FIVE-YEAR SURVIVAL AND GROWTH OF SIXTEEN HARDWOOD SPECIES PLANTED IN DIFFERENT MIXTURES

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Frontispiece. Silver maple and white ash in Experiment 1, 7 years after planting. Height of measuring pole 4.5 m.

ABSTRACT

Sixteen hardwood species were planted in different species mixtures in two experiments in a former field with an imperfectly drained sandy loam soil located near Parkhill, Middlesex County, Ontario. Five years after planting, survival ranged from 44 to 99 percent and height growth from 39 to 469 cm. Height growth of most species was very similar to that of seedlings planted in pure plantations. With few exceptions average survival and height growth were better in row plantings than in completely random mixture. Planted at a spacing of 3 x 1.5 m, most trees had heavy branches which will require pruning to produce stems of veneer quality. A closer spacing is recommended for future plantations to promote good stem form, the development of small branches, and early crown closure.

RÉSUMÉ

Seize essences feuillues ont été plantées en différentes compositions spécifiques dans deux expériences dans un ancien champ sur un limon sablonneux imparfaitement drainé, près de Parkhill, Comté de Middlesex, Ontario. Cinq ans après la plantation la survie se situait entre 44 et 99% et la croissance en hauteur entre 39 et 469 cm. La croissance en hauteur de la plupart des essences ressemblait beaucoup à celle des semis plantés dans des plantations pures. A quelques exceptions près, la moyenne de survie et de croissance en hauteur était meilleure dans les plantations en rangées que dans le mélange complètement aléatoire. Plantés avec un écart de 3 x 1.5 m, la plupart des arbres comportaient des branches massives qu'il faudra élaguer pour produire des tiges propres au déroulage. Un espacement moindre est recommandé pour les futures plantations afin de favoriser une bonne forme de tige, le développement de petites branches et la fermeture précoce du couvert.

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INTRODUCTION

Under natural forest conditions most hardwoods grow in association with other species and planting of species mixtures most closely approximates this natural state. Other advantages of mixed plantations are the reduction of their susceptibility to insect or disease attacks and their high aesthetic value. The main advantages of pure plantations are the yield of the largest number of trees of the most desirable species, and the ease of establishment and management.

Most existing plantations are monocultures and little is known at present about the establishment and management of mixed plantations. To determine the effects of species mixtures on the survival and growth of hardwood species planted in various arrangements, seedlings of 16 hardwood species were planted in two experiments in southern Ontario. This report presents the 5-year results of these experiments.

METHOD

Experiment 1

This experiment was carried out in a former field near Parkhill in Middlesex County, Ontario. The soil was an imperfectly drained sandy loam over sand of the Ontario Soil Survey Berrien Series. The pH of the plow layer was 6.8 and the organic matter content 2.5%.

The entire field was plowed and disked in the autumn of 1973. In April of 1974 seedlings of each of 10 species were machine planted on half of the field (Table 1).

The study was laid out in a randomized block arrangement with 16 seedlings per species in each of three treatments. Each treatment was replicated six times for a total of 288 seedlings per species. The only exception was white oak (*Quercus alba* L.) which was planted only in treatments 1 and 3. Spacing in all treatments was 3 m between rows and 1.5 m within rows.

Treatments consisted of:

1. Planting 16 seedlings of one species in a row followed by planting of a row of 16 seedlings of another species. All rows were distributed randomly within each replication.

Table 1. Five-year survival and height growth of hardwood seedlings planted in three arrangements with other hardwoods (Experiment 1).

Species	Age of seedlings	Survival (%) Treatment 1: 16 seedlings of one species planted in a row	Survival (%) Treatment 2: 4 seedlings of one species planted in a row	Survival (%) Treatment 3: Completely random mixture	Height growth (cm) Treatment 1: 16 seedlings of one species planted in a row	Height growth (cm) Treatment 2: 4 seedlings of one species planted in a row	Height growth (cm) Treatment 3: Completely random mixture
Black walnut *Juglans nigra* L.	1+0	95	98	95	218	193	171
White ash *Fraxinus americana* L.	2+0	91	86	89	183	165	171
Silver maple *Acer saccharinum* L.	2+0	96	97	91	431	422	340
Red oak *Quercus rubra* L.	2+0	57	56	68	89	39**	74
White oak *Quercus alba* L.	2+0	71	-	74	75	-	73
Basswood *Tilia americana* L.	2+0	97	92	93	189	200	177
Black-locust *Robinia pseudoacacia* L.	2+0	92	90	92	468	463	379**
Sycamore *Platanus occidentalis* L.	2+0	49	45	44	327	276	246*
Catalpa *Catalpa speciosa* Ward.	2+0	80	75	79	229	218	162*
European mountain ash *Sorbus aucuparia* L.	2+0	91	94	82*	267	261	203

