Interference by weeds and deer with Allegheny hardwood reproduction[1]

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Received March 29, 1982[2]

Accepted September 27, 1982

HORSLEY, S. B., and D. A. MARQUIS. 1983. Interference by weeds and deer with Allegheny hardwood reproduction. Can. J. For. Res. 13: 61–69.

Deer browsing and interference from forest weeds, particularly hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore), New York fern (*Thelypteris noveboracensis* L.), and short husk grass (*Brachyelytrum erectum* Schreb.), influence the establishment of Allegheny hardwood reproduction. We determined the independent interference by deer and weeds after a seed cut and a removal cut in a two-cut shelterwood sequence. Weeds, particularly the ferns, caused significant interference with germination, survival, and growth of desirable species following both cuttings. Deer browsing had no direct effect on desirable species because they did not grow enough to emerge from the herbaceous cover. Deer browsing did affect growth of *Rubus*, yellow and black birch (*Betula alleghaniensis* Britt, and *Betula lenta* L.), and pin cherry (*Prunus pensylvanica* L.) that grew above the herbaceous cover. Browsing of *Rubus* may be a serious problem in some stands because substantial reduction in fern and grass coverage occurred as the *Rubus* developed.

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Le broutage du chevreuil et la compétition de plantes herbacées forestières comme la dennstaedtia à lobules ponctués (*Dennstaedtia punctilobula* (Michx.) Moore), la thélyptéride de New York (*Thelypteris noveboracensis* L.) et le dylépirum dressé (*Brachyelytrum erectum* Schreb.) influencent l'établissement d'une régénération des feuillus dans la région Allegheny. Les auteurs ont déterminé séparément l'effet du broutage et la compétition des herbacées après une coupe d'ensemencement suivie d'une coupe définitive dans une succession pour assurer une protection de la régénération. Les plantes, particulièrement les fougères, furent à l'origine d'une compétition significative pour la germination, la survie et la croissance d'espèces désirables à la suite des deux abattages. Le broutage du chevreuil n'a eu aucun effet direct sur les espèces désirables du fait qu'elles ne purent croître suffisamment pour émerger au-dessus de la stratte herbacée. Lorsqu'elles émergèrent cependant, le broutage affecta la croissance du *Rubus*, des bouleaux jaunes et flexibles (*Betula alleghaniensis* Britt. et *Betula lenta* L.) et du cerisier de Pennsylvanie (*Prunus pensylvanica* L.). Du fait qu'une réduction substantielle de la stratte des fougères et des herbacées se produit en même temps que le *Rubus* se développe, le broutage du *Rubus* pourrait être un problème sérieux dans certains peuplements.

[Traduit par le journal]

Introduction

Natural regeneration of cherry–maple (*Prunus–Acer*) Allegheny hardwood stands on the Allegheny Plateau in northwestern Pennsylvania, United States, frequently fails after clear-cutting. Studies have shown that the presence of abundant advance reproduction was the most important factor determining whether satisfactory regeneration occurred (Grisez and Peace 1973). Stands that failed to regenerate usually lacked adequate advance seedlings before cutting. Subsequent studies have shown that the presence of white-tailed deer (*Odocoileus virginianus virginianus* (Boddaert)) and dense ground covers of fern and grass have a substantial impact on the establishment of advance reproduction (Horsley 1977*b*; Marquis 1981; Marquis and Brenneman 1981).

Since the 1920's the Allegheny Plateau has supported an unusually large white-tailed deer population, which has caused continuous damage to forest vegetation for many years (Marquis and Brenneman 1981). As a result, woody vegetation in the understory of Allegheny hardwood stands is extremely sparse and consists primarily of small seedlings only a few centimeters high. The large advance seedlings, common in northern hardwood forests with smaller deer populations, are almost nonexistent. Estimates of the impact of deer on the success of regeneration suggest that deer browsing is directly responsible for more than 85% of the regeneration failures (Marquis 1981).

Many Allegheny hardwood stands also contain dense ground covers of hayscented fern, New York fern, or short husk grass. On some sites they seem to be naturally abundant, but on others they probably invaded the stand following previous cuttings. Dense ground covers of these herbaceous plants can reduce the number of

[1]This article was written and prepared by United States Government employees on official time, and it is therefore in the public domain.

[2]Revised manuscript received September 22, 1982.

desirable[3] seedlings from 50 to 90%, and inhibit seedling height growth from 40 to 65% (Horsley 1977*b*).

