GRASS CONTROL IMPROVES EARLY GROWTH OF BLACK WALNUT MORE THAN EITHER DEEP RIPPING OR IRRIGATION

J. W. Van Sambeek and F. D. McBride

Abstract--Chemical control of a tall fescue sod (Festuca arundinacea Schreb.) using glyphosate and simazine improved early tree growth of black walnut (Juglans nigra L.) more than either deep ripping or irrigation on an upland old field site in southern Illinois. Growth of trees with irrigation and grass control was less than with grass control only; however, irrigation alone to maintain soil moisture levels above -0.5 atmospheres had no effect in the absence of grass control. Planting germinated seed at the intersection of the 30 inch deep ripping furrows was beneficial with grass control, but had no effect without grass control. None of the treatments significantly altered long-term soil mineral composition in the upper 24 inches. The study supports the conclusion that black walnut can be managed for nuts above a 9 foot long veneer log on marginal agricultural lands with shallow siltpans or fragipans using agroforestry practices.

Key words: Chemical weed control, subsoiling, Juglans nigra L., agroforestry, fragipans.

INTRODUCTION

Although black walnut (Juglans nigra L.) normally requires deep, well-drained sites for rapid growth, acceptable growth can potentially be obtained on many old field sites if properly managed. Old field sites with site indices as low 55 feet at age 50 years can be managed for black walnut using agroforestry techniques to produce both nuts and timber (Garrett et al. 1989). On such sites, trees are intensively managed for a high-quality veneer log and a large crown for nut production.

Many old field sites typically have shallow siltpans or fragipans which limit rooting depth and the amount of available soil moisture during the growing season. Potentially, deep subsoiling

---

[1]Research Plant Physiologist and Forestry Technician, USDA Forest Service, North Central Forest Experiment Station, Southern Illinois University, Carbondale, IL 62901.

or ripping 2 feet or more in depth can break up shallow hardpans and increase soil moisture storage capacity and effective rooting depth. Ripping may also improve water penetration and internal soil structure (Dennington 1989). Increased growth of both loblolly and shortleaf pines has been observed for 5 years after ripping on low-quality hardwood sites in Georgia (Berry 1979).

Nearly all studies with black walnut to evaluate weed control have demonstrated that some type of weed control during the establishment phase is essential for early acceptable growth (Van Sambeek and Rietveld 1982, Van Sambeek 1989). Most studies suggest black walnut is a poor competitor for limited available soil moisture. Irrigation during periods when soil moisture is limited, or deep ripping to increase water penetration and storage could potentially reduce the need for annual weed control on many of these old field sites. Past studies with irrigating black walnut have produced inconclusive results as to its benefits (Dey et al. 1987, Funk et al. 1982, Lucier and Hinckley 1982).

The purpose of this study was to determine how three pre- or post-planting cultural practices (1) affect the survival, growth, and mineral composition of black walnut trees and (2) alter the soil microenvironment. We planned to evaluate the interactions between chemical weed control, deep ripping, and irrigation on an upland old-field site for establishment of black walnut.

SITE DESCRIPTION

An upland, slightly eroded, old field ridge in Jackson County, Illinois was selected as our planting site in September 1979. This 2.2 acre site is part of a 40 acre Hardwood Research Demonstration Area maintained by the USDA Forest Service, North Central Forest Experiment Station on the Southern Illinois University Farms, Carbondale, Illinois. The planting is located on the eastern toe of an east-west ridge with south facing slopes of 5 to 15 degrees. The soil is Hosmer silt loam (fine-silty, mixed, mesic Typic Fragiudalfs) (Herman et al. 1979). This soil is classified as acceptable for mixed hardwood woodlands with a site index of 70 feet at age 50 for white oak.

Hosmer silt loams are alluvial deposits with moderately well drained soils above the fragipan (Grossman et al. 1959). These soils typically have an 8- to 12-inch deep loam topsoil overlaying an 8- to 12-inch deep clay loam subsoil with a well-formed 12- to 36-inch deep horizontal siltpan (fragipan). The fragipan is an indurated layer which impedes soil drainage, causing water-saturated conditions for extended periods in the winter and spring and physically impedes root growth when the soil dries in the summer (Funk et al. 1982). Hosmer silt loams are easily eroded; have naturally low pH, fertility, and organic matter content; and respond well to liming and fertilization.

