RESPONSE OF YOUNG BLACK CHERRY TO THINNING AND FERTILIZATION[1]

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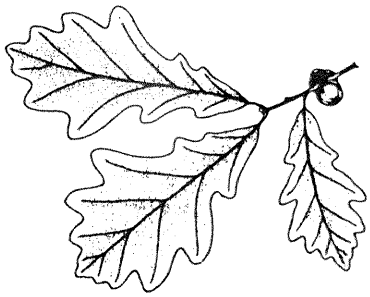

ABSTRACT.--Growth responses to thinning, fertilization, and thinning plus fertilization were evaluated in heavily stocked 12- and 7-year old natural black cherry (Prunus serotina Ehrh.) stands on the Allegheny Plateau in northwestern Pennsylvania over a 3-year period. Thinning plus fertilization in the 12-year-old stand was the only treatment that showed potential for increasing long-term growth rates. Fertilization alone produced major responses in height, diameter, and basal area growth rates, but these were short-lived. Height growth was greatest in unthinned fertilized stands, and in the year when fertilizers were applied. Thinning with fertilization resulted in less height response than fertilizing without thinning, and thinning without fertilization reduced height growth. Diameter and basal area responses were largest in stands that were thinned and fertilized, but fertilization without thinning also resulted in large but short-term responses. Thinning alone produced little response in diameter and basal area growth, showing that growth rates on these sites are limited by the deficient supplies of nitrogen and phosphorus.

INTRODUCTION

Overstocked stands of young black cherry (Prunus serotina Ehrh.) occupy about 19,000 acres of the Allegheny National Forest in northwestern Pennsylvania, and the number of acres will increase in future years as mature second growth stands are liquidated and reproduced. Because of extremely severe deer browsing (Marquis and Brenneman 1981), critically low soil nitrogen and phosphorus levels that inhibit seedling growth (Auchmoody 1982), and the interference to seedlings from detrimental ground cover and undesirable trees (Horsley and Marquis 1983), very large numbers of advance seedlings are necessary to ensure successful establishment of third-growth stands (Marquis, Ernst, and Stout 1984). In practice, areas selected for harvest cutting have averaged over 40,000 black cherry seedlings per acre (Marquis 1981). The result is that many emerging third-growth forests are very heavily stocked and contain a very high percentage of black cherry. These stands develop slowly and do not undergo the same rapid differentiation into dominance classes as other young hardwood forests. The slow growth is not only a result of crowding, but also of severe deficiencies of soil nitrogen and phosphorus which must be overcome before growth rates can be increased.

The purpose of this study was to determine the effects of fertilization, thinning, and thinning plus fertilization on height, diameter, and basal area growth rates in these heavily stocked young stands of black cherry. Fertilization of such stands is known to greatly increase their growth rates and to promote rapid crown class differentiation (Auchmoody 1982). However, thinning, and fertilization plus thinning, have not heretofore been investigated. This paper reports 3-year results from an experiment designed to compare these three treatments.

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METHODS

The study sites were located in the Allegheny High Plateau province on the Allegheny National Forest in northwestern Pennsylvania. This area is characterized by a cool moist climate having 44 inches of well-distributed precipitation and a frost-free period of about 120 days. Only rarely in this area does soil moisture become limiting for more than short periods during the growing season. Conditions are typical of those where black cherry thrives and attains its best development.

The study was established at two independent test sites. Four treatments were assigned at random to four plots at each site. The treatments were: (1) unthinned and unfertilized (control); (2) unthinned and fertilized; (3) thinned and fertilized; and (4) thinned and unfertilized. The fertilizer treatment consisted of one application of 200 lbs. per acre of elemental nitrogen (N) and 43 lbs. per acre of elemental phosphorus (P). The N source was ammonium nitrate and the P source was triple superphosphate. Fertilizers were broadcast uniformly upon the plots shortly after leaf-out in the spring of 1982. The thinning treatment reduced the number of stems to 200 per acre (about 14- X 14-foot spacing), all other trees being cut off at ground level and left on site. The trees retained were the largest and best formed dominants and codominants of seedling origin that could be retained within the spacing constraints.