* Within species significantly different (P .05) from all other treatments

** Within species significantly different (P .01) from all other treatments

2. Planting 16 seedlings in 4 rows of 4 seedlings with each row of 4 seedlings of one species followed by 4 seedlings of another species. All rows of seedlings were distributed randomly within each replication.

3. Planting 16 seedlings of each species in completely random mixture.

Weed control consisted of broadcast applications of 3.3 kg/ha of active simazine shortly after planting and in April of the second and third years after planting.

Seedling survival and height were recorded in the autumn of the first, third and fifth year after planting and the 5-year data were subjected to an analysis of variance.

Experiment 2

This experiment was carried out in the same field as experiment 1. Following the plowing and disking of the whole field in the autumn of 1973, the portion on which this experiment was conducted was disked several times during the summer and autumn of 1974 to control newly germinated weeds. In April of 1975, 12 seedlings of each of 12 species were machine planted at a spacing of 3 m between rows and 1.5 m within rows (Table 2).

The study was laid out in a randomized block arrangement with 12 seedlings per species in each of two treatments. Each treatment was replicated six times for a total of 144 seedlings per treatment.

Treatments consisted of:

1. Planting 12 seedlings of one species in a row followed by planting of a row of 12 seedlings of another species. All rows were distributed randomly within each replication.

2. Planting 12 seedlings of each species in completely random mixture.

Weed control consisted of broadcast applications of 3.3 kg/ha of active simazine shortly after planting and in April of the second and third years after planting.

Seedling survival and height were recorded in the autumn of the first, third, and fifth year after planting and the 5-year data were subjected to an analysis of variance.

Table 2. Five-year survival and height growth of hardwood seedlings planted in two arrangements with other hardwoods (Experiment 2).

Species	Age of seedlings	Survival (%) Treatment 1: 12 seedlings of one species planted in a row	Survival (%) Treatment 2: Completaly random mixture	Height growth (cm) Treatment 1: 12 seedlings of one species planted in a row	Height growth (cm) Treatment 2: Completely random mixture
Black walnut *Juglans nigra* L.	1+0	95	99	167	176
White ash *Fraxinus americana* L.	2+0	99	96	234	232
Silver maple *Acer saccharinum* L.	2+0	97	92	469	375*
Red oak *Quercus rubra* L.	2+0	80	70*	159	128
White oak *Quercus alba* L.	1+0	80	87	200	178
Butternut *Juglans cinerea* L.	2+0	92	92	174	147
Sugar maple *Acer saccharum* Marsh.	2+0	94	72**	174	167
Black cherry *Prunus serotina* Ehrh.	2+0	85	67*	215	244
Tulip poplar *Liriodendron tulipifera* L.	2+0	88	86	273	218
European mountain ash *Sorbus aucuparia* L.	2+0	89	66**	285	280
Amur maple *Acer ginnala* Maxim.	4+0	96	96	152	137
Thornless locust *Gleditsia triacanthos* L. var. *anermis*	2+0	89	89	299	277

* Within species significantly different (P .05) from other treatments
** Within species significantly different (P .01) from other treatments

RESULTS

Experiment 1

Average survival was 75 percent or better for all species except red oak (*Quercus rubra* L.), white oak and sycamore (*Platanus occidentalis* L.) (Table 1). With the exception of European mountain ash (*Sorbus aucuparia* L.) planting arrangement had no significant influence on survival. Average 5-year height growth (total height minus height at planting) ranged from 39 cm for red oak to 463 cm for black-locust (*Robinia pseudoacacia* L.). Planting arrangement had a significant influence on height growth: red oak seedlings exhibited significantly poorer growth in treatment 2, sycamore growth was significantly poorer in treatments 2 and 3 and the growth of black-locust and catalpa (*Catalpa speciosa* Ward.) was significantly poorer in treatment 3 than in the other planting arrangements.

