PLANTING SUGAR MAPLE: FOURTH-YEAR RESULTS OF AN EXPERIMENT ON TWO SITES WITH EIGHT SOIL AMENDMENTS AND THREE WEED CONTROL TREATMENTS

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Frontispiece. Sugar maple seedlings 4 years after planting as 2+0 stock in a sandy loam soil and rototilled four times each year.

ABSTRACT

Two-year-old sugar maple (*Acer saccharum* Marsh.) seedlings were planted in two former fields with a sandy loam and a clay loam soil, respectively, in Middlesex County, Ontario. The fields had been plowed and repeatedly disked in the summer and autumn previous to spring planting. There were eight amendments x three weed control treatments. Hardwood leaves, pine needles, peat moss, or fertilizer were placed in the bottom of planting holes, or fertilizer was placed in a hole beside the seedlings or spread on the soil surface around the seedlings. Weed control consisted of: (1) rototilling and hoeing, (2) spraying Gramoxone® on the vegetation growing in a circle 60 cm (2 ft) in diameter around the tree seedlings, or (3) mowing four times per year in each of the first 4 years after planting.

After four growing seasons, survival was 81% or better, except in treatments where fertilizer had been placed in the bottom of the planting hole. The organic soil additive or fertilization treatments had no significant effect on seedling height. On the sandy loam, height in the rototilled plots was significantly greater than in the sprayed and mowed plots, while on the clay loam, height growth was significantly better in the rototilled and sprayed plots than in the mowed plots.

Recommendations for establishing sugar maple plantations in southern Ontario include plowing and disking the total plantation area in the summer and autumn before spring planting; planting in April; rototilling and hoeing at least four times per year for the first 3 years after planting; and protecting seedlings from deer, rabbits and mice.

RÉSUMÉ

On a planté des semis d'Erable à sucre (*Acer saccharum*) âgés de deux ans, dans deux anciens champs agricoles au sol formé de loam sablonneux et argileux respectivement, situés dans le comté de Middlesex en Ontario. Les champs avaient été labourés et sillonnés plusieurs fois au cours de l'été et de l'automne précédent le plantage. Le sol fut amendé huit fois et subit trois traitements contre les mauvaises herbes. Des feuilles d'essences feuillues, des aiguilles de Pins, de la sphaigne ou du fertilisant furent placés au fond des trous de plantage, ou on mit du fertilisant dans un trou adjacent aux semis, ou bien on en répandit à la surface du sol autour des semis. La lutte aux herbes nuisibles se fit ainsi: (1) rotoculture et sarclage, (2) arrosage au Gramoxone® sur la végétation croissante en un cercle de 60 cm (2 pi) de diamètre autour des semis, ou (3) fauchage quatre fois l'an pendant les 4 premières années suivant le plantage.

Après quatre saisons de croissance, la survie fut de 81% ou plus, sauf pour les traitements où l'on avait placé le fertilisant au fond des trous de plantage. Les additifs organiques de sol ou les traitements aux fertilisants n'eurent pas une influence significative sur la hauteur des semis. Dans le loam sablonneux, la hauteur des semis dans les placettes rotocultivées fut significativement supérieure à celle des semis dans les placettes arrosées et fauchées alors que dans les sols à loam argileux, la croissance en hauteur fut significativement meilleure dans les placettes rotocultivées et arrosées que dans les placettes fauchées.

Au nombre des recommandations pour établir des plantations d'Erables à sucre dans l'Ontario méridional, soulignons le labourage et le sillonnage de toute la superficie de la plantation durant l'été et l'automne qui précèdent le plantage printanier; soulignons de plus qu'il faut planter en avril; qu'il faut aussi rotocultiver et sarcler au moins quatre fois l'an au cours des 3 premières années suivant le plantage; enfin qu'il faut protéger les semis contre les cerfs, les lièvres et les souris.

