Effects of Understory Removal in Hardwood Stands[1]

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ABSTRACT. Control of understory vegetation has frequently been suggested as a method of increasing overstory growth by reducing competition for soil moisture. However, past studies have given conflicting results: some show marked increases in growth rate resulting from understory removal, while others show no effect. Results of understory removal in an oak-dominated, mixed-species hardwood stand in central Massachusetts showed no growth increase compared to control plots, even over 13 growing seasons. Most other southern New England studies found no response on a variety of glacial till soils with a wide range in soil-moisture-holding capacity. Understory removal does not appear to be a useful technique to increase growth in hardwood stands on glacial till soils in the Northeast, apparently because soil moisture is not usually limiting to tree growth on these sites. Results are compared with those from other regions in the eastern United States.

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Forest stands often contain large numbers of understory trees and shrubs, particularly following thinnings that create temporary gaps in the overstory canopy. Removal of this understory vegetation has been suggested and repeatedly tested as a means of increasing growth rates of overstory trees. Because this vegetation does not compete with overstory trees for crown space, its removal increases overstory growth only insofar as it reduces root competition for water and nutrients (Smith 1962, Dale 1975). Direct measurements of soil moisture in stands of pine (Zahner 1958) and hardwoods (Johnson and Kovner 1956) have shown that removal of understory vegetation increases the water available to the overstory. Some studies clearly show an overstory growth response, particularly in southern pine stands (e.g., Bower and Ferguson 1968, Grano 1970). However, on sites where moisture is not a limiting factor to growth, a growth response would not be expected to occur even with increased water supplies. And indeed, no measurable growth increase occurred in other studies (e.g., Lotti et al. 1960, Karnig and Stout 1969).

Variation in both soil characteristics and climatic factors associated with water balance would be expected to control the range of conditions in which overstory growth response would occur. In the eastern half of the United States, climatic factors vary in broad geographic gradients: precipitation decreases from coastal areas northward and westward, while temperature increases from north to south. Upon these gradients is superimposed a relatively fine-scale variation in soil texture and depth.

Most studies documenting response to understory removal give results from a single site, and many give little information on site conditions of the study area. Failure to consider the difference in responses found on a range of sites may lead to unwarranted generalizations concerning the effectiveness of treatments. It is our observation that many foresters simply assume that an overstory growth response will occur, since it is logical to assume that a reduction in competition will occur.

This study reports the 13-year growth responses to understory removal in a mixed-species hardwood stand in Massachusetts, and compares results to those of similar studies in the eastern United States to assess the range of conditions in which treatments are likely to have effects on overstory growth rates.

STUDY SITE AND METHODS

The study site, on the Harvard Forest in central Massachusetts, lies on the northwest-facing slope of a drumloidal hill at an elevation of 1100 ft. Precipitation averages 44 in/yr, evenly distributed through the year. The soil is a podzolic stony loam developed in thick glacial till, and contains a hardpan at a depth of 20 to 30 in (Lyford et al. 1963). This compacted layer impedes internal drainage and improves soil moisture conditions for the growth of many hardwood species.

The study stand was 40 years old when understory treatments were applied in 1956. It had regenerated following clearcutting of an old-field stand of white pine. A light crown thinning had been made in 1935, at stand age 20, to release selected crop trees. This thinning also favored the survival and growth of understory trees. The stand was densely stocked with a closed overstory crown canopy at the time the experiment was begun.

Within the study stand, 48 contiguous plots were laid out, each 2500 ft^2 in area. On a block of 24 of these plots, all understory trees and shrubs were cut in May 1956 and removed from the study area. Understory trees were defined as all those completely overtopped by adjoining trees, plus those with tops of crowns below the midpoint of the live crowns of adjoining overstory trees. Removing these trees, then, did not increase the crown space available for residual trees. In 1956 and 1958, herbicide applications eliminated all seedlings and sprouts from cut stumps on these plots. The remaining 24 plots were left untreated to serve as controls. No overstory trees were cut in any of the 48 plots.

For all 48 plots, trees 2 in and greater in dbh were mapped, and diameters were measured prior to treatment in 1956. Additionally, a tally was made of numbers of trees less than 2 in dbh, but taller than 4.5 ft. Measurements were repeated in 1960, 1966, and 1969. For each measurement period, gross growth in basal area (ft^2/ac/yr) was calculated for all trees defined as "overstory" at the beginning of the experiment.

