REVITALIZING SLOW-GROWTH BLACK WALNUT PLANTINGS[1]

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Abstract.--Black walnut (Juglans nigra L.) can be successfully established on many sites; however, tree growth frequently declines to unacceptable rates because of interference by invading understory. In one slow-growing, 17-year-old walnut planting, eliminating the tall fescue (Festuca arundinacea Schreb.) understory by either semi-annual cultivation or annual reseeding with hairy vetch (Vicia vellosa Roth) reduced tree mortality and increased walnut diameter growth. Seeding with sericea lespedeza (Lespedeza cuneata (Dumont) G. Don.) was not as effective as cultivation. Black walnut lateral shoot growth, leaf length and number, leaf leaflet number and area, and leaflet retention also were increased when the tall fescue was removed. The results suggest that slow growth in walnut plantings with tall fescue understories results more from competition for soil nitrate nitrogen than for soil moisture.

INTRODUCTION

Successfully establishing black walnut plantations (Juglans nigra L.) is common now that the importance of controlling weeds during the first 3 to 5 years is recognized. It is commonly believed that continued weed control is not necessary after walnut trees have overtopped the herbaceous competition; however, pure walnut plantings usually do not dominate a site sufficiently to exclude interfering understory vegetation. Because walnut flushes later in the spring and drops its leaves sooner in the fall than most other hardwoods, many cool-season forbs and grasses are not shaded out. At full site occupancy, about 45 percent of the solar radiation still reaches the understory in walnut plantings (Schlesinger and Van Sambeek 1986).

Previous research has shown that the type of understory vegetation can affect walnut growth. Van Sambeek (1988) reported that sowing hairy vetch, an annual cool-season legume, between rows of walnut seedlings can accelerate early walnut growth. He also showed that underplanting perennials, such as crownvetch and sericea lespedeza, can stimulate growth of established walnut saplings. Roth and Mitchell (1982) tested the effects of eight ground covers on walnut growth and found the best growth with sericea lespedeza and the poorest growth with tall fescue. Todhunter and Beineke (1979) described an interaction for height growth among half-sib walnut progeny growing on an area with dense tall fescue cover and an area with 70 percent forbs. They attributed reduced walnut growth to severe competition for soil moisture and nutrients by tall fescue.

Black walnut is responsive to removing grass sods. Holt and Voeller (1975) demonstrated that after 4 years of complete weed control in a 10-year-old walnut orchard, diameter growth and nut production for treated trees were nearly double that of trees growing in fescue sod. Recently, von Althen (1985) reported that chemical weed control around 8-year-old walnut saplings increased annual height growth by more than 0.5 m over trees in quackgrass sod. Increased growth was accompanied by increases in leaf length and foliar nitrogen content. In one slow-growing walnut plantation, growth increased in proportion to the area of chemical weed control up to complete removal of a smooth bromegrass sod (Miller et al. 1987).

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The objectives of our study were to determine to what extent an observed growth decline in walnut trees with a tall fescue understory could be reversed, what types of vegetation management practices are most effective, and what factors are involved in the interference process.

MATERIALS AND METHODS

Our study began in 1981 in a walnut planting on a wide floodplain adjacent to Indian Creek in Jackson County, Illinois. The planting was established in the spring of 1965 with 1-0 seedlings at a spacing of 3.7 m by 6.1 m. Annual mowing between 1973 and 1981 resulted in the development of a dense, tall fescue (Festuca arundinacea Schreb.) sod. During this same period, walnut height growth slowed and some of the trees began to show top dieback and epicormic sprouting along the main bole. In addition, total mortality had increased from less than 2 percent in 1972 to 8 percent in 1981 when the ground cover study began.

The soils are a mixture of Sharon silt loam (a coarse-silty, mixed, acidic, mesic, Typic Udifluvent) and Bonnie silt loam (a fine-silty, mixed, acidic, mesic, Typic Fluvaquent). These soils are classified as suitable to questionable for growing walnut because of their poor internal drainage (Losche et al. 1980). Some mottling is present within the 1.5 m deep silty loam topsoil that overlies a fine gravelly or silty sand layer.

