FERTILIZATION AT TIME OF PLANTING FAILS TO IMPROVE GROWTH OF HARDWOOD SEEDLINGS

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REPORT O-X-249

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT

JULY 1976

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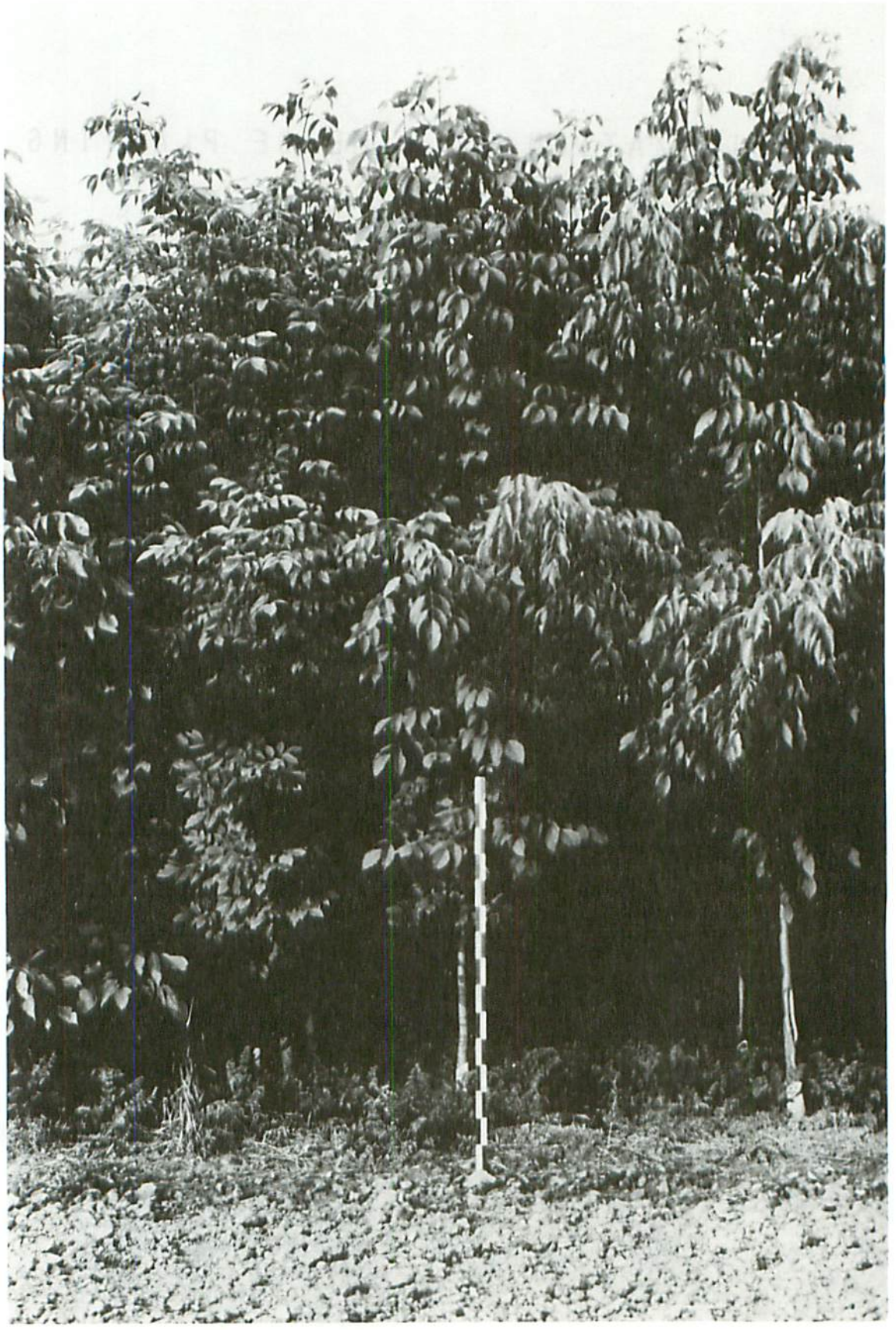

Frontispiece. White ash plantation seven years after planting. Measuring stick in foreground is 1.5 m (4.9 ft) high.

