SITE PREPARATION AND WEED CONTROL IN HARDWOOD AFFORESTATION IN ONTARIO[1/]

F.W. von Althen[2/]

Abstract.--Mechanical or chemical site preparation was combined with post-planting applications of simazine to determine their effects on 10-year survival and 10-year height increment of black walnut (*Juglans nigra* L.), basswood (*Tilia americana* L.), white ash (*Fraxinus americana* L.), and silver maple (*Acer saccharinum* L.) seedlings and cuttings of the hybrid poplar clone I 45/51 (*Populus* x *euramericana* [Dode] Guinier). The old-field site, near Hornby, Ontario (43°30'N, 79°45'W) has an imperfectly drained clay loam soil.

Ten-year survival of black walnut, basswood, white ash and silver maple ranged from 47 to 100%, with the best survival always occurring in the most intensively treated plots and the poorest survival in the untreated plots. Survival of the hybrid poplars ranged from 0% in the untreated and paraquat plots to 92% in the area plowed and disked in its entirety and treated with broadcast applications of simazine over the total area. Height increment of all species was highest in the area plowed and disked in its entirety and treated with broadcast applications of simazine over the total area, and lowest in the untreated and paraquat plots.

Keywords: Mechanical site preparation, chemical site preparation, weed control.

INTRODUCTION

The elimination or drastic reduction of broadleaf and grass competition is prerequisite to the successful establishment and satisfactory early growth of most hardwood species planted on former agricultural land (Lane and McComb 1953, Byrnes 1966, von Althen 1971). While plowing and disking of the total plantation area have provided excellent results, this treatment is expensive and may not always be feasible or desirable. Since the development of herbicides, zero tillage has received much attention in agriculture (Arnott and Clement 1966, Dowdell and Cannell 1975), but information is currently insufficient to permit recommendation of chemical site preparation for the establishment of hardwood plantations.

The experiment described in this report is the last of a series designed to develop techniques suitable for successful hardwood afforestation of abandoned farmland. The most promising treatments used in previous experiments in combination with plowing and disking of the total plantation area were examined in this experiment, and their effects on the 10-year survival and height increment of black walnut (*Juglans nigra* L.), basswood (*Tilia americana* L.), white ash (*Fraxinus americana* L.), and silver maple (*Acer saccharinum* L.) seedlings and hybrid poplar (*Populus* x *euramerican* [Dode] Guinier) cuttings were

EXPERIMENTAL AREA

The study was carried out in a former farm field near Hornby, Halton County, Ontario (43°30'N, 79°45'W). The soil was an imperfectly

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[2/] Research Scientist, Government of Canada, Canadian Forestry Service, Great Lakes Forestry Centre, P.O. Box 490, Sault Ste. Marie, Ont., Canada P6A 5M7.

drained clay loam 45-65 cm deep over compact clay. The pH of the plow layer was 6.8 and the organic matter content was 2.8%. The Ontario Soil Survey (Gillespie et al. 1972) places the soil in the Chinguacousy Series. In 1961 the field had been afforested with white pine *(Pinus strobus* L.) and white spruce *(Picea glauca* [Moench] Voss) at a spacing of 3.7 m between rows. By 1974 over 70% of the trees had died as a result of severe weed competition and stem girdling by meadow voles *(Microtus pennsylvanicus)*. The surviving trees were 3 to 4 m tall. Ground cover consisted mainly of goldenrod *(Solidago* spp.), wild aster *(Aster* spp.), tall buttercup *(Ranunculus acris* L.), wild carrot *(Daucus carota* L.), rough-fruited cinquefoil *(Potentilla erecta* L.) and quackgrass *(Agropyron repens* [L.] Beauv.)

METHOD

In the autumn of 1974 the few surviving pine and spruce trees were removed from approximately 1.2 ha of the former plantation. In July of 1975 this area was plowed and disked and then disked three more times between July and September. In November, 2.2 a.i. kg/ha of pronamide were broadcast over the total area to eliminate the quackgrass that had survived the plowing and disking. On an adjacent area of 4 ha that was essentially similar, either strips of different widths were plowed and disked or rototilled between the surviving conifers in the autumn of 1975, or else 1.1 a.i. kg/ha of paraquat were sprayed on the herbaceous vegetation in the spring of 1976 shortly before planting (Table 1).

