PLANTING OF SUGAR MAPLE ON ABANDONED FARMLAND IN SOUTHERN ONTARIO

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Abstract.--The results of a series of experiments conducted to determine the effects of age and size of planting stock, time of planting, cold storage, root growth capacity, weed control, soil amendments and fertilization on survival and early growth of sugar maple planted in open fields in southern Ontario indicated the following:

1. Age of planting stock had little effect on survival and growth. However, within age classes trees with large root collar diameters grew significantly better than trees with small diameters. Root growth capacity of seedlings and transplants was directly correlated with height growth during the first three years after planting.

2. Survival and height growth of seedlings lifted and fresh-planted from April to June were directly correlated with root growth capacity at time of planting. Survival and height growth of seedlings lifted in autumn and cold-stored at 1.0°C until planting in late May and early June were significantly higher than those of seedlings lifted and fresh-planted in late May and early June.

3. Temperature of overwinter storage and method of packaging significantly affected field performance. Best survival and growth were obtained from trees stored in polyethylene-lined Kraft bags at -5°C and poorest survival and growth from bare-root stock or from trees stored at -10°C. Root growth capacity was directly correlated with height growth during the first two years after planting.

4. Intensive weed control was essential for rapid height growth but soil amendments and fertilization at time of planting were ineffective in increasing seedling survival and height growth.

Additional keywords: Planting stock quality, time of planting, cold storage, root growth capacity, weed control, soil amendments, fertilization.

INTRODUCTION

In southern Ontario, sugar maple (*Acer saccharum* Marsh.) is a common component of most hardwood woodlots. Under forest conditions, natural regeneration is nearly always abundant, but attempts to establish plantations on abandoned farmland have generally been unsuccessful (Wallihan 1949, von Althen 1965, Yawney 1968, Yawney and Carl 1970). When a questionnaire given to landowners revealed that sugar maple was one of the

preferred species for the afforestation of abandoned farmland in southern Ontario, a series of studies was initiated to determine the relative importance of factors affecting successful plantation establishment. The ultimate aim of the studies is to develop nursery and silvicultural techniques suitable for the establishment of sugar maple plantations. Although most of the studies are not yet completed, substantial progress has been made in the development of improved nursery, planting and tending practices. The results obtained are described in this report.

AGE AND SIZE OF PLANTING STOCK

Although little information is available on sugar maple culture, the importance of planting stock age and size for successful outplanting is well documented (Limstrom et al. 1955, Ike 1962, Williams 1966, von Althen 1969). Also, landowners have often expressed a preference for large seedlings or transplants, believing that planting large trees would eliminate the need for site preparation and weed control. To determine the effects of age and size of sugar maple planting stock on survival and early height growth, the following studies were initiated in 1976, 1977 and 1978.

Experiment 1

In the spring of 1976, 2+0, 3+0 and 4+0 seedlings and 2+1 and 2+3 transplants were planted in two former agricultural fields in southwestern Ontario with soils of well drained gravelly loam and loamy sand. Both fields were plowed in the summer and disked several times in the autumn of 1975. All seedlings and the 2+1 transplants were machine planted whereas the 2+3 transplants were planted in auger holes 30 cm in diameter. Trees were spaced 3 m between rows and 1.5 m within rows. Weed control was maintained by rototilling between the rows and spraying the unwanted vegetation within the rows with 2.1 kg/ha of active glyphosate in 400 L of water. The experiment was laid out in a randomized block design with 16 trees per plot. There were 10 replications on the gravelly loam soil and 7 replications on the loamy sand for respective totals of 160 and 112 trees per treatment (Table 1).

Experiment 2

To determine the effects of root collar diameter on sugar maple survival and growth a second experiment was initiated in 1977. Although size of planting stock is dependent largely on age, the size of individual seedlings and transplants often varies widely within age classes, between nurseries, and between years of production. Sugar maple seedlings and transplants were graded into size classes by root collar diameters ranging from 4.5 to 12.7 mm (Table 2).

All seedlings and transplants were lifted in late autumn, graded into different stem diameter classes and cold-stored over winter in polyethylene-lined Kraft bags at 1.0°C. In April of 1977 the graded seedlings and transplants were machine planted in an abandoned field that had a loam soil which had been plowed in the preceding summer and disked several times in the autumn. Weed control was maintained by rototilling between the rows and spraying the unwanted vegetation within the rows with 2.1 kg/ha of active glyphosate in 400 L of water. The experiment was laid out in a

Table 1. Sugar maple planting stock size at time of planting, root growth capacity, and survival and height growth 4 years after planting. (Experiment 1)