Study plots were situated in two heavily stocked third-growth black cherry stands that had originated from complete clearcutting. One stand was 12 years old and the other 7 years. Dominant and codominant trees in the 12-year-old stand averaged 1.5 inches dbh and 18 feet tall; similar trees in the 7-year-old stand averaged 0.6 inches dbh and 9 feet tall. Both test sites had elevations of 2,100 feet; they had similar topography, and soil formed in residuum from acid grey sandstone of Pennsylvanian age (Typic Hapludults, fine-loamy, mixed, mesic). These soils have excellent physical properties for tree growth, are deeper than 4 feet, and receive ample precipitation during the growing season, but they are also extremely acid, infertile (table 1), and strongly deficient in nitrogen and phosphorus for black cherry (Auchmoody 1982, 1983).

TABLE 1.--Mean pH and concentration of nutrients in the upper 8 inches of soil at the two study sites (in parts per million).

Stand age (years)	pH	P	K	Ca	Mg	Mn
12	4.1	1.4	65	21	6	59
7	4.2	1.4	84	32	10	37

Each value is the mean of four composite samples.

Study plots were 0.1 acre, square, and selected for uniformity in pretreatment tree size and stocking. Twenty dominant or codominant black cherry trees, well distributed and representing the largest individuals of seedling origin on each plot, were selected to evaluate growth responses. These trees were numbered, marked at breast height measurement points with a paint stripe, and measured for height and diameter at the beginning of the study and annually for 3 years thereafter. Annual height growth was also determined for the 20 tallest stump sprouts that originated after stems were cut on the thinned plots, but other vegetation and trees on the plots were not measured.

The effects of treatments on diameter and basal area growth rates were evaluated by regression. Annual diameter measurements from individual trees were first converted to diameter and basal area growth in the usual way, and then the growth rates of individual trees were related to their annual starting diameters by linear regression. This method of analysis allows proper evaluation of treatment responses when the mean diameter of study trees is not the same among treatments (Auchmoody, submitted). Because there were major differences in tree size and in response patterns between the two study sites, data for each stand were evaluated separately.

Samples of autumn foliage were collected from each plot in both stands in the year that treatments were applied, and from each plot in the 12-year-old stand the following autumn (late August). Each sample was a composite consisting of 10 mature and undamaged leaves from the uppermost lateral branch of five dominant or codominant black cherry trees per plot (50 leaves total). These samples, with leaf petioles removed, were dried at 70°, ground in a stainless mill, and analyzed for N, P, K, Ca, Mg, and Mn. Nitrogen was determined by Kjeldahl digestion and, after wet ashing, P was determined colorimetrically and the cations by atomic absorption. Foliage samples from the 7-year-old stand were unavailable after the first season because of severe defoliation by the cherry scallop shell moth (Calocalpe undulata L.), and none were collected from the 12-year-old stand during year 3.

RESULTS

Height Growth

Height growth responses from fertilization were largest in unthinned stands and in the season when fertilizers were applied (fig. 1). In year 1, these increases were 1.7 and 2.4 feet for the 12- and 7-year-old stands, respectively, and were significant ($P \leq .05$). Smaller responses also occurred in the second year in the 7-year-old stand, and in the third year in the 12-year-old stand, though these increases were not significant. For

the 3-year period, trees in fertilized unthinned stands grew 2.1 and 3.1 feet more in height than control trees in the 12- and 7-year-old stands.

Height growth in thinned stands was also increased by fertilization. Released trees responded significantly in height during year 1, but to a lesser degree than the fertilized trees in unthinned stands. Their height growth was equal to that of control trees in year 2, and slightly less than that of controls in year 3. The total 3-year height response to fertilization in thinned stands was 1.5 and 1.1 feet for the 12- and 7-year-old stands, respectively.

Thinning without fertilization resulted in the least height growth of all treatments. In the 12-year-old stand, thinned trees gained substantially less height than control trees during all 3 years. In the 7-year-old stand, a small positive response to thinning occurred in year 1, but in year 2 height growth was the same as that of the controls, and in year 3 it was much less.

