Forest Ecology and Management, 9 (1984) 235—243
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

GROWTH RESPONSE OF BLACK WALNUT TO INTERPLANTED TREES

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(Accepted 22 March 1984)

ABSTRACT

Schlesinger, R.C. and Williams, R.D., 1984. Growth response of black walnut to interplanted trees. *For. Ecol. Manage.*, 9: 235—243.

Analyses of black walnut tree diameters 13 years after planting showed that interplanting autumn-olive, black locust, and European alder increased walnut tree growth, but only at certain locations. Interplanting autumn-olive resulted in increases of 56 to 351% at four of five locations and all species resulted in doubled walnut growth on an upland site. The interaction between treatment and location indicates that a fuller understanding of site and nurse species characteristics is needed to obtain the potential benefits of mixed plantings.

INTRODUCTION

The wood of black walnut (*Juglans nigra* L.) is highly regarded for furniture and paneling. Thus, there has been a strong and continuing interest in planting walnut trees. Growth of planted black walnut has been variable, depending on soil characteristics, topographic features, climate, silvicultural practices, and biotic factors such as insects, diseases, and associated vegetation. This paper is concerned with associated vegetation and reports the effects of interplanting autumn-olive (*Elaeagnus umbellata* Thunb.), black locust (*Robinia pseudoacacia* L.), and European alder (*Alnus glutinosa* (L.) Gaertn.) on the growth of black walnut and on the variation of the effects of these species at several locations.

A nurse crop, according to Ford-Robertson (1971), is a crop of trees, shrubs, or other plants introduced to foster another and generally more important crop during its youth. The objective of this study was to determine whether planting walnut in mixture with nitrogen-fixing nurse crops would improve growth of the walnut trees.

METHODS

Five locations were selected for the study, three in Illinois and one each in Missouri and Indiana. These included both bottomland and upland situa-

tions and soil types considered suitable and questionable for growing walnut (Table I).

Seedlings (1—0 nursery stock) of all species were planted in the spring of 1969 at four of the five locations. At the fifth, the nurse crop species were interplanted into an existing 2-year-old walnut planting. A randomized complete block design was used, consisting of two blocks, four treatments (walnut alone, walnut and autumn-olive, walnut and black locust, and walnut and European alder) at two locations (Ambeer Creek, Illinois (AC) and Hogthief Creek, Illinois (HC)). At Busch Wildlife Area, Missouri (BW), Camp Cadiz, Illinois (CC), and Pierson-Hollowell lands, Indiana (PH), the experiment included three blocks of the four treatments, using smaller treatment plots.

At four locations (AC, HC, BW, and CC), the distance between the walnut trees was 4.88 m within rows spaced 3.66 m apart with the nurse species alternating with the walnuts within the rows, creating a 2.44 m × 3.66 m

TABLE I

Characteristics of study location

Name	Location		Soil type	Topographic situation
	County	State		
Ambeer Creek (AC)	Alexander (Lat. 37°14'N, Long. 89°19'W)	IL	Haymond silt loam[1] (Typic Udifluvent)	Bottomland
Camp Cadiz (CC)	Hardin (Lat. 37°35'N, Long. 88°17'W)	IL	Hosmer silt loam[2] (Typic Fragiudalf)	Upland
Hogthief Creek (HC)	Hardin (Lat. 37°30'N, Long. 88°17'W)	IL	Belknap silt loam[3] (Aeric Fluvaquent)	Bottomland
Busch Wildlife (BW)	St. Charles (Lat. 38°41'N, Long. 90°44'W)	MO	Putnam silt loam[4] (Mollic Albaqualf)	Bottomland
Pierson-Hollowell (PH)	Morgan (Lat. 39°3'N, Long. 86°32'W)	IN	Parke silt loam[1] (Ultic Hapludalf)	Upland

[1] Considered suitable for black walnut (Losche et al., 1980).
[2] Considered questionable for black walnut because of the presence of a fragipan at 76 cm or less.
[3] Considered questionable for black walnut because it is somewhat poorly drained.
[4] Not listed in Losche et al. (1980), but considered suitable for black walnut based on soil properties and topographic position.

spacing between plants in the 1:1 mixture. The 2-year-old planting at PH consisted of walnut trees planted on a 3.35 m × 3.35 m spacing, and the 1:1 mixture was created by interplanting the nurse species between the walnuts within rows.