Bulk density averaged 1.48 g/cm^3 with an average available soil moisture content of 22% at field capacity above the fragipan. The soil moisture above the fragipan averaged 38% water by volume and 40% water by volume below the fragipan at field capacity (-0.1 atmospheres). Mean annual precipitation over the 10 year period from 1979 to 1990 was 43 inches and ranged from a minimum of 29 inches in 1980 and 1986 to a maximum of 55 inches in 1985.

In October 1979, the area was limed with 3.5 tons per acre of crushed limestone and fertilized with 150 pounds per acre each of 6-24-24 NPK starter fertilizer and 0-46-0 triple phosphate. The entire planting site, including the areas that were ripped in September, was disked to a depth of 6 inches to incorporate lime and fertilizer and to disturb an existing grass sod. Following disking, the planting site was reseeded to tall fescue (*Festuca arundinacea* Schreb. cultivar Ky-31) and winter wheat to prevent erosion.

EXPERIMENTAL METHODS

The area was divided into 24 plots each measuring 54 by 72 feet. The experiment was set out as three replications of a 2 x 2 x 2 factorial design with eight treatments. Treatments consisted of all combinations of with and without chemical weed control, with and without irrigation, and with and without ripping.

Chemical weed control was conducted in 12 plots using a mixture of glyphosate (2.7 quarts Roundup per acre) and simazine (4.4 pounds Caliper 90 per acre) applied in a 5-foot-diameter circle around each walnut each spring for the first 6 years after establishment. Occasionally, glyphosate (2.5 quarts Roundup per acre) was reapplied in late summer to control foxtail. Chemical weed control treatments to remove approximately 20 to 25% of the tall fescue ground cover were discontinued after the seventh growing season.

Irrigated plots were watered to field capacity after available soil moisture decreased to -0.5 atmospheres. One 2-foot-long soil moisture tensiometer (Irrometer) with a vacuum gauge was installed at a 45° angle in the center of each of the 12 irrigated plots to a depth of 12 inches. Soil water potential was monitored biweekly, and plots were individually irrigated with modified satellite rain birdies that delivered 1.1 inch per day for a 40 hour period. The irrigation treatment was continued through the 1986 growing season using water from a nearby farm pond.

One half of the plots were ripped to a depth of 30 inches on September 8, 1979 with a chisel plow having three tines 3 feet apart. Treated plots were cross-checked with the center tine on an 9- x 9-foot grid. Ripping was done when the soil was extremely dry to maximize fracturing and uplifting of the fragipan (Kardos 1960).

Germinating seed were direct-seeded in each plot on a 9- x 9-foot spacing in the spring of 1980 using seed collected in the fall of 1979 from 10 widely distributed black walnut trees in Jackson County, Illinois. Seed was husked, floated to retain sinkers, and stored in 2-mil-thick plastic bags over winter in a walk-in cooler at 35 to 39°F. In early April, seed was set in a warm greenhouse and allowed to germinate. We started planting germinated seed on April 23 and finished within six days. Two germinating seed were sown per planting spot and thinned to a single germinant in late June. In the ripped plots, germinating seeds were placed in the intersecting ripped furrows made by the center tine of the chisel plow.

Each fall for the first 6 years, each tree was correctively pruned to a single terminal shoot. Lateral pruning was started in 1984 and was repeated annually to maintain 60% live crown until a 9 foot clear bole was produced. To reduce incidence of insect and leaf diseases, all trees were sprayed each summer for 6 years with carbaryl (0.15 ounces Sevin 50W per gallon) and benomyl (0.07 ounces Benlate 50DF per gallon) applied to drip point.

In November 1987, we thinned all plots that had chemical grass control and a crown competition factor (CCF) over 50 (Schlesinger and Ashley 1981). Half of these plots were selectively thinned to retain the best tree out of each pair of trees within each row. The remaining plots were row thinned removing alternate diagonal rows of trees.

Height (HT) in meters and diameter at ankle height (DAH) in centimeters was taken 10 cm above the soil each fall through the eighth growing season. Height and diameter at breast height (DBH) was measured after the ninth and tenth growing seasons. Estimated DAH was calculated from measured DBH using the regression equation:

$$DAH = DBH + 0.1\ DBH + 2.0.$$

Stem biomass in grams was calculated according to Williams and McClenahen (1984) using the following equation for hardwoods with an ovendry specific gravity of 0.50 to 0.56:

$$\text{Log}_{10}\ \text{Biomass} = 1.1843 + 1.5327\ \log_{10} DAH^2.$$

Composite foliar samples of leaflets of one leaf from the upper, middle, and lower third of each crown from the center eight trees of each plot was sampled in September of the first two growing seasons. Leaf samples were analyzed for potassium, calcium, and magnesium using standard atomic absorption spectrophotometric methods.

