Methods for Successful Afforestation of a Weed Infested Clay Soil

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"The highest growth of all hardwood species was obtained after intensive site preparation, weed control, and fertilization".

Abstract

The effects of plowing and tilling, fertilization, and chemical weed control on survival and height growth of newly planted seedlings of black locust, silver maple, white ash, white pine, and white spruce were investigated in a non-replicated study in southern Ontario. Cost-benefit relationships of treatments were computed. Plowing and tilling improved growth of all species with average increases ranging from 37 per cent for white spruce to 750 per cent for white ash. Plowing and tilling plus weed control greatly improved growth of all hardwood species and resulted in the most favorable growth-cost relationship. Fertilization improved growth of locust, ash, and maple by 200, 500, and 700 per cent respectively, but failed to increase conifer growth. Application of 12 pounds of simazine increased ash mortality by 67 per cent. White spruce was subject to severe frost heaving following complete weed control.

Méthodes pour assurer les succès des reboisements sur des sols argileux infestés de mauvaises herbes

Résumé

A Richmond Hill, Ontario, l'auteur étudia les effets du labourage et de la culture du sol, de l'emploi de fertilisants et d'herbicides, sur la survie et la croissance en hauteur de semis récemment mis en terre des espèces suivantes: Robinier faux-acacias ou Acacias blancs (*Robinia pseudo-acacia*), Erables blancs ou Plaines blanches (*Acer saccharinum*), Frênes d'Amérique ou Frênes blancs (*Fraxinus americana*), Pins blancs (*Pinus strobus*) et Epinettes blanches (*Picea glauca*).

Une fois le bilan des traitements bien établi, il semble:

1 — Que le labourage et la culture des sols favorisent la croissance de toutes les essences avec des augmentations moyennes variant de 37% pour l'Epinette blanche à 75% pour le Frêne blanc.

2 — Que l'application d'herbicides sur les planches labourées produit sur les feuillus des résultats encore meilleurs, de fait, les meilleurs au point de vue financier.

3 — Que l'application de fertilisants améliore la croissance des feuillus suivants: Robinier, 200%, Frêne, 500%, Erable blanc, 700%, mais elle n'a aucun effet sur la croissance des conifères.

4 — Que par contre, l'application de 12 livres de simazine à l'acre (13.52 kg/hect.) augmente la mortalité des Frênes de 67% et consécutivement à l'élimination des mauvaises herbes, les Epinettes blanches furent fortement soulevées par les gelées.

Introduction

Hardwood afforestation has generally met with little success (7, 8). While most failures are probably the result of errors in site evaluation, (2, 3, 6), success has been limited even on suitable soils. Weed competition on good hardwood sites is nearly always intense, and planted seedlings that are incapable of fast initial growth are soon suppressed (1, 5). To study the effect of site preparation, fertilization, and chemical weed control on early height growth of six hardwood and two coniferous species, a non-replicated pilot experiment was set out in the spring of 1964. The type and dosage of the fertilizers and the herbicide were selected after a review of the literature and were primarily chosen to provide background information for the implementation of a complete, factorial hardwood fertilization study.

The Study Area

The experiment was carried out near Richmond Hill, Ontario. The planting site was a hayfield with a uniform neutral clay over compact clay till at a depth of 2 feet. The Ontario Soil Survey places the soil in the Cashel series (4). Ground cover consisted of the following weeds: found in all plots were goat's (*Taraxacum officinale* Weber); very dandelions (*Taraxacum officinale* Weber); very common were sweet clover (*Melilotus* spp.), golden rod (*Solidago* spp.), wild carrot (*Daucus carota* L.), chicory (*Cichorium intybus* L.), and vetch (*Vicia cracca* L.); Canada thistle (*Cirsium arvense* (L.) Scop.), wild aster (*Aster* spp.), quackgrass (*Agropyron repens* (L.) Beauv.), hawkweed (*Hieracium* spp.), St. John's-wort (*Hypericum perforatum* L.), black bindweed (*Polygonum convolvulus* L.), and common ragweed (*Ambrosia artemisiifolia* L.) occurred in scattered small patches. In all, weed competition was very severe.