Weeds were controlled annually with herbicides for the first 5 years by spraying a mixture of Atrazine plus Simazine (2.24 kg each active ingredient (a.i.) per ha) and Dalapon (13.45 kg a.i. per ha). The entire area was sprayed for the first 1 or 2 years, after which only strips (approximately 1.5 m wide) along the rows (Illinois and Missouri) or spots (1.5 m diameter) around each tree were sprayed.

Initial survival of the walnut, autumn-olive, and locust was excellent, but the alder suffered extensive herbicide damage. Missing trees of all species were replaced at the beginning of the second and fourth growing seasons.

Tree height and diameter (at 1.38 m above ground) were measured annually on 12-36 interior walnut trees within each treatment plot, the number depending on the size of the treatment plot at each location. Plot means were used in the analyses. Because there were no statistically significant differences after 7 years between plot means based on only the original walnut trees and means that included the few replanted ones, the plot means include all trees.

The data for height and diameter were analyzed with the procedure for an experiment repeated in several locations with unequal numbers of blocks (Cochran and Cox, 1957). Because the analyses for height and for diameter showed similar trends, only the analyses for diameter are discussed in this paper. The interaction between location and treatment was analyzed following the suggested procedure for partitioning the sums of squares into treatment within location components given in Steel and Torrie (1960). The least significant difference test was applied to the planned comparisons between each nurse crop treatment and the control (pure plot) treatment.

RESULTS

The effects of the nurse crops on walnut tree diameter were first observed to be significant at age 6 years (Table II). At that time, only the autumn-olive treatment produced a significant increase in the average walnut diameter (Table III), resulting in trees that were 24% larger than trees in pure plots. By the end of the 7th growing season, the black locust treatment also showed a significant benefit, amounting to 22% larger walnut trees in the black locust plots compared to the pure plots (Table III). By the end of the 9th growing season, the walnuts growing with autumn-olive were 69% larger than in pure plots and those grown with black locust were 26% larger.

At the end of the 10th year, a significant interaction was detected between the locations and the treatments (Table II). Analysis of this interaction showed that treatment effects occurred at only four of the five locations, a situation that continued through the 13th year (Table IV). The

treatment comparisons within locations revealed that the autumn-olive treatment was significant at all locations except BW, that black locust had a significant effect at locations CC and PH, and that the European alder treatment had resulted in significantly larger walnut trees at location CC (Table V).

TABLE II

Analyses of variance for average walnut tree diameter[1]

Variable	Degrees of freedom	Age (years)									
		4	5	6	7	8	9	10	11	12	13
Location	4	**	**	**	**	**	**	**	**	**	**
Blocks (L)	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment	3	NS	NS	*	**	**	**	**	**	**	**
Loc. x treat.	12	NS	NS	NS	NS	NS	NS	*	*	**	**
Error	24										

[1] NS = not statistically significant.
* = statistically significant for $P = 0.05$.
** = statistically significant for $P = 0.01$.

TABLE III

Planned comparisons for ages 6 through 9, differences in walnut diameters between interplanted and pure plots

Comparison (in cm) between	Age (years)			
	6	7	8	9
Autumn-olive (AO) — P	1.01**	1.74**	2.41**	3.32**
Black locust (BL) — P	0.59	0.81*	1.00*	1.22*
European alder (EA) — Pure (P)	0.28	0.43	0.46	0.49

TABLE IV

Analyses for treatment within location interaction

Location	Age (years)			
	10	11	12	13
	(significance level for treatment)			
CC[1]	**	**	**	**
AC	**	**	**	**
HC	**	**	**	*
PH	*	**	**	**
BW	NS	NS	NS	NS

[1] See Table I for location description.

By the end of the 13 growing seasons, all of the nurse-crop species tested showed some benefits to the walnut trees at one or more locations (Fig. 1). Significantly larger trees were produced with European alder only at Camp Cadiz, with the "gain" in diameter being 102% (Table VI). Interplanting with black locust resulted in significant "gains" of 31 and 135% at two locations. And autumn-olive produced significantly larger walnut trees at four of the five locations with "gains" ranging from 56 to 351%.