Composite soil samples were taken at the 0- to 8-inch, 8- to 16-inch, and 16- to 24-inch depths from three randomly chosen locations within each plot two to four times each growing season through 1984 for nutrient analyses. After drying at 140° F, soil samples were ground, subsampled, and analyzed for pH (1:1 soil: water solution by weight), for nitrate nitrogen and phosphorus colorimetrically, and for potassium, calcium, and magnesium content using standard atomic absorption spectophotometric methods. Gravimetric soil moisture determinations were periodically conducted in 1980 to determine effectiveness of irrigation treatments. Thermocouple wires were buried horizontally 6, 12, 18, and 24 inches deep in the center of each plot in 1983. Soil temperatures were periodically monitored until the wires were heavily damaged by field mice.

Data were analyzed using analysis of variance on plot means in a three-way factorial randomized block design to test for main effects (weed control, ripping, and irrigation) and their interactions at the alpha = 0.05 level. Scheffe's method of contrast at the alpha = 0.05 level was used to determine differences among significant main effects, and least significant difference was determined from ANOVA error mean square for interactions. After all data manipulations and analyses were complete, stem biomass in grams was converted to pounds (453.6 grams per pound) for presentation in the results section. Analysis of variance for split plots with either year or soil depth as subplots was done to determine if changes occurred over time or across the soil profile.

RESULTS

Treatment Effects on Tree Growth

Black walnut survival before thinning ranged from 64% to 99% among the eight treatment combinations. Chemical grass control resulted in reduced tree survival (71%) compared to tree survival in the plots without grass control (94%). Nearly all mortality occurred during the 1981 growing season which followed an exceptionally dry growing season. Mortality was apparently associated with herbicide damage, because simazine applied in 1980 was not dispersed before repeat herbicide treatments in the spring of 1981.

Overall, black walnut trees under intensive management showed minimally acceptable tree growth (1.6 to 2.0 feet per year or more of height growth) during the first ten growing seasons after establishment whether in plots without preplant ripping (Fig. 1) or on plots that had been ripped to a depth of 30 inches (Fig. 2). According to site index curves published by Carmean et al. (1989), site index of dominant and codominant walnuts with chemical grass control would be approximately 40 to 50 feet at age 50. Without grass control, projected site index curves were less than 20 feet at age 50.

To test for possible interactions among the various treatments, annual biomass increments were determined and subjected to analyses of variance (Table 1). Overall, these analyses showed that effects of grass control persisted throughout the study, although chemical control was discontinued after the six growing seasons. Once the walnut seedlings were established, interactions among weed control with ripping or with irrigation occurred after the third and fourth growing season, respectively. These interactions persisted through the eighth and ninth growing seasons.

Table 1.--Probability for difference within main effects and their interactions from analyses of variance for growth in walnut biomass during the first ten growing seasons.

Growth season	Chemical weed control	Ripping	Irrigation	WCxR	WCxI	RxI	WCxRxI
1980	0.1***	9.1	78.6	8.5	96.9	58.0	50.2
1981	0.1***	15.1	88.7	18.9	78.8	51.8	60.2
1982	0.1***	9.6	92.9	9.0	97.8	26.1	35.9
1983	0.1***	2.4*	65.7	1.7*	39.2	0.7**	0.9**
1984	0.1***	4.9*	1.3*	4.3*	0.9**	27.8	30.8
1985	0.1***	0.5**	0.1***	0.4**	0.1***	7.2	7.2
1986	0.1***	28.1	1.6*	23.5	1.4*	38.2	47.7
1987	0.1***	4.8*	0.6**	2.7*	0.6**	27.0	40.1
1988	0.1***	9.4	0.9**	9.9	0.9**	71.6	46.3
1989	0.1***	93.9	4.5*	69.5	9.8	38.7	77.2

Preplant ripping in combination with chemical grass control affected individual walnut biomass growth over that of walnut with grass control only in four of the first ten growing seasons (Table 1). Walnut trees with chemical grass control on ripped plots sequestered carbon at a higher rate than trees on plots that were