Method

A non-replicated pilot study was laid out, with 12 seedlings per species in each of 28 treatment

plots. Each plot covered an area of 0.037 acres. While half of the plots were plowed and tilled in autumn prior to spring planting, site preparation in the others was restricted to the removal of a scalp 18 inches in diameter at time of planting at each prospective planting spot. Seedlings of the following species and age classes were planted by spade in each plot: 1+0 sugar maple (*Acer saccharum* Marsh.), 2+0 red oak (*Quercus rubra* L.), 1+0 black locust (*Robinia pseudoacacia* L.), 2+0 basswood (*Tilia americana* L.), 2+0 white ash (*Fraxinus americana* L.), 2+0 silver maple (*Acer saccharinum* L.), 2+2 white pine (*Pinus strobus* L.), and 2+2 white spruce (*Picea glauca* (Moench) Voss). Shortly after planting ammonium nitrate, triple super phosphate, and potassium sulphate were broadcast on the surface in the following amounts (pounds of active ingredient per acre): level A: N-75, P-40, K-40; level B: N-150, P-80, K-80; level C: N-300, P-160, K-160. Herbicide treatment consisted of granular simazine applied together with the fertilizer in dosages of 3, 6, and 12 pounds of active ingredient per acre.

Survival and height growth of all seedlings were recorded in the autumn of the first 3 years after planting, whereas effectiveness of weed control was assessed each June and August during the same period. Since the experiment was not replicated, the results could not be analysed statistically. The effect of individual treatments has been examined, however, by averaging the data for all plots that received the same treatment regardless of treatment combination.

Results

Conifers

Plowing and tilling improved 3-year height growth of white spruce and white pine by 37 and 40 per cent respectively (Table 1), but had no influence on survival. Fertilization resulted in only slight improvement in height growth but increasing fertilization from level A to C reduced the survival of pine from 90 to 82 per cent and that of spruce from 69 to 50 per cent. Application of 3 and 6 pounds of simazine per acre resulted in moderately improved height growth and survival of both species, but the 12-pound dosage greatly reduced white spruce survival due to extensive frost heaving after the elimination of the ground cover (Figure 1).

Hardwoods

Sugar maple, basswood, and red oak seedlings were so severely browsed by rabbits that an assessment of growth responses was impossible; however, browsing was almost entirely restricted to these three species. Although the majority of the injured seedlings have survived, their form is very poor and extensive pruning would be necessary to produce stems of acceptable form.

Site preparation was the most constant factor affecting height growth of black locust, silver maple, and white ash (Table 2). For silver maple and locust the average growth on plowed plots was 3 and 4 times greater than on scalped plots; for ash the ratio was nearly nine to one. Survival of

Fig. 1. Frost-heaved white spruce.

TABLE 1. — Average 3-year height growth in inches of planted white pine and white spruce transplants under various combinations of site preparation, fertilization, and herbicide treatments.

Treatment	Fertilizer ¹ Level	Herbicide Treatment lb./acre	White pine		White spruce	
			plowed	scalped	plowed	scalped
0 control	0	0	10.9	5.9	9.2	4.6
	0	0	7.3	6.0	7.6	4.7
	0	3	17.2	4.9	10.8	6.9
A	6	6	9.5	7.4	9.1	10.0
	12	12	7.4	11.4	12.0	3.5
	3	3	9.4	8.6	13.8	7.4
B	6	6	11.3	7.1	10.3	6.1
	12	12	8.5	7.1	9.5	10.6
	3	3	9.6	8.1	12.1	12.1
C	6	6	10.2	9.0	10.2	8.8
	12	12	9.0	9.0	13.7	8.9
	3	3	11.2	8.0	18.0	7.0
Average all treatments	6	6	8.2	4.9	8.8	7.8
	12	12	12.6	5.8	10.1	8.5
			10.2	7.3	10.7	7.8

¹Fertilization (lb./acre)

Level	N	P	K
A	75	40	40
B	150	80	80
C	300	160	160

Hardwoods

silver maple and white ash was not affected by method of site preparation, but survival of black locust was 81 per cent in the plowed area and only 54 per cent on the scalps.

Fertilization improved growth of all species (Figure 2) but the favourable response was much greater in the plowed than in the scalped plots (Table 2). Although intensified rates of application increased growth, the improvement was not proportional to the increase in dosage (Table 3). Survival was slightly lower in the fertilized plots than in the control, but intensified weed competition rather than fertilizer poisoning probably caused this.

Effectiveness of herbicide treatment was clearly correlated with the intensity of site preparation. In the plowed and tilled area 3 pounds of simazine were moderately effective the first year, but heavy

TABLE 2. — Average 3-year height growth in inches of planted black locust, silver maple, and white ash seedlings under various combinations of site preparation, fertilization, and herbicide treatments.

