SPACING TRIALS IN BLACK WALNUT, WHITE ASH AND SILVER MAPLE PLANTATIONS

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ABSTRACT

Black walnut *(Juglans nigra* L.) seedlings were planted at spacings of 3 x 1.5 m, 3 x 3 m, 4.5 x 3 m and 4.5 x 4.5 m near Norwich, Ontario while white ash *(Fraxinus americana* L.) and silver maple *(Acer saccharinum* L.) were planted at spacings of 1.85 x 1.85 m, 2.75 x 2.75 m, and 3.65 x 3.65 m near Parkhill, Ontario. Weed control in all plantations consisted of applications of simazine shortly after planting and in April of the next year or two. Double leaders were pruned in years two and four.

Ten years after planting, spacing had no significant effect on the survival, diameter and height growth of black walnut and white ash or the survival and height growth of silver maple. Only the diameter growth of silver maple was significantly greater in the widest spacing than in the two narrower spacings. Stem form of black walnut and silver maple was superior in the narrowest spacings while stem form of white ash was unaffected. Recommendations are made for spacing of black walnut, white ash and silver maple seedlings in intensively and extensively managed plantations.

RÉSUMÉ

On a planté des semis de noyer noir *(Juglans nigra* L.) espacés de 3 m x 1.5, de 3 m x 3, de 4.5 m x 3 et de 4.5 m x 4.5 près de Norwich en Ontario et des semis de frêne blanc *(Fraxinus americana* L.) et d'érable argenté *(Acer saccharinum* L.) espacés de 1.85 m x 1.85, de 2.75 m x 2.75 et de 3.65 m x 3.65 près de Parkhill, en Ontario. Dans toutes les plantations, on a utilisé de la simazine, peu après la plantation et en avril de l'année ou des deux années suivantes, contre les mauvaises herbes. Aux années 2 et 4, on a émondé les pousses apicales doubles.

Dix ans après la plantation, l'espacement n'avait eu aucun effet notable sur la survie et sur la croissance en diamètre et en hauteur du noyer et du frêne ni sur la survie et la croissance en hauteur de l'érable. Dans ce dernier cas, seule la croissance en diamètre était notablement plus grande dans l'espacement maximal. La forme de la tige du noyer et de l'érable était supérieure dans les espacements les plus étroits, tandis que chez le frêne elle n'était pas modifiée. Des recommandations sont faites pour l'espacement des trois essences dans les plantations en intensive et en extensive.

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Cover photo: Ten-year-old silver maple plantation established at a spacing of 1.85 x 1.85 m near Parkhill, Ontario.

INTRODUCTION

Initial spacing is an important factor in plantation establishment because it affects not only the rate of growth and quality of wood produced, but also the cost of establishment, frequency of weed control treatments and thinnings, utilization of the site, land conservation and erosion. Hardwoods are generally more affected by initial spacing than conifers because many hardwood species lack the drive to upward growth unless they are forced upward by close spacing (Wardle 1967). For this reason, oak in Germany has long been planted at a spacing of 1 x 1 m, with thinnings carried out at regular intervals to provide the minimum required growing space (Hesmer and Guenther 1966, Wagenhoff 1974). Many of the most successful hardwood plantations established in Ontario before 1950 were planted at spacings of 1.2 x 1.2 m (4 x 4 ft) (von Althen 1965). Between 1950 and 1970 a spacing of 1.85 x 1.85 m (6 x 6 ft) was recommended for most species, including hardwoods. In recent years the trend has been to wider spacings to stretch the available planting stock and to delay thinning.

To determine the effects of initial spacing on the survival, growth and stem form of black walnut *(Juglans nigra* L.), white ash *(Fraxinus americana* L.) and silver maple *(Acer saccharinum* L.), seedlings were planted at different spacings. The 10-year results are reported herein.

METHOD

Black Walnut

The experiment was carried out in a farm field near Norwich, Oxford County, Ontario. The soil is a well drained clay loam 75 to 90 cm deep over compact clay. The pH of the plow layer is 6.8 and the organic carbon content is 2.5%. The Ontario Soil Series places the soil in the Huron Series (Wickland and Richards 1961). Ground cover consisted of a dense stand of mainly quack grass *(Agropyron repens* [L.] Beauv.), goldenrod *(Solidago* spp.) and wild aster *(Aster* spp.).