Stock age	Root collar diameter (mm)	Stem length (cm)	Oven-dry stem weight (g)	Oven-dry root weight (g)	Shoot:root ratio	Root growth capacity[a/]	Survival (%)		Height growth[b/] (cm)	
							Loam planting site	Sand site	Loam planting site	Sand site
2+0	5.6	44	3.4	3.9	.87	81	95^{a}	80^{b}	156^{v}	129^{z}
3+0	8.4	60	9.7	10.3	.94	145	95^{a}	90^{b}	157^{v}	146^{z}
4+0	9.7	64	13.7	18.3	.75	101	99^{a}	96^{b}	166^{w}	128^{z}
2+1	6.2	42	4.4	7.6	.58	133	98^{a}	91^{b}	154^{x}	134^{z}
2+3	19.5	109	108.0	97.0	1.11	103	98^{a}	87^{b}	212^{y}	125^{z}

a/ Mean number of new white roots per seedling or transplant.

b/ Within planting sites, common letters denote treatments without significant differences (p:05) in survival or height growth.

Table 2. Sugar maple planting stock size at time of planting, root growth capacity, and survival and height growth 3 years after planting. (Experiment 2)

Stock age	Root collar diameter (mm)	Stem length (cm)	Oven-dry stem weight (g)	Oven-dry root weight (g)	Shoot:root ratio	Root growth capacity[a/]	Survival[b/] (%)	Height growth[b/] (cm)
paperpots	-	10	-	-	-	9	70[a]	45[k]
2+0	4.5	28	2.3	5.1	.45	41	97[b]	59[l]
3+0 small	5.4	31	3.5	7.8	.45	12	94[c]	70[m]
3+0 large	10.3	63	18.7	27.1	.69	42	92[d]	84[no]
4+0 small	7.8	85	12.9	11.0	1.17	14	98[b]	39[p]
4+0 medium	11.2	102	27.6	19.2	1.44	21	97[b]	49[q]
4+0 large	12.7	103	35.6	30.3	1.18	33	98[b]	52[r]
2+1 small	5.7	36	4.3	9.6	.44	30	90[d]	77[s]
2+1 large	8.8	48	11.4	22.0	.52	40	88[f]	83[n]
2+2 small	8.0	55	11.3	23.9	.47	42	95[c]	74[t]
2+2 large	11.0	71	21.3	35.5	.60	35	97[b]	86[o]

a/ Mean number of new white roots per seedling.

b/ Common letters denote treatments without significant differences (p:05) in survival or height growth.

randomized block design with 16 trees per plot. Each block was replicated 10 times for a total of 160 trees per treatment. Twelve seedlings from each treatment were also planted in pots and root growth capacity was measured after 30 days' growth in a greenhouse, according to the procedures outlined by Webb (1977).

Experiment 3

Experiment 2 was repeated in 1978: graded seedlings and transplants were planted in the same field using the same experimental design, planting and weed control methods as above. Root growth capacity was not measured in the 1978 study.

Survival and height of all trees in the three studies were recorded each autumn; the 1979 data were analyzed by analysis of variance and Tukey's procedure.

Results

In experiment 1, average 4-year field survival was 80 percent or better in all age classes on both soils, with no significant differences among age classes (Table 1). Average 4-year field height growth in all age classes was significantly better in the gravelly loam than in the loamy sand. In the gravelly loam, height growth of the 2+3 transplants was significantly better than that of all other age classes and height growth of the 4+0 seedlings was significantly better than that of all other seedlings and the 2+1 transplants. In the loamy sand, height growth did not differ significantly among stock types.

In experiment 2, average 3-year field survival was 80 percent or better for all nursery-grown seedlings and transplants, but only 70 percent for seedlings grown in paperpots (Table 2). Three-year field height growth ranged from 39 cm for small 4+0 seedlings to 86 cm for large 2+2 transplants with large root collar diameters. Within age classes, height growth of trees with the largest root collar diameters was always significantly greater than that of trees with smaller diameters. Root growth capacity of seedlings and transplants was significantly correlated with height growth (r = 0.65 n = 11 p:05).

In experiment 3, average 2-year field survival was 91 percent or better for all nursery-grown seedlings and transplants, but only 16 percent for seedlings grown in paperpots (Table 3).

Two-year field height growth was closely and directly correlated with root collar diameter. Among the 2+2 transplants, however, trees with smaller root collar diameters grew faster than those with larger root collar diameters.