ABSTRACT

A series of experiments was carried out near Hornby, Halton County and near Thedford and Parkhill, Middlesex County, Ontario to determine the effects of fertilization at time of planting on the 3- or 5-year survival and height growth of hardwood seedlings. All seedlings in all experiments were planted in fully cultivated soil and weed competition was controlled by annual applications of Princep ® during the first 2 or 3 years after planting. Species planted were: black walnut (*Juglans nigra* L.), silver maple (*Acer saccharinum* L.), basswood (*Tilia americana* L.), red oak (*Quercus rubra* L.), and white ash (*Fraxinus americana* L.). None of the fertilization treatments tested significantly improved the survival or height growth of any of the five species planted. Placement of triple superphosphate in the bottom of planting holes increased the phosphorus concentration in black walnut leaves, but failed to improve height growth. Fertilization at time of planting is not recommended.

RÉSUMÉ

On a mené une série d'expériences près de Hornby, comté de Halton et près de Thedford et de Parkhill, comté de Middlesex, Ontario, en vue de déterminer les effets de la fertilisation au moment du plantage, sur la survie de 3 ou de 5 ans ainsi que la croissance en hauteur des semis de feuillus. Toutes les semences de toutes les expériences furent plantées dans un sol entièrement cultivé et on a réprimé les mauvaises herbes au moyen d'applications annuelles de Princep ® au cours des 2 ou 3 premières années après le plantage. Les essences plantées furent le Noyer noir (*Juglans nigra* L.), l'Érable argenté (*Acer saccharinum* L.), le Tilleul d'Amérique (*Tilia americana* L.), le Chêne rouge (*Quercus rubra* L.) et le Frêne blanc (*Fraxinus americana* L.). Aucun des traitements de fertilisation essayés n'a amélioré de façon significative la survie ou la survie ou la croissance en hauteur chez aucune des cinq essences plantées. La mise en place de triple superphosphate au fond des trous de plantage a augmenté la concentration de phosphore dans les feuilles du Noyer noir mais n'a pas amélioré la croissance en hauteur. Ainsi, la fertilisation au moment du plantage n'est pas recommandée.

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INTRODUCTION

During the early years after planting, seedlings of most hardwood species are highly susceptible to weed competition, browsing by rabbits, stem girdling by mice and damage from late spring frosts. One possibility of shortening the period during which a plantation is most vulnerable to such injuries is to increase seedling growth through fertilization. While improved growth from fertilization at time of planting has been reported for black walnut (*Juglans nigra* L.) (Finn 1966), red oak (*Quercus rubra* L.) (Buckley and Farmer 1974) and eastern cottonwood (*Populus deltoides* Bartr.) (Maisenhelder 1960, Aird 1962, Blackmon 1974) other authors have reported no growth improvement following fertilization or a decrease in survival (Cummings 1941, McComb 1949, Burke and Williams 1973, Geyer 1974). In 1964 a nonreplicated pilot study was established near Richmond Hill, Ontario which showed that the height growth of black locust (*Robinia pseudoacacia* L.), silver maple (*Acer saccharinum* L.), and white ash (*Fraxinus americana* L.) was greatly improved following a single application of NPK at time of planting (von Althen 1970, 1972). Encouraged by the results of this study we established a series of fertilizer experiments to determine the feasibility of fertilization at time of planting to improve the growth of different hardwood species during the early years after establishment. It was also hoped to determine the extent of growth improvement that could be expected from different intensities of fertilization. The results of these experiments are reported here.

METHOD

Study 1

The study area, a former field near Thedford, Middlesex County, Ontario has a deep, well drained, fine sandy loam soil of the Ontario Soil Survey Fox Series. The pH of the plow layer is 6.4 and the organic matter content is 2.4% (Appendix 1).

In April, 1969 the total experimental area was plowed and disked. Shortly thereafter, basswood (*Tilia americana* L.) (2+0) and red oak (2+0) seedlings were planted by spade at a spacing of 4x4 ft (1.2x1.2 m). Following planting and in April of 1970 and 1971, 4 lb per acre (4.5 kg/ha) of active Princep® were broadcast over the total planting area of both species.