Twelve plots of 9 to 15 trees each were identified in the summer of 1981. Each plot was separated by a 3.7-m- or 6.1-m-wide tall fescue isolation strip. The plots were stratified (blocked) into small, average, and large dbh-size classes. The following four treatments were assigned randomly within each stratum: (1) retain tall fescue sod (check), (2) cultivate semi-annually (May and August), (3) cultivate and seed to a perennial legume, and (4) cultivate annually and reseed to an annual legume. Because the crownvetch (Coronilla varia L.) seeded in 1981 failed to become established, treatment 3 was reseeded with sericea lespedeza (Lespedeza cuneata (Dumont) G. Don.) in the spring of 1983. Treatment 4 has been cultivated annually in August and reseeded with hairy vetch (Vicia vellosa Roth). Because the planting was on a wide floodplain, we did not use a complete chemical control treatment with pre- and post-emergent herbicides. The plantation was thinned in 1981 before beginning treatments to avoid possible confounding with intraspecific competition.

Annual measurements since 1982 include dbh, total live tree height and lateral shoot elongation. Composite foliage samples were collected in late June from each plot by removing leaflets of one mid-shoot leaf from a mid-crown branch on the south side of each tree. Foliar samples were analyzed for total nitrogen by the Kjehldahl method, phosphorus by the vanadomolybdophosphoric yellow method, and potassium by flame emission. Composite soil samples were collected each fall from each plot from three randomly located positions at four depths (0-20, 20-40, 40-60, and 60-80 cm). They were analyzed for pH in a 1:2 soil:water solution, for nitrate nitrogen and phosphorus by colorimetry, for potassium by flame emission, and for organic matter content by loss-on-ignition.

The study was expanded in 1985 and 1986 to determine what factors were associated with differences in tree growth. In the spring of 1985, point dendrometers were placed on three trees randomly located within each plot and read semi-weekly during the 1985 and 1986 growing seasons. In late June, number of leaves per elongating shoot, leaf rachis length, and number and area of leaflets per leaf were also determined on the same material used for the foliar nutrient analyses. In May, July, and October, standing biomass from six 0.3- by 0.3-m subplots within each plot was harvested at the ground line and separated into legumes, other forbs, grasses, and detritus to determine oven dry weights. Percent crown defoliation for all trees was visually estimated to within 5 percent weekly from August through September. Two observers independently estimated the defoliation and then these figures were averaged.

In the spring of 1986, three soil moisture tensiometers were placed randomly within each plot to determine soil moisture deficits at a depth of 60 cm. Daily readings of soil moisture deficit below -10 centibars (field capacity) were summed for each plot to determine cumulative stress days from April 10 to October 7. Daily rainfall was determined with a recording rain gauge.

Analysis of variance was used to interpret results; differences were considered significant at the 5 percent level. Because strata were the replications in this study, the interactions between strata and ground cover treatments could not be determined. A split-plot design using year as a subplot was used to examine for interactions between year and ground cover treatments. Multiple comparisons were made with Duncan's New Multiple Range Test. Average radial growth increments through the growing season were fitted to a polynomial equation to determine Julian dates for 10 and 90 percent of growth completion for each plot (Bocoum 1987). A similar procedure was used to determine Julian dates for 50, 75, and 95 percent defoliation.

RESULTS AND DISCUSSION

Tree Growth Characteristics

Retaining the tall fescue sod resulted in continued tree decline as previously reported by Schlesinger and Van Sambeek (1986) and subsequent mortality as reported here (fig. 1). Conversely,

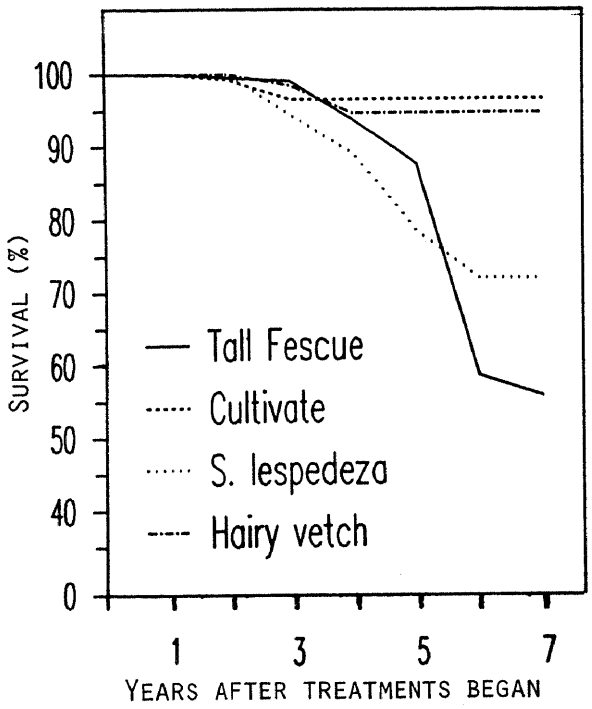

Figure 1.--Walnut survival in a 17-year-old, slow-growth planting by ground cover treatment.