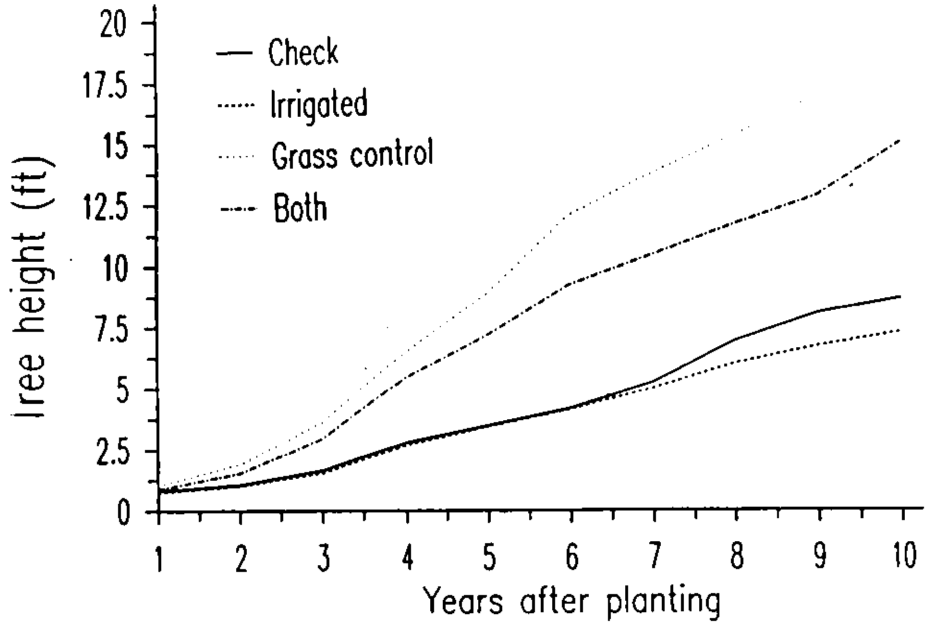

Figure 1.--Average tree height during the first ten growing seasons for walnuts with and without grass control and irrigation on plots without preplant ripping (subsoiling).

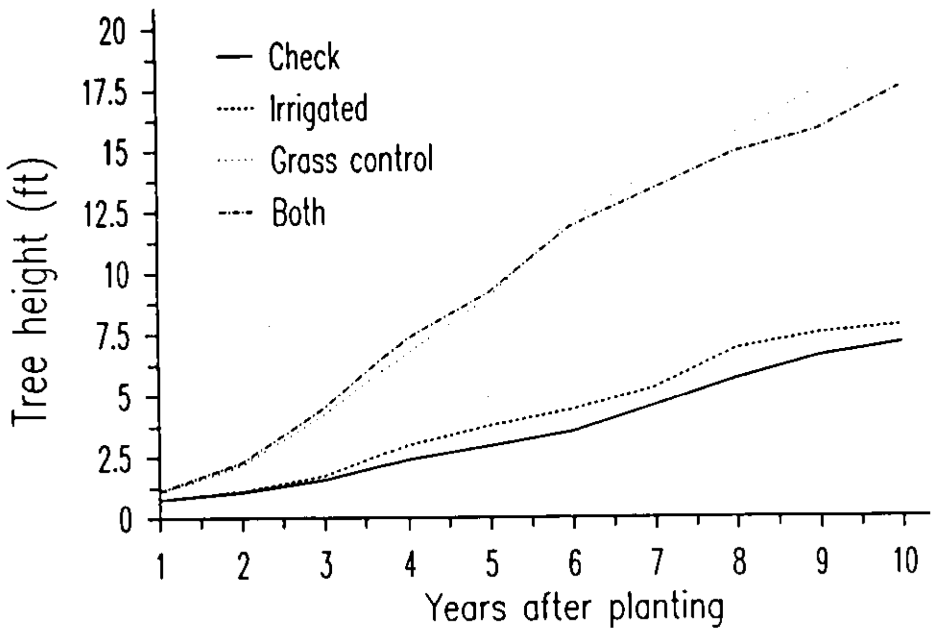

Figure 2.--Average tree height during the first ten growing seasons for walnuts with and without grass control and irrigation on plots with preplant ripping (subsoiling).

not ripped during the fourth through the seventh growing season (Table 2). During the same time period, tree growth was essentially the same on plots without chemical weed control with and without preplant ripping. After the use of chemicals to control tall fescue was discontinued in 1987, the beneficial effects of ripping did not persist.

Table 2.--Combined effects of chemical grass control and preplant ripping on annual stem biomass growth per tree during the first ten growing seasons.