Shortly after planting, ammonium nitrate, triple superphosphate and potassium sulphate were broadcast in 27 combinations over the surface of individual plots of both species (Table 1).

The experiment was laid out in a randomized block arrangement with 12 trees plus surrounds in each of 27 treatments. Each treatment was replicated three times for a total of 972 trees per species plus surrounds.

Table 1. Five-year survival and height growth of planted red oak and basswood seedlings by fertilization treatments

Treatments				Red oak		Basswood	
No.	N lb/ac[a]	P lb/ac	K lb/ac	Survival %	Ht growth ft[b]	Survival %	Ht growth ft
1	0	0	0	89	6	96	6
2	0	0	50	94	7	100	5
3	0	0	100	67	5	100	4
4	0	50	0	97	6	100	5
5	0	50	50	92	7	92	6
6	0	50	100	92	5	78	4
7	0	100	0	100	7	96	6
8	0	100	50	86	5	96	5
9	0	100	100	86	6	92	6
10	100	0	0	83	5	94	4
11	100	0	50	94	6	92	4
12	100	0	100	89	8	100	5
13	100	50	0	94	4	96	4
14	100	50	50	78	5	83	4
15	100	50	100	83	7	100	6
16	100	100	0	92	8	97	6
17	100	100	50	81	6	100	5
18	100	100	100	100	7	100	5
19	200	0	0	78	7	100	6
20	200	0	50	86	6	100	4
21	200	0	100	81	4	96	6
22	200	50	0	83	7	92	5
23	200	50	50	53	6	94	4
24	200	50	100	97	7	100	5
25	200	100	0	75	5	97	4
26	200	100	50	86	7	92	5
27	200	100	100	81	7	94	5

[a] 1 lb/acre = 1.12 kg/ha

[b] 1 ft = 30.48 cm

Seedling survival and height growth were recorded after the first, third and fifth year with the fifth-year data subjected to an analysis of variance. Composite foliage samples (two leaves from each tree within a plot) were collected from each plot in August of the first 2 years after planting and all samples were analyzed for their N, P, and K concentrations (Appendix 2).

In this and the other three experiments described in this report N was determined by a micro-Kjeldahl procedure, P was determined colorimetrically by a molybdophosphoric blue method, and K was determined by flame emission spectroscopy, using the flame emission conversion Unicam SP 90 atomic absorption spectrophotometer.

Study 2

The study area, a former field near Parkhill, Middlesex County, Ontario has an imperfectly drained loam soil over clay loam at a depth of 22 in. (56 cm). The pH of the plow layer is 7.2 and the organic matter content 3.2% (Appendix 1). The Ontario Soil Survey places the soil in the Parkhill series.

The total experimental area was plowed and disked in the autumn of 1968. In the spring of 1969 black walnut (1+0) and silver maple (2+0) seedlings were planted by spade at a spacing of 4x4 ft (1.2x1.2m). Shortly after planting and in April of the next 2 years 6 lb per acre (6.7 kg/ha) of active Princep® were broadcast over the total planting area of both species.

Shortly after planting, ammonium nitrate, triple superphosphate and potassium sulphate were broadcast in 27 combinations over the surface of individual plots of both species (Table 2).

The experiment was laid out in a randomized block arrangement with 12 trees plus surrounds in each of 27 treatments, replicated three times for a total of 972 trees per species.

Seedling survival and height growth were recorded after the first, third and fifth year with the fifth-year data subjected to an analysis of variance. Composite foliage samples (two leaves from each tree within a plot) were collected in August of the first 2 years and all samples were analyzed for their N, P, and K concentrations (Appendix 2).