Black cherry sprouts that originated from the stumps of the cut trees in the thinned plots at both sites grew very rapidly (fig. 2), with fertilized sprouts attaining heights of more than 12 feet in the 12-year-old stand and 9 feet in the 7-year-old stand by the end of 3 years. Fertilization produced only small increases in the annual height growth of the tallest sprouts, amounting to about 1.5 feet for the 3-year period. However, height measurements of the 20 tallest sprouts do not reflect major differences that did result from fertilization in the number of tall sprouts per plot and in the degree and rapidity of their crown closure. On fertilized plots, sprouts were dense and formed a nearly continuous cover by the end of the first year. In contrast, without fertilization, the largest number of sprouts were short and many were held in check by deer browsing, so that even after 3 years the crowns had not closed (fig. 3). In unfertilized plots, the inability of sprouts to gain rapid and full control of the site allowed rapid establishment of sod-forming grasses (poverty grass, Danthonia spp., and shorthusk grass, Brachyelytrum erectum Schreb.) and deterioration of the original forest floor, and reduced the vigor and growth rates of the study trees.

DIAMETER GROWTH

Fertilization produced immediate large increases in diameter growth in thinned and unthinned stands at both sites (fig. 4). These responses were largest where fertilizers were applied to thinned stands, and during the first two seasons after their application. In the 12-year-old stand, response to fertilization plus thinning continued through year 3, response to fertilization in unthinned stands was limited to the first year, and thinning without fertilization had little effect on diameter growth. The short response period to fertilization in unthinned stands appeared to be the result of greatly

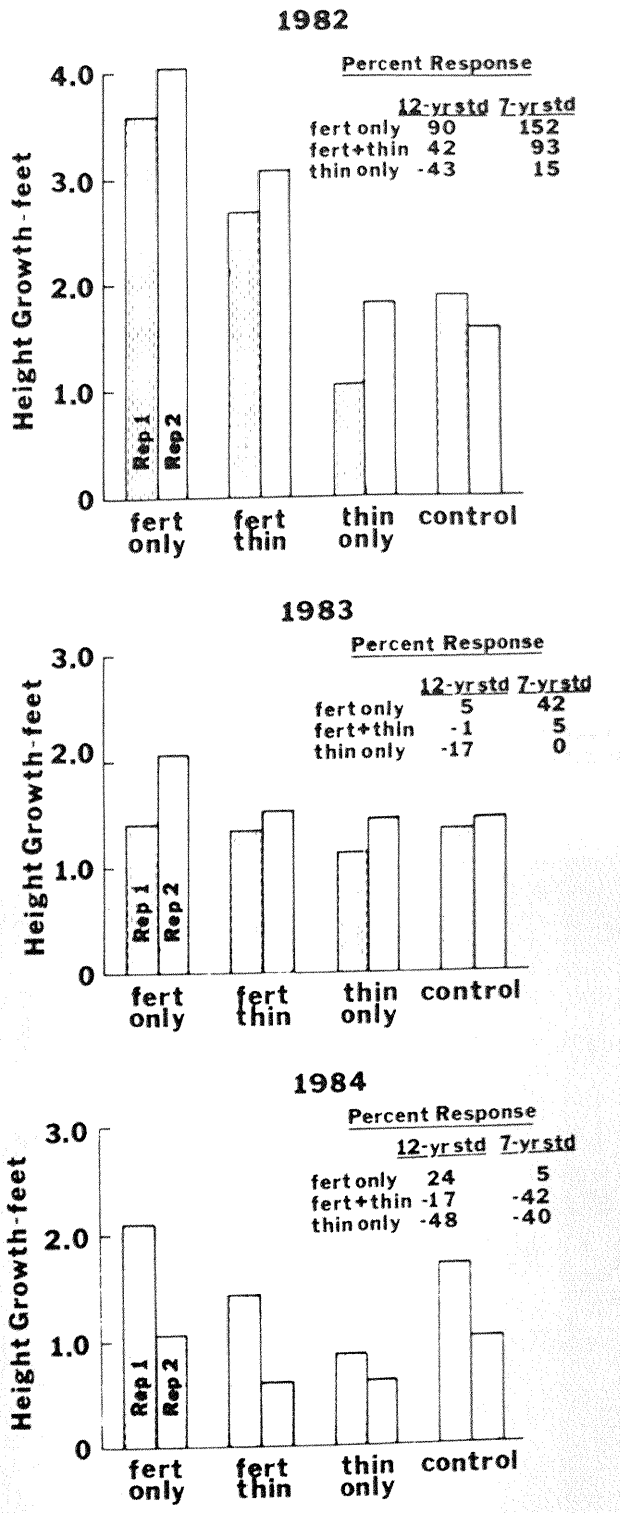

FIGURE 1.--Annual height growth responses of black cherry to fertilization, thinning, and fertilization plus thinning (rep 1 = 12-year-old stand; rep 2 = 7-year-old stand).