The total experimental area was plowed and disked in the autumn of 1973. In April of 1974, 1+0 black walnut seedings were machine-planted at spacings of approximately 3 x 1.5 m, 3 x 3 m, 4.5 x 3 m and 4.5 x 4.5 m. Shortly after planting and in April of the following year, 6.7 kg/ha of active simazine were broadcast over the total area. In the second and fourth year after planting, double leaders and some lower branches were pruned.

The experiment was laid out in a randomized block design with two replications of each of four treatments. Each replication covered an area of approximately 0.2 ha. In all, 1,800 seedlings were planted. Survival, height and DBH were recorded at the end of the tenth growing season. At the same time a visual assessment of stem form was made. The 10-year survival, height and diameter data were subjected to analyses of variance.

White Ash and Silver Maple

The experiment was carried out in a farm field near Parkhill, Middlesex County, Ontario. The soil is an imperfectly drained, fine, sandy loam 60-80 cm deep over silty sand. The pH of the plow layer is 7.2 and the organic matter content is 2.4. The Ontario Soil Survey places the soil in the Tuscola Series (Anon. 1931). Ground cover consisted of wheat stubble with patches of quack grass.

The total experimental area was plowed and disked in the autumn of 1973. In April of 1974, 2+0 white ash and silver maple seedlings were planted by spade at spacings of approximately 1.85 x 1.85 m, 2.75 x 2.75 m and 3.65 x 3.65 m. Shortly after planting and in April of 1974 and 1975, 3.3 kg/ha of active simazine were broadcast over the total area planted with white ash and 4.5 kg/ha over the area planted with silver maple. In the second and fourth year after planting, double leaders were pruned in both plantations.

The experiment was laid out in a randomized block design with two replications of three treatments for each of the two species planted. Each replication covered an area of approximately 0.2 ha. In all, 2,000 seedlings were planted per species. Survival and height were recorded at the end of the first, fifth and tenth growing seasons and diameter was recorded at the end of the tenth growing season. At the same time a visual assessment of stem form was made. The 10-year survival, height and diameter data were subjected to analyses of variance.

RESULTS

Black Walnut

Initial spacing had no significant effect on the 10-year survival, diameter or height growth of black walnut (Table 1). However, stem form was best at the narrowest spacing and worst at the widest spacing (Fig. 1 and 2). At wide spacings, many trees had forked stems and large branches. Also, nearly 10% of the crowns of trees planted at 4.5 x 4.5 m had sustained wind damage ranging from broken branches to the total loss of the crown (Fig. 3).

Table 1. Ten-year survival, diameter and height of black walnut seedlings planted at different spacings.

Initial spacing (m)	No. of trees planted per ha	Survival (%)	No. of live trees	DBH (cm)	Height (m)
3.0 x 1.5	2,222	96	2,133	6.1	4.4
3.0 x 3.0	1,111	94	1,044	6.1	4.4
4.5 x 3.0	741	98	726	6.0	4.4
4.5 x 4.5	494	95	469	5.8	3.9

Figure 1. Good form of walnut trees planted at a spacing of 3 x 1.5 m.

Figure 2. Bushy crowns of walnut trees planted at a spacing of 4.5 x 4.5 m.

Figure 3. Damaged crowns of walnut trees planted at a spacing of 4.5 x 4.5 m.

White Ash and Silver Maple

Initial spacing had little effect on the survival and height growth of white ash and silver maple or the diameter growth of white ash (Table 2). Only the diameter growth of silver maple was significantly higher at the widest spacing than at the two narrow spacings. Stem form of white ash was good in all plots, and there was no apparent difference between spacings (Fig. 4). Stem form of silver maple was best at the closest spacing because stems were straighter and more trees had single stems or fewer stems per clump than at the wider spacings (Fig. 5-7).

Table 2. Ten-year survival, diameter and height growth of white ash and silver maple seedlings planted at different spacings.