Study 3

The study area, a former field near Hornby, Halton County, Ontario has an imperfectly drained clay loam soil 18 to 24 in. (46 to 61 cm) deep

Table 2. Five-year survival and height growth of planted black walnut and silver maple seedlings by fertilization treatments

Treatments				Black walnut		Silver maple	
No.	N lb/ac[a]	P lb/ac	K lb/ac	Survival %	Ht growth ft[b]	Survival %	Ht growth ft
1	0	0	0	94	8	100	13
2	0	0	50	92	7	94	15
3	0	0	100	83	7	100	16
4	0	50	0	97	7	100	16
5	0	50	50	97	7	100	12
6	0	50	100	97	7	94	15
7	0	100	0	89	7	97	14
8	0	100	50	94	7	97	15
9	0	100	100	100	7	89	12
10	100	0	0	92	10	89	10
11	100	0	50	94	8	94	11
12	100	0	100	100	7	83	13
13	100	50	0	97	7	81	11
14	100	50	50	100	7	83	10
15	100	50	100	81	7	97	16
16	100	100	0	89	8	94	16
17	100	100	50	81	7	89	13
18	100	100	100	83	8	94	14
19	200	0	0	92	7	94	12
20	200	0	50	94	7	75	13
21	200	0	100	92	7	94	15
22	200	50	0	94	7	94	12
23	200	50	50	100	9	97	14
24	200	50	100	92	9	89	12
25	200	100	0	92	6	89	12
26	200	100	50	97	8	97	15
27	200	100	100	86	8	94	16

[a] 1 lb/acre = 1.12 kg/ha

[b] 1 ft = 30.48 cm

over compact clay. The pH of the plow layer is 6.4 and the organic matter content 2.8% (Appendix 1). The Ontario Soil Survey places the soil in the Chinguacousy series.

In the autumn of 1970 the total experimental area was plowed and disked. In April, 1971 black walnut (1+0) seedlings were planted by spade at a spacing of 8x8 ft (2.4x2.4 m). Shortly after planting and in April of the following year 6 lb per acre (6.7 kg/ha) of active Princep ® were broadcast over the total plantation area.

Fertilization treatments consisted of surface applications of different dosages of 10-10-10 fertilizer, either around individual trees or broadcast over the total plot area. Either the entire dosage was applied shortly after planting in the spring of the second year, or one half of the dosage was applied shortly after planting and the second half in the spring of the second growing season (Table 3).

The experiment was laid out in a randomized block arrangement with nine trees plus surrounds in each of 19 treatments replicated four times for a total of 684 trees plus surrounds.

Seedling survival and height growth were recorded after the first, third and fifth year with the fifth-year data subjected to an analysis of variance. Composite foliage samples (two leaves from each tree within a plot) were collected in August of the first 2 years after planting and all samples were analyzed for their N, P, and K concentrations (Appendix 2).

Study 4

The study area, a former field near Parkhill, Middlesex County, Ontario, has an imperfectly drained clay loam soil 17 to 20 in. (43 to 51 cm) deep over compact clay. The pH of the plow layer is 6.9 and the organic matter content 3.4% (Appendix 1). The Ontario Soil Survey places the soil in the Perth series.

In the summer of 1972 the total experimental area was plowed and disked and disked again in August and September of the same year. In April, 1973 black walnut (1+0) and white ash (2+0) seedlings were planted by spade at a spacing of 6x6 ft (1.8x1.8 m). Following planting and in April of the next year Princep ® was broadcast over the total experimental area at the following dosages of active ingredient per acre: black walnut 6 lb (6.7 kg/ha), white ash 3 lb (3.4 kg/ha).

Fertilization treatments consisted of: (1) broadcast application on the soil surface shortly after planting, (2) placement in the bottom of the planting holes, (3) placement in a 6-in (15-cm) hole dug 6 in. (15 cm) from individual seedlings shortly after planting (Table 4).

Table 3. Five-year survival and height growth of planted black walnut by fertilization treatments

No.	Treatments: Dosage and date of 10-10-10 fertility applications			Survival	Height growth
	Spring 1971	Spring 1972	Spring 1971, 1972	%	ft[a]
1	-	-	-	97	4
2	3 oz/tree[b]	-	-	90	4
3	6 oz/tree	-	-	86	4
4	12 oz/tree	-	-	86	5
5	-	3 oz/tree	-	100	5
6	-	6 oz/tree	-	97	4
7	-	12 oz/tree	-	94	5
8	-	-	1.5 oz/tree each yr	100	5
9	-	-	3 oz/tree each yr	92	6
10	-	-	6 oz/tree each yr	83	4
11	127 lb/acre[c]	-	-	100	5
12	254 lb/acre	-	-	97	5
13	508 lb/acre	-	-	97	5
14	-	127 lb/acre	-	94	4
15	-	254 lb/acre	-	97	5
16	-	508 lb/acre	-	97	5
17	-	-	63.5 lb/acre each yr	94	5
18	-	-	127 lb/acre each yr	92	5
19	-	-	254 lb/acre each yr	97	6

