LEGUMINOUS COVER CROPS CAN SUPPRESS WEEDS AND ACCELERATE GROWTH OF BLACK WALNUT SEEDLINGS IN INTENSIVELY CULTURED PLANTATIONS

J. W. Van Sambeek and W. J. Rietveld[1/]

Abstract.--Plots of walnut seedlings coestablished with covers of hairy vetch, crownvetch, sericea lespedeza, Korean lespedeza, and a mixture of crimson clover + Korean lespedeza were compared after 3 years to naturally revegetated plots on an upland and a bottomland site in southern Illinois. Seedling survival was reduced by crownvetch and to a lesser extent by sericea lespedeza and Korean lespedeza. Hairy vetch and crimson clover + Korean lespedeza significantly improved growth of walnut seedlings at both locations. Walnut benefited from chemical weed control around individual trees regardless of the cover type; however, tree growth on plots seeded with hairy vetch without chemical weed control was almost equal to tree growth on naturally revegetated plots with chemical weed control. Establishing cover types before outplanting walnut seedlings increased walnut seedling mortality and increased growth only in the hairy vetch cover type at both locations. The ability of the six cover types to suppress non-leguminous forbs, grasses, and woody plants for the first 3 years was ranked as follows: crownvetch > hairy vetch > sericea lespedeza > crimson clover + Korean lespedeza > Korean lespedeza > naturally revegetated. Our results demonstrate that seeding plantations with cool-season legumes, both with and without chemical weed control around outplanted walnut seedlings, can accelerate tree establishment and growth in intensively managed plantations.

Keywords: *Juglans nigra*, *Vicia villosa*, *Coronilla varia*, *Lespedeza cuneata*, *Lespedeza stipulacea*, *Trifolium incarnatum*, ground cover, afforestation.

INTRODUCTION

Black walnut (*Juglans nigra* L.) seedlings grow best without competition from other plants, especially herbaceous weeds (Krajicek 1975). Controlling herbaceous weeds, however, can be costly and laborious. One alternative is to establish leguminous cover crops, which may suppress weeds and enrich the soil. This practice has been used successfully in agronomic systems for centuries, but has received little attention in forestry until recently (Haines 1978). The development of compatible species associations requires evaluation of such factors as site requirements, ease of establishment, growth,

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[1/] Research Plant Physiologist and Principal Plant Physiologist, North Central Forest Experiment Station, Carbondale, Illinois 62901 and Rhinelander, Wisconsin 54501, respectively. The authors acknowledge the assistance of Danny McBride and Darrell Alley in plantation establishment, Valerie Roe in data collection, and Dave Polak in data analysis.

phenology, competitiveness, effects on soil, and longevity--all in relation to the growth requirements of the tree species. The specific objectives of our research were (1) to compare the effects of five leguminous covers on survival and growth of black walnut seedlings, (2) to compare the effects of leguminous covers on weed suppression, and (3) to identify growth characteristics and species of legumes that are most compatible with establishing walnut plantations.

METHODS

Site Selection and Preparation

A deep, well-drained bottomland and a recently cleared upland in southern Illinois were selected for the study. Both areas were plowed and disked three times during the summer of 1978. Based on calculated lime requirements for pH 6.5 to the depth of 15 cm, we applied 11.0 metric tons/hectare lime to the bottomland and 5.5 metric tons/hectare to the upland area. Additionally, we applied 8.2 kg/ha nitrogen, 26.3 kg/ha phosphorus, and 27.2 kg/ha potassium to each area. The lime and fertilizers were lightly disked into the soil before establishing cover types in the fall of 1978 or spring of 1979.

Treatments and Experimental Design

We evaluated five leguminous cover crops [hairy vetch (HV), crownvetch (CV), sericea lespedeza (SL), Korean lespedeza (KL) and the mixture of crimson clover + Korean lespedeza (CC)] representing different growth habits, phenologies, and longevities (Table 1). Detailed information on the establishment and growth of the cover crops is reported in our previous paper (Van Sambeek and Rietveld 1981) and will only be highlighted in this paper.

The cover crops were seeded in the fall of 1978 or the spring of 1979 depending on the species requirements. The control treatment consisted of plots that were allowed to naturally revegetate (NR). We preestablished cover types 1 year before outplanting black walnut seedlings and coestablished cover types simultaneously with walnut seedlings. Herbaceous vegetation around individual walnut seedlings was controlled on one-half of the study plots by applying 3.2 kg/ha isopropylamine salt of glyphosate (Roundup®)[2/] plus 4.4 kg/ha simazine (Princep® 80W) in a 1.5-m diameter spot around each walnut seedling for 3 years after establishment.