TABLE V

Planned comparisons for ages 10 through 13, differences in walnut diameters within locations

Location	Comparisons (in cm) between	Age (years)			
		10	11	12	13
CC[1]	AO — P[2]	5.93*	7.49**	8.53**	9.65**
	BL — P	2.45*	2.91**	3.26**	3.72**
	EA — P	1.04	1.37	2.05	2.81*
AC	AO — P	5.56**	6.17**	6.60**	6.85**
	BL — P	0.63	0.98	1.29	1.58
	EA — P	0.17	0.97	1.49	2.00
HC	AO — P	4.77**	4.67**	4.59**	4.34**
	BL — P	0.95	0.83	0.82	0.76
	EA — P	1.25	1.15	1.08	0.98
PH	AO — P	3.38**	4.22**	4.18**	4.31**
	BL — P	2.20*	2.41*	2.44*	2.35*
	EA — P	1.54	1.88	2.04	1.96
BW	AO — P	0.54	0.80	0.97	1.25
	BL — P	0.38	0.44	0.41	0.62
	EA — P	−0.95	−0.92	−1.07	−1.07

[1] See Table I for location descriptions.
[2] See Table I for treatment descriptions.

TABLE VI

Differences in walnut diameters (%) after 13 years relative to pure plots

Treatment[1]	Location[2]				
	CC	AC	HC	PH	BW
AO	351**	120**	56**	56**	11
BL	135**	28	10	31*	5
EA	102*	35	13	25	−9

[1] See Table III for treatment descriptions.
[2] See Table I for location descriptions.

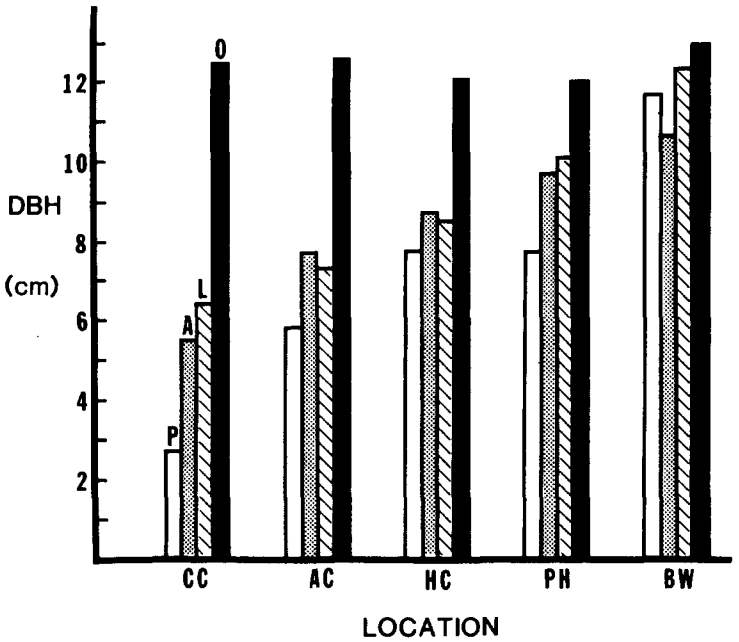

Fig. 1. Black walnut diameter after 13 years (plot averages) in pure (P) and mixed plantings (A = European alder, L = black locust, and 0 = autumn-olive). (See Table I for location descriptions.)

DISCUSSION

The initial question, will nurse crops planted with black walnut increase the growth of the walnut trees, can be answered with a qualified yes. Black walnut is considered to be a site-demanding species (Losche, 1973) and is known to respond both positively and negatively to the availability of growth factors such as moisture and nutrients (Ponder, 1981). The locations selected provided for a large range of test conditions in so far as available growth factors are concerned. The diameter of the walnut trees in the pure plots reflect this site diversity, ranging from 2.8 cm at CC to 11.7 cm at BW after 13 years. The effects of the nurse crops on the growth of the walnut trees appear to depend on both the characteristics of the nurse crop species and on the characteristics of the site.