[a] 1 ft = 30.48 cm

[b] 1 oz = 28.3 g

[c] 1 lb/acre = 1.12 kg/ha

Table 4. Effects of dosage and placement of phosphorus fertilizer on the 3-year survival and height growth of planted black walnut and white ash seedlings

Treatment no.	Treatments	Black walnut		White ash	
		Survival (%)	Height growth (ft)[a]	Survival (%)	Height growth (ft)
1	Control, no treatment	100	3	92	4
2	1 oz/tree[b] placed in the bottom of the planting hole	100	3	94	4
3	2 oz/tree placed in the bottom of the planting hole	100	3	100	5
4	4 oz/tree placed in the bottom of the planting hole	86	3	88	5
5	1 oz/tree placed in a hole 6 in. deep and 6 in. from tree	100	4	86	4
6	2 oz/tree placed in a hole 6 in. deep and 6 in. from tree	94	3	100	4
7	4 oz/tree placed in a hole 6 in. deep and 6 in. from tree	97	3	88	5
8	76 lb/acre[d] broadcast on surface	100	3	80	4
9	152 lb/acre broadcast on surface	97	3	80	4
10	304 lb/acre broadcast on surface	100	3	92	4

[a] 1 ft = 30.48 cm

[b] 1 oz = 28.3 g

[c] 1 in. = 2.54 cm

[d] 1 lb/acre = 1.12 kg/ha

The experiment was laid out in a randomized block arrangement with nine trees per species plus surrounds in each of 10 treatments and replicated four times for a total of 360 trees per species plus surrounds.

Seedling survival and height growth were recorded after the first and third year with the third-year data subjected to an analysis of variance. Composite foliage samples (two leaves from each tree within a plot) were collected from each plot in August of the first two growing seasons and all samples were analyzed for their N, P, and K concentrations (Appendix 2).

RESULTS

None of the fertilization treatments in any of the four studies had any significant effect on the survival or height growth of the five species planted (Tables 1-4). Survival of all species was high in all studies with the average black walnut survival ranging from 93% in Study 2 to 97% in Study 4. Average survival of basswood was 95%, silver maple 93%, white ash 90% and red oak 86%. Height growth of all species was fair to good, with the exception of black walnut in Study 3. The average 5-year height growth of silver maple was 13.4 ft (4.08 m), black walnut 7.4 ft (2.26 m) and 4.8 ft (1.46 m) in Studies 2 and 3, respectively, red oak 6.1 ft (0.86 m) and basswood 5.0 ft (1.52 m). The average 3-year height growth of black walnut and white ash in Study 4 was 3.1 ft (0.94 m) and 4.3 ft (1.31 m), respectively.

Placement of triple superphosphate in the bottom of the planting holes greatly increased the phosphorus concentration in the black walnut leaves collected in August of the first year (Table 5). However, in August of the second year the concentration was no higher than that in the leaves of the control trees. The concentration of phosphorus in the white ash leaves collected in August of the first year was slightly higher in all fertilized trees than in the control trees, but this increase also was no longer present in the foliage samples collected in August of the second year.

DISCUSSION

Southern Ontario is a predominantly agricultural area, and forests are generally restricted to sites unsuited to agriculture. Most of the land available for afforestation is therefore either of marginal productivity or unsuited to the economic use of farm machinery. Though much of the available land will not support quality hardwood growth, many fields contain areas that are capable of growing good hardwood timber. While some of the available sites may have the required physical soil properties for hardwood planting, they may be deficient in available nutrients as a result of years of exploitation farming. These are the sites on which

Table 5. Effects of phosphorus fertilizer placement on the foliar nutrient concentrations of planted black walnut and white ash seedlings