At both areas, a randomized complete block design was used, consisting of 3 blocks, 6 treatments (NR, NV, CV, SL, KL, and CC), 2 chemical weed control treatments (spot spraying, no spot spraying) and 2 establishment times

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[2/] Mention of a commercial product does not imply endorsement by the United States Department of Agriculture. This research involves the use of pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered by the appropriate State and/or Federal agencies before they can be recommended. CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Table 1.--Characteristics and seeding rates for legumes by cover types.

Cover Type	Species	General Description	Seeding rate[1/] kg/ha
Hairy vetch	*Vicia villosa*	Vining winter annual	48
Crownvetch	*Coronilla varia*	Deep-rooted perennial with semi-erect or decumbent stems	78
Sericea lespedeza	*Lespedeza cuneata*	Deep-rooted summer perennial with erect stems	42
Korean lespedeza	*Lespedeza stipulacea*	Low-growing, shade-tolerant summer annual	56
Crimson clover + KL	*Trifolium incarnatum* + *Lespedeza stipulacea*	Erect winter annual + low-growing summer annual, respectively	30 40

[1/] Rates are based on germination percentages and were atypically high to insure full establishment. Consult your local extension specialists for appropriate varieties and seeding rates for your area.

(preestablished cover types, coestablished cover types). Each block consisted of 24 plots (6 cover types x 2 chemical weed control treatments, x 2 establishment times). Each 12- x 18-m plot was planted with 24 walnut seedlings on a 3- x 3-m spacing in the spring of 1979 (coestablished cover types) or spring of 1980 (preestablished cover types).

Data Collection and Analyses

Height and stem diameter (3 cm above soil line) were measured at the time of outplanting and at the end of the first, second, and third growing seasons. We also recorded if seedlings had been overtopped by herbaceous vegetation and deformed. Measurements from the interior 2 rows of trees in each plot (12 trees/plot) were used for data analyses.

During June or July of each growing season, plots were surveyed for composition and coverage of herbaceous vegetation by using the reconnaissance method (Forbes 1955). First, we estimated the percent plot area covered with dead plant residues or bare ground and then we estimated the percent coverage of the remaining plot area for each of the following categories: legumes, Astereae tribe of Compositae, other annual forbs, other perennial forbs, grasses, and other vegetation (vines, shrubs, and trees).

Plot means were determined for all variables and subjected to analysis of variance to determine the probability of significant differences among location and treatment components. Separate analyses were run to determine the effects of preestablishing and coestablishing cover types for each growing

season (Table 2). Duncan's multiple range test ($\alpha = 0.05$) was used to identify significant differences among treatment means where highly significant interactions did not occur.

Table 2.--Percent probability of committing a Type I error or rejecting a true null hypothesis for response of walnut seedlings to either coestablished or preestablished cover types by growing season.

Variables tested	Walnut growing season	ANOVA Components: Location (L)	Cover type (CT)	Weed control (WC)	L X CT	L X WC	CT X WC	L X CT X WC
		- - - - - percent probability > F-value - - - - - - - - -						
		COESTABLISHED COVER TYPES						
Survival	1	3.53	84.20	28.90	47.35	82.15	21.28	65.18
	2	24.02	82.02	4.79	20.63	14.25	82.27	84.27
	3	20.20	0.58	0.02	23.77	8.42	0.76	88.46
Height	1	0.35	1.15	76.62	32.11	35.08	99.35	43.91
	2	16.92	0.01	0.01	17.13	0.87	54.11	59.22
	3	0.68	0.01	0.01	17.18	8.19	22.91	88.01
Diameter	1	1.14	0.01	0.01	1.86	34.48	34.98	33.15
	2	29.40	0.01	0.01	10.19	0.33	48.33	52.33
	3	0.68	0.01	0.01	18.82	12.26	63.06	59.77
Vegetation bent trees	1	82.26	0.01	47.23	2.58	44.60	4.26	61.52
	2	47.46	11.47	10.90	90.79	99.82	22.41	97.80
	3	61.70	0.03	0.95	38.46	1.81	40.07	37.06
		PREESTABLISHED COVER TYPES						
Survival	1	26.39	0.02	41.97	8.13	0.01	2.58	33.12
	2	42.09	0.01	0.01	3.47	1.05	0.01	80.71
Height	1	11.31	0.08	0.01	13.65	7.87	48.09	81.93
	2	14.79	7.36	0.01	29.33	22.00	15.66	72.33
Diameter	1	0.33	26.06	0.01	28.71	20.40	27.41	3.50
	2	7.33	0.06	0.01	3.35	41.78	9.17	28.24
Vegetation bent trees	1	86.39	0.14	21.57	99.89	73.43	3.49	93.35
	2	3.46	0.01	3.27	26.41	55.92	3.00	78.00

RESULTS

Black Walnut Seedling Survival

Black walnut seedling survival on the two sites averaged 92%, 82%, and 78% after the first, second, and third growing seasons, respectively, when seedlings were coestablished with the various cover types (Table 3). Survival was better on the bottomland site only after the first growing season. Of all the cover types, only crownvetch significantly reduced walnut survival. It produced dense vegetative growth that overtopped most walnut seedlings during the second growing season and produced a humid microenvironment. Many of the surviving walnut seedlings had decayed regions along the stems, especially on the new growth.