TIME OF PLANTING

Taylor and Dumbroff (1975) found that the roots of sugar maple seedlings that were heeled in out-of-doors at Waterloo, Ontario in October never entered a dormant state. After a burst of activity in the autumn, the production and subsequent elongation of roots ceased or was markedly

Table 3. Sugar maple planting stock size at time of planting and survival and height growth 2 years after planting. (Experiment 3)

Stock age	Root collar diameter (mm)	Stem length (cm)	Oven-dry stem weight (g)	Oven-dry root weight (g)	Shoot:root ratio	Survival[a/] (%)	Height growth[a/] (cm)
paperpots	-	10	-	-	-	16^{a}	6^{w}
2+0 small	4.9	36	1.9	2.3	.83	91^{b}	30^{x}
2+0 large	8.2	52	6.5	8.1	.80	99^{c}	56^{y}
3+0	6.5	39	3.4	5.9	.58	99^{c}	43^{z}
2+2 small	14.0	85	30.3	35.6	.85	98^{c}	52^{y}
2+2 large	20.6	121	89.4	83.4	1.07	96^{bc}	43^{z}

[a/] Common letters denote treatments without significant differences (p:05) in survival and height growth.

inhibited only during the few weeks when the ground was actually frozen in December and January. Active growth resumed in early February and a rapid burst of growth began in late March or early April, some 4 to 5 weeks before normal budbreak occurred in early May. These findings suggest that seedlings lifted in early April may already have undergone a vigorous burst of root growth and metabolic activity in the nursery beds, and that if so, the loss of new roots at time of lifting would limit subsequent growth.

To determine the effects of time of planting on the survival and growth of sugar maple seedlings, either lifted in autumn and cold-stored until planting or lifted and fresh-planted in spring, the following two studies were initiated in 1975 and 1976.

Experiment 1

In 1975, 2+0 and 3+0 sugar maple seedlings were lifted from nursery beds at 2-week intervals from 16 April to 10 June and planted the same day in a fully cultivated field with a well drained loam soil.

Experiment 2

In 1976, 2+0 and 3+0 sugar maple seedlings were either lifted from nursery beds or removed from cold storage where they had been stored over winter in polyethylene-lined Kraft bags at 1.0°C. The seedlings were planted at 2-week intervals from 7 April to 2 June in the same field in which seedlings were planted in 1975. At the time of planting, 12 seedlings from each treatment were planted in pots and root growth capacity was measured after 30 days' growth in a greenhouse according to procedures outlined by Webb (1977).

Results

The 3-year and 4-year field results of these studies were reported previously (von Althen and Webb 1978). Five years after planting, survival of the 2+0 and 3+0 seedlings planted in 1975 was significantly higher for the first two and three planting dates respectively than for the later plantings (Table 4). The same held true for the 4-year survival of seedlings planted in 1976. However, survival of the autumn-lifted and cold-stored seedlings was equally high for all planting dates.

Height growth of the spring-lifted stock of both age classes planted in 1975 and 1976 closely followed the trend in seedling survival with best growth recorded for seedlings planted either in early spring or autumn-lifted and cold-stored over winter at 1°C. However, it is important to note that the average height growth of the seedlings planted in June 1975 and 1976 was still lower in the fourth and fifth year after planting than that of seedlings planted in April or early May of the same years. In contrast, height growth of the autumn-lifted, cold-stored seedlings was not influenced significantly by planting date.

Height growth of both 2+0 and 3+0 seedlings was strongly correlated with the ability of the seedlings from the same lots to initiate and elongate new roots following planting in a greenhouse ($\underline{r}$ = 0.93 $\underline{n}$ = 9 p:05).

Table 4. Survival and height growth of sugar maple seedlings planted at 2-week intervals in the spring of 1975 and 1976.

	1975 Planting									
	2+0 stock planting date					3+0 stock planting date				
	16 Apr.	28 Apr.	14 May	26 May	10 June	16 Apr.	28 Apr.	14 May	26 May	10 June
5-year survival (%)[a/]	96^{a}	100^{a}	58^{b}	8^{c}	44^{d}	98^{x}	100^{x}	100^{x}	56^{y}	75^{z}
Cumulative 5-year height growth (cm)	196^{a}	195^{a}	176^{a}	183^{a}	144^{a}	217^{w}	185^{x}	186^{x}	162^{y}	105^{z}

	1976 Planting									
	Lifted from nursery beds shortly before planting date					Lifted in November and stored at 1.0°C until planting date				
	7 Apr.	21 Apr.	5 May	19 May	2 June	7 Apr.	21 Apr.	5 May	19 May	2 June
4-year survival (%)										
2+0 stock	97^{a}	100^{a}	89^{ab}	86^{b}	8^{c}	97^{a}	97^{a}	100^{a}	100^{a}	100^{a}
3+0 stock	100^{x}	100^{x}	94^{x}	64^{y}	8^{z}	100^{x}	100^{x}	100^{x}	97^{x}	100^{x}
Cumulative 4-year height growth (cm)										
2+0 stock	128^{a}	143^{b}	127^{a}	92^{c}	43^{d}	134^{a}	161^{b}	131^{a}	127^{a}	150^{b}
3+0 stock	153^{v}	160^{w}	136^{x}	118^{y}	52^{z}	177^{u}	152^{v}	163^{w}	160^{w}	165^{w}
Root growth[b/] capacity at time of planting	82	84	-	29	0	100	97	58	60	55

a/ Within years of planting and stock ages, common letters denote treatments without significant differences (p:05) in survival or height growth.

b/ Mean number of white roots per seedling.