Marquis (1979) recommended shelterwood cutting to regenerate Allegheny hardwood stands that lack adequate advance seedlings to qualify for clear-cutting. The moderate environmental conditions created by the first or seed cut favor seed germination and early seedling establishment. Although little height growth is made at this time, many seedlings become established. When the overstory is removed with the second or removal cut, rapid seedling growth ensues, and some seedlings grow out of the reach of deer before they are eaten. However, the presence of dense herbaceous covers is a major impediment to use of the shelterwood method. Such covers prevent the buildup of desirable seedlings after the seed cut and reduce seedling growth after the removal cut; so, seedlings are exposed to deer browsing for a longer time. However, in stands with dense herbaceous ground covers and heavy deer browsing, the relative impacts of deer and forest weeds at these two critical stages in the regeneration of shelterwood stands are not known. This paper presents the results of such an evaluation.

Methods

Two experiments were conducted in stands with both dense herbaceous ground cover and a high deer population. One stand received the seed cut, and the other the removal cut of a two-cut shelterwood. In both stands, effects of weeds and deer on regeneration were evaluated on 20 randomly located clusters of three circular plots with a 1.83-m radius. Each plot in a cluster was randomly assigned one of three treatments. (*i*) Fenced with a 1.52-m-high fence (fenced treatment). Deer were excluded from the plot, but weeds were present. (*ii*) Fenced as in one, hand weeded, and maintained weed free throughout the 5-year duration of the study (fenced–weeded treatment). Both deer and weeds were excluded from the plot. (*iii*) Unfenced and unweeded (control treatment). Both deer and weeds were permitted on the plot.[4]

Plots in a cluster were located within a few metres of each other where site and environmental factors, overstory conditions, and seedfall were expected to be similar. Effects of these treatments on hardwood regeneration were evaluated by seedling counts and measurements of seedling height. Effects of deer were estimated from the differences between reproduction on control and fenced plots. Similarly, the effects of weeds were estimated from differences in reproduction on fenced–weeded and fenced plots.

Each plot was measured initially in July 1975 before treatments were applied; then annually in August or September for the next 4 years. Percent ground coverage by herbaceous species was estimated visually by two independent observers and an arbitrated value was recorded. Number and species of regeneration were obtained by four height classes: <0.3, 0.3–0.9, 0.9–1.5, and >1.5 m. The height of the tallest stem of each species on each plot was recorded. Ten black cherry seedlings on each fenced and each fenced–weeded plot were marked with small plastic rings, and annual elongation of the terminal and lateral long shoots were measured to the nearest 0.5 cm. Adequacy of stocking with desirable reproduction was evaluated by the method of Marquis and Bjorkbom (1982). This method uses different criteria during progressive stages of the regeneration process. In the stand receiving the shelterwood seed cut, stocking was considered adequate when treatments resulted in at least 70% of the 1.83-m plots with at least 25 black cherry stems or 100 stems of all desirable species. In the stand receiving the removal cut, stocking was considered adequate when either of the following resulted from treatments: (*i*) two stems taller than 1.5 m on 70% of the sample plots, or (*ii*) the average of the proportion of plots with five desirable stems taller than 0.9 m and the proportion of plots with a total of 25 desirable stems was at least 70%. Each of the proportions in (*ii*) was determined separately, then the two were averaged. Estimates of seed crops were made visually by species.

Differences among treatments were tested using the analysis of variance. Percentage data were transformed using the arc sine transformation before analysis. Duncan's new multiple range test was used for mean separation. The 0.05 level of probability was accepted as significant throughout the work.

Study areas

Shelterwood seed cut

A cherry–maple stand near Smethport, Pennsylvania, with a dense understory of hayscented fern covering 75–80% of the ground was selected for the shelterwood seed cut. Soil at the location was a moderately well-drained Cookport sandy loam, typical of many hardwood sites on the Allegheny Plateau. The pH of the A horizon ranged from 4.2 to 4.4. The seed cut reduced overstory stocking to 75% of full stocking (Roach 1977), which left 5.11 m^2/ha of basal area in 16 black cherry/ha and 5.48 m^2/ha of basal area in 92 sugar and red maple/ha in trees 2.5 cm and larger.

Shelterwood removal cut

A cherry–maple stand near Roulette, Pennsylvania, with an understory containing a mixture of hayscented fern and short husk grass was selected for the shelterwood removal cut. Ten of the 20 clusters were chosen in each ground cover. Ground coverage by fern or grass averaged 95 and 80%, respectively, before treatment. Soil was similar to that at the Smethport location. The overstory had received a shelterwood seed cut 6 years earlier, and stocking had been reduced to 50% of full stock (Roach 1977). Immediately, before the removal cut, overstory basal area was distributed as follows: black cherry, 4.27 m^2/ha; sugar maple, 2.97 m^2/ha; beech (*Fagus grandfolia* Ehrh.), 0.46 m^2/ha; red maple, 0.19 m^2/ha; and

[3]Desirable species include black cherry (*Prunus serotina* Ehrh.), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), and white ash (*Fraxinus americana* L.).