In April of 1976, 2+0 seedlings of white ash, silver maple and basswood, 1+0 seedlings of black walnut, or 30-cm-long cuttings of the hybrid poplar clone I 45/51 were planted both in the area plowed in its entirety and in all strips. All seedlings were machine planted; the cuttings were planted with a dibble. Spacing in the area plowed in its entirety was 3 m between rows and 1.5 m within rows. On the site-prepared strips a single row of trees was planted along the center line, with a spacing of 1.5 m between trees.

Simazine was applied as a weed control treatment in all plots shortly after planting and in April of the next two years. In the area plowed and disked in its entirety simazine was broadcast over the total area by a tractor-mounted sprayer. In the site preparation strips simazine was sprayed with a motorized backpack sprayer in continuous bands of different widths which corresponded with the widths of the site preparation treatments. In the plots without site preparation, simazine was applied in a continuous band 1.2 m wide. In all walnut plots, simazine was applied at a dosage of 6.7 kg/ha active ingredient. In plots planted with white ash, silver maple, basswood or poplar, simazine was applied at a dosage of 3.3 kg/ha active ingredient. Weed competition was assessed by ocular estimate during July of the first, third, fifth and tenth growing seasons.

Table 1.--List of treatments.

Treatment number	Site preparation	Post-planting weed control
1	Control, no treatment	Continuous band of simazine[1] 1.2 m (4 ft) wide sprayed shortly after planting and in April of the next two years
2	Continuous band of paraquat (1.1 a.i. kg/ha) 1.2 m (4 ft) wide applied shortly before planting	Continuous band of simazine 1.2 m (4 ft) wide sprayed shortly after planting and in April of the next two years
3	Three furrows plowed from either side to the middle and disked. Total width 1.5 m (5 ft)	Continuous band of simazine 1.5 m (5 ft) wide sprayed shortly after planting and in April of the next two years
4	Six furrows plowed to one side and disked. Total width 1.8 m (6 ft)	Continuous band of simazine 1.8 m (6 ft) wide sprayed shortly after planting and in April of the next two years
5	Six furrows plowed from either side to the middle and disked. Total width 3.3 m (11 ft)	Continuous band of simazine 3.3 m (11 ft) wide sprayed shortly
6	Nine furrows plowed to one side and disked. Total width 2.7 m (9 ft)	Continuous band of simazine 2.7 m (9 ft) wide sprayed shortly after planting and in April of the next two years
7	Rototilled strip 1.8 m (6 ft) wide	Continuous band of simazine 1.8 m (6 ft) wide sprayed shortly after planting and in April of the next two years
8	Total area plowed and disked four times; 2.2 a.i. kg/ha of pronamide broadcast over total area in November before spring planting	Broadcast application of simazine over the total area shortly after planting and in April of the next two years

[1] In all plots planted with black walnut, simazine was applied at a dosage of 6.7 a.i. kg/ha. In plots planted with white ash, silver maple, basswood and poplar, simazine was applied at a doage of 3.3 a.i. kg/ha.

The study consisted of a randomized block design with 12 trees of each of the five species assessed in each plot. There were three replications of each of the eight treatments. Therefore, a total of 288 seedlings or cuttings per species was measured. Survival was recorded at the end of the first, third, fifth and tenth growing seasons and total height was recorded shortly after planting and at the end of the first, third, fifth and tenth growing seasons. The total height increment over 10 years was computed by deducting the height of the seedlings at time of planting from the height recorded at the end of the tenth growing season. The 10-year survival data were subjected to chi-square tests of independence and the 10-year height increment data were analyzed by analysis of variance and Tukey's test of significance.

RESULTS

During the first three years after planting, competition control was 90% effective in the area plowed and disked in its entirety (Treatment 8), and sprayed with pronamide in autumn before planting and with simazine shortly after planting and in April of the next two years (Table 2). Ten years after planting, competition remained noticeably lower in the area treated in its entirety than in the strips. One application of 1.1 kg/ha of active paraquat (Treatment 2) shortly before planting killed the aboveground parts of all vegetation, but in the strips treated with 3.3 kg/ha of active simazine only 50% of the competition was controlled three years after planting, and five years after planting no reduction in weed cover was apparent. In the same strips, planted with black walnut and sprayed with 6.7 kg/ha of active simazine, competition control was 80% effective during the first three years, and a 30% reduction in competition was still apparent in the fifth year after planting.