This suggests that root growth capacity may be an important factor in the successful establishment of sugar maple plantations in southwestern Ontario.

In tests of autumn versus spring planting and sugar maple underplanting or interplanting with hybrid poplars versus open field planting, there were no significant differences in either survival or growth of sugar maple seedlings in any of the treatments (von Althen and Jaciw, unpublished data).

OVERWINTER COLD STORAGE OF PLANTING STOCK

Taylor and Dumbroff (1975) found that active root growth of sugar maple seedlings started several weeks before the usual spring lifting of planting stock in southern Ontario nurseries, and von Althen and Webb (1978) found that survival and growth of spring planted sugar maple seedlings was significantly improved by autumn lifting and overwinter cold storage. Experiments were therefore initiated in 1977 and 1978 to determine the effects of various cold storage temperatures and packaging methods on the physiological quality and outplanting success of sugar maple seedlings and transplants.

Experiment 1

In October of 1977, 3+0 seedlings and 2+2 transplants were lifted from nursery beds, packaged by three methods, and stored over winter at five temperatures (Tables 5 and 6). In April of 1978, the trees were removed from storage and machine-planted within a few days, together with seedlings newly lifted from the same nursery beds from which the cold-stored trees had been lifted. The planting site was a former agricultural field with a loam soil that had been plowed in summer and disked several times in the autumn of 1977. The trees were spaced 3 m between rows and 1.5 m within rows. Weed control was maintained by rototilling between the rows and spraying the unwanted vegetation within the rows with 2.1 kg/ha of active glyphosate in 400 L of water. The experiment was laid out in a randomized block design with 10 trees per treatment. Each treatment was replicated three times for a total of 30 trees per treatment. At the time of field planting, 12 trees of both age classes for each treatment were potted for root growth capacity measurements according to the procedures outlined by Webb (1977).

Experiment 2

In October of 1978, 2+0 sugar maple seedlings were lifted from nursery beds, packaged by five different methods and cold-stored over winter at 0.5°C (Table 7). In April of 1979, the seedlings were removed from cold storage and machine-planted together with seedlings lifted in spring from the same nursery beds as the cold-stored stock. The experiment was laid out in a randomized block design with 16 trees per treatment. Each treatment was replicated three times for a total of 48 trees per treatment.

The planting site, method of planting, spacing, weed control, and root growth capacity determination were the same as in experiment 1.

Table 5. Survival, height growth and root growth capacity at time of planting of 3+0 sugar maple seedlings following overwinter cold storage, (Oct. 1977-April 1978).

Storage temp. (C)	-10°			-5°			0.5°			+5°			+10°			Spring lifted from nursery bed
packaging method[a]	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	
							Survival (%)									
1st year	3	7	0	100	100	100	100	100	93	100	97	100	97	93	97	100
2nd year	0	0	0	100	97	80	100	100	93	97	93	97	97	93	93	100
							Height growth (cm)									
1st year	0	0	0	4	5	3	7	7	7	6	8	7	9	5	7	6
2nd year	0	0	0	27	27	19	28	29	31	28	31	30	25	30	26	30
Cumulative height growth 2 years after planting	0	0	0	31	32	22	35	36	38	34	39	37	34	35	33	36
Root growth[b] capacity at time of planting	0	0	0	11	9	3	68	49	66	47	61	84	0	21	9	84

[a] a. Roots in moist peat, only roots enclosed in polyethylene-lined Kraft bag.

b. Roots in moist peat, total seedling enclosed in polyethylene-lined Kraft bag.

c. Bare roots, total seedling enclosed in polyethylene-lined Kraft bag.

[b] Mean number of new white roots per seedling.