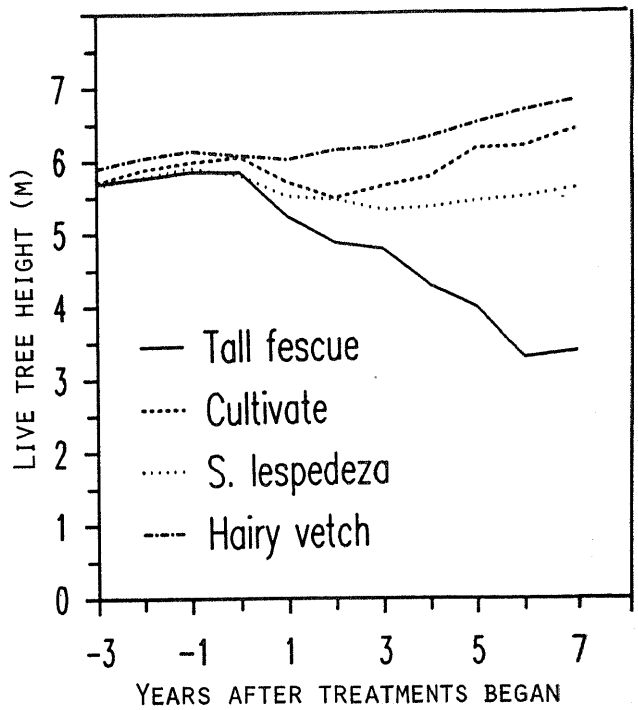

Figure 2.--Average height of study trees before and after ground cover treatments. Treatments began in the fall of 1981 (year 0).

most trees in the semi-annually cultivated and hairy vetch plots ceased crown dieback and developed normal crowns. Trees in the plots seeded with a perennial legume showed a mixed response where tall fescue remained the dominant vegetation until 1986 when sericea lespedeza became the dominant vegetation.

After beginning ground cover treatments, the check treatment showed net negative height growth because each year one or two trees had crown dieback that was not offset by the small increment of height growth on the other live trees (fig. 2). Before beginning ground cover treatments, height growth for all the walnut trees still alive in 1982 had averaged only 0.07 meters annually for the three preceding years. If all live trees during this period had been included, overall annual height growth would have been negative and similar to the growth observed in the check plots after ground cover treatments and begun.

Annual height growth improved first in the plots seeded to hairy vetch and next in those that were cultivated semi-annually (fig. 2). Net negative height growth continued for 3 years in the sericea lespedeza plots where a few trees continued to decline while the majority eventually began to recover. The initial recovery when underplanted with sericea lespedeza was probably in response to the fall 1981 cultivation when seeded to crownvetch and the spring 1983 cultivation when seeded to sericea lespedeza.

Walnut dbh growth showed a slightly different pattern from that of height growth because declining trees do not show marked reductions in stem diameter (fig. 3). Annual dbh growth for the check trees averaged only 0.07 cm, which was less than the 0.12 cm of annual dbh growth that occurred for the 5 years preceding the start of ground cover treatments. Annual dbh growth in the semi-annually cultivated, hairy vetch, and sericea lespedeza plots averaged 0.39, 0.35, and 0.17 cm, respectively. None of the treatments restored annual dbh growth to 0.66 cm, the level that occurred for the first 10 years following plantation establishment (Schlesinger and Van Sambeek 1986).