RESULTS

Stand conditions at the beginning of the experiment are given in Table 1. The overstory was dominated by northern red oak and paper birch, with these species comprising 80% of basal area. Red maple and white ash were also important overstory species, with 13 other species occurring in small numbers. Little difference existed between the treated and control plots in initial composition or density. The control plot had slightly greater average basal area (t-test, not significant at $P = 0.05$) and somewhat less northern red oak and more paper birch. Important understory species included white pine, red maple, white ash, black birch, and paper birch. The understory comprised about 25% of

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Table 1. Stand conditions in 1956 (stand age of 40) at beginning of experiment. Each number represents the average of 24 plots.

	Control		Treated	
	Basal area (ft^2/ac)	Density (stems/ac)	Basal area (ft^2/ac)	Density (stems/ac)
Overstory				
Red oak	34.8	148	43.6	189
Paper birch	18.7	144	11.3	65
Red maple	3.5	43	4.8	59
White ash	6.1	75	4.4	49
Total	70.6	468	68.0	398
Understory[a]				
>2 in dbh	20.0	430	[c]	[c]
<2 in dbh	7.4[b]	1525	[c]	[c]

[a] See definition in text.
[b] Estimated by assuming average dbh of 1 in for understory less than 2 in dbh.
[c] Eliminated by treatment.

total stand basal area and 81% of total numbers of stems.

The herbicide treatments that followed cutting successfully eliminated sprouts, so that regrowth of a woody understory was prevented. Thus, the treated plots lacked understories for the entire 13-year study period.

Gross basal area growth of the overstory is shown in Table 2 for each measurement period. Treated plots showed no growth increase over controls for any measurement period. Indeed, the control plots grew at a consistently higher rate than treated plots (t-test, $P < 0.05$) for each period and for the total 13-year interval, although this difference was small (12% difference for the total interval).

Overstory mortality was low in both areas (Table 2), so that net growth reflects the slightly greater gross growth of the control plots.

DISCUSSION

Northeastern Region

This study is one of a series conducted at the Harvard Forest in central Massachusetts and the Black Rock Forest in eastern New York that examined effects of understory vegetation on growth of overstory trees. These provide comparisons of overstory response to understory removal occurring on different sites within a single climatic region (Black Rock Forest is 120 miles southwest of Harvard Forest and averages 41 in/yr precipitation compared to 44 at Harvard Forest.) All of these studies concern mixed-hardwood stands in which northern red oak is the principal species.

Table 2. Average annual basal area growth and mortality ($ft^2/ac/yr$) of overstory in treated and control areas (n = 24 plots for each) on Harvard Forest. Standard errors given in parentheses.

	Control	Treated
Gross growth		
1956–60	2.88 (.10)	2.54 (.09)*
1961–66	2.80 (.10)	2.51 (.08)*
1967–69	2.54 (.10)	2.22 (.09)*
Total (13 yr)	2.77 (.09)	2.45 (.08)*
Mortality		
Total (12 yr)	0.28	0.37
Net growth		
Total (13 yr)	2.49	2.08

Note: * = significant difference at $P = 0.05$ level.

The present study showed that no increase in overstory growth occurred following removal of understory trees and shrubs on stony loam soils containing a hardpan. Another study at Harvard Forest (Kelty 1984) examined the growth of untreated stands on stony, fine sandy loam soils that lacked a well-developed hardpan and therefore had lower moisture storage than the above site. That study compared a stand that contained a dense hemlock understory with an adjacent stand lacking a dense understory, and found that overstory growth was similar, regardless of the presence of the understory.

Similar results were obtained in a Black Rock Forest study (Karnig and Stout 1969), where the understory was removed in part of a heavily thinned oak stand; basal area growth of individual oaks was similar for trees in treated and control areas. This occurred on a clay loam soil, even during years of relative drought: during 3 of the 4 years of measurement, growing-season precipitation was 18–27% below normal. In an earlier Black Rock Forest experiment (Stout 1959) on very stony loam underlain by glacial till, a small, statistically nonsignificant basal area growth increase occurred on plots following understory removal as compared to control plots, for 2 years of measurement when growing-season precipitation was near normal. During a third year when growing-season precipitation was only 40% of normal, a highly significant difference in growth rate of nearly 100% was recorded. For all 3 years, growth on plots treated by understory removal plus irrigation was not significantly different from that resulting from understory removal alone.