[4]An unfenced–weeded treatment was not included in this experiment because previous studies on the Allegheny Plateau have shown that in stands lacking dense herbaceous cover, unprotected seedlings are readily eaten by deer (Marquis 1981).

TABLE 1. Percentage of ground cover, by herbaceous plants and treatment,* over time, in a shelterwood seed cut stand†

Measurement date‡	Control			Fenced		
	Rubus	Fern	Grass	*Rubus*	Fern	Grass
1975	1*a*	79*a*	1*a*	1*a*	78*a*	1*a*
1976	1*a*	88*a*	2*a*	4*b*	91*a*	2*a*
1977	5*a*	97*a*	7*a*	16*b*	97*a*	10*a*
1978	2*a*	99*a*	4*a*	11*b*	99*a*	4*a*
1979	3*a*	89*a*	3*a*	17*b*	92*a*	4*a*

*Percent ground cover in 1975 on fenced—weeded plots by *Rubus*, fern, and grass were, respectively, 1, 77, 1. These plants were subsequently removed by weeding on fenced—weeded plots.

†Means within the same treatment and species of ground cover followed by the same letter were not significantly different at the 0.05 level of probability.

‡1975 measurements were made before understory treatment or overstory shelterwood cutting.

white ash, 0.09 m^2/ha. All stems larger than 2.5 cm in diameter were removed during cutting.

Results

Shelterwood seed cut

Small, nonsignificant increases in fern and grass ground cover occurred on fenced and control plots following treatment; *Rubus*[5] cover increased significantly on fenced, but not on control plots (Table 1). Weeding eliminated all herbaceous cover, including fern, grass, and *Rubus*.

The numbers of tree seedlings present in all treatments varied substantially from year to year, increasing in years with good seed crops and decreasing as seedlings succumbed to the stresses of the environment. A large black cherry seed crop produced in the fall of 1976 resulted in increased numbers of black cherry seedlings in 1977. Similarly, a very large red maple seed crop produced in the spring of 1978 resulted in increased numbers of seedlings the same year. The effects of deer and weeds are shown when this sawtooth trend in number of seedlings is compared over time by treatment (Table 2).

Removal of fern significantly increased the number of desirable seedlings on fenced—weeded plots during the 4 years after treatment (Table 2). The number of seedlings on fenced plots was similar to that on control plots. Number of desirable seedlings increased on weeded plots because of both more germination and better survival of black cherry and red maple seedlings. Number of black cherry seedlings that resulted from the seed crop of 1976 was 60% greater in 1977 on fenced—weeded plots than that on either fenced or control plots. Fenced—weeded seedlings survived better, too. In 1978, fenced—weeded plots had only 2% fewer black cherry seedlings than in 1977, whereas fenced and control plots had 48% fewer. Survival of individually marked black cherry seedlings 4 years after marking was 65% on fenced—weeded plots, but only 12% on fenced plots.

The red maple seed crop in the spring of 1978 increased the number of red maple seedlings 244% on fenced—weeded plots the same year, versus a 34% increase on fenced or control plots. Survival was also substantially better on weeded plots. Ninety percent of the number of seedlings present in 1978 were present in 1979, whereas only 36% survived on fenced or control plots. Four years after treatment, there were 43 000 desirable seedlings per hectare on fenced—weeded plots and only 8 000 on fenced or control plots (Table 2). Stocking was 95, 45, and 40%, respectively.

Pin cherry seedlings germinated on all plots (Table 2). Few pin cherry seedlings were present in any treatment at the beginning of the experiment; however, weeding resulted in germination of large numbers of formerly dormant pin cherry seeds from the seed bank in the forest floor. Two years after treatment there were slight increases on fenced or control plots. None of these seedlings lived long; by 1979 most were dead.

Height growth was significantly greater for all species of reproduction on fenced—weeded plots than that on fenced or control plots (Table 3). After 4 years, the tallest desirable seedling averaged 52 cm on fenced—weeded plots, but only 18 and 15 cm, respectively, on fenced and control plots. Individually marked black cherry seedlings on fenced plots were typically unbranched, whereas those on fenced—weeded plots had elongated terminal and lateral long shoots.

Shelterwood removal cut

In 1975, immediately before the shelterwood removal cut, the east half of the study area had predominantly fern cover, the west half of the area had predominantly grass cover (Table 4). After the removal cut, fern and grass ground cover changed on fenced and control plots. During the 4 years after removal cutting, *Rubus* increased significantly from less than 5% ground cover in 1975 to 70—75% on plots with predominantly fern cover, and to 80—85% on plots with predominantly grass cover. As *Rubus* increased in ground cover, fern and grass declined significantly in importance. Fern cover decreased 25—45%, and grass cover decreased 30—40% on control and fenced plots, respectively. Deer had little effect on *Rubus* ground cover in this study. Most control plots had less *Rubus* than fenced plots during the first few years of the study, but after 4 years the amount of *Rubus* inside and outside of the fences was the same.