Autumn-olive was of significant benefit on four of the five sites. Autumn-olive survival was excellent, with 99% alive at the end of 5 years and this rate of survival continuing to the end of the 13-year period. Its rate of growth appears to be compatible with that of the walnut trees, because it maintained a 0.5-m height advantage during the first 6—7 years, after which the walnut trees became taller than the autumn-olive plants. Since then, the autumn-olive has maintained a height of about 5 m, while the walnut trees have continued to increase in height, now averaging about 9 m.

The benefits from the autumn-olive mixture appear to be inversely related to the productivity of the sites for walnut in pure stands. Judged on the basis of the growth in pure plots, the upland CC location is the poorest site for growing walnut trees while the BW location is the best of the five locations tested in this study. The increased growth of the walnut trees in the autumn-olive mixture was highly significant at CC but not significant at BW. Overall, the average diameter of the walnut trees in mixture with autumn-olive was essentially the same after 13 years for all locations (Fig. 1).

Black locust was of significant benefit at only two of the five locations, partly due to its apparently incompatible growth rate relative to black walnut. Black locust survival averaged 95% at the end of 5 years. At that time, the locust trees were more than twice as tall as the walnut (6.3 m vs. 2.9 m) and almost 3 times as large in diameter (7.1 cm vs. 2.5 cm). In order to reduce what appeared to be excessive competition to the walnut trees, we girdled or poisoned the locust trees. Subsequently, the locust treatment consisted of stump and root sprouts in the understory.

European alder was the least successful of the three species in terms of its benefit to the walnut trees. It was the most difficult species to establish successfully, but at the end of 5 years survival was 94% at four of the five locations (at BW it was only 44%). Survival has subsequently declined at all locations, the result of an allelopathic reaction of the alder trees to the walnut trees (Rietveld et al., 1983). The alder mortality was observed after the 8th and 9th growing seasons at HC and BW respectively, and after the 11th, 12th and 13th at PH, AC, and CC, respectively. Average survival was only 38% after 13 years, with a range of 0 (HC) to 76 (AC). Only at location CC, which ranks as the poorest site based on the growth of the walnut in pure plots, did this species significantly benefit black walnut.

CONCLUSIONS

Nurse crops may alter a site through soil influences (e.g., nitrogen accretion (Hansen and Dawson, 1982)), microclimate changes (e.g., temperature modification (Funk et al., 1977)), vegetation changes (e.g., rate or direction of succession), and/or through pest habitat changes (e.g., leaf disease incidence). Although this study was not designed to determine which, or what combination, of the above contributed to the observed walnut response, we can conclude that all three of the species tested can improve growing conditions for black walnut on some soil types and topographic conditions.

Autumn-olive stimulated the walnut trees on four of the five sites tested and was especially effective on the sites where the walnut trees grew slowest in pure plots. Thus, it may have potential for obtaining successful walnut plantings on sites currently considered questionable for this site-demanding species.

Black locust has been interplanted with black walnut for many years, with mixed success (Chapman, 1935; Seidel and Brinkman, 1962). General-

ly, the rapid growth of the locust has been detrimental to the walnut, unless an infestation of locust borer or other removal mechanism intervened. In this study, after the locust trees were girdled at age 5, they continued to stimulate walnut growth, as was noted also by Carmean et al. (1976).

European alder does not appear to be a good nurse crop for black walnut. It was beneficial only on the poorest site tested. And it appears to be sensitive to allelopathic competition from the walnut.

Based on the results of this study, it appears that nurse crops can play an important role in walnut management. However, it is necessary to select and match the nurse crop to the growth characteristics of the primary crop species and to determine the interaction of the nurse crop with the planting site. Experiments such as this one with a variety of species on a variety of sites can provide leads in this research. However, a better long range approach to the development of this cultural practice for forest management may be to determine the basic growth factor needs of the primary crop, determine how and to what extent nurse crop species alter the availability of growth factors on given sites, and then match the primary crop to the nurse crop and the site.

ACKNOWLEDGEMENTS

This experiment was planned by Robert E. Phares and John E. Krajicek. We thank the Shawnee National Forest, the Missouri Department of Conservation, and the Pierson-Hollowell Company, Inc., for providing experimental areas. And we thank the many people who assisted in collecting data and maintaining the plantations during the years of this study, especially Ray Vinyard, Mike Cook, Elbert Rendleman, and Mace Clark.

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