Table 3.--Survival of black walnut seedlings with either coestablished or preestablished cover types for two sites with and without weed control.[1/]

Treatment components	Walnut seedling survival coestablished cover type			Walnut seedling survival preestablished cover type	
	Year 1	Year 2	Year 3	Year 1	Year 2
	- - - - percent - - - -			- - - - percent - - - -	
LOCATION:					
Bottomland	95 a	85	81	81 *	80
Upland	89 b	89	75	84 *	75
COVER TYPE:					
Naturally revegetated	90	86	86 a	92 *	90 *
Hairy vetch	90	85	83 a	96 *	91 *
Crownvetch	92	81	61 b	86 *	56 *
Sericea lespedeza	93	81	78 a	76 *	64 *
Korean lespedeza	94	79	78 a	82 *	78 *
Crimson clover + KL	94	82	81 a	88 *	85 *
SPOT WEED CONTROL:					
With	94	86 a	85 a	88	84 *
Without	91	79 b	71 b	86	70 *

[1/]Values are means taken across all three components. Values followed by the same letter are not significantly different at $\alpha = 0.05$ according to Duncan's multiple range test. Values marked with * could not be evaluated because of highly significant interaction ($\alpha = 0.01$) between this component and another treatment component. These interactions are discussed in the text.

Spot spraying of herbicides significantly improved survival after the second growing season for all cover types, especially for seedlings planted with crownvetch. Survival in the crownvetch plots without herbicides averaged only 38%, in contrast to 85% survival where herbicides were used around individual seedlings.

Results were more variable when cover types were sown 1 year in advance of outplanting black walnut seedlings (Table 2). Herbicides were more beneficial

on the upland area than on the bottomland for both the first and second growing seasons with some variation between cover types (Table 3). Spot spraying of herbicides again improved early survival of walnut seedlings planted in crown-vetch and herbicides improved to a much lesser extent the survival of those seedlings planted in hairy vetch, crimson clover, or naturally revegetated plots. For some unexplained reason, survival with spot spraying in sericea lespedeza or Korean lespedeza was less than without spot spraying after the first growing season. However, at the end of the second growing season, walnut survival had been reduced to 63% with or without the use of herbicides in the sericea lespedeza plots.

Walnut Seedling Growth

During the first 3 years, significant differences exist in growth of walnut seedlings coestablished with the six cover types due to location, cover type, and weed control (Table 2). The seedlings outplanted on the bottomland area were grown in an Illinois nursery. They were significantly larger than the bedrun, Kentucky nursery seedlings outplanted on the upland site even after the first growing season (Tables 4 and 5).

Table 4.--Average height after each growing season for black walnut seedlings with either coestablished or preestablished cover types across two sites with and without weed control.[1/]

Treatment components	Seedling height with coestablished cover types			Seedling height with preestablished cover types	
	Year 1	Year 2	Year 3	Year 1	Year 2
	cm			cm	
LOCATION:					
Bottomland	29 b	62 *	117 a	48	76
Upland	43 a	57 *	99 b	46	68
COVER TYPE:					
Natural revegetated	37 ab	55 c	97 bc	47 ab	68 b
Hairy vetch	39 a	78 a	131 a	51 a	82 a
Crown vetch	37 ab	53 c	91 c	47 ab	73 ab
Sericea lespedeza	32 b	55 c	123 a	40 c	76 ab
Korean lespedeza	33 b	50 c	95 c	44 bc	66 b
Crimson clover + KL	37 ab	67 b	113 ab	48 ab	67 b
SPOT WEED CONTROL:					
With	36	72 *	135 a	49 a	87 a
Without	36	47 *	83 b	43 b	57 b

[1/]Means followed by the same letter are not significantly different at $\alpha = 0.05$ according to Duncan's multiple range test. Means marked with * could not be evaluated because of highly significant interactions ($\alpha = 0.01$) between treatment components. These interactions are discussed in the text.