Experiment 2

Average survival in the row mixture (treatment 1) ranged from 80 to 99 percent (Table 2). In the completely random mixture (treatment 2), survival ranged from 66 to 99 percent with significantly lower survival of red oak, sugar maple (*Acer saccharum* Marsh.), black cherry (*Prunus serotina* Ehrh.) and European mountain ash than in the row mixture.

Average height growth in the row mixture ranged from 152 to 469 cm and in the completely random mixture from 137 to 375 cm. Only with silver maple (*Acer saccharinum* L.) was height growth significantly lower in the completely random mixture than in the row mixture.

DISCUSSION

Although the advantages of mixed plantations are well recognized, most hardwoods have been planted in monocultures and relatively little information is available on the establishment, management, and growth and yield of mixed plantations. The largest number of species mixtures has been planted on strip-mined lands. In most of these plantations the survival and growth of the commercially important species have been poor because these species are very exacting in their site requirements and grow well only in nutrient-rich soils (Den Uyl 1962, Seidel and Brinkman 1962, Plass 1975). The only hardwood species which survived and grew well on strip-mined land were hybrid poplars (*Populus* spp.), black-locust and black alder (*Alnus glutinosa* [Gaertn.]) (Czapowskyj 1970, 1978).

A few species mixtures have been planted for timber production. In 18- to 22-year-old mixed plantations of black cherry, red oak, tulip poplar (*Liriodendron tulipifera* L.), white ash (*Fraxinus americana* L.), black walnut (*Juglans nigra* L.), sugar maple, and American elm (*Ulmus americana* L.) in southwestern Michigan, most trees grew satisfactorily, but their potential stem quality was fairly low (Rudolph et al. 1964). Many trees had multiple stems or short boles because of frequent forking. In a mixed plantation of tulip poplar, sugar maple, red maple (*Acer rubrum* L.), red oak, white ash and basswood (*Tilia americana* L.) in an oak clearcut in southern Wisconsin, 1+1 white ash transplants survived and grew best for the first 4 years after planting. Eight years after planting, however, sugar maple and red maple, followed closely by white ash and tulip poplar, had outgrown all other species (Johnson 1971, 1978).

Growth of black walnut and other commercially valuable species has been improved by underplanting or interplanting with black-locust and autumn olive (*Elaeagnus umbellata* Thunb.). Most of the growth improvement has been attributed to the nitrogen-fixing ability of these species, but shelter and protection from wind probably contributed as well (Deitschman 1956, Funk et al. 1979).

Schneider et al. (1970) reported that wind can be a critical factor in the early establishment of black walnut in open field soils, and Fleming (1979) reported excellent growth of black walnut in mixture with white pine (*Pinus strobus* L.). The Ontario Ministry of Natural Resources has established a number of promising plantations of black walnut and white pine mixtures and is at present advocating this mixture for the establishment of black walnut on abandoned farm land in southern Ontario (Johnson, personal communication).

All seedlings in Experiment 1 were planted as rows of 16 trees per species, in rows of four, or in completely random mixture. In theory the planting of rows of four seedlings per species appeared to be a good arrangement because at least one of the four seedlings was expected to attain a dominant position in the canopy at time of crown closure. However, during planting it was found that the planters had great difficulty in switching quickly from species to species so that an additional person was required to prepare bundles of four seedlings per species. This design was dropped, therefore, in Experiment 2.

In Experiment 1 significantly lower survival was recorded for white oak, red oak and sycamore seedlings than for all other species (Table 1). The low survival of the oak seedlings was probably caused by severe root pruning. The two-year-old seedlings had very thick tap roots and very few fibrous roots. To allow machine planting, the tap roots were pruned to a length of 20 cm. It is believed that the short, thick stubs of the pruned roots were unable to support the existing shoots or to produce the apical growth necessary for successful competition with the herbaceous vegetation. Many sycamore seedlings had dead upper stems at time of planting. While some of these seedlings resprouted from the lower stem or the root collar and produced excellent growth, other seedlings failed to sprout or produced only weak sprouts which soon died.

In Experiment 2 the difference in survival between the row mixture and the completely random mixture cannot be explained fully; however, more stems were girdled by mice in the random mixture than in the row mixture because the weed cover was generally denser in the forest. The improved survival of oak seedlings in Experiment 2 was most likely caused by planting of smaller seedlings which required less severe root pruning.