Differences in radial growth, determined with point dendrometers, were found for time of growth initiation and completion among the dbh strata but not among ground cover treatments (table 1). Trees in the semi-annually cultivated and hairy vetch plots grew approximately 10 days longer than trees with a fescue or sericea lespedeza understory. This difference was not statisticially different because the error term contains a large stratum x treatment interaction. For the semi-annually cultivated plots,

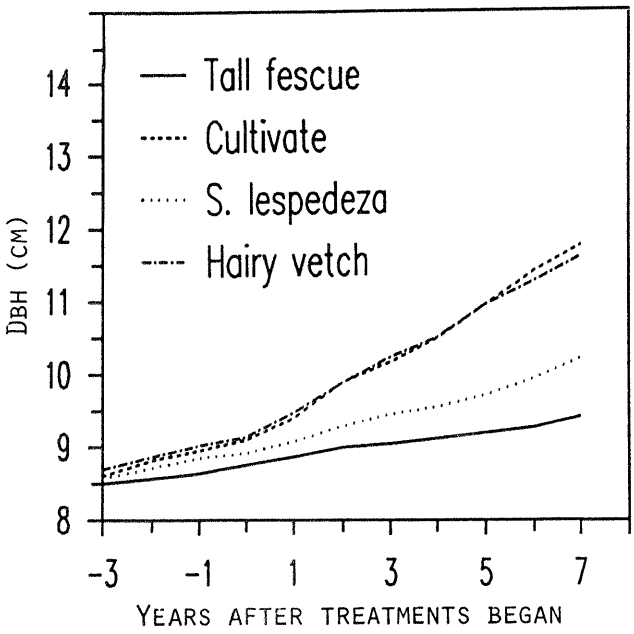

Figure 3.--Average stem diameter before and after ground cover treatments. Treatments began in the fall of 1981 (year 0).

annual growth of the trees in the small dbh stratum was more than twice (0.30 cm) that of the trees in the average dbh stratum (0.13 cm).

Lateral shoot or limb growth for walnut in the semi-annually cultivated and hairy vetch plots was nearly two times that of trees with a tall fescue understory (table 2). Holt and Voeller (1972) found similar increases during the first year after walnuts were chemically released from tall fescue understories.

Walnut leaf rachis length for trees in the semi-annually cultivated and the hairy vetch plots was 19 and 17 percent greater, respectively, than for trees in the fescue sod plot (table 2). Increased walnut leaf length also was reported by von Althen (1985) for trees chemically released from a quackgrass sod. In addition to increased leaf length, trees in the semi-annually cultivated and hairy vetch plots averaged 15.7 leaflets per leaf compared to 14.3 for trees with a tall fescue or sericea lespedeza understory. Increased leaf length was accompanied by a 42- to 57-percent increase in total leaflet area per leaf. The increase in leaflet area, along with a greater number of leaves, gave the trees in the treated plots a 31- to 68-percent increase in potential photosynthetic area on each limb over trees in the check plots. New growth on trees in the large dbh stratum also had more and longer leaves than trees in the small dbh stratum (table 2).

Semi-annual cultivation and annual reseeding with hairy vetch affected leaf color and retention. Leaflets in these treatments were greener in July and August than those for trees with a tall fescue or sericea lespedeza understory. In addition, the foliage for these same treatments remained on the trees 6 to 13 days longer than for trees with a tall fescue or sericea lespedeza understory (table 3). A similar pattern was observed among dbh strata. The large dbh trees retained their greener foliage for 13 to 15 days longer than the small dbh trees.

Table 1.--Mean dates for initiation and completion of walnut radial growth in 1985 and 1986 by ground cover treatments and dbh strata.

Variable	Date for 10% of growth	Date for 90% of growth	Growth duration
			-days-
GROUND COVER:			
Cultivated	May 6 a[1]	July 15 a	70 a
Hairy vetch	May 3 a	July 14 a	72 a
S. lespedeza	May 5 a	July 5 a	61 a
Tall fescue	May 5 a	July 6 a	62 a
DBH STRATA:			
Large	May 8 a	July 19 a	71 a
Average	May 4 b	July 12 a	69 a
Small	May 2 b	June 28 b	58 b

[1] Dates and means followed by the same letter within groups are not different at the P > 0.05 level.

Table 2.--Effect of ground cover treatment and dbh strata on walnut lateral shoot and leaf growth.