Table 6. Survival, height growth and root growth capacity at time of planting of 2+2 sugar maple seedlings following overwinter cold storage, (Oct. 1977-April 1978)

Storage temp. (c) packaging method[a]	-10°			-5°			0.5°			+5°			+10°			Spring lifted from nursery bed
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	
							Survival (%)									
1st year	15	11	11	96	100	100	100	100	96	100	100	100	85	100	96	100
2nd year	4	4	4	96	100	93	100	100	96	100	100	100	85	100	96	100
							Height growth (cm)									
1st year	2	0	0	13	9	5	7	7	9	8	12	8	9	7	6	13
2nd year	5	3	2	51	47	31	54	47	41	52	48	51	46	42	44	43
Cumulative height growth 2 years after planting	7	3	2	64	56	36	61	54	50	60	60	59	55	49	50	56
Root growth[b] capacity at time of planting	0	0	0	25	24	10	114	78	81	65	80	56	0	0	24	143

[a] a. Roots in moist peat, only roots enclosed in polyethylene-lined Kraft bag.

b. Roots in moist peat, total seedling enclosed in polyethylene-lined Kraft bag.

c. Bare roots, total seedling enclosed in polyethylene-lined Kraft bag.

[b] Mean number of new white roots per seedling.

Table 7. First year survival, height growth, and root growth capacity at time of planting of 2+0 sugar maple seedlings stored over winter in various containers at 0.5°C.

Packaging method	Bare root, not enclosed in container	Bare roots enclosed in polyethylene-lined Kraft bag	Roots in moist peat enclosed in polyethylene-lined Kraft bag	Roots in moist peat, total seedling enclosed in polyethylene-lined Kraft bag	Roots in moist peat wrapped in waxpaper and burlap	Spring-lifted from nursery bed
Survival (%)	0	96	98	100	88	98
Height growth (cm)	0	6	5	10	0[a]	13
Root growth capacity at time of planting[b]	0	66	46	54	6	44

[a] Nearly all trees had dead stems and resprouted from the root collar.

[b] Mean numbers of new white roots per seedling.

Results

In experiment 1, overwinter storage at -10°C was detrimental to field survival of all 3+0 seedlings and most 2+2 transplants (Tables 5 and 6). Survival at all other temperatures ranged from 80 to 100 percent. Method of packaging had no significant effect on seedling or transplant survival. If one disregards the growth of the few surviving transplants stored at -10°C, average height growth of all cold-stored and spring-lifted seedlings and transplants ranged from 3 to 13 cm during the first year after field planting. In the second year, average height growth of the 3+0 seedlings and 2+2 transplants at -10°C increased to 27 and 46 cm, respectively. Packaging had no significant effect on seedling or transplant growth.

In experiment 2, bare-root storage of seedlings with both roots and stems exposed to the storage environment resulted in 100 percent mortality (Table 7). Survival of all seedlings with only roots or the total tree enclosed in polyethylene-lined Kraft bags and with or without moist peat around the roots ranged from 96 to 100 percent. Survival of seedlings with roots in moist peat wrapped in waxpaper and burlap was 88 percent. First-year height growth of all seedlings stored either with roots only or with the total seedling enclosed in polyethylene-lined Kraft bags ranged from 5 to 10 cm. Nearly all seedlings with roots packed in moist peat and covered with waxpaper and burlap suffered stem dieback, but most trees resprouted from the root collar or the lower stem.

The results of the greenhouse investigations have been reported previously (Webb and von Althen 1980). Highest root growth capacity and best growth were obtained at storage temperatures of 0.5° and 5.0°C. At 10°C a large number of new roots that were not included in the root growth capacity measurements and were excluded from the analysis were produced in storage. Root growth capacity of seedlings and transplants was strongly correlated with height growth ($\underline{r}$ = 0.77 and 0.68 respectively, $\underline{n}$ = 13 $p \geq 0.01$).

SOIL AMENDMENTS AND WEED CONTROL

Wallihan (1949) suggested that competition from herbaceous vegetation was one of the reasons for poor plantation performance while Yawney and Carl (1970) demonstrated that the growth of planted sugar maple seedlings improved in relation to the degrees of weed control achieved by cultural treatments.

In a study of the effects of competition on survival of potted and bare-root sugar maple seedlings in an abandoned field in southwestern Ontario, Webb (1974) observed that the removal of competing vegetation markedly increased seedling survival. Significant differences in microclimate were observed between competition and no-competition areas. Decreased absorption of solar radiation, decreased maximum temperatures and the absence of transpiring vegetation resulted in a significant increase in soil moisture. The overall decrease in soil moisture throughout the study period and the increase in the no-competition areas suggested that soil moisture was probably the factor of greatest importance in seedling survival. To determine the effects of weed control and soil amendments on seedling survival and early growth an experiment was initiated in 1973.