Initial spacing (m)	No. of trees planted per ha	White ash				Silver maple			
		Survival (%)	No. of live trees	DBH (cm)	Height (m)	Survival (%)	No. of live trees	DBH (cm)	Height (m)
1.85 x 1.85	2,924	81	2368	3.6	4.2	88	2866	5.7a	6.6
2.75 x 2.75	1,323	85	1125	3.5	4.2	92	1217	6.3a	6.8
3.65 x 3.65	751	80	601	3.3	4.1	90	676	8.0b	7.5

Note: Means followed by a different letter differ significantly ($P > 0.05$).

Figure 4. Good stem form of white ash at a spacing of 1.85 x 1.85 m.

Figure 5. Planted at a spacing of 1.85 x 1.85 m, most silver maple trees have single stems.

Figure 6. Planted at a spacing of 2.75 x 2.75 m, most silver maple trees have multiple stems.

Figure 7. Silver maple planted at a spacing of 3.65 x 3.65 m have the largest diameters but stem form is poor.

DISCUSSION

There is no ideal spacing for the planting of all species on all sites or for the achievement of all management objectives. Since initial spacing can greatly influence rate of growth and tree form, appropriate spacings vary widely depending on species, the purpose of the planting and the economics of plantation establishment and tending. For example, to produce maximum fiber yield a very close spacing is generally best. Hybrid poplar has been planted at a spacing of 0.3 x 0.9 m, with a planned rotation of 3 years (Anderson 1979). For the production of high-quality black walnut timber, however, a spacing of approximately 3 x 3 m has been recommended, together with a planned series of thinnings designed to reduce the number of trees gradually according to the growth requirements of the crop trees (Schlesinger and Funk 1979). To establish a nut orchard it might be best to plant black walnut trees at a spacing of approximately 12 x 12 m to produce trees with large, spreading crowns (Bolar 1973). If the primary objective of the planting is protection from wind, close spacing in the rows and wide spacing between them has been recommended. This produces trees with branches extending nearly to the ground to provide the greatest protection (Tillotson 1921).

Although millions of hardwood seedlings are planted each year in eastern North America the results of very few hardwood spacing trials have been reported. Evert (1973) searched the literature on initial tree spacing and found

very few references to trials with black walnut, white ash or silver maple. This scarcity of research results is probably attributable to the difficulty of maintaining long-term studies which may span a period from stand establishment to rotation age (Evert 1971). Most information on spacing has been derived from observing the development of plantations and natural regeneration (Rudolph 1950, Wilde 1964, Volk 1970, Rudolph et al. 1972, Kleinschmit et al. 1978).

In the experiments described here, initial spacing had little effect on the 10-year mean survival and height of black walnut, white ash and silver maple seedlings or on the mean diameter of black walnut and white ash. Without further analysis it may therefore appear that initial spacing is of little consequence in the early plantation development of these species. However, the small differences in means express only the relationships in average survival and size of the trees planted at different spacings and do not give any weight to the number of trees represented by the means.

Plotting the number of live trees per hectare by initial spacings over the mean diameter 10 years after planting graphically shows the much larger number of trees per hectare present in the plantations with close spacings (Fig. 8-10). However, not only are there more trees in total at the closer spacings, but there are also proportionally more trees in the larger diameter classes. This is important for future plantation growth and yield because the larger trees are expected to maintain their above-average growth and will therefore provide the majority of crop trees.

Another approach to evaluating the effects of initial spacing on future plantation growth and yield is a comparison between the number of trees currently growing at the different spacings, and the number of trees required to form a fully stocked stand. Since it is impossible to predict accurately the growth rate of trees planted on a variety of sites and managed at different intensities, the following comparisons are based on a range of assumed mean diameters of a fully stocked plantation. For example, 1,300 trees per ha, with a mean diameter of 15 cm, are required to form a fully stocked plantation with a basal area of 23 m^2. Similarly, only 325 trees per ha are required when the mean diameter of the trees has reached 30 cm.