Treatment no.	Treatments	Black walnut						White ash					
		First year			Second year			First year			Second year		
		N %	P %	K %	N %	P %	K %	N %	P %	K %	N %	P %	K %
1	Control, no treatment	3.6	.22	.96	3.0	.17	1.01	2.4	.14	.61	2.5	.14	.81
2	1 oz[a] per seedling placed in the bottom of the planting hole	3.4	.35	.83	3.2	.18	.87	2.9	.18	1.06	2.5	.16	1.04
3	2 oz per seedling placed in the bottom of the planting hole	3.8	.31	.97	2.9	.17	.87	2.6	.19	.99	2.2	.15	.85
4	4 oz per seedling placed in the bottom of the planting hole	4.5	.33	1.04	3.1	.17	.99	2.7	.20	.89	2.5	.14	.95
5	1 oz per seedling placed in a hole 6 in. deep and 6 in. from seedling	3.4	.29	1.10	2.7	.15	.94	2.3	.16	.86	2.3	.17	.85
6	2 oz per seedling placed in a hole 6 in. deep and 6 in. from seedling	3.5	.23	.98	3.1	.17	.95	2.6	.17	1.07	2.4	.15	.91
7	4 oz per seedling placed in a hole 6 in. deep and 6 in. from seedling	3.5	.24	.80	2.9	.16	.91	2.6	.18	.96	2.3	.16	.88
8	76 lb/acre[c] broadcast on surface	3.6	.22	.85	2.8	.16	.84	2.7	.16	.96	2.5	.15	.94
9	152 lb/acre broadcast on surface	3.3	.20	.90	2.9	.15	.93	2.3	.17	1.01	2.5	.14	.89
10	304 lb/acre broadcast on surface	3.5	.22	.84	2.8	.16	.93	2.6	.18	1.03	2.5	.15	.81

[a] 1 oz = 28.3 g

[b] 1 in. = 2.54 cm

[c] 1 lb/acre = 1.12 kg/ha

fertilization will be of the greatest benefit to tree establishment and growth. However, even on sites of average fertility newly planted tree seedlings with their small, bunched, and often mutilated root systems should, theoretically, benefit from an extra supply of nutrients until their root systems have developed sufficiently to take advantage of the natural fertility of the soil.

Chemical soil tests can show how much of a given element is present in soil, but these tests alone cannot predict accurately how much of this element will actually be available to a planted tree seedling or how much a seedling may actually take up, since these processes depend on the interactions of many variables (Fisher 1971). Little information is available at present on the nutrient requirements of most hardwood species. Without this information, however, seedling growth cannot be predicted on the basis of soil tests. This lack of basic knowledge makes it therefore impossible to predict, with any degree of accuracy, the growth response of a tree seedling, growing in a given soil, to different intensities of fertilization.

Finn (1966) pointed out that little growth response will be obtained from fertilization unless a limiting deficiency is relieved. However, failure to obtain a response does not necessarily mean that a particular element is not limiting growth, because one also needs to know whether or not the applied element was actually taken up by the tree before one can evaluate its effect on growth. This can be done by foliar analyses of samples.

Failure of the fertilization treatments to improve seedling growth significantly in the four experiments described here was probably the result of any one or a combination of the following conditions: (1) the soils of the experimental areas contained a sufficient supply of available nutrients to satisfy the nutrient requirements of the newly planted seedlings; (2) the applied fertilizer either did not reach the roots or was not taken up by the seedlings; (3) the dosages of fertilizer applied were too small to produce measurable growth responses; (4) soil physical condition, e.g., poor drainage, or a deficiency in nutrients other than those applied, was more limiting to seedling growth than was the deficiency in the applied nutrients.

The success of our pilot experiment of 1964 appears to have been the result of a rare combination of soil physical conditions favorable to hardwood growth and a serious deficiency in available NPK brought about by years of exploitation farming.

A comparison of the concentrations of NPK in the leaves of black walnut seedlings growing in the control plots of our studies with samples collected from trees of various ages growing in former fields in the United States shows no consistent differences in the

nutrient concentrations of leaves from trees growing in different soils (Table 6). The most notable differences between our samples and the samples from the United States is the low phosphorus content in the leaves of the walnut trees growing in the Chinguacousy clay loam. It therefore appears possible that a high dosage of phosphorus might have increased growth. However, our dosages of 10-10-10 fertilizer were probably too low to produce a significant growth response.