In the strips plowed and disked or rototilled and sprayed with simazine at dosages of 3.3 or 6.7 kg/ha of active simazine, respectively (Treatments 3-7), competition control was 60 and 90% effective in the third year. Five years after planting, some reduction in competition was still apparent in these strips, but most weed species present before site preparation had reinvaded the strips.

Treatments significantly affected the survival of all species except black walnut (Table 3). Basswood survival was lowest in the control and highest in the area plowed and disked in its entirety. Survival of white ash and silver maple was significantly lower in the control than in most treatments. All poplar trees died in the two treatments without mechanical site preparation, while 92% of the trees survived in the area plowed and disked in its entirety.

Although height increment of all species was highest in the area plowed and disked in its entirety, there was no significant difference among treatments for black walnut. Height increment of white ash was significantly lower in the two treatments without mechanical site preparation, while height increment of the silver maple

Table 2.--Effectiveness of site preparation treatments and post-planting applications of simazine in achieving weed control (as indicated by years since planting).

Treatment	Years since planting							
	1 Simazine a.i. kg/ha		3 Simazine a.i. kg/ha		5 Simazine a.i. kg/ha		10 Simazine a.i. kg/ha	
	3.3	6.7	3.3	6.7	3.3	6.7	3.3	6.7
	Percent control							
1	20	40	10	30	0	0	0	0
2	70	80	50	80	0	30	0	0
3	70	90	60	80	10	20	0	10
4	70	90	60	80	10	20	0	10
5	70	90	60	80	10	20	0	10
6	70	90	60	80	10	20	0	10
7	90	90	90	90	20	40	0	10
8	90	90	90	90	30	50	10	20

Table 3.--Effects of site preparation and post-planting weed control on the survival and height increment of planted basswood, black walnut, white ash, and silver maple seedlings and hybrid poplar cuttings, 10 years after planting.

Treatment number	Site preparation	Post-planting weed control with simazine applied annually in the first 3 years after planting	Basswood		Black walnut		White ash		Silver maple		Hybrid poplar	
			Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
1	Control, no treatment	Continuous band 1.2 m (4 ft) wide	64a	184xy	83a	140x	61a	295xy	47a	125x	0a	0x
2	Continuous band of paraquat 1.2 m (4 ft) wide shortly before planting	Continuous band 1.2 m (4 ft) wide	80ab	144x	92a	128x	92bc	221x	89bc	129x	0a	0x
3	Three furrows plowed from either side to the middle and disked	Continuous band 1.5 m (5 ft) wide	95bc	244xy	94a	239x	92bc	377xyz	100c	272x	75cd	592y
4	Six furrows plowed to one side and disked	Continuous band 1.8 m (6 ft) wide	92bc	245xy	92a	183x	72a	398yz	100c	262x	64bcd	572y
5	Six furrows plowed from either side to the middle and disked	Continuous band 3.3 m (11 ft) wide	92bc	249xy	92a	232x	100c	401yz	67ab	203x	53bc	542y
6	Nine furrows plowed to one side and disked	Continuous band 2.7 m (9 ft) wide	69ab	287xy	97a	170x	83abc	335xyz	89bc	247x	81cd	634y
7	Rototilled strip 1.8 m (6 ft) wide	Continuous band 1.8 m (6 ft) wide	92bc	213xy	94a	174x	92bc	341xyz	95bc	224x	28b	521y
8	Total area plowed and disked several times; pronamide broadcast in autumn before planting	Broadcast over total area	100c	380y	92a	264x	97bc	483z	100c	568y	92d	1068z

Note: Within columns common letters denote treatments without significant differences (P 0.05) according to Tukey's test of significance

seedlings and the hybrid poplar cuttings was significantly greater in the area plowed and disked in its entirety than in all other treatments.

DISCUSSION

Most hardwood species of high timber value are very demanding in their site requirements and grow well only in deep, fertile soil. At the same time, young hardwood trees are very susceptible to competition from grasses and broadleaved weeds, which abound on these sites. To afforest fertile agricultural land successfully with high-value hardwood species it is therefore essential to eradicate the existing vegetation by site preparation and to prevent its regrowth through post-planting weed control.

One highly effective method of site preparation is eradication of the established vegetation by broadcast application of glyphosate in late summer, followed by plowing and repeated disking of the entire area (von Althen 1979). This combination of treatments destroys all weeds, including deep-rooted perennials, incorporates the organic material into the soil and reduces soil bulk density (Ponder 1981).