Planted at the initial spacing of 3 x 1.5 m, the black walnut plantation contained 2,133 live trees at age 10, with an average diameter of 6.1 cm (Table 1). Selection of the largest 1,300 trees (with a mean diameter of 15 cm) required for a fully stocked plantation would raise the present mean diameter to 7.5 cm (Table 3). Planted at spacings of 3 x 3, 4.5 x 3 and 4.5 x 4.5 m, however, only 1,044, 726 and 469 trees, respectively, are available to form a fully stocked plantation and their present diameters are 6.1, 6.0 and 5.8 cm, respectively.

At the initial spacing of 4.5 x 4.5 m, the required number of trees to form a fully stocked plantation is therefore not reached until the mean diameter of the trees is nearly 30 cm, or until approximately half way through the rotation.

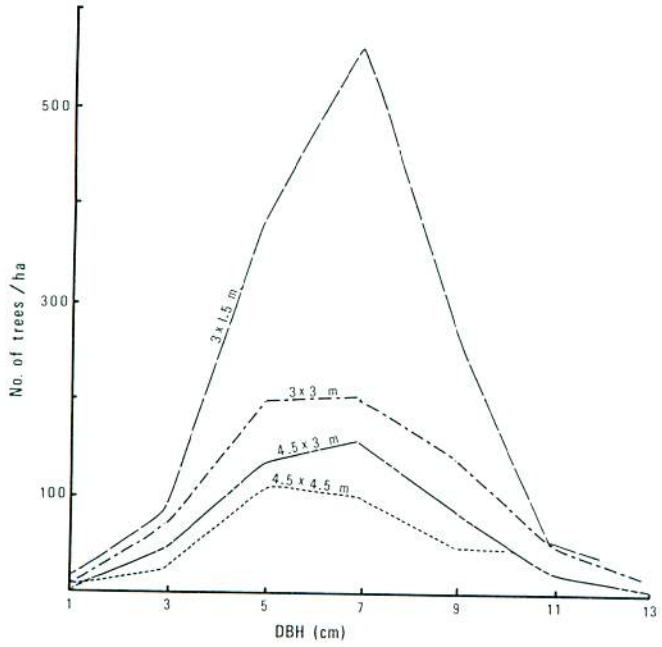
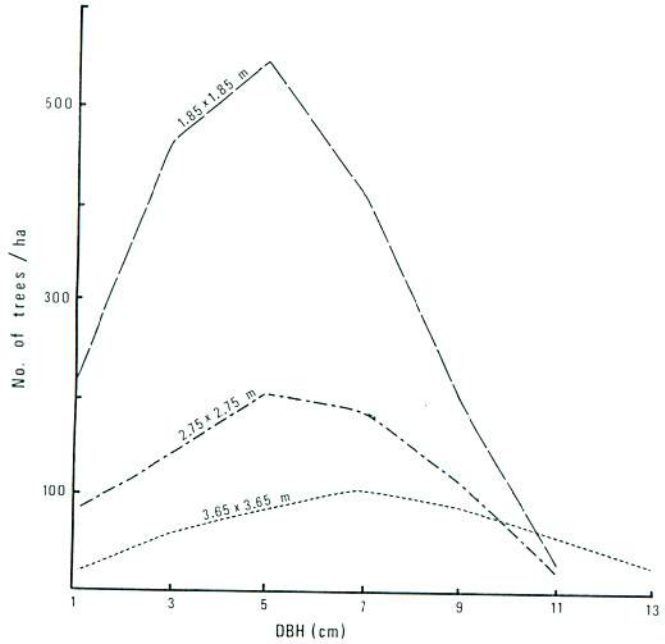


Figure 8. (left) Distribution of black walnut by diameter classes 10 years after planting at different spacings.

Figure 9. (right) Distribution of white ash by diameter classes 10 years after planting at different spacings.