Variable	Lateral shoot length	Leaves per new shoot	Leaf rachis length	Leaflet area per leaf
	-cm-	-no.-	-cm-	-cm^2-
GROUND COVER:				
Cultivated	11.7 a[1]	11.2 a	31.2 a	210 ab
Hairy vetch	11.0 a	10.3 ab	30.7 ab	232 a
S. lespedeza	8.0 b	10.2 ab	27.8 b	183 bc
Tall fescue	6.6 b	9.6 b	26.2 c	148 c
DBH STRATA:				
Large	9.9 a	11.3 a	30.9 a	226 a
Average	9.2 a	9.9 b	29.1 ab	200 a
Small	8.8 a	9.8 b	26.9 b	154 b

[1] Means followed by the same letter within groups are not different at the P > 0.05 level.

Table 3.--Dates for 50, 75, and 95 percent walnut defoliation by ground cover treatment and dbh strata.

Variable	Date for 50 % defoliation	Date for 75 % defoliation	Date for 95 % defoliation
GROUND COVER:			
Cultivated	Sept. 7 a[1]	Sept. 18 ab	Oct. 1 b
Hairy vetch	Sept. 9 a	Sept. 21 a	Oct. 5 a
S. lespedeza	Sept. 1 ab	Sept. 11 bc	Sept. 25 c
Tall fescue	Aug. 25 b	Sept. 8 c	Sept. 25 c
DBH STRATA:			
Large	Sept. 12 a	Sept. 24 a	Oct. 7 a
Average	Aug. 29 b	Sept. 11 b	Sept. 27 b
Small	Aug. 28 b	Sept. 9 b	Sept. 23 c

[1] Dates followed by the same letter within groups are not different at the P > 0.05 level.

Table 4.--Average oven-dry biomass for grasses, legumes, other forbs, and detritus during the 1985 and 1986 growing season by ground cover treatment and season of harvest.

Variable	Grasses	Legumes	Other forbs	Detritus
	- - - - - -	g/m^2	- - - - - - - -	
GROUND COVER:				
Cultivated	77 b[1]	26 b	10 a	45 c
Hairy vetch	97 b	34 b	4 a	124 b
S. lespedeza	177 a	122 a	40 a	231 a
Tall fescue	224 a	5 b	18 a	193 a
SEASON:				
Spring	164 a	45 ab	15 a	189 a
Summer	103 b	34 b	16 a	146 b
Autumn	165 a	61 a	22 a	110 b

[1] Means followed by the same letter within groups are not different at the P > 0.05 level.

Site Factors Affecting Tree Growth

Understory biomass in the semi-annually cultivated and hairy vetch plots was approximately half that in the tall fescue plots (table 4). Although grasses were the predominant live ground cover in all treatments, tall fescue made up only 40 and 51 percent of the grasses in the semi-annually cultivated and the hairy vetch plots, respectively. Within the check and the sericea lespedeza plots, tall fescue made up 82 and 78 percent of the grasses, respectively. Legume biomass increased rapidly between the 1985 and the 1986 growing seasons in the sericea lespedeza plots, averaging 35 g/m^2 during the second year after seeding and 208 g/m^2 during the third year after seeding. The principal legumes in the cultivated plots were annual hop clover and invading hairy vetch. Other forbs made up a minor component in this planting and showed no differences among treatments or dbh strata. The average amount of dead and decaying vegetation was highest in the sericea lespedeza and the tall fescue plots and lowest in the semi-annually cultivated plots.

Differences in cumulative soil moisture deficits among ground cover treatments were not well correlated with the amount of understory biomass. The cumulative soil moisture deficit for the 180-day growing season was greatest in the hairy vetch plot and least in the tall fescue plots (fig. 4). Soil moisture was below field capacity for 136, 150, 165, and 143 days in the tall fescue, sericea lespedeza, hairy vetch, and semi-annually cultivated plots, respectively. It rained frequently throughout the growing season except for one 22-day period during which we recorded soil moisture tensions of -70 centibars in a dense stand of sericea lespedeza. The high average soil moisture deficits in the hairy vetch