Treatment ¹	Herbicide Treatment lb./acre	Black Locust		Silver Maple		White Ash	
		plowed	scalped	plowed	scalped	plowed	scalped
0 control	0	35.1	11.0	7.2	2.0	10.4	2.1
0 control	0	45.7	6.0	7.3	4.2	6.2	1.3
0	3	93.0	15.1	30.4	4.3	24.5	2.1
	6	103.9	8.6	57.8	14.5	22.6	1.9
	12	93.4	19.9	59.0	16.7	38.0	2.8
A	3	73.1	12.3	54.7	3.5	45.7	1.6
	6	102.6	24.3	55.9	20.2	39.2	5.4
	12	93.1	52.6	52.5	29.7	41.1	6.4
B	3	65.2	23.4	54.5	5.0	30.9	5.9
	6	88.5	26.3	53.4	27.9	28.4	1.7
	12	111.2	29.5	83.7	19.3	70.3	6.4
C	3	96.9	27.8	69.9	24.0	51.2	7.2
	6	120.2	60.6	74.4	24.9	64.7	15.5
	12	85.1	64.2	40.5	38.7	23.2	9.5
Average all treatments		85.0	23.2	49.3	15.4	35.2	4.1

¹ Fertilization (lb./acre)			
Level	N	P	K
A	75	40	40
B	150	80	80
C	300	160	160

TABLE 3. — Effect of various levels of fertilization on survival and height growth of hardwood seedlings planted after plowing and tilling.

Species	Three-year survival				Three-year height growth			
	Control	Fertilization		Level C	Control	Fertilization		Level C
		Level A	Level B			Level A	Level B	
	%	%	%	%	inches	inches	inches	inches
Black Locust	100	75	83	86	40.4	90.3	89.0	102.1
Silver Maple	92	81	97	81	7.2	54.4	63.3	61.9
White Ash	100	75	75	69	8.3	42.4	41.9	53.2

new growth occurred during the middle of the second growing season (Figure 3). Six and 12 pounds effectively controlled weeds for 3 years. In the scalped area, 3 pounds of simazine were completely ineffective; 6 pounds controlled weeds satisfactorily only in the unfertilized plots (Figure 4); 12 pounds controlled most of the established weeds for 3 years regardless of intensity of fertilization.

Weed control greatly improved growth of all species but the response was much better in the plowed and tilled than in the scalped area (Table 2). After plowing and tilling, but without fertilization, the application of simazine increased average height growth of black locust, silver maple, and white ash by 140, 580, and 240 per cent, respectively. Even more important was the effect of weed suppression on the fertilized plots (Figures 5 & 6); without weed control, fertilization would most certainly have resulted in greatly intensified competition and eventual suppression of many seedlings.

Increased rates of simazine application did not result in proportional growth improvement of any of the tree species (Table 4). Although survival of black locust and silver maple was only slightly reduced by increased dosages of simazine, white ash mortality was greatly increased, indicating that species' sensitivity to simazine dosages of 6 and 12 pounds per acre.

Per acre costs of individual treatments were computed on the basis of the following 1964 prices which were paid for labor and supplies: plowing and tilling — \$12; fertilization at level A — \$18, level B — \$36, level C — \$72; granular simazine at

Fig. 2. Control plot after three growing seasons. Notice small silver maple to the right of sign.

the medium dosage of 6 pounds of active ingredient — \$67.50 and as wettable powder — \$20.40. Only the additional costs of intensive site preparation, fertilization, and chemical weed control were computed, excluding the cost of planting and planting stock which would have been incurred in any planting operation. Since the granular simazine used in this experiment is 3 times more expensive than the wettable powder in common use today, the costs of both formulations were used in the computation of Table 5.

TABLE 4. — Effect of various levels of simazine application on survival and height growth of hardwood species planted after plowing and tilling.

Species	Three-year survival				Three-year height growth			
	Control	Simazine			Control	Simazine		
		3 lb.	6 lb.	12 lb.		3 lb.	6 lb.	12 lb.
	%	%	%	%	inches	inches	inches	inches
Black Locust	100	87	81	79	40.4	83.2	104.6	97.5
Silver Maple	92	94	92	81	7.2	51.4	60.0	60.7
White Ash	100	92	75	33	8.3	39.3	40.5	52.2

Fig. 3. Application of 3 lbs. of simazine did not control re-growth of weeds after complete site preparation.

Fig. 4. Six lbs. of simazine failed to control weeds after fertilization in the scalped area.