Table 6. Comparison of foliar concentrations of nutrient elements of black walnut growing in the control plots of the studies described here with samples taken from trees growing in old fields in the United States (Finn 1966)

Location	Soil	Percent		
		N	P	K
Ontario	Parkhill	2.8	.10	.73
"	Chinguacousy	2.8	.04	.50
"	Perth	3.5	.22	.96
Iowa	Shelby	2.0	.18	.64
"	Fayette silt loam	2.3	.21	.45
"	Waukegan loam	2.9	.18	.95
Missouri	Clarksville	2.1	.12	.97
Indiana	--	1.2	.10	1.48

In Studies 2, 3, and 4 the soils of the experimental areas were imperfectly drained loams or clay loams. Texture and lack of drainage might therefore have been limiting the growth of black walnut which grows best on sandy loams with good drainage. However, neither texture nor imperfect drainage should have limited the growth of silver maple or white ash because both species grow well in these soils.

Following an analysis of the 2- and 3-year growth date of Studies 1, 2, and 3 it appeared possible that the failure to obtain growth responses was, to a large degree, the result of surface applications of the fertilizers at time of planting. Newly planted seedlings with their small roots bunched in narrow planting holes probably have little capacity to utilize the fertilizer cast on the soil surface before the nutrients are either

converted into insoluble form or lost by gaseous exchange or leaching (Meagher and Armson 1963).

In Study 4 the effects of phosphorus placement on foliar concentrations were therefore studied as well as the effects on seedling survival and height growth. Placement of fertilizer in the planting holes greatly increased the first-year concentration of phosphorus but failed to have any effect on height growth. The only conclusions which can be drawn from these results are that only the phosphorus dosages placed in the bottom of the planting holes were taken up by the tree seedlings in measurable quantities, and that in the planting soil of the study area phosphorus was not the main factor limiting walnut growth.

CONCLUSIONS

The results of these studies show that fertilization at time of planting is ineffective in improving hardwood seedling survival and growth. At present insufficient information is available on which species to fertilize, on what sites, by application of which fertilizer, at what dosage and by what method. Until this information is available, fertilization at time of planting is inadvisable because it may do more harm than good by increasing weed competition and adding to the pollution of rivers and lakes. Fertilization is also expensive and money spent on fertilizer applications at time of planting could be put to better use by intensifying site preparation and weed control treatments which have a proven beneficial effect on hardwood plantation establishment and seedling growth during the early years after planting.

LITERATURE CITED

Aird, P. L. 1962. Fertilization, weed control and the growth of poplar. For. Sci. 8: 413-328.

Blackmon, B. G. 1974. Hardwood growth can be increased by fertilization. South. Lumberman 229: 86-87.

Buckley, W. B. and R. E. Farmer Jr. 1974. Fertilization of Tennessee Valley pines and hardwoods: response during the second 5 years after application. Tree Plant. Notes 25: 14-15.

Burke, R. D. and R. D. Williams. 1973. Establishment and early culture of plantation. p. 36-41 *in* USDA For. Serv., North Central For. Exp. Stn. Black Walnut Symp. Proc., Carbondale, Ill.

Cummings, W. H. 1941. Fertilizer trials for improved establishment of short leaf pine, white ash and yellow poplar plantings on adverse sites. J. For. 39: 942-946.

Finn, R. F. 1966. Mineral nutrition of walnut trees. p. 35-41 *in* USDA For. Serv., North. Central For. Exp. Stn., Walnut Workshop Proc., Carbondale, Ill.

Fisher, R. F. 1971. Basic soil fertility and tree growth. Arborist's News 36(11): 148-152.

Geyer, W. A. 1974. Effects of weeds control and fertilizer in establishing hardwood seedlings. Tree Plant. Notes 25: 3-4.

Maisenhelder, L. C. 1960. Cottonwood plantations for southern bottom lands. USDA For. Serv., Southern For. Exp. Stn. Occas. Pap. 179. 24 p.