	Without Grass Control		With Grass Control		5% Least
	Without	With	Without	With	sign.
Year	Ripping	Ripping	Ripping	Ripping	diff.
	- - - - - - - - - - pounds dry weight - - - - - - - - - -				
1980	0.003	0.003	0.010	0.011	0.004
1981	0.008	0.011	0.068	0.121	0.055
1982	0.040	0.037	0.586	0.876	0.244
1983	0.086	0.072	1.701	2.158	0.266
1984	0.154	0.132	4.500	5.800	0.904
1985	0.22	0.18	7.63	10.14	1.15
1986	0.51	0.42	9.88	11.49	2.36
1987	1.57	1.30	11.75	15.92	2.73
1988	1.01	1.06	9.04	12.33	2.80
1989	1.63	1.41	14.88	15.21	2.09

Irrigation in combination with chemical grass control affected individual walnut biomass growth in six of the ten growing seasons (Table 1). Irrigation to maintain available soil moisture above -0.5 atmospheres in the plots with chemical grass control showed reduced tree growth compared to the plots with chemical weed control only during the fourth through the ninth growing season (Table 3). During this same period, tree growth on plots without chemical weed control was essentially the same on plots with and without irrigation. The irrigation effects appeared to have rapidly diminished after chemical weed control and irrigation treatments were terminated.

After eight growing seasons, the crown competition factor (CCF) in plots with chemical weed control exceeded 60 (Table 4). Selective thinning of one half of the plots resulted in a selection gain of nearly 9% in average tree diameter compared to average tree diameter before thinning. Row thinning resulted in a slight

Table 3.--Combined effects of chemical grass control and six years of irrigation on annual stem biomass growth per tree during the first ten growing seasons.

Year	Without Grass Control		With Grass Control		5% Least Sign. Diff.
	Without Irrigation	With Irrigation	Without Irrigation	With Irrigation	
	- - - - - - - - - - - pounds dry weight - - - - - - -				
1980	0.003	0.003	0.010	0.011	0.004
1981	0.008	0.011	0.098	0.091	0.055
1982	0.034	0.043	0.728	0.733	0.244
1983	0.060	0.098	1.988	1.871	0.266
1984	0.110	0.154	5.998	4.278	0.904
1985	0.20	0.22	10.69	7.08	1.15
1986	0.42	0.51	12.72	8.42	2.36
1987	1.46	1.43	16.76	10.94	2.73
1988	1.04	1.04	13.43	7.94	2.80
1989	1.65	1.37	16.41	13.67	2.09

Table 4.--Selection gains for black walnut for first pre-commercial thinning after seventh growing season.

Thinning method	Before Thinning			After Thinning			
	# of trees	Average DBH	CCF	# of trees	Average DBH	New CCF	Selection Gain
		-in-	-%-		-in-	-%-	-%-
Selection	119	3.83	63	71	4.17	41	9.0
Row	110	3.71	57	58	3.65	29	-1.7

decrease in average tree diameter. The CCF after thinning was substantially higher in the selectively thinned plots because if a tree had died during the first seven growing seasons it was chosen as the poorer of each pair of trees. No adjustments were made for mortality in the plots that were row thinned. As a result, the latter plots averaged almost 30% fewer trees after thinning.

Effects on Walnut Foliar Nutrients

There were substantial differences in foliar potassium, calcium, and magnesium between the first and second growing seasons (Table 5). The reduced levels of foliar nutrients during the first growing season may have resulted because foliage was collected from recent germinants or because the 1980 drought resulted in premature nutrient reabsorption. The latter conclusion is partially supported by the increased foliar potassium levels (0.5%) of the trees in the irrigated plots compared to foliar potassium levels (0.37%) of the trees without irrigation. Irrigation had no effect on foliar potassium levels at the end of the second growing season which had near normal levels of precipitation. Irrigation also had no effect on foliar calcium or magnesium during either year.

Table 5.--Average black walnut foliar nutrient levels in September of the first and second growing season.

Year	Potassium	Calcium	Magnesium
	- - - - - - -	% - - - - - - -	
1980	0.43	1.45	0.42
1981	1.29	2.76	0.48
5% LSD =	0.6	0.9	0.30

Foliar concentrations of both calcium and magnesium were increased by chemical control of the tall fescue sod. In 1980 and 1981, leaflets on trees in the plots with chemical weed control contained 0.26 and 0.28% more calcium than leaflets on trees from plots without chemical weed control. Likewise, leaflets on trees in plots with chemical weed control contained 0.055 and 0.048% more magnesium during 1980 and 1981, respectively, than leaflets from trees in plots without chemical weed control.