Before treatment, grass-covered plots had more than three times as many desirable seedlings as fern-covered

[5]*Rubus allegheniensis* Porter and *Rubus occidentalis* L.

TABLE 2. Mean number of hardwood seedlings, thousand per hectare, by species and treatment,* over time, in a shelterwood seed cut stand†

Measurement date‡	Black cherry			Sugar maple			Red maple			All desirable			Pin cherry		
	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W
1975	28.7*a*	24.9*a*	27.1*a*	1.1*a*	0.9*a*	0.9*a*	8.8*a*	9.7*a*	7.7*a*	38.6*a*	35.5*a*	35.8*a*	0.1*a*	0.1*a*	0*a*
1976	17.0*a*	17.0*a*	20.9*a*	0.4*a*	0.4*a*	0.4*a*	6.3*a*	7.7*a*	6.1*a*	23.6*a*	25.1*a*	27.4*a*	1.1*a*	0.4*a*	10.6*b*
1977	27.8*a*	27.5*a*	36.7*a*	0.4*a*	0.4*a*	0.3*a*	5.9*a*	6.1*a*	6.0*a*	33.0*a*	34.0*a*	43.1*a*	0.5*a*	0.4*a*	63.8*b*
1978	14.8*a*	13.4*a*	35.9*b*	0.2*a*	0.2*a*	0.2*a*	8.5*a*	7.6*a*	20.7*b*	23.4*a*	21.0*a*	56.9*b*	0*a*	0*a*	7.2*b*
1979	4.6*a*	4.7*a*	24.0*b*	0.1*a*	0.1*a*	0.2*a*	2.9*a*	3.0*a*	18.7*b*	7.6*a*	7.8*a*	42.9*b*	0*a*	0*a*	0.5*b*

*Treatments were control (C), fenced (F), and fenced−weeded (F−W) as described in the text.
†Means within a species and year followed by the same letter were not significantly different at the 0.05 level of probability.
‡1975 measurements were made before understory treatment or overstory cutting.

TABLE 3. Mean height, in centimetres, of the tallest desirable hardwood seedlings, by species and treatment, over time, in a shelterwood seed cut stand*

Measurement date‡	Black cherry			Sugar maple			Red maple			All desirable†		
	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W
1975	15*a*	18*a*	18*a*	12*a*	18*a*	18*a*	15*a*	15*a*	15*a*	18*a*	21*a*	21*a*
1976	12*b*	18*a*	18*a*	12*a*	18*a*	18*a*	15*a*	15*a*	15*a*	15*b*	21*a*	21*a*
1977	12*b*	15*b*	21*a*	15*b*	15*b*	21*a*	15*b*	15*b*	27*a*	15*b*	21*ab*	27*a*
1978	9*b*	12*b*	27*a*	12*b*	12*b*	27*a*	15*b*	15*b*	34*a*	15*b*	15*b*	37*a*
1979	9*b*	12*b*	27*a*	12*b*	12*b*	27*a*	15*b*	18*b*	49*a*	15*b*	18*b*	52*a*

*Differences among treatment means within the same species and year followed by the same letter were not significantly different at the 0.05 level of probability.
†Mean of the tallest desirable stem on each plot regardless of species. Means in this category are sometimes larger than means for individual desirable species. Desirable species in this stand include black cherry, sugar maple, and red maple.
‡1975 measurements were made before understory treatment or overstory cutting.

TABLE 4. Percentage of ground cover, by herbaceous plants and treatment,* over time, in a shelterwood removal cut stand†

Measurement date‡	Plots with predominantly fern cover				Plots with predominantly grass cover			
	Fern		*Rubus*		Grass		*Rubus*	
	Control	Fenced	Control	Fenced	Control	Fenced	Control	Fenced
1975	96*a*	94*ab*	2*e*	2*e*	81*a*	79*a*	4*g*	3*g*
1976	75*de*	91*abc*	5*e*	12*d*	86*a*	82*a*	13*f*	24*e*
1977	83*cd*	86*bcd*	19*d*	33*c*	36*bcd*	26*d*	44*d*	77*a*
1978	61*fg*	75*de*	43*c*	60*b*	35*cd*	32*cd*	68*b*	82*a*
1979	50*g*	68*ef*	70*ab*	73*a*	38*bc*	47*b*	83*a*	54*c*

*Percent ground cover in 1975 on fenced−weeded plots by fern and *Rubus* on fern-covered plots were 96 and 2, respectively, and by grass and *Rubus* on grass-covered plots were 80 and 3, respectively. These plants were subsequently removed by weeding on fenced−weeded plots.
†Treatment by year interaction means within the same ground cover followed by the same letter do not differ significantly at the 0.05 level of probability.
‡1975 measurements were made before understory treatment or overstory shelterwood cutting.

plots; which suggests that fern interference was the stronger of the two species (Table 5). Black cherry was the most numerous species on all plots accounting for more than 90% of the desirable stems present; the birches (yellow and black) were the next most abundant (Table 5).