McComb, A. L. 1949. Some fertilizer experiments with deciduous forest tree seedlings on several Iowa soils. Iowa State Coll. Agric. Mech. Art. Res. Bull. 369: 406-448.

Meagher, M. D. and K. A. Armson. 1963. The effect of phosphorus placement on the growth of white spruce seedlings. J. For. 61: 918-920.

von Althen, F. W. 1970. Methods for the successful afforestation of a weed-infested clay soil. For. Chron. 46: 139-143.

von Althen, F. W. 1972. Eight-year results of an afforestation study. For. Chron. 48: 325-326.

APPENDICES

APPENDIX 1. RESULTS OF SOIL ANALYSES

	Horizon	Depth (in.)[a]	pH[b]	N %	P %	K %	Org. C[c] %
Study 1	Ap	0-8	6.4	.11	.00006	.07	2.4
	A_2	8-16	6.7	.03	.00004	.04	1.1
	B_2	16-22	7.8	.01	.00050	.12	.2
	C	22+	8.2	-	.00080	.30	.1
Study 2	Ap	0-8	7.2	.13	.0007	.025	3.2
	B_1	8-14	7.3	.09	.0005	.020	2.1
	B_2	14-22	7.6	.07	.0005	.061	0.5
	C	22+	7.9	.02	.0010	.123	0.1
Study 3	Ap	0-8	6.4	.17	.0002	.05	2.8
	A_2	8-12	6.6	.15	.0003	.05	1.5
	B	12-18	6.7	.04	.0005	.06	0.7
	C	18+	7.8	.02	.0009	.09	.03
Study 4	Ap	0-8	6.9	.16	.0002	.03	3.4
	A_2	8-12	7.1	.16	.0003	.06	2.8
	B	12-20	7.5	.05	.0008	.06	0.8
	C	20+	8.0	.02	.0008	.08	0.3

[a] 1 in. = 2.54 cm.

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

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

APPENDIX 2. NPK CONCENTRATIONS IN THE LEAVES OF FERTILIZED AND UNFERTILIZED SEEDLINGS

Study 1	Basswood						Red oak					
	N		P		K		N		P		K	
	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %
High	3.1[a]	3.2	.14	.11	1.5	2.9	2.6	3.0	.12	.12	.98	.94
Low	2.2[b]	2.2	.09	.05	.91	1.3	2.0	2.2	.07	.09	.52	.51
Average	2.5[c]	2.8	.11	.07	1.2	1.9	2.4	2.5	.09	.10	.75	.71
Control	2.5[d]	2.9	.12	.06	1.1	1.8	2.4	2.2	.11	.09	.79	.65

Study 2	Black walnut						Silver maple					
	N		P		K		N		P		K	
	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %
High	3.3[a]	3.3	.12	.11	1.30	1.07	3.3	3.4	.14	.12	.86	.95
Low	2.7[b]	2.6	.07	.08	.57	.47	2.6	2.2	.06	.07	.38	.50
Average	3.0[c]	2.9	.10	.10	.80	.74	2.9	2.7	.09	.09	.63	.68
Control	2.8[d]	3.0	.10	.10	.73	.87	3.0	2.9	.13	.09	.54	.55

Study 3	Black walnut					
	N		P		K	
	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %
High	3.5[a]	3.6	.05	.03	.68	.72
Low	2.8[b]	2.8	.03	.03	.44	.45
Average	3.0[c]	3.0	.04	.03	.56	.58
Control	2.8[d]	2.7	.04	.03	.50	.51

Study 4	Black walnut						White ash					
	N		P		K		N		P		K	
	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %	1st year %	2nd year %
High	3.8[a]	3.2	.35	.18	1.10	1.01	2.7	2.5	.20	.17	1.07	1.04
Low	3.3[b]	2.7	.20	.15	.80	.73	2.3	2.2	.14	.14	.86	.81
Average	3.5[c]	2.9	.26	.16	.93	.90	2.6	.24	.17	.15	.94	.89
Control	3.5[d]	.30	.22	.17	.96	1.01	2.4	2.5	.14	.14	.61	.81

[a] Highest value obtained in all treatments except control

[b] Lowest value obtained in all treatments except control

[c] Mean value of all treatments except control

[d] Mean value of control