Experiment 1

In the spring of 1973 2+0 sugar maple seedlings were planted in two former agricultural fields in southwestern Ontario with soils of sandy loam and clay loam. The fields were plowed in summer and disked several times in the autumn prior to spring planting. Treatments consisted of placing either hardwood leaves, pine needles, peat moss or fertilizer in the bottom of planting holes made with a soil auger, or placing fertilizer in a hole beside the seedlings or spreading it on the soil surface around the seedlings. Weed control consisted of rototilling between the rows and manual hoeing around the trees, spraying paraquat on the vegetation within a circle 60 cm in diameter around the tree seedlings, or mowing between the rows and around the seedlings. All weed control treatments were applied four times per summer in each of the first four years after planting. When weed control treatments were discontinued, competition increased greatly and tree growth slowed during the summer of the fifth year after planting. It was therefore decided to apply additional weed control treatments. In November of the fifth growing season, 2.1 kg/ha of active pronamide in 400 L of water were broadcast over the mowed plot on the sandy loam soil to eliminate the dense cover of quackgrass (*Agropyron repens* [L.] Beauv.). In April of the sixth and seventh growing seasons, 4.5 kg/ha of active simazine in 400 L of water were broadcast over all plots on both soils with the exception of the mowed plot on the clay loam soil. This plot was split. In November 1978, 2.1 kg/ha of active pronamide in 400 L of water were broadcast over half of the plot and the unwanted vegetation was sprayed with 2.1 kg/ha of active glyphosate in 400 L of water in June and August of 1979. In the other half of the plot the weeds were mowed four times during the summer of 1979.

Results

Seven years after planting, survival was 80 percent or better in all treatment plots, with the exception of those in which fertilizer had been placed in the bottom of the planting holes. In these plots, survival ranged from 25 to 72 percent (von Althen 1977).

No soil amendment significantly affected seedling growth. However, weed control treatments produced significant growth differences (Fig. 1 and 2). Best growth on both soils was obtained in plots which were rototilled and hoed for the first four years after planting and sprayed with simazine in April of years six and seven. When the weed competition in the mowed plot on the sandy loam soil was eliminated by an autumn application of pronamide and a spring application of simazine, the seedlings responded with better growth in the following year than the cumulative growth of the previous five years. In the split plot on the clay loam soil, seedling growth also increased greatly following the application of pronamide and glyphosate.

Apart from the physical competition for nutrients, moisture, light, and growing space, the presence of inhibitors or toxins liberated by many old field species can have marked effects on plant growth (Bonner 1950, Börner 1960, Horsley 1977). However, in a greenhouse study undertaken to examine possible inhibitory effects of quackgrass on sugar maple seedling growth, no allelopathic interference between living quackgrass and 2-year-old sugar maple seedlings was found (Webb and von Althen 1980).