Fig. 5. Good growth as a result of intensive site preparation, fertilization, and weed control.

Per cent growth improvement of Table 5 was computed using the formula

$$\frac{A}{B} \times \frac{1}{C} \times 100$$

Average growth of white ash after scalping, for example, was 1.7 inches. Plowing at a cost of \$12 produced a growth increase of 6.6 inches, resulting in a 32 per cent growth improvement per dollar expended.

Table 5 shows, for each species, the percentage

Fig. 6. Excellent 3-year growth as a result of intensive site preparation, fertilization, and weed control.

increase in growth per dollar expended for each treatment and combination of treatments. Plowing alone produced a more favorable cost-benefit ratio for locust and ash than scalping plus herbicide;

TABLE 5. — Per cent growth improvement per dollar expended for plowing and tilling, fertilization, and chemical weed control.

Species	Scalping and Simazine		Flowing	Flowing and Simazine		Plowing, and Simazine, and Fertilization					
	4G ¹	50W ²		4G	50W	Level A		Level B		Level C	
	4G	50W		4G	50W	4G	50W	4G	50W	4G	50W
Black Locust	1	3	31	13	32	10	19	8	14	7	10
Silver Maple	4	14	11	19	46	17	33	17	29	12	18
White Ash	0	2	32	20	48	24	47	21	36	17	25
White Pine	1	2	5	1	3	1	1	1	1	1	1
White Spruce	1	2	7	2	4	1	3	1	2	1	2

¹Granular simazine (4% active ingredient)²Wettable powder (50% active ingredient)

however, plowing plus herbicide (simazine 50W) resulted in the greatest growth increase per dollar expended for all three hardwood species. The addition of fertilizer improved growth of all hardwood species but the increase per dollar expended was not as great as for plowing plus herbicide.

For white pine and white spruce the growth improvement per dollar expended was negligible for all fertilization and weed control treatments and only a very small improvement resulted from plowing and tilling.

Discussion

Successful afforestation of moderately fertile agricultural land depends very largely on a fast initial growth rate of planted seedlings. Any prolonged period of slow growth during the early life of the plantation greatly increases the danger of seedling loss or permanent injury due to suppression by weeds, rabbit browsing, or ground frosts occurring after leaf flushing. This study shows that hardwood afforestation of former farmland is possible. It also provides a rating of establishment costs related to growth increase by species and the application of special planting methods. No doubt, the cost of hardwood plantation establishment will be higher than that of coniferous plantations; however, the cost-benefit relationship of Table 5 draws attention to the yet unexplored possibilities of maximizing returns on investment by the application of treatments best suited to the requirements of individual species. The conventional site preparation treatments of scalping and scalping plus weed control failed to produce adequate hardwood growth in this experiment. The additional investment of \$12 for plowing and tilling greatly improved growth, but total height growth remained unsatisfactory. Intensive site preparation plus weed control resulted in very satisfactory growth and the best cost-benefit relationship of all treatments. However, the highest growth of all hardwood species was obtained after intensive site preparation, weed control, and fer-

tilization. Although the growth of black locust and silver maple was good even without fertilization, white ash and other equally demanding species will probably require fertilization on most afforestation sites. It would appear, however, that increased treatment costs on these sites will be justified by higher survival and faster growth.

The lack of growth response of white pine and white spruce to the fertilization and weed control treatments was probably the result of nutrient and moisture supplies in the soil being adequate for the growth of these less demanding species.

While the limitations of this experiment do not allow specific recommendations for future hardwood afforestation, the study, nevertheless, shows that plowing, tilling, and weed control are prerequisites for successful hardwood afforestation on moderately fertile clay soils and that further growth improvement can be obtained through fertilization.

Dense rabbit populations generally preclude success of hardwood afforestation; however, in areas with medium to light populations, species selection and rabbit repellents may be used successfully.

Summary

1. Plowing and tilling improved growth of all species.
2. Plowing and tilling plus weed control resulted in the most favorable growth-cost relationship of black locust, silver maple, and white ash.
3. Fertilization improved growth of black locust, silver maple, and white ash.
4. Fertilization did not produce a noticeable increase in the growth of white pine and white spruce.
5. Plowing and tilling, fertilization, and weed control resulted in highest growth of black locust, silver maple, and white ash.
6. Mortality of white ash was increased by the application of 6 and 12 pounds of simazine.
7. White spruce was subject to severe frost heaving after complete weed control.

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