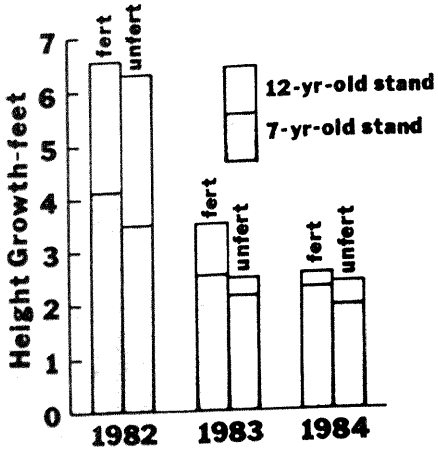

FIGURE 2.--Annual height growth of the 20 tallest fertilized and unfertilized black cherry sprouts in thinned stands.

increased crowding and competition brought on by the fertilizers in stands that were already overstocked, and the lack of response to thinning without fertilization was the result of severe soil nitrogen and phosphorus deficiencies. In the 7-year-old stand, thinned and unthinned trees responded to fertilization stands during year 1, but in following years differences among treatments were less pronounced because of mid-season defoliation by the cherry scallop shell moth.

Diameter growth increases (relative to control trees) from fertilization plus thinning are given in table 2. Because these responses were strongly affected by tree size, growth increases are shown for the smallest, largest, and mean size trees.

During the 3-year period in the 12-year-old stand, the mean increase in diameter growth from fertilization plus thinning was 0.8 inches, a 263% response over control trees. In the 7-year-old stand that was defoliated in years 2 and 3, the mean 3-year increase in diameter growth from fertilization plus thinning was 0.7 inches, or 148% more than that of the controls.

FIGURE 3.--The effect of thinning without fertilization (left) and thinning plus fertilization (right) 3 years after treatment, showing differences in diameter of retained trees and major differences in density and development of sprouts.