Chemical weed control in both experiments was only fair because the annual applications of 3.3 kg/ha of active simazine were insufficient to prevent the reestablishment of quackgrass (*Agropyron repens* L. [Beauv.]), goldenrod (*Solidago* spp.) and other simazine resistant species. However, heavier dosages of simazine were not possible because of the known susceptibility of white ash and black cherry to dosages of more than 3.3 kg/ha.

Average height growth of most species in both experiments was as good as that in most single-species plantations growing on similar sites (von Althen 1965, 1974a,b). The significantly lower growth of black-locust, sycamore and catalpa in the random mixture of Experiment 1 and silver maple in the random mixture of Experiment 2 was probably due to weed competition. When the simazine applications were discontinued after the third growing season herbaceous growth increased greatly. In the row mixture the fast-growing species were generally able to suppress weed growth by shading. However, when planted in completely random mixture the individual trees of these species were surrounded mostly by slow-growing species which produced less shade and, therefore, less weed suppression.

The 16 species planted in the two experiments may be divided into three groups according to their total height growth during the first five years after planting:

(1) species that grew more than 4 m were black-locust and silver maple;

(2) species that grew between 2.5 and 4 m were thornless locust (*Gleditsia triacanthos* L. var. *enermis*), sycamore, European mountain ash, tulip poplar and catalpa;

(3) species that grew between 1 and 2.5 m were white ash, basswood, black walnut, black cherry, sugar maple, butternut (*Juglans cinerea* L.), Amur maple (*Acer ginnala* Maxim.), white oak, and red oak (Fig. 1-3).

This grouping illustrates that all species of commercial value in Ontario grew between 1 and 2.5 m in the first five years after planting. Black-locust was the fastest growing species. Its value as a nitrogen supplier is well known. However, landowners should also be aware that black-locust is very susceptible to the locust borer (*Megacyllene robiniae* Forster), which often prevents the production of large-diameter stems. The species also spreads rapidly by means of root suckers and seeds. In our plantations thickets had formed within three years after planting, and this made it difficult to walk or drive a tractor between the rows of planted trees (Fig. 4).

The spacing of 3 m between rows and 1.5 m within rows was chosen to allow the application of simazine with a tractor-mounted sprayer. However, at this spacing, most trees developed heavy branches which will require pruning to produce stems of veneer quality. If simazine could be applied manually it would be possible to plant all seedlings at a closer spacing. This would improve tree form and facilitate early crown closure, which helps to suppress unwanted vegetation by shading (Fig. 5). Manual applications of simazine would be required only in the spring of the second and third years after planting. Spraying shortly after planting could still be done with a tractor-mounted sprayer because the newly planted seedlings would be small enough to pass under the tractor and the sprayer boom. At a spacing of 2 x 2 m, thinnings would be required at 20-year intervals to release the crop trees. However, the cost of such thinnings might be recovered by the sale of the saplings for firewood.

Figure 1. Well formed black walnut in single-tree mixture 7 years after planting.

Figure 2. Catalpa with spreading branches caused by too wide spacing and low survival of white oak in alternate row.

Figure 3. Tulip poplar 6 years after planting.

Figure 4. Black locust with poor stem form, 7 years after planting. In background root suckers have formed a thicket between the rows of black locust and black walnut.

Figure 5

At a spacing of 3 m x 1.5 m the crowns of the faster growing species are expected to close at 8-9 years after planting.

SUMMARY AND RECOMMENDATIONS

The results of these experiments show that the 5-year height growth of most species was very similar to that of seedlings planted in pure plantations. In the experiments reported here, species selection was dictated by the availability of planting stock and the aim to obtain survival and height growth data on as many species as possible rather than by careful matching of species with similar growth rates. Great differences were therefore recorded in height growth between fast and slow growing species. These differences may add to the aesthetic value of plantations, but are undesirable in the production of high-value timber because they promote poor stem form and heavy branching.

In plantations established for aesthetics or the afforestation of severely disturbed or infertile soils, any species may be planted in mixture with other species as long as their site requirements match those of the planting site. However, in plantation mixtures established for high-value timber production it is strongly recommended that only species with similar growth rates be planted. When planted at spacings of approximately 2 x 2 m, such mixtures are expected to promote good stem form, small branches and early canopy closure.

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