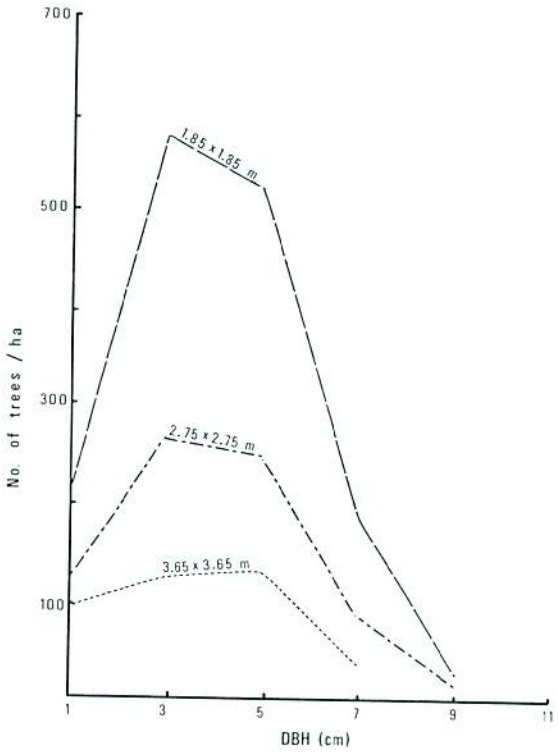


Figure 10. (left) Distribution of silver maple by diameter classes 10 years after planting at different spacings.

Table 3. Comparison between the number of trees required for a fully stocked plantation of trees with different mean diameters, and black walnut trees planted 10 years previously at different spacings.

Assumed mean diameter of trees of fully stocked plantation[a] (cm)	No. of trees required for fully stocked plantation	No. of black walnut available for fully stocked plantation by initial spacing (m)				Present mean diameter (cm) of trees required for fully stocked plantation by initial spacing (m)			
		3.0 x 1.5	3.0 x 3.0	4.5 x 3.0	4.5 x 4.5	3.0 x 1.5	3.0 x 3.0	4.5 x 3.0	4.5 x 4.5
15	1,300	1,300	1,044[b]	726	469	7.5	6.1	6.0	5.8
20	727	727	727	726	469	8.3	7.4	6.0	5.8
25	472	472	472	470	469	8.6	8.3	7.4	5.8
30	325	325	325	330	330	9.0	9.0	8.1	7.0

a 23 m^2/ha (100 ft^2/ac) of basal area
b No. of trees planted minus mortality

Table 4. Comparison between the number of trees required for a fully stocked plantation of trees with different mean diameters, and white ash trees planted 10 years previously at different spacings.

Assumed mean diameter of trees of fully stocked plantation[a] (cm)	No. of trees required for fully stocked plantation	No. of white ash available for fully stocked plantation by initial spacing (m)			Present mean diameter (cm) of trees required for fully stocked plantation by initial spacing (m)		
		1.85 x 1.85	2.75 x 2.75	3.65 x 3.65	1.85 x 1.85	2.75 x 2.75	3.65 x 3.65
15	1,300	1,300	1,125[b]	601	4.9	3.5	3.3
20	727	727	727	601	5.7	4.5	3.3
25	472	472	472	472	6.3	5.2	3.9
30	325	325	325	325	6.7	5.7	4.6

a 23 m^2/ha (100 ft^2/ac) of basal area
b No. of trees planted minus mortality

Although the diameter growth of trees generally increases with increased growing space, this holds true only in closely spaced plantations where lack of growing space is a limiting factor. This was not the case in the study plantations during the first 10 years after planting. Actually, the opposite was true insofar as close spacing promoted growth by protecting the young walnut trees from wind damage (Schneider et al. 1968), and from the reinvasion of weeds after the herbicide treatments were discontinued (Byrnes 1966, Byrnes et al. 1973, von Althen 1971, 1977). Ten years after planting at the initial spacing of 4.5 x 4.5 m, the trees are at least 5 years away from canopy closure, while trees planted at 3 x 1.5 m closed their canopy approximately 5 years ago. Few weeds are therefore present under the closed canopy, while the widely spaced trees are surrounded by a dense cover of mainly goldenrod and grasses.

Although no detailed stem form assessment was carried out in this study, visual assessment revealed that tree form was greatly superior in the plots planted at the two closer spacings than at the widest spacing. Despite light pruning treatments in the second and fourth years after planting, more trees planted at the widest spacing had forked leaders, broken crowns or larger branches than did trees planted at the closest spacing (Fig. 3).

