Six-Year Effects of Two Late Spring Frosts on Appalachian Hardwoods

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ABSTRACT. Severe late spring frosts can kill new shoots and leaves on commercial tree species at higher elevations. A previous short-term study has shown that the resulting defoliation and dieback does not seriously affect the radial growth or mortality of most species except American beech. In this study we found that defoliation, dieback, and radial growth increment were related to species and crown class. The radial growth increment of American beech was reduced to 70% of the previous 6-yr growth during the first year after the frost. The annual growth then increased consistently over the measurement period. Black cherry and sugar maple radial increment was only reduced to 88% of the previous 6-yr growth, but subsequent increments were much more variable. Epicormic branching on the lower bole of black cherry and beech increased significantly after defoliation occurred. At elevations above 3,200 ft, managers should discourage beech regeneration if timber production is *the primary management objective. The potential for higher value products may be reduced because of increased variability in growth rate.*

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In the spring of 1977, two frosts severely damaged the trees in large areas of eastern West Virginia and western Virginia. The frosts occurred on May 8th and June 9th. On the Monongahela National Forest, where this study was conducted, 48,000 ac of hardwood forests were damaged in varying degrees at elevations mainly above 3,000 ft. The major tree species in the area are black cherry, American beech, and sugar maple. Other commercial species included in this study are black birch, yellow birch, cucumber tree, and red maple.

Others have found late freezes to adversely affect trees. In a study of the effect of a spring frost on the radial increment of American beech, Tryon and True (1966) found increasing damage with increasing elevations. Above 3,200 ft, most leaves and new shoots were killed. Radial increment of the trees with heavy foliar damage was reduced to 20 to 40% of the previous 3 yrs growth. Tryon and True (1968) also reported on the relationship of foliage damage with 2-yr radial increment response for several hardwood species. After 2 years, American beech radial increment was only 41% of the increment on undamaged trees from a lower elevation. Black cherry and sugar maple sustained little defoliation; radial increment was 92 to 94% of undamaged control trees. They concluded that severe injury of foliage as a result of spring frosts does not result in significant radial growth reductions for most species. The purpose of our study was to determine the effects of late spring frosts on Appalachian hardwoods and compare the results with previous studies.

STUDY AREA AND METHODS

Thirteen 1/5-ac plots were established in August, 1977, along a 15-mi stretch of road on Middle Mountain on the Greenbrier Ranger District, Monongahela National Forest, in Pocahontas and Randolph counties, West Virginia. All plots were above 3,000 ft elevation. Basal area, site index, aspect, slope percent, and site class were determined for all plots. For all living trees 5 in dbh and over, the following data were collected: species, dbh, total height, crown class, crown ratio, percent defoliation, tree grade, number of epicormic branches, height to first limb, and extent of visible decay. After the first year, data collected for each tree for 5 consecutive years included percent defoliation and dieback, number and location of epicormic and dead branches, and whether the tree was alive or dead. Our definition of defoliation is the untimely reduction in the volume of foliage. Dieback is the proportion of the small twigs on the extremities of the crown's branches that did not recover from the frost. Defoliation and dieback were ocularly estimated, in 5% increments, by the same individual for all measurement periods.

Monthly precipitation and temperature records for the 6-yr period were obtained from weather stations at Glady, WV (approximately 6 mi from the plots and at an elevation of 2,840 ft) and Alpena, WV (approximately 13 mi from the plots and at an elevation of 3,020 ft) (US Dep. Commer.). No abnormal weather patterns that would have significantly affected growth were apparent from these data.

In the fall of 1982, four plots were selected (at least one in each major species group), and all trees felled and bucked into 8- or l0-ft lengths to a 6-in top. The number of sample trees that this analysis is based on is shown in Table 1 by species and crown class. At the stump and the end of each log, a 2-in-thick disk was removed. Each disk was randomly divided into four equal quadrants, and one quadrant from each was randomly selected, sanded, and examined using a stereo-zoom binocular microscope equipped with an extendable calibrated arm capable of measuring in millimeters. One measurement for the 6-yr growth from 1971 through 1976 and for each annual growth increment for 1977 through 1982 were made. We examined radial growth increments in the lower bole by averaging ring widths from disks cut from the top of the first log of each tree. Ring widths were then expressed as a percentage of the average annual growth for the previous 6 years. Ring widths were also analyzed from disks in the crown of each tree.