TABLE OF CONTENTS

INTRODUCTION

Sugar maple (*Acer saccharum* Marsh.) regenerates and grows well in natural hardwood woodlots but has great difficulty in establishing itself or growing well in competition with old field vegetation (Yawney and Carl 1970, Webb 1974). Since sugar maple is an attractive, high-value, long-lived tree, many plantings have been attempted, but few have succeeded (Wallihan 1949, von Althen 1965). Sugar maple will, however, readily invade open-grown or thinned pine plantations (von Althen 1974). Some foresters have therefore suggested planting pine and waiting for the sugar maple to establish itself under the pine canopy. While this method has been successful, few tree planters are prepared to wait 10 to 20 years to obtain sugar maple regeneration.

In the search for improved afforestation methods for sugar maple several studies have been carried out. The 4-year results of one of these studies are reported here.

METHOD

The study was carried out on two former fields in Middlesex County, Ontario. The first field near Thedford had a deep, well-drained, fine sandy loam soil of the Ontario Soil Survey Fox Series. The pH of the plow layer was 6.4 and the organic matter content was 2.4% (Appendix I). The second field near Parkhill had an imperfectly drained clay loam soil 42 to 50 cm (17-20 in.) deep over compact clay. The pH of the plow layer was 6.9 and the organic matter content 3.4%. The Ontario Soil Survey placed the soil in the Perth Series.

Both fields were plowed in the summer and repeatedly disked in the late summer and autumn of 1972. In April of 1973, planting holes 25 cm (10 in.) deep, 30 cm (12 in.) in diameter, 1.8 m (6 ft) between rows and 1.2 m (4 ft) within rows, were drilled with a tractor-powered soil auger.

The study was laid out in the following arrangement: two sites x eight amendment treatments x three weed control treatments x three replications = 144 x 12 seedlings = a total of 1728 seedlings plus surrounds.

The soil amendment and fertilizer treatments consisted of:

1) Control
2) 1.1 ℓ (1 qt) of a mixture of undecomposed sugar maple, white ash (*Fraxinus americana* L.) and black cherry *Prunus serotina* Ehrh.) leaves placed in the bottom of each planting hole (Appendix II)
3) 1.1 ℓ (1 qt) of a mixture of undecomposed white oak (*Quercus alba* L.), red oak (*Q. rubra* L.), and black oak (*Q. velutina* Lam.) leaves placed in the bottom of each planting hole

4) 1.1 ℓ (1 qt) of undecomposed red pine (*Pinus resinosa* Ait.) needles placed in the bottom of each planting hole
5) 1.1 ℓ (1 qt) of commercially available peat moss placed in the bottom of each planting hole
6) 170 g (6 oz) of 10-10-10 fertilizer placed in the bottom of each planting hole
7) 170 g (6 oz) of 10-10-10 fertilizer placed in a hole 15 cm (6 in.) deep and 15 cm (6 in.) away from each planted seedling
8) 170 g (6 oz) of 10-10-10 fertilizer spread on the soil surface in a circle 30 cm (12 in.) in diameter around each planted seedling.

Leaves and pine needles were deposited in the planting holes to determine if these organic materials, which are an important component of sites where natural sugar maple regeneration is prolific, could increase seedling survival and growth. Peat moss was placed in the planting holes to determine the effect of increased organic soil matter content on seedling survival and growth. While no mycorrhizal studies as such were carried out, it was hoped that the addition of leaves and needles to the soil would stimulate mycorrhizal growth, which in turn would increase seedling growth.

Following placement of the leaves, needles, peat moss or fertilizer in the bottom of the planting holes, a layer of soil approximately 5-8 cm (2-3 in.) deep was placed over the plant material or the fertilizer, and 2+0 sugar maple seedlings, obtained from the St. Williams nursery of the Ontario Ministry of Natural Resources, were planted in the holes.

Weed control consisted of four treatments per year, applied during each of the first four summers after planting, according to the following methods:

1) Mowing around the seedling with a hand-pushed, gasoline-powered lawn mower
2) Spraying 2.8 ℓ per treated ha (1 qt per treated acre) of active Gramoxone®[1] in 120 ℓ (33 gal) of water on the vegetation growing in a circle 60 cm (2 ft) in diameter around each tree seedling
3) Rototilling between the seedlings with a gasoline-powered, hand-held rototiller, and hoeing around the seedlings.