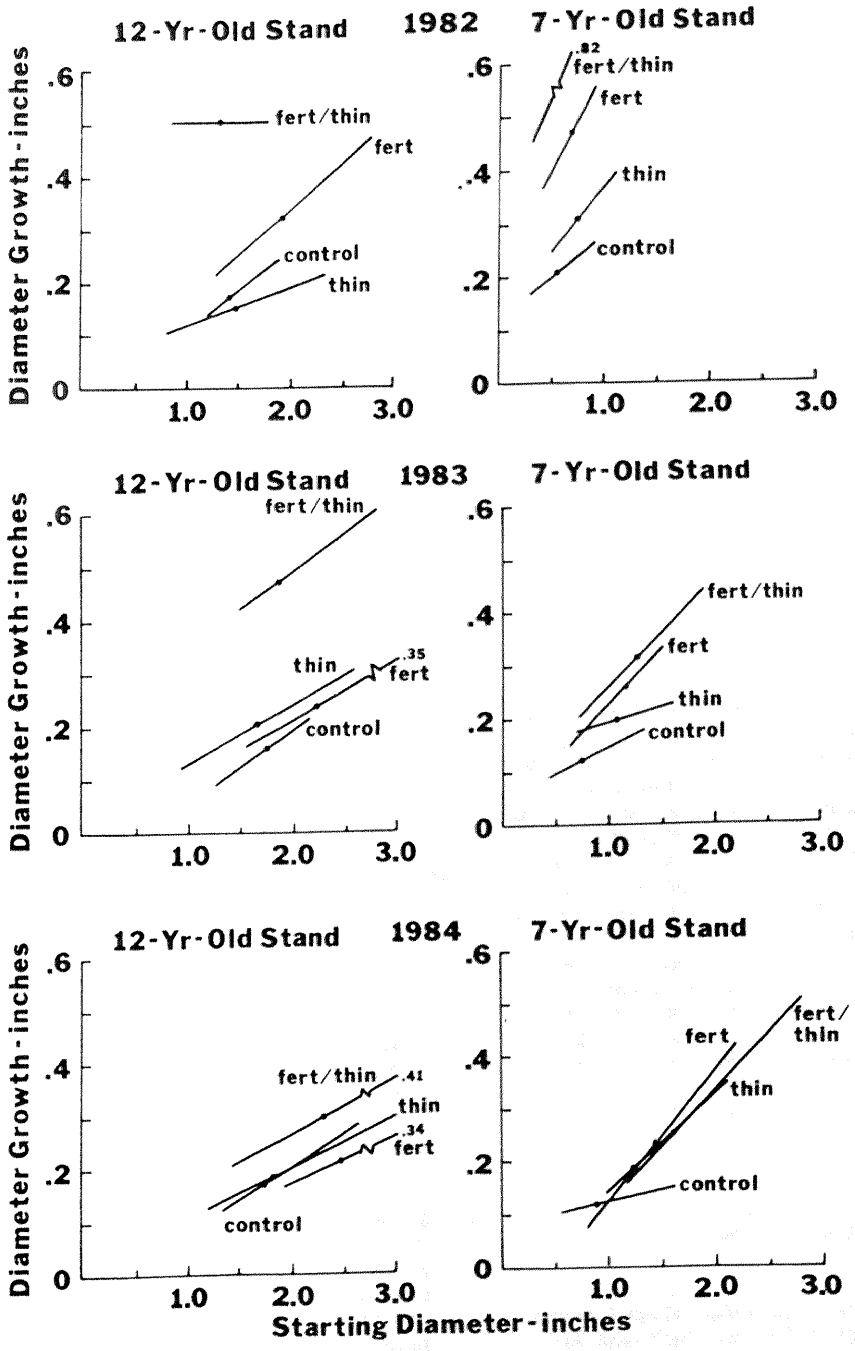

FIGURE 4.--Diameter response of black cherry to fertilizaton, thinning, and thinning plus fertilization. Solid lines indicate the range in annual starting diameter, and (o) the mean diameter growth of the average size tree. All regression lines are significant ($P \leq .05$), except for thinning plus fertilization in the 12-year-old stand in 1982.

TABLE 2.--Annual diameter growth increases of young black cherry from fertilization plus thinning (relative to control trees).

Year	Smallest Tree		Largest Tree		Mean Tree	
	inches	%	inches	%	inches	%
			12-year-old stand			
1982	.41	426	.28	124	.34	209
1983	.30	239	.31	105	.30	179
1984	.08	60	.03	9	.06	25
			7-year-old stand			
1982	.29	168	.52	177	.40	173
1983	.08	66	.21	90	.14	81
1984	.02	11	.28	108	.09	52

TABLE 3.--Annual basal area growth increases of young black cherry from fertilization plus thinning (relative to control trees).

Year	Smallest Tree		Largest Tree		Mean Tree	
	ft^2	%	ft^2	%	ft^2	%
			12-year-old stand			
1982	.0060	1500	.0063	137	.0061	235
1983	.0057	259	.0118	157	.0072	206
1984	.0003	14	.0040	37	.0021	34
			7-year-old stand			
1982	.0014	233	.0089	241	.0049	245
1983	.0001	8	.0058	145	.0027	108
1984	(-.0003)	(-16)	.0096	178	.0025	86

BASAL AREA GROWTH

Basal area response patterns to fertilization were similar to those for diameter (fig. 5). Immediate fertilizer responses were obtained at both sites, responses were largest in thinned stands, and were largest in the first and second years after fertilizers were applied. In the 12-year-old stand, responses to fertilization plus thinning continued through year 3, response to fertilization in unthinned stands lasted only for the first season, and there was no response to thinning without fertilization. In the 7-year-old stand, responses in the first year were largest for fertilization plus thinning, intermediate for fertilization only, and least for thinning. However, in following years there were only minor differences among the three cultural treatments, and their growth rates were only slightly better than growth rates of comparable size control trees. Annual basal area responses from the fertilization plus thinning treatment are given in table 3 for the smallest, largest, and average size trees at each site.

FOLIAR NUTRITION

Foliar analyses show that unfertilized trees at both study sites were deficient in N and P; that K, Ca, Mg, and Mn were not limiting growth; and that applied N and P were readily available to the study trees and were assimilated in amounts exceeding the requirements for maximum growth (table 2). Further, similar high levels of foliar N and P in thinned and unthinned fertilized stands indicate that the rate of fertilizer applied was more than adequate to satisfy nutrient requirements at both stocking conditions, and therefore that the short-term growth response to fertilization in unthinned stands was not nutrient-related. These data also show that thinning had very little effect on the availability of N and P to the 12-year-old retained trees through year 2, and to the 7-year-old retained trees during year 1, suggesting that the response to thinning without fertilization was limited by N and P on these highly deficient sites.