Effects on Soil Microenvironment

Of the three cultural practices tested, only chemical weed control altered the average soil temperature within the rooting zone (6 to 24 inches) during the 1980 growing season. Soil temperatures in the rooting zone of the plots with a tall fescue cover during early June averaged 61.3^{o} F and were 2.9^{o} F lower than in plots with chemical grass control. By mid-June and early July, differences in average soil temperature increased to 4.5° F. By late July, average soil temperatures in the plots with and without a grass cover had increased to 72.9 and 74.8° F, respectively. Average soil temperature during the growing season at 6, 12, 18, and 24 inches ranged from 69.8, 68.4, 67.5, and 66.4° F, respectively. Although chemical weed control raised the average soil temperature, it did not significantly alter the soil temperature gradient for 6 to 24 inches below the soil surface.

Although both chemical weed control and irrigation affected the gravimetric soil moisture levels, they did so at different times during the 1980 growing season (Table 6). In June, during the early part of the growing season, plots with chemical weed control averaged 6.0% more available soil moisture than the plots without chemical weed control. After the tall fescue sod had

Table 6.--Average gravimetric soil moisture levels within the 0-24 inch deep rooting zone during the 1983 growing season for plots with and without chemical weed control and with and without irrigation.

Month	Weed Control[a] Without	Weed Control[a] With	Irrigation[a] Without	Irrigation[a] With
	- - - % - - -		- - - - % - - -	
June	30.4	36.4	33.3	33.5
July	38.1	38.8	38.1	38.8
August	35.0	36.2	36.0	35.2
October	25.2	27.6	23.8	28.9

[a] The 5% LSD value for differences between treatments is 1.1%.

seeded and became quiescent, differences in available soil moisture averaged between 0.7 and 2.4% for the remainder of the growing season. Conversely, the effects of irrigation became more pronounced near the end of the growing season. At the end of the growing season, available soil moisture in the irrigated plots was approximately 5% higher than in the plots without irrigation. Differences during most of the growing season averaged less than 1% between plots with and without irrigation.

Soil pH increased following liming in the fall of 1979; however, effects persisted only for one year (Table 7). None of the eight treatments significantly altered the average soil pH in the 0 to 24 inch rooting zone, suggesting that all changes in soil pH were related to the liming done in the fall of 1979. Although differences in soil pH were found across the rooting zone (Table 8), none of the eight treatments altered the pH gradient.

Of the three cultural practices tested, only chemical weed control altered the available soil nitrate nitrogen concentrations during the first four growing seasons. In plots where approximately 20% of the tall fescue sod was removed, soil nitrate nitrogen levels averaged 51.4 ppm compared to 43.1 ppm for plots without chemical weed control. Soil nitrate nitrogen varied with depth through the soil profile, but did not show an interaction with any of the three factors tested. Soil nitrate nitrogen in the top 8 inches (A horizon) averaged 4 to 8 ppm higher than in the B horizon and upper subsoil (Table 8).

Table 7.--Average soil pH, nitrate nitrogen, available phosphorus, and exchangeable potassium, calcium, and magnesium in top 24 inches of soil before (1979) and after liming and fertilizing.

Year	pH	Nitrate nitrogen	Available Phosphorus	Potassium	Calcium	Magnesium
		- - - - - - - - - - - - -	- - - -	ppm - - - -	- - - - - - -	- - - - -
1979	5.45	44.7	13.7	56	734	161
1980	5.99	46.9	56.7	106	1982	276
1981	5.28	52.4	29.8	125	2112	281
1982	5.41	45.0	39.9	118	2152	252
1983	5.49	ND	29.6	104	1754	256
1984	5.50	ND	ND	114	1397	246
5% LSD =	0.18	7.8	5.4	8	182	34

Unlike soil nitrate nitrogen, available soil phosphorus did not show differences related to any of the three factors tested. Significant differences were found from year to year during the first four growing seasons with the highest levels of 56.7 ppm found in 1980 (Table 7). After peaking in 1980, available soil phosphorus averaged between 30 and 40 ppm during the third to the

Table 8.--Soil pH, nitrate nitrogen, available phosphorus, and exchangeable potassium, calcium, and magnesium at 8 inch intervals for 3 to 5 years after liming and fertilizing.

Depth	pH	Nitrate nitrogen	Available Phosphorus	Potassium	Calcium	Magnesium
		- - - - - - - - - - - -		ppm - - - - - - - - - - - - - -		
0-20	6.00	51.2	42.7	88	2181	156
20-40	5.52	47.2	31.0	105	1628	244
40-60	5.01	43.3	28.0	118	1256	335
5% LSD =	0.10	6.6	5.4	7	149	18

fifth growing season. Available soil phosphorus was concentrated in the upper soil layer (Table 8).