The experimental design did not include a control for the weed control treatments because previous experiments (von Althen 1971, Webb 1974) had shown that, unless the competing vegetation is controlled, complete loss of the plantation can result.

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[1] The identification of commercial products is solely for the information and convenience of the reader, and does not constitute endorsement by the Great Lakes Forest Research Centre.

During Gramoxone® spraying the trees were not shielded. To avoid herbicide damage the spraying was carried out only on windless days, and the spray was directed away from the trees. Rototilling consisted of at least two passes over the area at right angles to each other. However, in areas with heavy weed growth, rototilling was continued until all weeds were uprooted. The soil was rototilled to within 45 cm (1.5 ft) of each seedling. The area not rototilled was hoed by hand.

Seedling survival and height were recorded in each of the first 4 years after planting. Fourth-year data on survival, and total height were subjected to an analysis of variance and Duncan's New Multiple Range Test (Steel and Torrie 1960).

RESULTS

Seedling survival after 4 years was 81% or higher in all treatments except treatment No. 6, where fertilizer had been placed in the bottom of the planting holes and where many trees died during the first summer (Table 1). In the sandy loam, survival in treatment No. 6 was significantly lower than in all other treatments, while in the clay loam, survival was also lower but the difference was not statistically significant.

Table 1. Survival of sugar maple, by sites and treatments, 4 years after planting

Treatment	Sandy loam			Clay loam		
	Mowed (%)	Gramoxone® (%)	Rototilled (%)	Mowed (%)	Gramoxone® (%)	Rototilled (%)
1	94	94	89	97	100	92
2	92	89	92	95	100	97
3	86	89	94	97	100	92
4	97	81	92	94	92	95
5	95	97	95	95	95	92
6	25[a]	72[a]	61[a]	83	86	83
7	81	89	86	95	97	89
8	85	86	86	89	97	95

[a] Significantly lower (P .05) than all other treatments.

Height growth of all seedlings in all treatments was slow during the first 2 years after planting, but greatly accelerated in the third and fourth years (Fig. 1). The only seedlings showing no acceleration in height growth were those growing in the mowed plots on the clay loam site.