After the removal cut, the number of most species present in 1975 declined continuously over the next 4 years. Data for black cherry indicate that fencing had little or no effect on seedling survival, but fencing and weeding significantly increased survival 4 years after cutting on both fern and grass plots (Table 6). Survival

TABLE 5. Mean number of tree seedlings, thousand per hectare, in 1975 before fencing and weeding treatments on plots with fern or grass cover in a shelterwood removal cut stand

Ground cover	Species of reproduction*								
	BC	SM	RM	DES	BI	PC	STM	BE	ALL
Fern†	14.8*a*	0.1*a*	0.7*a*	16.4*a*	1.8*a*	0*a*	0.2*a*	0.2*a*	17.8*a*
Grass	54.7*b*	0.4*b*	0.7*a*	57.2*b*	2.0*a*	0*a*	0*a*	0.1*a*	59.3*b*

*BC = black cherry, SM = sugar maple, RM = red maple, DES = all desirable species, BI = yellow and black birch, PC = pin cherry, STM = striped maple (*Acer pensylvanicum* L.), BE = beech, ALL = all species.

†Means in the same column followed by the same letter were not significantly different at the 0.05 level of probability.

of individually marked black cherry seedlings was also substantially greater on fenced–weeded plots than that on fenced or control plots (Table 7).

Pin cherry was absent in 1975. During the first 2 years after cutting, pin cherry appeared on some plots in all treatments but significantly more were found on fenced–weeded plots 4 years after treatment (Table 6).

The effects of treatments on seedling height growth varied according to species. Fenced treatment of black cherry did not increase growth of seedlings (Fig. 1). Seedlings on fenced and control plots typically were poorly developed, having small leaves and nonerect stems that did not emerge above the herbaceous cover. Thus, deer browsing had no effect on these seedlings. Fencing and weeding resulted in significantly increased growth compared with fenced or control plots. Ferns inhibited black cherry seedling growth more than grass. Long shoot elongation of individually marked black cherry seedlings showed the same trends (Table 8).

Furthermore, calculations of stocking with desirable reproduction, which reflect both the adequacy of the number of desirable seedlings and their growth, provide a similar picture (Table 9). On the control and fenced fern-covered plots, number of seedlings precipitously declined, and residual seedlings did not grow much. Thus, stocking declined throughout the study. On plots where ferns were removed, the number of seedlings remained higher, and those seedlings grew well resulting in adequate stocking in the 4th year after treatment. On grass-covered plots, growth of desirable seedlings was slower on fenced and control plots than that on fenced–weeded plots, but stocking was adequate.

Growth of birch showed an entirely different picture (Fig. 2). Deer browsing significantly reduced the growth of birch; seedlings on fern- or grass-covered control plots were significantly shorter than those on fenced plots. Fern and grass had little or no effect on birch growth. Fenced birch seedlings were similar in height to fenced–weeded birch seedlings. Fern may have caused reduction in birch growth during the first few years, but during the last 2 years of the study, birch

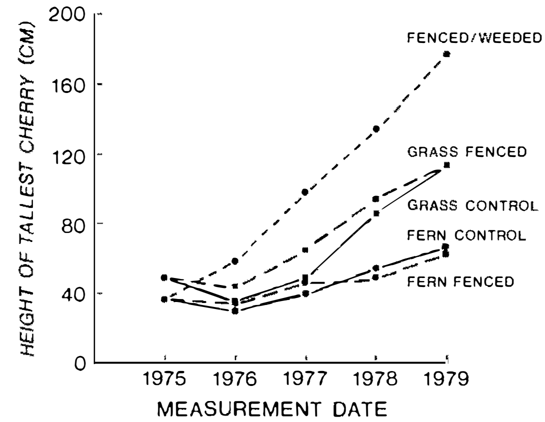

FIG. 1. Height of the tallest black cherry seedling over time on control, fenced, and fenced–weeded plots in a shelterwood removal cut stand.