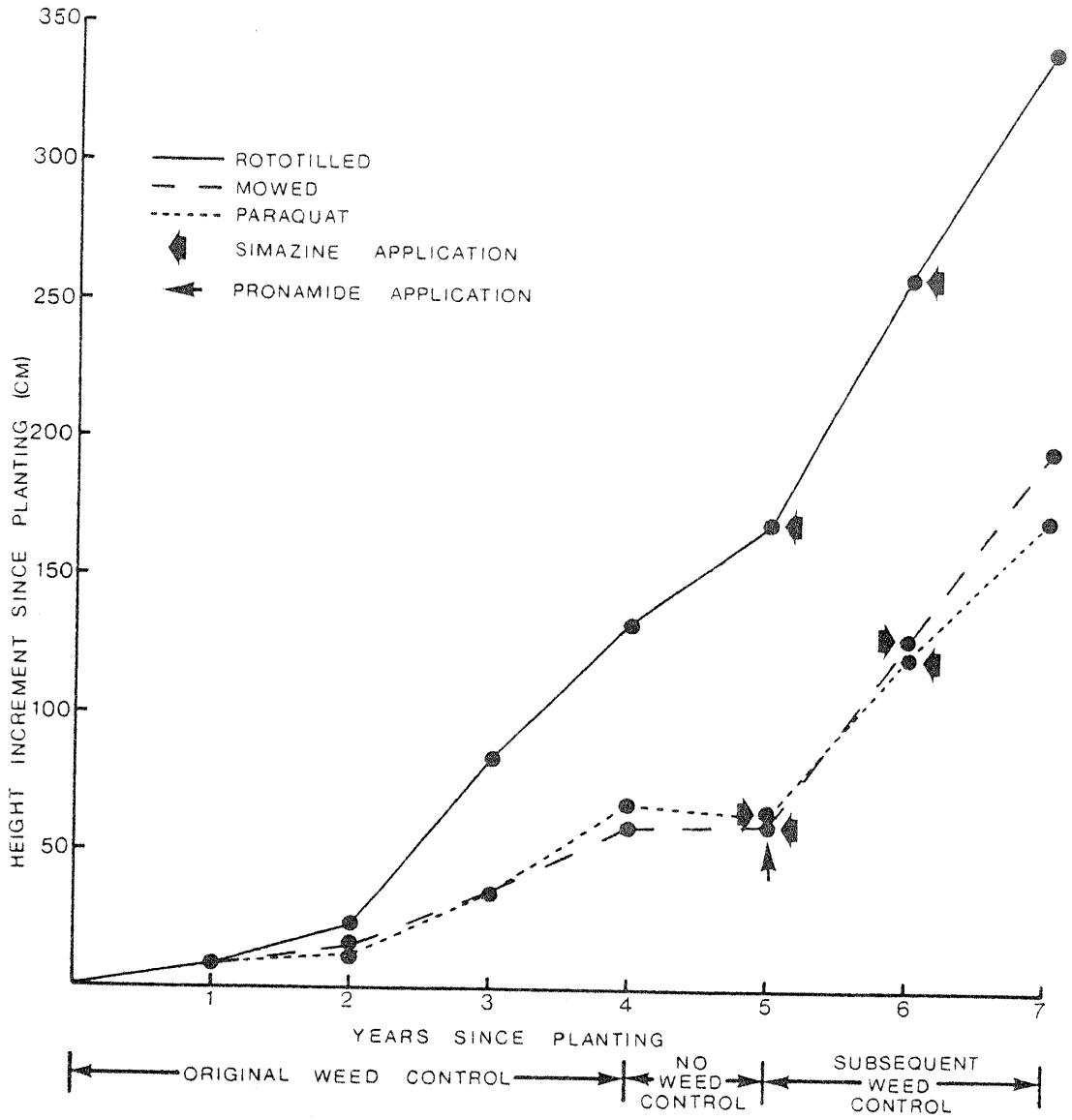

Figure 1. Height increment since planting of sugar maple seedlings (2+0) by weed control treatments and years since planting (sandy loam soil).