Treatment of the entire plantation area may not always be possible, however, or even desirable, because the site may be inaccessible to farm machinery, or the soil may be too stony, subject to erosion, or partially treed. Also, treating the entire area is generally more expensive than treating only strips or individual planting spots.

While much research has been carried out on the effects of zero tillage on agricultural crops (Cannell and Finney 1973), little is known about the effects of this method on the growth of hardwood trees. The main advantages of zero tillage are: (1) protection from erosion through increased mechanical strength of the soil and the presence of surface mulch (Wilkinson 1973), (2) high soil moisture and organic matter content near the soil surface (Blevins et al. 1972), and (3) higher earthworm populations with their beneficial effects on soil physical properties (Edwards and Lofty 1972). The disadvantages of zero tillage are: (1) greater soil compaction and increased bulk density, which may reduce root penetration (van Ouwerkerk and Boone 1970), and (2) lower soil temperature because of the insulating effect of mulch (Moody et al. 1963, Gauer et al. 1982).

The 10-year results of the study reported here show that different tree species responded differently to the site preparation treatments. For example, hybrid poplar height increment was significantly greater in the area plowed and disked in its entirety than on the plowed strips (Table 3). Without mechanical site preparation, planted poplar did not survive. At the other end of the scale, black walnut showed no significant differences in either survival or height increment after any of the treatments. This lack of response strongly suggests that black walnut was planted off-site since the species generally reacts very favorably to intensive site preparation and weed control (Byrnes et al. 1978). The factor limiting good walnut growth on this site was probably imperfect drainage of the clay loam soil.

For all species, height increment was greatest in the area plowed and disked in its entirety. However, differences in height increment with this and the other mechanical site preparation treatments were significant only for hybrid poplar and silver maple.

The poorest height increment in all species was in the untreated control and the strips site-prepared with paraquat. Most seedlings in both treatments, in addition to facing intense weed competition, suffered severe root damage when the planting slit reopened in the early years after planting (von Althen 1977). This reopening to a maximum width and depth of 5.5 and 15-20 cm, respectively, was caused by soil drying and shrinkage. As a result, the newly planted seedlings and cuttings lost their support, leaned or fell over, exposing roots to drying and to the depredations of mice. The planting slit partially closed during periods of high soil moisture and reopened to a lesser extent each summer. In the plowing and disking treatments the slit did not reopen.

Since only combinations of site preparation and post-planting weed control treatments were tested, it is impossible to state with certainty how much of the improved growth was due to site preparation and how much to post-planting weed control. However, other experiments have shown that site preparation without subsequent weed control is generally unable to defer reinvasion of the competing vegetation for more than one year, especially on the fertile planting sites required for good hardwood growth (von Althen 1976, 1981). On the other hand, post-planting weed control with simazine, but without prior site preparation, has generally failed because simazine, applied at dosages tolerated by most hardwood species, is unable to eradicate deep-rooted, perennial weeds. The only exception might be found in black walnut plantations because this species has a higher simazine tolerance than most weeds. To apply simazine at dosages of 9 a.i. kg/ha or more, however, is generally more expensive than mechanically site preparing and applying simazine dosages of 4 to 6 a.i. kg/ha.

For chemical site preparation paraquat was used because glyphosate had not yet been registered for forestry use. While glyphosate will provide better weed control than paraquat did, the reopening of the planting slit will remain a problem on heavy-textured soils.

The decision of whether to use mechanical or chemical site preparation depends mainly on the soil of the plantation site, the species to be planted, the accessibility of the site to farm machinery, the danger of erosion, the treatment cost and, last but not least, the wishes of the owner. Initial survival and height increment of the most commonly planted hardwood species are generally positively correlated with the effectiveness of weed control during the early years after planting, and this in turn depends on the intensity of site preparation.

SUMMARY AND CONCLUSIONS

In this experiment the best growth was obtained after plowing and disking of the entire planting area, followed by one application of pronamide in autumn before spring planting and simazine applications for three years after planting. With the registration of glyphosate for forestry use, the best results in hardwood afforestation in Ontario have recently been obtained with eradication of the existing vegetation through fall application of 2.2 a.i. kg/ha of glyphosate followed by plowing and disking of the total plantation area (von Althen 1979). Spring planting is followed by one application of simazine at a dosage tolerated by the planted species. Further applications of simazine are made in early spring of the next two years, by which time the trees are expected to have closed the canopy and thereby provide their own weed control. Where this is not the case, further herbicide applications may be necessary to maintain tree growth until crown closure is obtained.

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