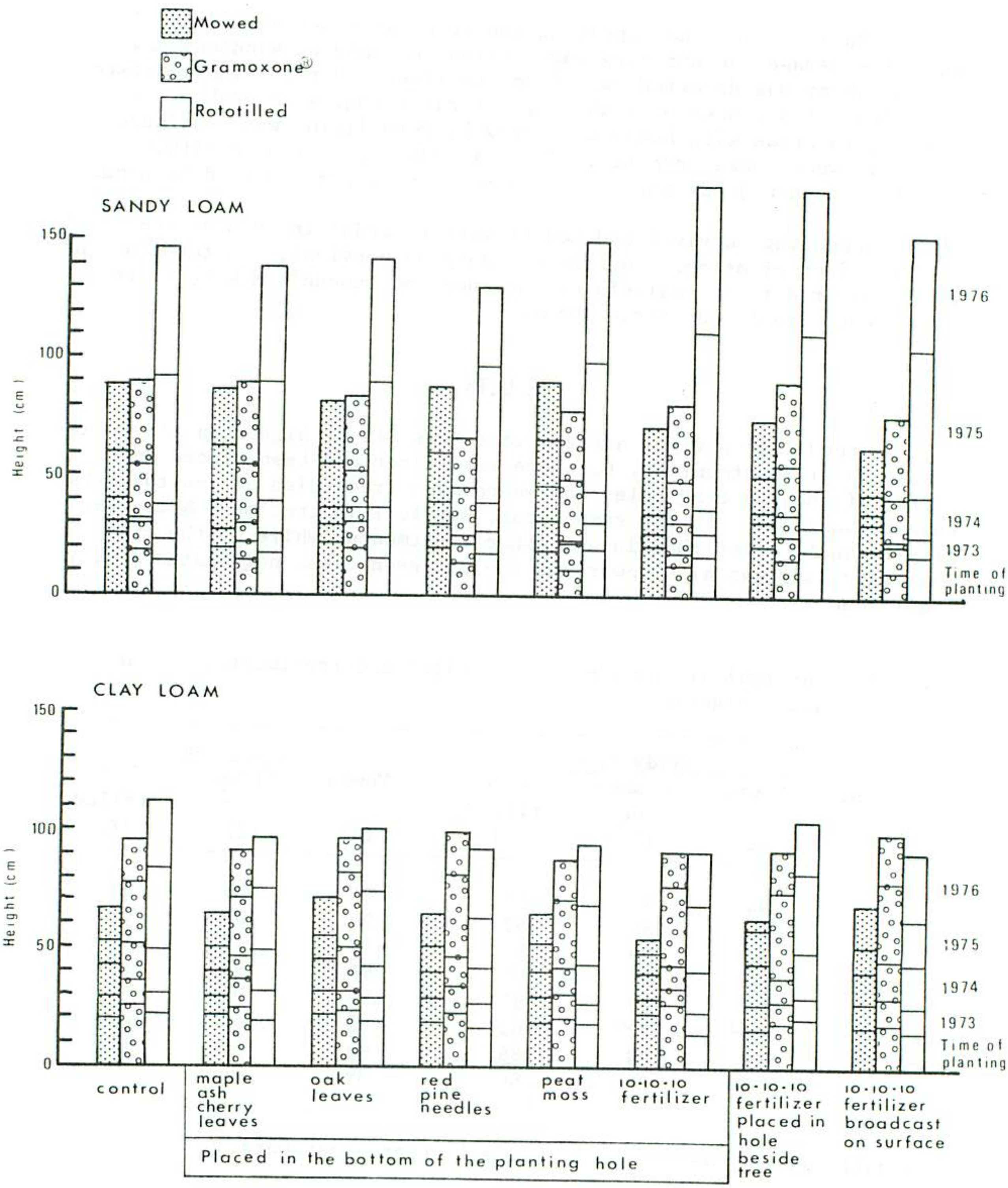

Figure 1. Effects of soil amendments, fertilization and weed control on the height of sugar maple seedlings by years since planting.

None of the soil amendments or fertilizer treatments had any significant effect on the height of the seedlings 4 years after planting. However, in the sandy loam soil, height was significantly better in the rototilled plots than in the Gramoxone®-sprayed and mowed plots (Fig. 1). In the clay loam soil, height growth in the rototilled and Gramoxone®-sprayed plots was significantly better than in the mowed plots.

Rototilling and hoeing around the trees four times per year kept the plots nearly weed-free during all 4 years subsequent to planting.

In the Gramoxone®-sprayed and mowed plots the following broad-leaved weeds and grasses invaded the plots during the first year: common ragweed (*Ambrosia artemisiifolia* L.), yarrow (*Achillea lanulosa* Nutt.), wild carrot (*Daucus carota* L.), common plantain (*Plantago major* L.), annual daisy fleabane (*Erigeron annuus* [L.] Pers.), goldenrod (*Solidago* spp.), quackgrass (*Agropyron repens* [L.] Beauv.) and timothy (*Phleum pratense* L.).

Starting in the second summer after planting, goldenrod, wild carrot, and yarrow became the dominant weed species in the Gramoxone®-sprayed plots while quackgrass, timothy, and wild carrot were dominant in the mowed plots.

Competition caused a much-shortened growth period. Height growth of all seedlings started during the middle of May and reached its peak during the middle of June. In the mowed plots, height growth terminated during the second half of June, the terminal bud was set, and the leaves started to turn yellow (Fig. 2). In contrast, the leaves of the seedlings in the intensively weeded plots maintained their dark green color until the beginning of September. Following a short rest period at the end of June, most of the weeded seedlings made a second and third flush during July and August, and often the terminal bud was not set until the middle of September (Fig. 3). This led to some damage to the succulent foliage by early autumn frosts; this damage caused forked leaders the next year. However, frost damage appeared to have had little effect on total height growth during the next year.