Table 5.--Average diameter after each growing season for black walnut seedlings with either coestablished or preestablished cover types across two sites with and without weed control.[1/]

Treatment components	Seedling diameter with coestablished cover types			Seedling diameter with preestablished cover types	
	Year 1	Year 2	Year 3	Year 1	Year 2
	- - - - - mm	- - - - - -		- - - - - - mm	- - - - - -
LOCATION:					
Bottomland	7.2 b	12.9 *	26.9 a	8.4 b	15.8
Upland	9.2 a	12.3 *	20.1 b	10.0 a	13.6
COVER TYPE:					
Naturally revegetated	7.0 c	12.0 bc	22.0 b	8.9	13.7 bc
Hairy vetch	10.1 a	16.1 a	30.9 a	9.5	17.8 a
Crownvetch	7.9 bc	11.1 c	21.3 b	8.9	15.7 ab
Sericea lespedeza	7.6 bc	11.4 c	21.2 b	8.9	11.8 c
Korean lespedeza	7.9 bc	11.3 c	21.2 b	9.6	14.2 bc
Crimson clover + KL	8.5 b	13.7 b	24.5 b	9.3	14.8 b
SPOT WEED CONTROL:					
With	8.8 a	16.1 *	31.9 a	9.9 a	18.6 a
Without	7.6 b	9.1 *	15.1 b	8.5 b	10.6 b

[1/] Means followed by the same letter are not significantly different at $\alpha = 0.05$ according to Duncan's multiple range test. Means marked with * could not be evaluated because of highly significant interactions ($\alpha = 0.01$) between treatment components. These interactions are discussed in the text.

A highly significant interaction occurred after the second growing season between location and method of weed control for both height and diameter (Table 2). Herbicide treatment resulted in substantially more additional height growth (33 vs 18 cm) and diameter growth (8.9 vs 5.1 mm) on the upland site than on the bottomland site.

Walnut seedlings under current management practices with weeds and spot herbicide spraying averaged 1.42 m high and 3.6 cm in diameter on the upland area and only 1.06 m high and 2.6 cm in diameter on the bottomland area after three growing seasons. Walnut seedling growth was stimulated by only two cover types. On the upland area, walnut seedlings with spot weed control in the hairy vetch cover type averaged 1.63 m in height and 4.5 cm in diameter, and seedlings in the crimson clover + Korean lespedeza averaged 1.54 m in height and 3.6 cm in diameter after the third growing season. On the bottomland area, seedlings with spot weed control in the hairy vetch plots averaged 1.25 m high and 3.1 cm in diameter; seedlings on the crimson clover + Korean lespedeza plots averaged 1.36 m high and 3.2 cm in diameter. We feel the growth stimulation in the latter plots is due to crimson clover, not Korean lespedeza, because most of the Korean lespedeza was shaded out shortly after it germinated in the spring and Korean lespedeza by itself had no effect. Korean lespedeza was planted with crimson clover in an attempt to produce a cover type that would remain green all year.

Spot spraying of herbicides significantly increased diameter growth at both sites during the first growing season and increased height growth at both sites during the second growing season (Tables 4 and 5). Seedling growth on all the leguminous cover types in conjunction with spot spraying was equivalent or exceeded seedling growth on the naturally revegetated plots with spot weed control. This finding indicates that establishing leguminous covers may be better than allowing plantations to naturally revegetate as under current management practices. Of all the leguminous cover types, only hairy vetch without herbicides allowed tree growth similar to trees in naturally revegetated plots with weed control.

Results for height and diameter growth of black walnut seedlings after the first two growing seasons in preestablished cover types are similar to those of seedlings coestablished with the cover types (Tables 4 and 5). Spot spraying of herbicides significantly increased both height and diameter growth during the first growing season, a very dry year in southern Illinois. Apparently seedlings were better able to use what little soil moisture was available when free of herbaceous competition. The highly significant three-way interaction observed after the first growing season probably results from the variable response of walnut seedlings outplanted in plots sown with Korean lespedeza.

Establishing the cover type before planting black walnut seedlings or coestablishing the cover type generally had a similar impact on growth after the first two growing seasons except for the plots seeded with crimson clover (Tables 4 and 5). The beneficial effects of this cover type failed to persist after the crimson clover was winter killed. Hairy vetch also failed to reseed the second year, but the potential benefits of this cover type to walnut seedlings persisted. Whether cover types were coestablished or preestablished, the height to diameter ratio (using treatment means) was approximately 45 for all cover types except sericea lespedeza, which had an average ratio of 61. Walnut seedlings on the sericea lespedeza plots had an etiolated appearance and few branches. We assume that once the walnuts have overtopped the sericea lespedeza, they will take on a more normal appearance and a shoot to diameter ratio approaching 45.