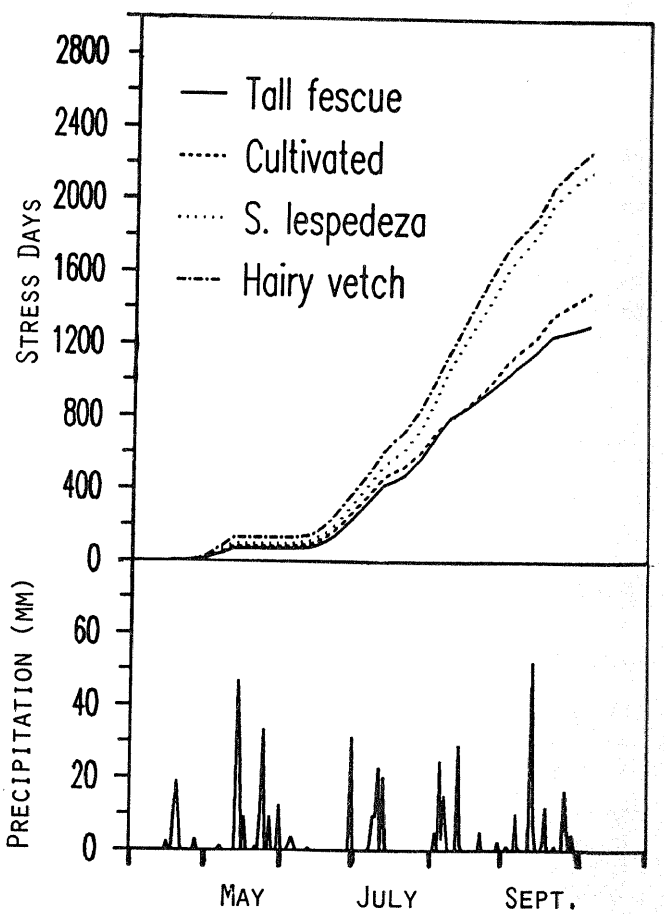

Figure 4.--Cumulative stress days (centibars per day) by ground cover treatments and daily precipitation from April 10 to October 7.

plots (table 5) possibly resulted from a dense stand of green and yellow foxtail that developed after the thin stand of hairy vetch matured and died in June. Available soil moisture under tall fescue, a cool-season grass, may have remained high because the fescue was not cut and allowed to seed and mature. The mature vegetation thereby acted as a mulch for most of the growing season.

Cumulative soil moisture deficits were greater in the large dbh stratum than in the small dbh stratum (table 5). Soils in the large dbh stratum are primarily Sharon silt loams, which have less silt and more sand than soils in the small dbh stratum, which are primarily Bonnie silt loams. Clay averaged 9 percent across the planting with no differences among strata. Thus, soil moisture deficits may have been highest in the large dbh stratum because of reduced water holding capacity and/or higher transpiration rates from the larger trees and understory vegetation. In addition, the coarse-silty nature of the Sharon silt loams probably resulted in better soil aeration leading to better walnut root growth.

Soil nitrate nitrogen was significantly higher in the semi-annually cultivated and hairy vetch plots than in the tall fescue plots, especially in the top 40 cm (fig. 5). Examination of the interaction between ground cover treatments and soil depth revealed that soil nitrate nitrogen in the upper soil depths (0 to 20 and 20 to 40 cm) for the semi-annually cultivated or hairy vetch plots averaged between 7 and 18 mg/kg nitrate nitrogen, while the plots with a tall fescue cover averaged less than 6 mg/kg at all four soil depths. Soil nitrate nitrogen increased in the sericea lespedeza plots after the two cultivations and four years after seeding sericea lespedeza.

Table 5.--Soil texture and average growing season soil moisture tension in 1986 by ground cover treatment and dbh strata.

Variable	Texture Silt	Texture Sand	Organic matter	Soil moisture tension
	- - - - percent		- - - -	- bars -
GROUND COVER:				
Cultivated	65.3 a[1]	27.3 a	3.00 a	-0.166 a
Hairy vetch	62.0 a	28.7 a	2.90 a	-0.237 b
S. lespedeza	66.0 a	24.7 a	3.03 a	-0.195 ab
Tall fescue	61.3 a	27.3 a	2.92 a	-0.140 a
DBH STRATA:				
Large	58.5 a	31.0 a	2.95 a	-0.216 b
Average	68.0 b	24.7 a	3.02 a	-0.173 ab
Small	64.5 ab	26.5 a	2.91 a	-0.164 a

[1] Means followed by the same letter within groups are not different at the P > 0.05 level.