DISCUSSION

From this study, only the fertilizer/thinning treatment appears to have potential for improving long-term growth rates of individual trees in these heavily stocked young stands. In the 12-year-old stand, thinned and fertilized trees responded with greatly increased diameter and basal area growth, and with moderate increases in height. For example, the mean diameter of these study trees increased from 1.3 to 2.6 inches during the 3-year period, representing responses of 263% and 227% compared to control and thinned-only treatments, respectively. After three growing seasons, all trees remain dominant and have large vigorous crowns that should allow rapid growth rates to continue. Rapid regrowth of stump sprouts is providing the lateral competition needed to preserve stem quality and to ensure suitable future height growth. In addition, the full occupancy of the site by stump sprouts has prevented establishment of undesirable grasses, preserved the integrity of the forest floor, and avoided any major disruption of nutrient cycling processes on these highly deficient sites.

In the 7-year-old stand, the fertilizer/thinning treatment was not nearly as effective as in the older stand, suggesting that either the stand was

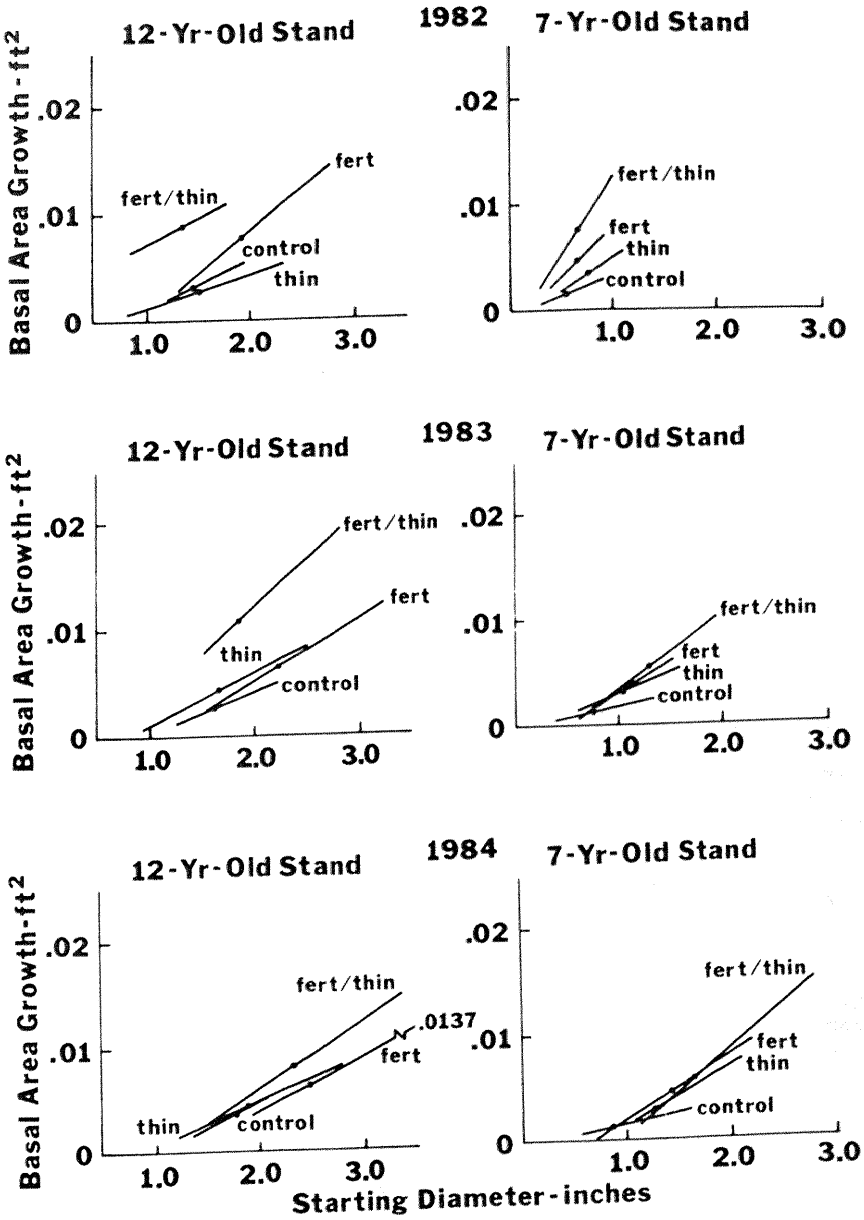

FIGURE 5.--Basal area response of black cherry to fertilization, thinning, and thinning plus fertilization. Solid lines indicate the range in annual starting diameters, and (o) the mean diameter growth for the average size tree. All regressions are significant ($P \leq .05$).