Walnut Seedling Morphology

One aspect of this study was to control weeds without using herbicides; however, cover types that develop sufficient vegetative growth to suppress weeds are also likely to overtop the walnuts and affect their morphological form for the first 2 or 3 years. Only hairy vetch produced sufficient vegetative growth to overtop walnut seedlings the first year; however, 2-year-old stands of crownvetch and sericea lespedeza can also overtop 1- and 2-year-old walnut seedlings and produce crooked stems (Table 6).

Hairy vetch, a winter annual, overtopped most walnut seedlings by vining around the seedlings and eventually bending them over under their weight. In southern Illinois, hairy vetch matured and died early in the growing season, allowing bent walnut seedlings to produce new lateral shoots near the base of the seedling. By the end of the growing season, these new shoots tended to be nearly as tall and larger in caliper than the original shoots. However, emergence of lateral shoots near the base of bent seedlings resulted in severe morphological deformities that continue to exist 3 years later as crooks within the lower 30 cm of the stem in many of these trees.

Table 6.--Percentages of seedlings with abnormal morphology due to being overtopped or lodged by herbaceous vegetation with either coestablished or preestablished cover types on two sites with and without weed control.[1/]

Treatment components	Deformed walnut seedlings coestablished cover types			Deformed walnut seedlings preestablished cover types	
	Year 1	Year 2	Year 3	Year 1	Year 2
	- - - -	percent	- - - -	- - - - -	percent - - - -
LOCATION:					
Bottomland	9	4	25	3	27 a
Upland	10	6	20	4	10 b
COVER TYPE:					
Naturally revegetated	5 b	3 b	13 b	0 b	5 c
Hairy vetch	31 a	6 ab	35 a	1 b	40 a
Crownvetch	4 b	13 a	43 a	19 a	25 b
Sericea lespedeza	7 b	6 ab	29 ab	1 b	25 b
Korean lespedeza	4 b	3 b	10 bc	1 b	12 bc
Crimson clover + KL	6 b	1 b	4 c	0 b	4 c
SPOT WEED CONTROL:					
With	9	3	15 b	2	14 b
Without	10	7	29 a	5	23 a

[1/]Means followed by the same letter are not significantly different at $\alpha = 0.05$ level according to Duncan's multiple range test.

Hairy vetch significantly affected walnut stem morphology during the first and third growing season when coestablished (Table 2). The hairy vetch residues produced during the first growing season prevented germination of the vetch seed. The dense mulch decomposed sufficiently during the second year to allow residual seed to germinate and again produce a heavy stand of hairy vetch during the third growing season for walnuts outplanted with coestablished cover types and for the second growing season for walnuts outplanted in preestablished cover types (Table 5). Spot spraying of herbicides around the walnuts significantly reduced the percentage of deformed seedlings.

Crownvetch and sericea lespedeza also affected tree morphology after the second growing season when walnuts were coestablished and after the first growing season when walnuts were postestablished (Table 5). Both of these perennial species produced a well-developed root system and crown the first year after sowing and then produce vigorous vegetative growth in subsequent years. Most walnuts during the second and potentially the third growing season were overtopped by the vigorous vegetative growth and were frequently bent or lodged as the herbaceous stems died at the end of each growing season. Using herbicides around walnut seedlings consistently reduced the percentage of deformed seedlings in crownvetch plots; however, spot spraying in sericea lespedeza frequently increased the percentage of deformed seedlings. Apparently the stiff upright dying stems of sericea lespedeza fall into the open areas created by the herbicide and deform the atypically tall walnut seedlings in these plots.

Seedling deformities in naturally revegetated plots or in plots seeded to Korean lespedeza or crimson clover are probably due to lodging of the erect dying stems of such weeds as Solidago, Erigeron, or Aster or to being overtopped by vines such as Ipomoea or Cynanchum. Composition and coverage of these species are discussed in the next section.

Weed Suppression by Cover Types

Another aspect of the study was suppression of non-legumes or to increase the percentage of each plot covered by dead vegetation or legumes. During the first year, all legume cover types had a higher percentage plot coverage of the desired composition (dead vegetation, bare ground, and legumes) than did the naturally revegetated plots. During the second year, all the cover types, except crimson clover + Korean lespedeza, still had significantly greater amounts of the desired plot coverage than did the naturally revegetated plots. During the third growing season, however, only plots sown with hairy vetch, crownvetch, and sericea lespedeza had significantly more of the desired plot coverages.