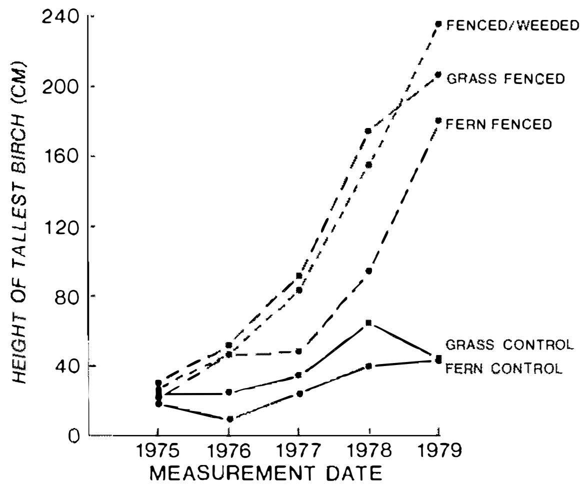

FIG. 2. Height of the tallest birch over time on control, fenced, and fenced–weeded plots in a shelterwood removal cut stand.

seedlings on fern-covered plots grew at the same rate as those on fenced–weeded plots. Typically, birch seed-

TABLE 6. Mean number of hardwood seedlings, thousand per hectare, by species and treatment,* over time, in a shelterwood removal cut stand†

Measurement date‡	Black cherry			Sugar maple			Red maple			All desirable			Birches			Pin cherry		
	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W	C	F	F−W
								Plots with predominantly fern cover										
1975	18.5*a*	14.5*a*	11.4*a*	0.1*a*	0.1*a*	0.1*a*	0.7*a*	0.3*a*	0.6*a*	20.1*a*	15.7*a*	13.3*a*	2.6*a*	1.2*a*	1.7*a*	0*a*	0*a*	0*a*
1976	6.3*a*	7.7*a*	9.4*a*	0.3*a*	0.4*a*	0*a*	0.1*a*	0.2*a*	0.3*a*	7.0*a*	8.6*a*	10.2*a*	1.0*a*	0.4*a*	1.0*a*	0.6*a*	0.1*a*	1.2*a*
1977	4.4*a*	5.8*a*	7.5*a*	0*a*	0.9*a*	0*a*	0.2*a*	0.2*a*	0.2*a*	5.0*a*	7.2*a*	8.0*a*	0.7*a*	0.4*a*	0.6*a*	0.1*a*	0*a*	3.0*a*
1978	3.3*a*	4.8*a*	6.8*a*	0*a*	0.6*a*	0*a*	0*a*	0.2*a*	0.3*a*	3.6*a*	5.7*a*	7.4*a*	0.4*a*	0.2*a*	0.6*a*	0.1*a*	0*a*	2.5*a*
1979	1.4*b*	2.7*b*	5.9*a*	0*a*	0.6*a*	0*a*	0*a*	0.1*a*	0.1*a*	1.6*b*	3.5*b*	6.4*a*	0.3*a*	0.2*a*	0.5*a*	0*b*	0*b*	2.1*a*
								Plots with predominantly grass cover										
1975	54.9*a*	56.8*a*	52.3*a*	0.3*a*	0.3*a*	0.5*a*	0.7*a*	0.7*a*	0.6*a*	56.0*a*	57.8*a*	53.4*a*	2.3*a*	2.2*a*	1.3*a*	0*a*	0*a*	0*a*
1976	40.4*a*	42.2*a*	46.3*a*	0.5*a*	0.4*a*	1.7*a*	0.2*a*	0.4*a*	0.3*a*	41.1*a*	43.1*a*	46.7*a*	0.9*a*	1.4*a*	1.2*a*	0*a*	0*a*	0.3*a*
1977	36.5*a*	33.9*a*	36.2*a*	0.4*a*	0.3*a*	0.1*a*	0.2*a*	0.2*a*	0.3*a*	37.0*a*	34.4*a*	36.6*a*	0.4*a*	1.3*a*	0.9*a*	0.3*a*	0.1*a*	0.4*a*
1978	25.0*a*	24.3*a*	35.9*a*	0.1*b*	0.3*a*	0.1*b*	0.2*a*	0.2*a*	0.2*a*	25.3*a*	24.9*a*	36.2*a*	0.5*a*	1.1*a*	1.3*a*	0.1*a*	0*a*	0.2*a*
1979	12.5*b*	13.1*b*	21.8*a*	0*a*	0.3*a*	0.1*a*	0.2*a*	0.2*a*	0.2*a*	12.7*b*	13.6*b*	22.1*a*	0.2*a*	0.6*a*	0.3*a*	0*b*	0*b*	0.2*a*

*Treatments were control (C), fenced (F), and fenced−weeded (F−W) as described in the text.
†Treatment means within a species, year, and ground cover followed by the same letter were not significantly different at the 0.05 level of probability.
‡1975 measurements were made before understory treatment or overstory cutting.