TABLE 4.--Autumn foliar nutrient concentrations in young dominant and codominant black cherry trees at both study sites in 1982 and at the 12-year-old stand in 1983 (in percent of dry weight).

Treatment	N	P	K	Ca	Mg	Mn
			12-year-old stand - 1982			
Unthinned and unfertilized	2.50	.14	1.86	.51	.23	.27
Unthinned and fertilized	3.24	.20	1.32	.60	.22	.28
Thinned and fertilized	3.73	.24	1.25	.56	.26	.24
Thinned and unfertilized	2.51	.14	1.51	.58	.31	.30
			7-year-old stand - 1982			
Unthinned and unfertilized	2.36	.14	1.82	.93	.31	.35
Unthinned and fertilized	3.65	.24	1.83	.58	.28	.27
Thinned and fertilized	3.82	.20	2.37	.39	.19	.23
Thinned and unfertilized	2.82	.16	1.74	.57	.24	.24
			12-year-old stand - 1983			
Unthinned and unfertilized	2.52	.13	2.45	.64	.31	.26
Unthinned and fertilized	3.02	.15	2.93	.54	.31	.21
Thinned and fertilized	2.87	.20	1.82	.59	.29	.23
Thinned and unfertilized	2.61	.14	1.59	.52	.42	.24

too young to respond adequately or that the heavy defoliation in years 2 and 3 prevented a response to such a severe treatment. In either event, sparse regrowth of sprouts and rapid invasion of the site by a dense cover of poverty grass and shorthusk grass has resulted in leave-trees with declining stem quality, small low-vigor crowns, and poor diameter and height growth rates.

Thinning without fertilization was clearly not effective in stimulating height or diameter growth at either site. Without fertilization, sprout regrowth was not dense enough to prevent invasion of sod-forming grasses, deterioration of the forest floor, and loss of stem quality on the retained trees. The study trees had critically low foliar N and P concentrations, visual symptoms of N and P stress, thin crowns with low vigor, and slow growth rates, which strongly suggest that deficiencies of N and P were limiting growth responses to thinning. Deficient nutrient supplies may also have been compounded by grass encroachment and deterioration of the forest floor. Although these results appear to contrast with positive responses found elsewhere after black cherry crop trees were released (Lamson and Smith 1978, Smith 1979, and Smith and Lamson 1983), these other studies were conducted on much more productive and less nutrient-deficient sites.

Fertilization without thinning did not stimulate growth rates after the first season, and therefore this treatment appears not to be an effective means for increasing long-term growth rates under these extremely crowded stand conditions. The short response period was unexpected and conflicts with results from other fertilization experiments conducted nearby, where responses have lasted 3 to 5 years and strong differentiation into crown classes has been promoted (Auchmoody 1982). Although the exact reason for these differences is unclear, previous tests were conducted with higher rates of N and P and in much younger stands. Thus, it is possible that fertilizers could still produce favorable and longer-lasting effects if they were applied at higher rates and to younger stands.

It appears that stimulating long-term growth rates in these crowded and nutrient-deficient black cherry stands depends on: (1) eliminating existing N and P deficiencies by fertilization, (2) providing adequate room for crown expansion of retained trees by thinning, and (3) assuring that regrowth from stump sprouts quickly and fully occupies the space among the retained trees. Although thinning provides the room for retained trees to expand, fertilization is crucial to promote healthy, large, photosynthetically efficient crowns and ensure rapid dense development of sprouts from the individuals removed in thinning. Dense regrowth of sprouts is essential to inhibit encroachment by undesirable grasses, to maintain the integrity of the forest floor and promote continued nutrient cycling, and to provide the lateral subdominant competition essential for leave-trees to maintain good form and remain in strong dominant crown class positions to continue rapid growth over the long term.

Although 3 years are hardly enough to predict the long-term outcome of thinning and fertilization on yields, results to date are encouraging. Therefore, further larger-scale studies seem warranted to better evaluate stand development, yields, and spacing requirements of retained trees.

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