In the white ash plantation, 2,924 seedlings per ha were planted at an initial spacing of 1.85 x 1.85 m. Of these, 81% or 2,368 trees survived 10 years after planting and their mean diameter was 3.6 cm (Table 2). Selection of the largest 1,300 trees (with a mean diameter of 15 cm) required for a fully stocked plantation would raise the present mean diameter to 4.9 cm (Table 4). At the initial spacings of 2.75 x 2.75 m and 3.65 x 3.65 m, however, only 1,125 and 601 live trees per hectare, respectively, are available, and their present mean diameters are 3.5 and 3.3 cm, respectively.

Growth of all white ash was relatively slow when compared with that of trees in other plantations established on similar sites (von Althen 1965). Even the trees planted at the relatively close spacing of 1.85 x 1.85 m had not closed their canopy 10 years after planting. All trees, therefore, continued to be subjected to severe competition from weeds and grasses, and this is believed to be the main reason for the slow growth.

Of the 2,924 silver maple seedlings planted at a spacing of 1.85 x 1.85 m, 2,866 trees survived 10 years after planting and their mean diameter was 5.7 cm. If the largest 1,300 trees required to form a fully stocked plantation with a mean diameter of 15 cm were selected, the present mean diameter would be 7.9 cm (Table 5). However, because of the larger diameter of trees planted at the initial spacing of 3.65 x 3.65 m, the mean diameter of all 676 trees surviving at this spacing was 8.0 cm. Although stem form was best at the closest spacing, the savings in establishment cost and the possible delay in the first thinning suggest that silver maple might best be planted at a wider spacing than either black walnut or white ash.

Table 5. Comparison between the number of trees required for a fully stocked plantation of trees with different mean diameters, and silver maple trees planted 10 years previously at different spacings.

Assumed mean diameter of trees of fully stocked plantation[a] (cm)	No. of trees required for fully stocked plantation	No. of silver maple available for fully stocked plantation by initial spacing (m)			Present mean diameter (cm) of trees required for fully stocked plantation by initial spacing (m)		
		1.85 x 1.85	2.75 x 2.75	3.65 x 3.65	1.85 x 1.85	2.75 x 2.75	3.65 x 3.65
15	1,300	1,300	1,217[b]	676	7.9	6.2	8.0
20	727	727	727	676	8.9	8.0	8.0
25	472	472	472	472	9.4	8.9	9.5
30	325	325	325	325	9.9	9.5	10.4

[a] 23 m^2/ha (100 ft^2/ac) of basal area

[b] No. of trees planted minus mortality

RECOMMENDATIONS

While the available information is insufficient to make detailed recommendations for the spacing of black walnut, white ash and silver maple seedlings, the following recommendations are made to provide the prospective plantation owner with some spacing guidelines until better information becomes available.

For intensively managed plantations it is recommended that black walnut seedlings be planted at a spacing of 3 m between rows and 1.5 m within rows. This allows a medium-sized tractor to pass between the rows to apply weed control. This spacing also promotes canopy closure at approximately 5 years after planting and thereby reduces the number of weed control treatments required. The disadvantage of this spacing is that a series of thinnings starting approximately 10 to 15 years after planting is required.

For extensively managed plantations a spacing of 3 x 3 m may be preferable because the first thinning may be delayed until age 20. However, weed control treatments may have to be extended because the trees will not be able to close their canopy until 8 to 10 years after planting. Pruning may also be required to remove large branches.

White ash should always be planted as close as possible and preferably at a spacing not wider than 1.5 x 1.5 m. This spacing requires the planting of 4,444 trees per ha (1,800 trees/ac) but plantations established at this spacing have generally shown excellent growth (von Althen 1965, 1974). The disadvantages are high establishment costs and the necessity of repeated thinnings, starting approximately 10 years after planting.

Silver maple might best be planted at a spacing of 3 x 3 m. This requires the planting of 1,111 trees per ha (450 trees/ac). However, to produce trees with single stems it will be necessary either to thin clumps or to plant