TABLE 7. Percentage of survival of black cherry seedlings growing among fern or grass cover, by treatment, over time, in a shelterwood removal cut stand

Measurement date*	Control	Fenced	Fenced−weeded
	Plots with predominantly fern cover		
1975†	100*a*	100*a*	100*a*
1976	34*b*	53*b*	83*a*
1977	24*b*	40*ab*	66*a*
1978	18*b*	33*ab*	60*a*
1979	1*c*	19*b*	52*a*
	Plots with predominantly grass cover		
1975	100*a*	100*a*	100*a*
1976	74*a*	74*a*	88*a*
1977	67*a*	60*a*	69*a*
1978	46*b*	43*b*	69*a*
1979	23*b*	23*b*	42*a*

*1975 measurements were made before understory treatment or overstory cutting.
†Values in the same horizontal line followed by the same letter were not significantly different at the 0.05 level of probability.

lings emerged from the herbaceous cover on fenced plots after 1 or 2 years.

Discussion

This study indicates that in Allegheny hardwood stands with a dense ground cover of hayscented or New York fern or short husk grass, interference[6] from these plants is the primary cause that hinders establishment of desirable reproduction; deer browsing has little or no direct effect because the desirable seedlings never grow large enough to be browsed. In the stand receiving the shelterwood seed cut, dramatically fewer seedlings grew on fern-covered plots. Calculations of stocking showed that the number of desirable seedlings where fern was present was the same or less than at the beginning of the study and that these seedlings did not grow in height. By contrast, the number of desirable seedlings increased continuously on fenced−weeded plots and was considered adequate after 4 years. Growth of seedlings growing in the partial shade of a shelterwood seed cut is usually limited; however, substantial growth was made by seedlings on fenced−weeded plots. Similar trends in number and growth of desirable seedlings, growing with the same species of fern and grass, were found in a previous study conducted in thinned Allegheny hardwood stands (Horsley 1977*b*).

Shelterwood seed cutting on the Allegheny Plateau frequently increases ground cover by fern and grass, if they are present in the stand before cutting. Fern cover

[6]The term interference as used by Muller (1969) denotes the combined deleterious effect of all forms of interaction between two species.

TABLE 8. Cumulative elongation, centimetres, of terminal and lateral long shoots on individually marked black cherry seedlings on fenced and fenced–weeded plots in a shelterwood removal cut stand*

Measurement date†	Fenced		
	Fern cover	Grass cover	Fenced–weeded
1975	3*b*	6*a*	3*a*
1976	8*b*	12*b*	19*a*
1977	18*b*	37*b*	148*a*
1978	31*b*	74*b*	375*a*
1979	48*b*	104*b*	624*a*

*Values in horizontal lines followed by the same letter were not significantly different at the 0.05 level of probability.
†1975 measurements were made before understory treatment or overstory shelterwood cutting.

increased in this study. Clearly, it is inappropriate to use shelterwood seed cutting in stands with dense fern cover. Other studies suggest that if fern cover is greater than 30% on more than 30% of the area, the seed cut should be deferred until action can be taken to reduce or remove the fern cover (Marquis *et al.* 1975). Procedures for removal of fern cover with herbicides have been detailed by Horsley (1981, 1982).

Following the shelterwood removal cut, fern or grass cover interfered with establishment of desirable reproduction. The effects were more serious than those following seed cutting because the source of seed was removed with the overstory. The ferns interfered more strongly than grass in this stand. Fern-covered plots had fewer seedlings than grass-covered plots at the beginning of the experiment, but percent survival was equally as poor with either ground cover. Growth of black cherry seedlings was significantly reduced by either fern or grass cover; fern inhibited growth more than grass. Calculations of stocking showed that fern-covered plots almost certainly will fail to regenerate successfully. All measures of stocking were very low. The prognosis for grass-covered plots is better. All grass-covered plots had adequate numbers of seedlings 4 years after cutting, and growth and stocking were slowly increasing. Thus, grass-covered plots would probably regenerate successfully in the absence of deer. In the presence of deer, these seedlings invariably would be browsed when they grow above the herbaceous cover. Palatable species, i.e., birch, pin cherry, and *Rubus*, that grew above the herbaceous cover were browsed intensively by deer.

Fern and grass cover did not appreciably affect species that grew above it. *Rubus* and pin cherry, though low in abundance at the beginning of the study, grew rapidly through fern and grass. Birch, which is similar in shade tolerance to black cherry in seedling sizes, also grew through the herbaceous cover rapidly, whereas cherry did not. This differential sensitivity to associated species is a keynote of allelopathic interference (Horsley 1977*a*; Larson and Schwarz 1980). Although these observations do not prove an allelopathic interference between black cherry and fern or grass, previous studies have demonstrated growth reduction in black cherry seedlings watered with nutrient solutions containing foliage extracts from hayscented fern, New York fern, or short husk grass (Horsley 1977*b*). Thus, an allelopathic relationship cannot be dismissed.