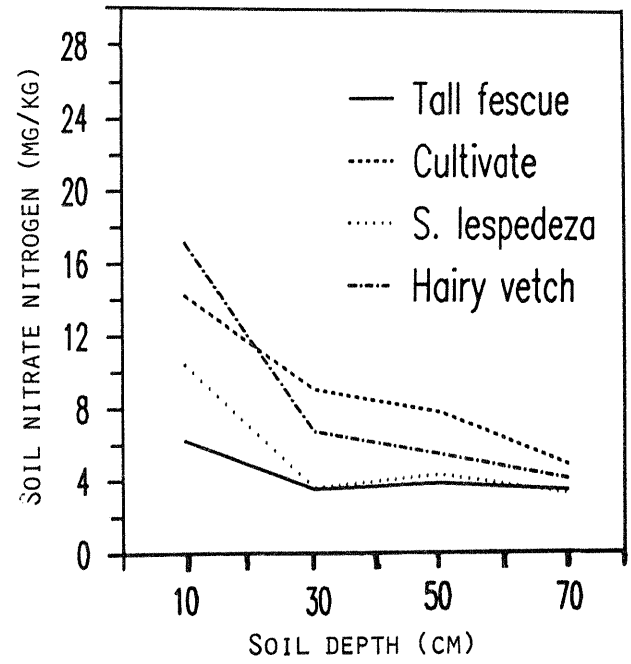

Figure 5.--Average soil nitrate nitrogen in the top 80 cm during the 6 years after the ground cover treatments were established.

The ground cover treatments have had no measurable effect on soil pH, available phosphorus, exchangeable potassium, or organic matter content. Soil pH, phosphorus, potassium, and organic matter averaged 6.0, 75 mg/kg, 84 mg/kg, and 2.96 percent across the planting, respectively. Except for potassium, which is low, these nutrients are at an acceptable level for growing black walnut. No differences among the strata were found for soil pH, phosphorus, potassium, or organic matter.

Increased soil nitrate nitrogen was associated with increased walnut foliar nitrogen (table 6). An interaction for foliar nitrogen content occurred among the ground cover treatments and the number of years after begining treatments. Initially, foliar nitrogen increased in all plots that were cultivated to establish the ground cover treatments but not in the check treatment where tall fescue was retained. Thereafter, walnut foliar nitrogen content was higher in the semi-annually cultivated and the hairy vetch plots than in the sericea lespedeza and tall fescue plots. Walnut foliar nitrogen again increased in sericea lespedeza plots following its establishment in 1986. Throughout the ground cover study, walnuts with a hairy vetch understory consistently had the highest foliar nitrogen content.

Although foliar nutrient levels were not determined before beginning the study, the

Table 6.--Average walnut foliar nutrient content for the 6 years after ground cover treatment.

Variable	Leaflet dry wt. per leaf	Total N	P	K
	- g -	- - - - percent - - - - -		
GROUND COVER:				
Cultivated	1.74 a[1]	2.10 b	0.23 a	1.00 a
Hairy vetch	1.68 a	2.24 a	0.24 a	1.24 a
S. lespedeza	1.58 a	1.97 c	0.24 a	1.30 a
Tall fescue	1.22 a	1.91 c	0.25 a	1.26 a
DBH STRATA:				
Large	1.61 a	2.12 a	0.24 a	1.24 a
Average	1.53 a	2.05 b	0.24 a	1.20 a
Small	1.53 a	2.00 b	0.24 a	1.16 a

[1] Means followed by the same letter within groups are not different at the P > 0.05 level.

observed increases in leaf rachis length, number and area of leaflets per leaf, and leaf color following cultivation suggest that the trees were nitrogen deficient (Phares and Finn 1971). Fertilization studies with young walnut suggest that trees with foliar nitrogen levels below 2.0 percent will usually respond to adding nitrogen. Walnuts released from a tall fescue understory apparently have responded to nitrogen released from decaying tall fescue residues, increased mineralization of organic matter, and/or fixed nitrogen released by the introduced legumes.

Our results suggest that periodically adding a high nitrogen fertilizer to slow-growth plantings with a tall fescue understory might revitalize these plantings. Both Peters and Luu (1984) and Creek and Wade (1985) have shown that tall fescue produces phytotoxins that slow the growth of associated vegetation. Subsequently, Rink and Van Sambeek (1985) demonstrated that growth of black walnut seedlings could be reduced by applying tall fescue leachates. The above studies on tall fescue interference combined with the results reported in this manuscript strongly suggest that grass sods must be removed to revitalize slow-growth walnut plantings.

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