As expected for a low fertility soil, all plots showed significant changes in exchangeable potassium, calcium, and magnesium following tilling, fertilizing, and liming (Table 7). Overall, exchangeable potassium showed an interaction in response to preplant ripping and postplanting irrigation. Plots with neither treatment averaged only 94 ppm potassium. Plots that were only irrigated averaged 110 ppm. When ripped, irrigated plots averaged 102 ppm compared to 108 ppm for plots without irrigation.

Available soil calcium showed a similar interaction as for soil potassium. Plots with neither treatment averaged only 1478 ppm calcium, while ripped plots averaged 1807 ppm. Irrigated plots without ripping averaged 1699 ppm calcium compared to 1769 ppm for irrigated plots that were ripped. Overall ripping increased the soil calcium concentrations. Because none of the three factors tested affected the soil magnesium concentrations, we assume that a portion of the increased calcium was released from the fragipan.

DISCUSSION

Overall, of the three pre- and post-planting cultural practices evaluated, chemical control of a tall fescue sod had the greatest effect on growth of black walnut, its foliar nutrient content, and several of the measured soil microenvironment parameters. Improved black walnut biomass growth was associated with increased concentrations of soil nitrate nitrogen and available soil moisture in response to removal of approximately 10 to 20% of the tall fescue ground cover. Improved walnut growth outside a tall fescue ground cover has been attributed to increased levels of available soil moisture (Todhunter and Beineke 1979). Recent studies have suggested increased concentrations of soil nitrate nitrogen following removal or conversion of a tall fescue sod to a herbaceous cover may be more important than altered available soil moisture levels (von Althen 1985, Van Sambeek et al. 1989). Several papers have reported on the production of phytotoxins by tall fescue that can adversely affect growth of associated vegetation including black walnut (Rink and Van Sambeek 1985). Potentially, phytotoxins produced by tall fescue reduces the soil microflora populations responsible for conversion of ammonium nitrogen to nitrate nitrogen and, thereby, result in reduced levels of soil nitrate nitrogen and reduced tree growth.

Ripping of a shallow fragipan was beneficial for establishing black walnut when done in combination with chemical weed control. Our results suggest the trees quickly utilized the increased rooting depth around the ripped furrows; however, improved biomass growth was not sustained. Potentially, slumping occurred after several years, and increased rooting depth was lost. Several past studies have shown that ripping is beneficial if done in association with fertilization and liming (Engelbert and Troug 1956, Fehrenbacher et al. 1958, Losche 1972). In our study, soil nitrate nitrogen, available phosphorus, and exchangeable potassium and calcium showed temporary increases during the first four years after fertilization and liming of the entire site. Potentially, the lack of a sustained fertilizer and liming response resulted in a reduced tree growth response to deep ripping.

In general, irrigation resulted in no effect or reduced tree growth when soil moisture levels were maintained above -0.5 atmospheres. Reduced growth could have been associated with reduced soil aeration within the root zone or increased levels of leaf spotting diseases. Irrigation may have reduced soil aeration and extended the period when perched water tables existed above the fragipans. Irrigation for 40 hour periods may have led also to increased incidence of anthracnose, which can result in premature leaf fall and reduced tree growth (Dey et al. 1987, Kessler 1984). Results from this study support the conclusions from several previous studies (Funk et al. 1979, Van Sambeek et al. 1989) that increased availability of soil nitrogen will offset reduced available soil moisture. In these studies, black walnut growth was improved when walnut was interplanted with either nitrogen-fixing autumn olive or hairy vetch, although available soil moisture had been significantly reduced compared to non-nitrogen-fixing ground covers.

Overall this study confirms previous observations that black walnut can achieve acceptable growth rates on an upland old field site with a relatively low site index if intensively managed. Management options will probably be limited to a high quality 9 foot long veneer log and a large crown for nut production.

ACKNOWLEDGMENT

We would like to acknowledge the assistance of Southern Illinois University for providing the study site, Springdale Orchards for donating the ripping equipment, Lisa Lambus for conducting the nutrient analyses, Felix Ponder, Jr. for his advice during the study establishment, and Richard C. Schlesinger for assistance with the precommercial thinning.

LITERATURE CITED

Berry, C. R. 1979. Subsoiling improves growth of pine on a Georgia Piedmont site. USDA Forest Service Research Note SE-284. 3 p.

Carmean, W. H.; Hahn, J. T. and Jacobs, R. D. 1989. Site index curves for forest tree species in the eastern United States. USDA Forest Service General Technical Report NC-128, p. 31-33.