The amount of vegetation coverage does not appear to be as important as the type of vegetation. First-year walnut seedling diameter growth was excellent on hairy vetch plots, which produced the greatest amount of herbaceous biomass; seedlings on the naturally revegetated plots had less growth with the least herbaceous biomass. Weeds in the family Compositae, especially in the tribe Astereae (see Fernald 1950), make up a large proportion of the biomass and coverage in the naturally revegetated plots (Table 7). Previous studies summarized by Fisher (1980) have shown that most forbs that inhibit hardwood seedling growth by allelopathic interactions are in this tribe. Hairy vetch and crownvetch were the only two cover types to significantly reduce the coverage by forbs in this tribe in all 3 years at both sites. At this time, however, we do not know if any of the members in the genus Erigeron, Soladigo, or Aster are allelopathic to walnut or are just very competitive. In any event, it seems desirable to reduce their occurrence in intensively managed walnut plantations.

The composition of annual forbs excluding both legumes and members of the tribe Astereae showed highly significant interactions between cover types and location for all 3 years. Much of the interaction the first year is apparently due to the high percentage (68%) of annual weeds in the naturally revegetated plots on the bottomland compared to only 15% on the upland area. The interaction the second and third year is apparently due to a higher percentage of annual weeds in the Korean lespedeza and in the crimson clover + Korean lespedeza cover types on the upland area than on the bottomland area.

Plots seeded to hairy vetch tended to have a high component of perennial forbs excluding legumes and members of the Astereae tribe for all 3 years (Table 7). The perennials on these plots were primarily in the genera of Phytolacca, Solanium, and Rumex; in the other five cover types they were primarily Sonchus, Cirsium, and Asclepias species.

The composition and coverage of the grasses, vines, and woody species were quite variable from year to year (Table 7). The grasses on the upland site were primarily a mixture of Bromus, Andropogon, and Setaria species; on

Table 7.--Vegetative composition and coverage across cover type and location during late June or early July during the first three growing seasons.

Year	Treatment combination	Vegetation classes[1] Grd	Leg	Ast	Ann	Per	Gra	Oth
		- - - - - - - - - - percent[2] - - - - - - - - - -						
Late June 1979	Cover type:							
	Naturally revegetated	23 a	2 e	22 *	42 *	0 b	11 ab	0
	Hairy vetch	2 c	95 a	0 *	1 *	3 a	0 d	0
	Crownvetch	14 b	40 c	8 *	28 *	3 a	8 bc	0
	Sericea lespedeza	15 b	19 d	15 *	37 *	2 ab	13 a	0
	Korean lespedeza	13 b	43 c	5 *	29 *	1 ab	9 ab	0
	Crimson clover + KL	10 b	77 b	2 *	6 *	1 ab	4 c	0
	Location:							
	Bottomland	15 a	45	2 *	15 *	0 b	5 b	0
	Upland	9 b	47	16 *	33 *	3 a	10 a	0
Early July 1980	Cover type:							
	Naturally revegetated	31 ab	3 d	43 a	6 *	0 b	14 *	3 a
	Hairy vetch	39 a	13 c	30 b	6 *	3 a	9 *	1 b
	Crownvetch	6 c	76 a	12 c	4 *	0 b	2 *	0 b
	Sericea lespedeza	26 ab	35 b	32 b	4 *	0 b	3 *	1 b
	Korean lespedeza	35 a	21 c	32 b	6 *	1 b	5 *	1 b
	Crimson clover + KL	21 b	18 c	36 ab	13 *	1 b	12 *	0 b
	Location:							
	Bottomland	32 a	23	37 a	3 *	1	4 *	2 a
	Upland	20 b	32	25 b	10 *	2	11 *	0 b
Early July 1981	Cover type:							
	Naturally revegetated	14 b	4 c	45 ab	13 *	8 b	3 bc	12 ab
	Hairy vetch	33 a	4 c	19 c	14 *	12 a	3 bc	14 a
	Crownvetch	2 c	85 a	5 d	2 *	3 c	1 c	3 d
	Sericea lespedeza	5 c	55 b	24 c	4 *	4 bc	1 c	6 cd
	Korean lespedeza	16 b	6 c	41 b	16 *	5 bc	5 ab	11 abc
	Crimson clover + KL	14 b	4 c	50 a	13 *	6 bc	6 a	8 bcd
	Location:							
	Bottomland	13	25	36 a	8 *	4	2	12
	Upland	15	28	25 b	13 *	9	4	7

[1] Vegetation classes are as follows: Grd = dead vegetation or bare ground, Leg = legumes, Ast = tribe Astereae of family Compositae, Ann = annual forbs excluding legumes and Astereae, Per = perennial forbs excluding legumes and Astereae, Gra = grasses, and Oth = vines, brambles, shrubs, and woody plants.