DISCUSSION

The results of this study confirm earlier findings by Yawney and Carl (1970) and Webb (1974) that the elimination of the competing vegetation is a prerequisite to successful sugar maple establishment in old fields. Nursery-grown 2+0 seedlings, the age class most commonly planted, appear to require at least 3 years of intensive weed control before they are able to compete successfully with grasses and forbs. However, a few successful plantations have also been established with wildlings 1.2-3 m (4-10 ft) tall and having stem diameters of 2-4 cm

Figure 2. Sugar maple seedlings 4 years after planting in the mowed plots.

Figure 3. Sugar maple seedlings 4 years after planting in the rototilled plots.

(0.8-1.6 in.) measured 30 cm (1 ft) above the root collar (von Althen 1965). These larger trees appear to require a shorter period of weed control because they are able to compete more quickly with the herbaceous vegetation.

Yawney and Carl (1970) found that the growth of sugar maple seedlings improved in relation to the degree of weed control achieved by cultural treatments. The best growth was obtained in plots where the soil had been covered with black plastic film: this not only eliminated the competing vegetation during the first year after planting but also greatly retarded evaporation, thereby increasing the available soil moisture. Webb (1974) observed significant differences in microclimate between areas in which there was competing vegetation and areas in which there was no competition. The decreased absorption of solar radiation, decreased maximum temperatures, and the absence of transpiring vegetation resulted in a significant increase in soil moisture in non-competitive areas. Because of the overall decrease in soil moisture in all plots with competition, and the increased amount present in the no-competition plots, Webb suggested that soil moisture was probably the limiting factor of greatest importance to seedling survival.

In the mowed plots of the experiment described here, grasses had formed a dense sod in the summer of the first year after planting. Although soil moisture was not determined, it was observed that the dense sod intercepted most of the moisture supplied by dews and light rainfalls before this moisture could reach the seedling roots. Since it has been shown that water loss is usually higher from soil supporting vegetation than from bare soil (Geiger 1966), moisture loss through evapotranspiration was no doubt also higher from the grass-covered than the rototilled plots. It is therefore most likely that the poorer growth in the mowed plots was, to a large extent, the result of stress induced by lack of moisture.

A further cause of the poor seedling growth in the mowed plots could have been severe competition for the available soil nutrients. However, the following conditions make it unlikely that nutrient deficiency was a major cause of poor growth. First, both planting sites were relatively fertile fields supporting very vigorous growth of grasses and broadleaved weeds. Second, fertilization had no significant effect on seedling growth in any of the plots. Had there been a deficiency in NPK, the fertilized seedlings should have grown significantly better. But Messenger (1976) stated that grass roots will compete with shallow, lateral roots of trees for essential substances, especially nitrogen, and that all parts of the trees may be adversely affected. Because of its severe interference with the growth of other plants, quackgrass has been investigated for a possible production of toxins. No inhibition of the germination or growth of turnip (*Brassica* sp.) (Welbank 1960), alfalfa (*Medicago* sp.) and oats (*Avena sativa* L. var. *Ajax*) (Ohman and Kommedahl 1964) was found from living quackgrass roots or rhizomes, but toxins were extracted from dried and ground material and were found in decaying quackgrass rhizomes (Welbank 1963).

Woods[2] found that root competition from goldenrod and wild aster (*Aster nova-angliae* L.) inhibited nitrogen and phosphorus uptake of sugar maple seedlings. He suggested that the interfering plants may either absorb nitrogen and phosphorus more efficiently and in greater quantities, or chemically block nutrient uptake by the maples. In either case, the sugar maple seedlings appeared to be poor nutrient competitors in the presence of aster and/or goldenrod.

All this points to the fact that although it has been clearly demonstrated that sugar maple grows poorly in competition with grasses and broadleaved weeds, little is known about the relative importance of the various factors contributing to this poor growth. Until this information is available, sugar maple plantation establishment must be carried out by trial and error and at possibly higher cost than necessary, because at present only intensive weed control for at least 3 years after planting guarantees successful establishment and early growth.