Dennington, R. W. 1989. Ripping can improve tree planting success. USDA Forest Service Management Bulletin R8-MB 31, 2 p.

Dey, D.; Conway, M. R.; Garrett, H. E.; Hickley, T. S. and Cox, G. S. 1987. Plant-water relationships and growth of black walnut in a walnut-forage multicropping regime. Forest Science 33:70-80.

Engelbert, L. E. and Troug, E. 1956. Crop response to deep tillage with lime and fertilizer. Soil Sci. 20:50-54.

Fehrenbacher, J. G.; Vavra, J. P. and Lang, A. L. 1958. Deep tillage and deep fertilization experiments on a claypan soil. Soil Sci. Soc. Proceedings 22:553-557.

Funk, D. T.; McBride, F. D.; Robinson, G. L.; Losche, C. K. and Roth, P. L. 1982. Interactive effects of provenance and irrigation treatments on growth and anthracnose incidence of black walnut. In: Proceedings, Seventh North American Forest Biology Workshop. University of Kentucky Press, Lexington, KY. p. 172-178.

Funk, D. T.; Schlesinger, R. C. and Ponder, F., Jr. 1979. Autumn-olive as a nurse plant for black walnut. Bot. Gaz. 140(Suppl.):S110-S114.

Garrett, H. E.; Jones, J. E. and Slusher, J. P. 1989. Integrated forestry-farming (agroforestry) with eastern black walnut--a case study. In: The Continuing Quest for Quality. Walnut Council, Indianapolis, IN. p. 248-259.

Grossman, R. B.; Fehrenbacher, J. B. and Beavers, A. H. 1959. Fragipan soil of southern Illinois. Soil Sci. Soc. Amer. Proc. 23:65-70.

Herman, R. J.; Miles, C. C.; Dungan, L. A.; Currie, B. E. and Ice, P. W. 1979. Soil Survey of Jackson County, Illinois. USDA Soil Conservation Service and Forest Service in cooperation with Illinois Agricultural Experiment Station. 380 p.

Kardos, M. 1960. Deep chiseling gives short-lived benefits. Sci. Farm. 15:7.

Kessler, K. J., Jr. 1984. Similarity of annual anthracnose epidemics in young Juglans nigra plantations from 1978 through 1982. Plant Disease 68:571-573.

Losche, C. K. 1972. Vertical tillage fails to improve black walnut seedling growth on a poorly drained site. Tree Planters' Notes 23(1):7-9.

Lucier, A. A. and Hinckley, T. M. 1982. Phenology, growth, and water relations of irrigated and non-irrigated black walnut. Forest Ecology and Management 4:127-142.

Ponder, F., Jr. 1980. Fertilization improves black walnut growth on a poorly drained site. Tree Planters' Notes 31(4): 17-19.

Rink, G. and Van Sambeek, J. W. 1985. Variation among black walnut seedlings families in resistance to competition and allelopathy. Plant and Soil 88:3-10.

Schlesinger, R. C. and Ashley, B. S. 1981. Quick reference for thinning black walnut. USDA Forest Service Miscellaneous Publication. 32 p.

Todhunter, M. N. and Beineke, W. F. 1979. Effect of fescue on black walnut growth. Tree Planters' Notes 30(3):20-23.

Van Sambeek, J. W. 1989. Vegetation management in established stands. In: The Continuing Quest for Quality. Walnut Council, Indianapolis, IN. p. 114-125.

Van Sambeek, J. W. and Rietveld, W. J. 1982. Leguminous cover crops can suppress weeds and accelerate growth of black walnut seedlings in intensively cultured plantations. In: Proceedings, Fourth Central Hardwood Forest Conference, University of Kentucky, Lexington, KY. p. 229-243.

Van Sambeek, J. W.; Schlesinger, R.C.; Roth, P. L. and Bocoum, I. 1989. Revitalizing slow-growth black walnut plantings. In: Proceedings, Seventh Central Hardwood Forest Conference; USDA Forest Service General Technical Report NC-132; p. 108-114.

Williams, R. A. and McClenahen, J. R. 1984. Biomass prediction equations for seedlings, sprouts, and saplings of ten central hardwood species. Forest Science 30: 523-527.

PROCEEDINGS

THE 2ND CONFERENCE
ON
AGROFORESTRY
IN NORTH AMERICA

Springfield, Missouri
August 18-21, 1991

Edited By
H.E. 'GENE' GARRETT
The School of Natural Resources
University of Missouri
Columbia, Missouri 65211

Printed on recycled paper