[2] Means followed by the same letter are not significantly different at $\alpha = 0.05$ level according to Duncan's multiple range test.

the bottomland they were primarily a mixture of Festuca, Juncus, and Sorghum species. On the upland site, the vines and woody species were primarily Parthenocissus quinquefolia, Acer negundo, Rubus species, and Cynanchum nigrum, which tended to climb and deform the walnut seedlings. On the bottomland, the vines and woody species were primarily A. negundo, several Ipomoea species, and Campis radicans, which may have a significant impact on tree form in the future.

Plantation Maintenance

Maintenance of a newly planted walnut plantation normally requires controlling competing weeds for at least 3 years, annual mowing in the fall to reduce the potential for wildfires and animal damage, and possibly some pruning. Without proper maintenance, herbaceous weed growth after soil disturbance on good walnut sites may reach 3 m or taller producing obvious detrimental effects. Thus, comparing the heights of herbaceous covers can help us see the potential benefits of cover crops in reducing plantation maintenance.

The height of the herbaceous cover in late June or early July during the first 3 years after walnut establishment ranged from 0.4 m in the hairy vetch plots to more than 1.1 m in the naturally revegetated plots on the upland site and from 0.7 m in the hairy vetch plots to more than 1.3 m for the sericea lespedeza plots on the bottomland area. If chemical weed control must be continued until the walnuts overtop the herbaceous competition, then weed control is needed only during the first year with hairy vetch and is still needed during the fourth year in most plots on the bottomland area.

Fall mowing, done annually on some plantations, is seldom figured into plantation maintenance costs (Marty and Kurtz 1982). The need for fall mowing, i.e. to reduce the potential risk from wildfires, depends largely on the amount and type of plant residues present. Walnut is sensitive to fire and even a light ground fire generates enough heat to damage or kill the cambium (Kellogg, unpublished manuscript on file at Carbondale, IL). Both hairy vetch and crownvetch produce a dense vegetative mat close to the ground with a few scattered forbs. These dense residues will probably hold enough moisture to prevent the spread of wildfires. The persistent upright stems of sericea lespedeza (1.1 to 1.2 m tall), however, do present a fire hazard (Jorgensen, personal communication). The other three cover types tended to have a mixed canopy of tall upright stems (1.1 to 1.5 m tall) mixed with dry grasses that probably would sustain a wildfire through a plantation if not mowed.

Corrective pruning is now thought not to be necessary (Schlesinger 1981). Most trees will naturally straighten if given enough time. In the plots seeded with hairy vetch, most of the walnuts that were overtopped and completely bent over now have a single stem arising from one of the lateral branches that emerged from the base of the seedlings. After the third growing season, approximately 40% of all the trees had multiple leaders. Plots seeded with sericea lespedeza had the fewest trees with multiple leaders (25%) and plots seeded with hairy vetch had the most (56%). All other cover types averaged between 36 and 48%. This pattern was similar for both the upland and bottomland areas. Although corrective pruning may not be necessary, lateral pruning will be necessary at least on the potential crop trees. At the end of the third growing season, the percentage of the excessively branched trees (> 3 branches/m of height) was 44% in hairy vetch plots, 40% in crimson clover + Korean lespedeza

plots, 32% in naturally revegetated plots, 28% in Korean lespedeza plots, 22% in crownvetch plots, and 14% in sericea lespedeza plots.

DISCUSSION

Each of the cover types needs to be evaluated according to the major benefits that might be expected during hardwood plantation establishment such as: (a) reducing seedling mortality; (b) stimulating height growth, thus reducing the number of times spot spraying of herbicides is required; (c) stimulating diameter growth, which, apparently, is concomitant with root growth (Van Sambeek and Rietveld 1982); (d) reducing amount of plantation maintenance after initial establishment through natural persistence of desired cover type; (e) reducing fall plantation maintenance by eliminating need for mowing to reduce risk from wildfires; and (f) reducing the amount of lateral pruning required. In an attempt to evaluate the overall benefits for each cover type, we ranked them according to the above potential benefits (Table 8). Based on the first three benefits, which directly involve tree growth and survival during the establishment phase (first 2 years), the cover types can be ranked as follows: hairy vetch > crimson clover + Korean lespedeza > naturally revegetated > sericea lespedeza > crownvetch > Korean lespedeza. If we look at all the listed potential benefits, the cover types rank as follows: hairy vetch > crimson clover + Korean lespedeza > crownvetch > sericea lespedeza > Korean lespedeza > naturally revegetated. All the leguminous cover types now rank ahead of allowing plantations to naturally revegetate.