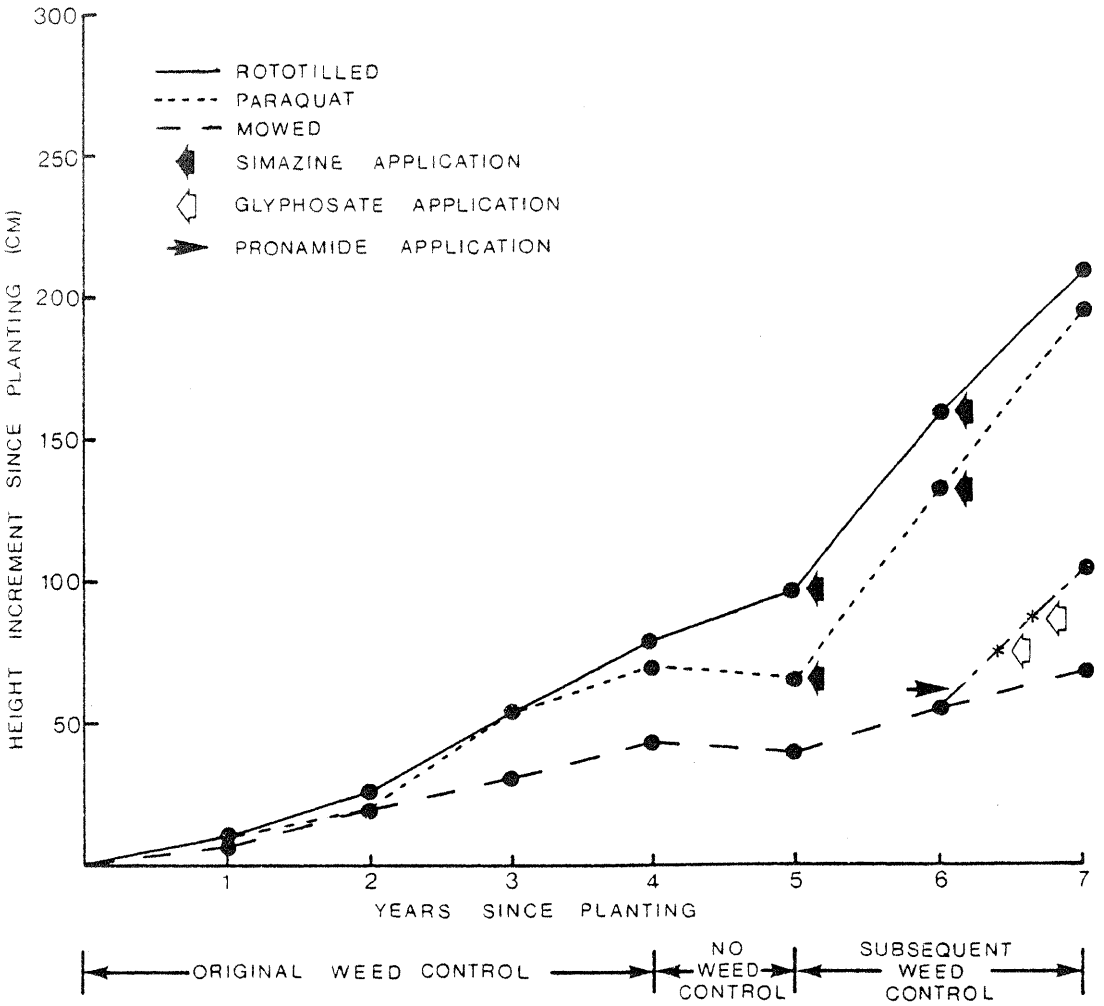

Figure 2. Height increment since planting of sugar maple seedlings (2+0) by weed control treatments and years since planting (clay loam soil).

DISCUSSION AND SUMMARY

With few exceptions, planting stock age had little effect on seedling or transplant growth after outplanting. However, when seedlings and transplants, within age classes, were graded by root collar diameters, trees with the largest diameters nearly always grew significantly better than those with smaller diameters. Since it is very expensive to grow, transport and plant large transplants which may grow only marginally better than seedlings with large root collar diameters, it appears more profitable to establish plantations with 2+0 or 3+0 seedlings with root collar diameters of at least 6 mm rather than with transplants. However, transplants may have their place in landscape plantings of selected trees where total height and size of crown are important features.

The results of experiments on the effects of planting date show that the periodicity of sugar maple root growth, with its early spring flush, makes it imperative either to plant seedlings and transplants in early spring or to place the stock in overwinter cold storage until the planting sites are ready. This is especially important in Ontario where the hardwood nurseries are located a considerable distance south of most sugar maple planting sites. If seedlings and transplants are lifted when the more northerly planting sites are ready, the trees will have undergone a major burst of root activity in the nursery beds and will be unlikely to produce the root extensions necessary to support adequate shoot growth during the first field season. Lifting the seedlings in early spring and heeling them in out-of-doors or cold storing them while the sites are ready for planting is also undesirable since sugar maple is capable of root growth at temperatures just above freezing (Dumbroff and Brown 1975), and root growth, once initiated, will not stop in the heeling-in beds or in above-freezing cold storage.

Autumn planting is an alternative to late spring planting on sites which are inaccessible in early spring. However, our experiments showed that the survival and height growth of autumn-planted seedlings were very similar to those of seedlings fresh-planted in late spring. In addition, the autumn-planted seedlings were exposed to rabbit browsing for another winter and some seedlings experienced frost heave.

The results of experiments on the effects of overwinter cold storage collectively showed that seedlings and transplants stored at 0.5°C and 5.0°C had the highest root growth capacity, highest survival and best height growth. Seedlings stored at -5° had a lower root growth capacity and height growth. At 10°C large numbers of new roots were produced in storage, and this resulted in reduced survival and height growth. Storage at -10°C was detrimental to the survival of all seedlings and most transplants.

The best type of packaging for overwinter storage was the enclosure of either the roots or the total seedlings in polyethylene-lined Kraft bags. The addition of wet peat to the bags had little effect on seedling survival or growth. Nearly all seedlings with roots packed in moist peat and covered with waxpaper and burlap suffered stem dieback, but most trees resprouted from the root collar or the lower stem. Exposed-root storage resulted in 100 percent mortality.

All seedlings and transplants were planted in fully cultivated soil because previous experiments had shown that site preparation was a prerequisite to successful hardwood plantation establishment (von Althen 1971, 1976). Effective postplanting weed control requires either the elimination or drastic reduction of the competing vegetation as evidenced by the slow growth of seedlings in our mowed plots. Height growth of all seedlings in these plots terminated in late June, two months earlier than that of seedlings in adjacent rototilled or chemically weeded plots. However, when the weed competition in the mowed plot was eliminated by an autumn application of pronamide and a spring application of simazine, the seedlings responded with better growth in the following year than the cumulative growth of the previous five years.

Additions of organic materials or fertilizer at time of planting in and around the planting holes failed to increase seedling growth because soil fertility was probably adequate for the growth of the newly planted seedlings.

The results of these experiments collectively show that sugar maple can be planted successfully in open field plantations as long as the following conditions are met:

(1) Removal of all established weeds by site preparation.
(2) Planting of seedlings or transplants with root collar diameters of at least 6.0 mm.
(3) Planting in early spring or overwinter cold storage of trees in polyethylene-lined Kraft bags at 0.5° to +5°C.
(4) Postplanting weed control to keep competition to a minimum during the first 3 to 5 years after planting.

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