbicide treatments, presumably interpretable as a failure on their part to release significant quantities of N for use by the target organism, may be

explained, in part at least, in the light of evidence published by Foster and Morrison (1976): for 30-year-old jack pine stands, for example, it was estimated that only 6 kg N/ha was tied up in the ground vegetation, as opposed to 171 kg/ha in the phytomass (trees plus ground vegetation) as a whole or 4428 kg N/ha in the entire ecosystem including organic and mineral soil horizons. In the same general locality as the present experiment, Morrison and Foster (1977) determined that only approximately 4% of a total application of 300 kg/ha of urea-N was captured initially by ground vegetation beneath 45-year-old jack pine, whereas 23% was captured by the trees themselves. Presumably, elimination of the ground vegetation could at best release, for the possible use of the target organism, only an additional 18 kg N/ha, made up of 6 kg/ha N from the original vegetation and 12 kg N/ha captured from the fertilizer.

LITERATURE CITED

- Anon. 1974. The system of soil classification for Canada. Can. Dep. Agric. Publ. 1455. 255 p.
- Chapman, L.J. and M.K. Thomas. 1968. The climate of northern Ontario. Can. Dep. Transp., Meteorol. Br., Climatol. Stud. 6.
- Conner, B.J. and D.P. White. 1968. Triazine herbicide and the nitrogen nutrition of conifers. Mich. Quart. Bull. 50(4): 497-503.
- Costen, R.A. 1968. Bipyrldyl herbicides Gramoxone (paraquat) and Reglone A (diquat) for use in forestry and associated areas. Paper presented Feb. 21, 1968 to Herbicide Seminar, Ont. Prof. For. Assoc., Toronto. Chipman Chem. Ltd., Hamilton, Ont. Tech. Serv. Note. Mimeogr. Rep. 11 p.
- Foster, N.W. and I.K. Morrison. 1976. Distribution and cycling of nutrients in a natural *Pinus banksiana* ecosystem. Ecology 57: 110-120.
- Gagnon, J.D. 1965. Effect of magnesium and potassium fertilization on a 20-year-old red pine plantation. For. Chron. 41: 290-294.
- Hagner, S., J. Saraste, B. Johansson and A. Ahgren. 1966. [Timber production by forest fertilization.] Sver. Skogs. Tid. Heft. 2, Stockholm. (transl. from Swedish) 171 p.
- Hills, G.A. 1960. Regional site research. For. Chron. 36(4): 401-423.
- Honer, T.G. 1967. Standard volume tables and merchantable conversion factors for the commercial tree species of central and eastern Canada. Can. Dep. For. Rur. Dev., Ottawa, Ont. Inf. Rep. FMR-X-5. 12 p. + tables.

- Morrison, I.K., F. Hegyi, N.W. Foster, D.A. Winston and T.L. Tucker. 1976a. Fertilizing semimature jack pine (*Pinus banksiana* Lamb.) in northwestern Ontario: fourth-year results. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-240. 42 p.
- Morrison, I.K., D.A. Winston and N.W. Foster. 1976b. Urea dosage trial in semimature jack pine forest, Chapleau, Ontario: fifth-year results. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-251. 8 p.
- Morrison, I.K. and N.W. Foster. 1977. Fate of urea fertilizer added to a boreal forest *Pinus banksiana* Lamb. stand. Soil Sci. Soc. Amer. J. 41(2): 441-448.
- Plonski, W.L. 1974. Normal yield tables (metric) for major forest species of Ontario. Ont. Min. Nat. Resour., Div. For. 40 p.
- Ries, S.K., H. Chmiel, D.R. Dilley and P. Filner. 1967. The increase in nitrate reductase activity and protein content of plants treated with simazine. Proc. Nat. Acad. Sci. 58: 526-532.
- Ries, S.K. and V. Wert. 1972. Simazine-induced nitrate absorption related to plant protein content. Weed Sci. 20(6): 569-572.
- Rottman, G.A., J.A. Tweedy and G. Kapusta. 1974. Effect of simazine and diuron on the nitrogen content and dry weight of wheat and sorghum. Agron. J. 66: 701-702.
- Rowe, J.S. 1972. Forest regions of Canada. Can. Dep. Environ., For. Serv., Ottawa, Ont. Publ. 1300. 172 p.
- van Tuil, H. 1967. How fertilizers can influence timber trends and prospects. Stikstof No. 11. The Hague, Netherlands. p. 41-52.
- Weetman, G.F. 1968. The nitrogen fertilization of three black spruce stands. Pulp Pap. Res. Inst. Can. Woodl. Pap. No. 6. 45 p.
- Winston, D.A. and V.F. Haavisto. 1974. Greenhouse and field trials of Gramoxone and PP493 herbicides on boreal forest vegetation of northern Ontario. Environ. Can., For. Serv., Bi-mon. Res. Notes 30(6): 37-38.

APPENDIX

APPENDIX

Occurrence of lesser plant species, prior to treatment in 1969, expressed as percentage of plots on which species occurred; based on sample of two 1 m² subplots per plot.

Species	Occurrence (%)
LICHENS	
<i>Cladonia</i> spp.	11
MOSSES	
<i>Dicranum polysetum</i> SW.	56
<i>Pleurozium schreberi</i> (BSG.) Mitt.	100
CLUB MOSSES	
<i>Lycopodium obscurum</i> L.	11
HERBS AND SHRUBS	
<i>Abies balsamea</i> (L.) Mill.	11
<i>Amelanchier</i> spp.	11
<i>Anemone quinquefolia</i> L.	89
<i>Carex</i> spp.	67
<i>Comptonia peregrina</i> (L.) Coult.	67
<i>Coptis groenlandica</i> (Oeder) Fern.	11
<i>Cornus canadensis</i> L.	89
<i>Diervilla lonicera</i> Mill.	22
<i>Epigaea repens</i> L.	56
<i>Fragaria virginiana</i> Duchesne	11
<i>Linnaea borealis</i> L.	67
<i>Maianthemum canadense</i> Desf.	100
<i>Oryzopsis asperifolia</i> Michx.	100
<i>Oryzopsis pungens</i> (Torr.) Hitchc.	11
<i>Picea mariana</i> (Mill.) B.S.P.	22
<i>Pinus banksiana</i> Lamb.	11
<i>Polygala paucifolia</i> Willd.	44
<i>Rosa acicularis</i> Lindl.	44
<i>Salix</i> spp.	22
<i>Solidago bicolor</i> L.	44
<i>Sorbus decora</i> (Sarg.) Schneid.	11
<i>Vaccinium angustifolium</i> Ait.	100
<i>Vaccinium myrtilloides</i> Michx.	78
<i>Viola</i> spp.	33