These studies indicate that on a wide range of glacial till soils in southern New England, soil moisture is ample enough that understory vegetation does not provide serious competition to overstory trees, except during severe droughts. Observations by Walters (1978) and Karnig and Lyford (1968) provide evidence of the kind of site that does not have serious soil moisture limitation even in less extreme climatic conditions. Walters found a significant overstory growth response in an open, park-like, sugar maple stand in Vermont following removal of a dense coniferous understory. This site contained numerous outcrops and ledges, and soil depth averaged less than 20 in to bedrock. The soil was described as a shallow, excessively drained, very rocky loam with low available soil moisture capacity. Karnig and Lyford found that during a 5-yr drought at Black Rock Forest (growing-year precipitation consistently 15–28% below normal), oak mortality occurred, but primarily on ridgetops or steep, west-facing upper slopes with very shallow soils and considerable amounts of exposed bedrock. This was the same drought during which understory treatments had no effects on growth on nearby sites with deeper, finer-textured soils, as described above (Karnig and Stout 1969). Thus, water is clearly a limiting factor on these ridgetop sites, and understory control might produce a growth response as in the Vermont study, but growth is so poor on these locations that they are not considered commercial timber sites in any case.

The studies described above all concern glacial till soils. Soils developed in glacial outwash sands and gravels have low moisture-holding capacity, and understories may provide important competition to overstory growth on these, just as in the examples of the shallow till soils. However, studies are lacking for these kinds of sites in the Northeast, and reliable predictions cannot be made. Overstories on outwash sites often contain high proportions of pine, so growth responses would be affected by different species' sensitivities to moisture shortage as well as by soil differences.

Other Regions

A study by Dale (1975) extends the range of observations across the Central States to areas of lower precipitation. A series of five experiments in stands dominated by black oak or white oak showed that understory removals produced no overstory growth response in the eastern portion of the region (eastern Kentucky and Ohio), whereas basal area growth increases of 25% occurred on 2 of 3 sites in Mis-

souri and Iowa. Dale attributed this geographical trend to the lower average precipitation at the more western sites. Detailed site descriptions were not given, but site index figures (59–73 ft at 50 years) indicate that all were of average site quality.

Further support for this geographical trend is given by a series of studies of growth of loblolly pine and shortleaf pine stands with hardwood understories. Studies from Missouri (Rogers and Brinkman 1965) and Arkansas (Bower and Ferguson 1968, Grano 1970) showed 20 to 33% increases in basal area growth for stands where understories were removed. Similar studies in areas of higher precipitation on the Atlantic and Gulf coastal plains (Lotti et al. 1960, Russell 1961) showed no response. This pattern is not without exception; Langdon and Trousdell (1974) reported a 20% increase in growth of loblolly pine following understory removal on the coastal plain of North Carolina. Exceptions such as this are principally due to variations in local site characteristics.

Tree Quality Considerations

During the 13-year duration of the present study, few epicormic sprouts developed on overstory trees in either the control or treated plots. However, the study was subsequently continued by reducing overstory density in the treated plots; residual oaks sprouted prolifically following this treatment. In other Harvard Forest stands where the understory was deliberately left in place during overstory thinning, the incidence of epicormic sprouting appeared to be much lower. Thus, while understory trees have little or no negative effect on growth of overstory trees, the shade they cast on overstory stems may markedly increase stem quality.

CONCLUSION

The overstory growth responses found in certain southern pine stands following understory removal were not observed in studies of oak-dominated hardwood stands in southern New England growing on a variety of glacial till soils. Soil moisture appears not to be an important factor limiting tree growth, except on shallow, excessively drained soils or during severe droughts. Other studies of oak stands show a greater likelihood of obtaining a growth response in the western part of the central hardwoods region where precipitation is less than in the Northeast.

These studies indicate that removal of understory trees and shrubs is not a useful technique for influencing overstory growth rates in most oak-dominated hardwood stands in the Northeast. Consideration of stem quality suggests that the opposite technique—deliberate retention of as many understory trees as possible during overstory thinning operations—would be the most logical silvicultural choice in many situations. Shade from the understory suppresses epicormic sprout growth on overstory stems, especially of oaks, reducing the deterioration in quality of residual trees that often occurs after thinning. □

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