The difference in seedling growth between the rototilled and Gramoxone® plots is believed to have been mainly the result of differences in the intensity of weed control. In the rototilled plots all weeds were completely eliminated four times per year. In the Gramoxone® plots only an area 60 cm (2 ft) in diameter was treated around each seedling. Not only did this allow weeds to grow vigorously outside this circle, but the Gramoxone® generally burned off only the tops of the weeds. Root competition therefore continued, although probably at a much reduced rate, and regrowth was quicker and competition more intense than in the rototilled plots.

The differences in growth between the Gramoxone® plots on the sandy loam and the clay loam soil were due partly to Gramoxone® damage of the tree seedlings. Although great care was taken to avoid contact of the herbicide with the tree leaves, some spray accidentally drifted onto the leaves of the seedlings growing in the sandy loam during the second year after planting. No seedlings were killed and damage was restricted to some brown spots on the maple leaves. Nevertheless, growth appeared to slow down in these plots for the remainder of that year.

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[2] Woods, R.A. 1976. Allelopathic interference by *Solidago canadensis* L. and *Aster nova-angliae* L. on the early seedling growth of *Acer saccharum* Marsh. M.Sc.F. thesis, Univ. Toronto. 62 p.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study confirm earlier findings that 2+0 sugar maple seedlings, planted on former farmland, will survive for the first few years after planting. However, to obtain satisfactory growth it is essential to eliminate competing vegetation for a period of at least 3 years after planting. The most effective weed control treatments were: 1) rototilling four times per year or 2) four applications per year of Gramoxone® in a circle 60 cm (2 ft) in diameter around each tree seedling. Mowing four times per year around the sugar maple seedlings failed to promote satisfactory growth.

The placement of leaves, needles, peat moss or fertilizer in the bottom of planting holes, or fertilizer placement in a hole beside the seedlings or on the surface around the seedlings failed to stimulate seedling growth.

On the basis of this and previous studies a cautious recommendation is made for sugar maple afforestation of abandoned farmlands in southern Ontario. The following procedures should be employed:

1) Plowing and repeated disking of the total plantation area in the summer and autumn of the year previous to spring planting
2) Wedge planting by hand or machine planting in April (Planting later than the end of April will greatly reduce survival and growth.)
3) Rototilling and hoeing at least four times per year for the first 3 years after planting (More frequent treatments over a longer period will greatly benefit the seedlings.)
4) Where required, protection of the seedlings from browsing by deer and rabbits and stem girdling by mice

Caution: Sugar maple is one of the most difficult hardwood species to plant and plantation establishment and care are expensive. If money and manpower supplies are not assured to carry out the required work, sugar maple planting should not be attempted since it will invariably end in failure.

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APPENDICES

APPENDIX I

Results of soil analyses

	Horizon	Depth (cm)[a]	pH[b]	N (%)	P (%)	K (%)	Org. C[c] (%)
Sandy loam	Ap	0–20	6.4	.11	.00006	.07	2.4
	A_2	20–40	6.7	.03	.00004	.04	1.1
	B_2	40–56	7.8	.01	.00050	.12	.2
	C	56+	8.2	–	.00080	.30	.1
Clay loam	Ap	0–20	6.9	.16	.0002	.03	3.4
	A_2	20–30	7.1	.16	.0003	.06	2.8
	B	30–50	7.5	.05	.0008	.06	.8
	C	50+	8.0	.02	.0008	.08	.3

[a] 1 cm = 0.4 in. approx.

[b] Determined by 1:1 soil:water mixture with glass electrode pH meter.

[c] Determined by Walkley-Black wet combustion procedure.

APPENDIX II

N, P, K, Ca and Mg concentrations and pH values of leaves, needles, and peat moss placed in the bottom of the planting holes

	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	pH[a]
Maple, ash, cherry leaves	1.11[b]	.071	.153	1.96	.168	4.9
White, red and black oak leaves	1.00	.054	.095	1.75	.160	4.4
Red pine needles	.42	.038	.053	.586	.099	4.2
Peat moss	.79	.020	.031	.120	.086	3.3

[a] Determined by 4:1 organic matter:soil mixture with glass electrode pH meter.

[b] Mean value of five samples each.