We expect some changes in the relative rankings of several cover types in the next few years. Many of the surviving walnuts in the crownvetch or sericea lespedeza plots have now overtopped the herbaceous cover, and tree growth appears to be stimulated. Mitchell (1980) reported that sericea lespedeza initially slowed height and diameter growth of black walnut seedlings, then later stimulated growth after walnuts were established. In the same study sericea lespedeza and tall fescue were the only cover types out of eight able to maintain themselves for 6 or more years. Vogel (1980) has also found that perennial herbaceous species like crownvetch, sericea lespedeza, and flatpea are generally detrimental to the establishment of hardwood seedlings. Vogel recommends using annual legumes during the establishment phase of hardwoods on reclaimed mine sites.

Our findings support Vogel's conclusions. In southern Illinois, winter annuals outperformed both summer annuals and perennials in black walnut plantations during establishment. Apparently winter annuals like hairy vetch and crimson clover undergo rapid growth in the spring at the same time as walnut height growth when soil moisture tends to be adequate. The growth period of summer annuals and perennials coincides with the period of walnut diameter growth when soil moisture is likely to be inadequate.

Several of the problems encountered with using winter annuals can be easily overcome, especially for hairy vetch. Rather than being broadcast seeded, hairy vetch can be drilled in rows between the walnuts. It will then become established during the first growing season of the outplanted walnut seedlings and will suppress the weeds between the walnut rows by its many long vining shoots. Without the dense mat formed by broadcast seeding, hairy vetch may be able to reseed in the fall and spread over the plantation during the second growing season, when the walnuts are not so likely to be overtopped and

Table 8.--Ranking of cover types based on assessment of potential benefits during walnut seedling establishment (first 2 years) on 2 sites.

Potential benefits	Site	Cover types					
		NR	HV	CV	SL	KL	CC
		Numerical ranking[1]					
Improve tree survival	Bottom	1	2	4	6	5	3
	Upland	2	1	6	4	3	5
Stimulate height growth	Bottom	5	1	4	2	6	3
	Upland	6	1	5	3	4	2
Stimulate diameter growth	Bottom	4	1	2	5	6	3
	Upland	4	1	5	6	3	2
Naturally suppress weeds[2]	Bottom	6	2	1	4	5	3
	Upland	6	2	1	4	5	3
Reduce plantation mowing	Bottom	6	1	2	5	4	3
	Upland	6	1	2	5	4	3
Reduce lateral pruning	Bottom	3	6	4	1	2	5
	Upland	5	6	1	2	4	3
Totals		54	25	37	47	51	38

[1] Ranked from best (=1) to poorest cover type (=6). Abbreviations are as follows: NR = naturally revegetated, HV = hairy vetch, CV = crownvetch, SL = sericea lespedeza, KL = Korean lespedeza, and CC = crimson clover + Korean lespedeza.

[2] Summed across first 3 years for the desired coverage of bare ground, plant residues, and legumes only.

bent over. Alternatively, if hairy vetch is broadcast seeded, the plantation could be lightly disked between the walnut rows in August to disturb the plant residues and allow the vetch seed to germinate. Crimson clover can be used only in the southern part of the black walnut range because it is easily winter killed, even in southern Illinois.

LITERATURE CITED

Fernald, Merritt Lyndon. 1950. Gray's Manual of Botany. 8th ed. American Book Company, New York. 1632 p.

Fisher, Richard F. 1980. Allelopathy: a potential cause of regeneration failure. J. Forestry 78:346-350.

Forbes, Reginald D. (ed.) 1955. Section 11. Forest range management. Forestry Handbook. The Ronald Press Company, New York. p. 11-1 to 11-34.

Haines, Sharon G. (ed.) 1978. Nitrogen fixation in southern forestry. International Paper Company, Southlands Experimental Forest, Bainbridge, GA. 169 p.

Marty, Timothy D. and William B. Kurtz. 1982. Black walnut management costs: results of 1981 survey. Walnut Council Bull. 9:5-7.

Mitchell, Robert J. 1980. The effects of selected cover crops on the growth, development and mineral nutrition of black walnut (Juglans nigra L.). Master of Science Thesis, Southern Illinois University, Carbondale, IL. 76 p.

Schlesinger, Richard C. 1981. Pruning for quality. North. Nut Grow. Assoc. Annu. Rep. 72:135-140.

Van Sambeek, J. W. and W. J. Rietveld. 1981. Seeding forage legumes in black walnut plantations. Walnut Council Bull. 8:6-8.

Van Sambeek, J. W. and W. J. Rietveld. 1982. Preplant indolebutyric acid treatment of outplanted black walnut seedlings. 7th North American Forest Biology Workshop Proceedings. (In press.)

Vogel, Willis G. 1980. Revegetating surface-mined lands with herbaceous and woody species together. In: Trees for Reclamation. USDA For. Serv. Gen. Tech. Rep. NE-61, 135 p.