Rubus seems to play an important role in the succession of Allegheny hardwood and perhaps other northern hardwood stands. Species of *Rubus* are a component of the early stage of succession throughout the northern hardwood forest (Marks 1974). Dormant seeds stored in the forest floor germinate after cutting, and the seedlings grow rapidly, often becoming the dominant vegetation during the first few years after cutting. *Rubus* is usually superseded by pin cherry, the birches, aspen, black cherry, or other faster growing pioneer species upon which it seems to have no effect. In Allegheny hardwood stands, *Rubus* seems to interfere with fern and grass, resulting in a decline in importance of these species, thus preparing the site for longer lived species which are inhibited by the presence of fern or grass. The mechanism of this interference is unknown.

We have said that deer browsing had no direct effect on reproduction of desirable species in stands with dense fern or grass ground covers because the seedlings never grew above the herbaceous cover where they could be browsed. However, deer browsing did have indirect effects. For example, deer browsing of *Rubus* can prevent its interference with fern or grass. In this study, deer browsing caused some reduction in the cover of *Rubus*, but apparently not enough to prevent it from reducing the fern and grass cover. However, Marquis and Grisez (1978) reported that deer prevented the development of *Rubus* on plots outside of fences, while inside the fences, as *Rubus* coverage increased, fern and grass coverage decreased. It seems that this reduction in fern or grass cover must take place before longer lived species such as black cherry become

TABLE 9. Stocking with desirable reproduction, by treatment, over time, in a shelterwood removal cut stand

Measurement date*	Control				Fenced				Fenced–weeded			
	25 or 100†	5>0.9 m	2>1.5 m	Stocking	25 or 100	5>0.9 m	2>1.5 m	Stocking	25 or 100	5>0.9 m	2>1.5 m	Stocking
	Plots with predominantly fern cover											
1975	96	0	0	45	80	0	0	40	80	0	0	40
1976	60	0	0	30	50	0	0	25	80	0	0	40
1977	50	0	0	25	50	0	0	25	80	30	0	55
1978	50	0	0	25	50	10	10	30	70	50	20	60
1979	0	0	0	0	20	10	10	15	80	70	70	75
	Plots with predominantly grass cover											
1975	100	0	0	50	100	0	0	50	100	0	0	50
1976	100	0	0	50	100	0	0	50	100	0	0	50
1977	100	0	0	50	100	0	0	50	100	20	0	60
1978	100	10	10	55	100	20	0	60	100	40	10	70
1979	100	20	10	60	100	40	20	70	100	70	20	85

*1975 measurements were made before understory treatment or overstory shelterwood cutting.
†25 or 100 = proportion of plots with 25 black cherry stems or 100 stems of desirable species; 5 > 0.9 m = proportion of plots with 5 desirable stems >0.9 m tall; 2 > 1.5 m = proportion of plots with 2 desirable stems >1.5 m tall; stocking = mean of 25 or 100 and 5 > 0.9 m, a measure of adequacy of development of Allegheny hardwood reproduction.

established.

In the present situation in Pennsylvania, browsing by the excessively large deer herd often results in a "climax" of self-perpetuating fern and grass when these species are present in great abundance[7] before the removal cut. In this situation, removal cutting should be deferred until action can be taken to reduce or remove the fern or grass cover (Horsley 1981), and adequate numbers of advance seedlings are present (Marquis *et al.* 1975).

Finally, a larger number of pin cherry seedlings were found on fenced–weeded plots than on fenced or control plots in both stands; in the stand with the shelterwood seed cut, the differences were very large. These seedlings germinated from seed stored in the forest floor. The disturbance caused by weeding probably stimulated the seeds to germinate (Marks 1974; Marquis 1975). Recently, Auchmoody (1979) showed that NO_3^--ion applied without physical disturbance to the forest floor of uncut Allegheny hardwood stands resulted in germination of a very large number of pin cherry from seed stored in the forest floor. He suggested that the increase in soil N caused by use of nitrogen fertilizers may trigger germination of these buried seeds. Thus, the increase in NO_3^--N that results in northern hardwood stands following forest cutting (Smith *et al.* 1968) may be the environmental cue that causes germination of pin cherry seed. Germination of other species is stimulated by NO_3^--ion (Toole *et al.* 1956; Hendricks and Taylorson 1974; Vincent and Roberts 1977; Freijsen *et al.* 1980). Thus, changes caused by weeding may have increased the rate of nitrification that resulted in germination of pin cherry seed. Alternatively, if pin cherry germination is light or temperature sensitive, weeding may have exposed the seeds to light or increased temperature that resulted in their germination. It is not possible to decide between these alternatives based on the evidence at hand.

Acknowledgments

We thank the Hammermill Paper Company for providing the forest stands used in this study and for performing the cutting operations. We also thank Vonley Brown, Virgil Flick, James Moore, David Saf, and Stephen Steele, whose technical help made this study possible.

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[7] Fern or grass cover is considered too abundant if 70% of the sample plots are stocked with more than 30% coverage of these species before the removal cut (Marquis *et al.* 1975).

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