Because there were only three intermediate and suppressed black cherry trees, they were excluded from this analysis. Initial basal area of the four plots averaged 170 ft^2/ac. The stands were 65 to 70 years old.

RESULTS AND DISCUSSION

There were three readily recognizable effects due to the frosts. The first was an immediate defoliation of the current-year's foliage. Individual sample-tree defoliation ranged from 0 to 90%, depending on species and crown class. On the average, beech sustained the most defoliation in the first year in all crown classes. Black cherry and sugar maple had much less defoliation the first year (Fig. 1). Defoliation was reduced considerably in 1978 for beech and sugar maple. By 1979, beech showed no signs of defoliation, but sugar maple defoliation had again increased. Dominant and codominant black cherry trees gradually decreased in percent of defoliation over the 6-yr period.

The second effect, related to defoliation but not evident until the year after the frost damage, was dieback (Fig. 2). For beech, dieback peaked 2 years after frost injury and dropped back to almost normal by the sixth year. About 10% more dieback occurred in the dominant and codominant crown classes than in the intermediate and suppressed classes. Dieback in dominant and codominant cherry exhibited a more gradual increase over the first 4 years, but it was still relatively high after 6 years. Sugar maple had little die back in any crown class.

Table 1. Sample tree data.

Species/crown class	No. of trees	Percent of total	Average dbh (in) 1977	1982
Black cherry	49	39		
Dominant and codominant	46		13.2	13.9
Intermediate and suppressed	3		12.1	12.5
American beech	25	20		
Dominant and codominant	15		14.8	15.2
Intermediate and suppressed	10		8.5	8.8
Sugar maple	26	21		
Dominant and codominant	8		11.3	12.2
Intermediate and suppressed	18		7.3	7.8
Other	26	21		
Dominant and codominant	9		9.1	9.9
Intermediate and suppressed	17		7.1	7.5

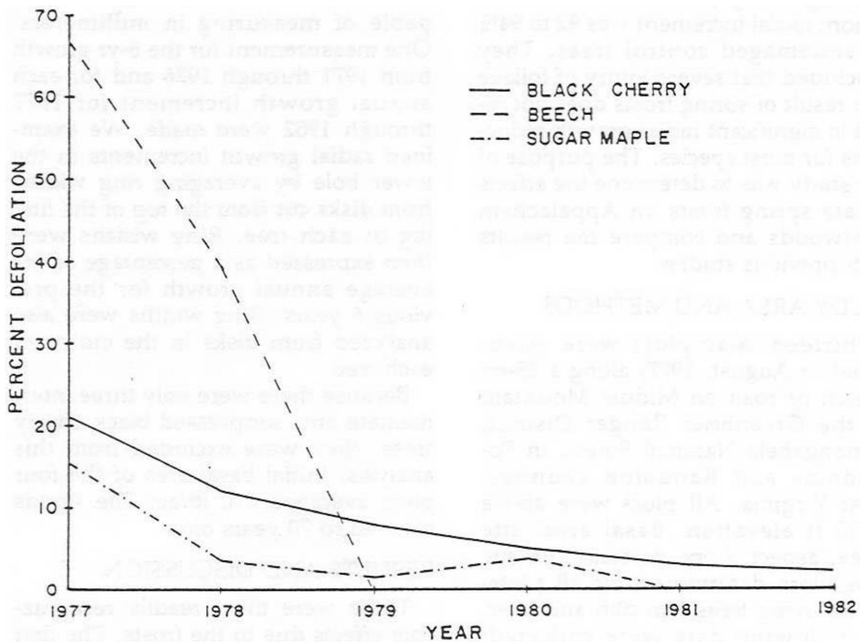

Fig. 1. Average percent defoliation for dominant and codominant crown classes by species for all plots.

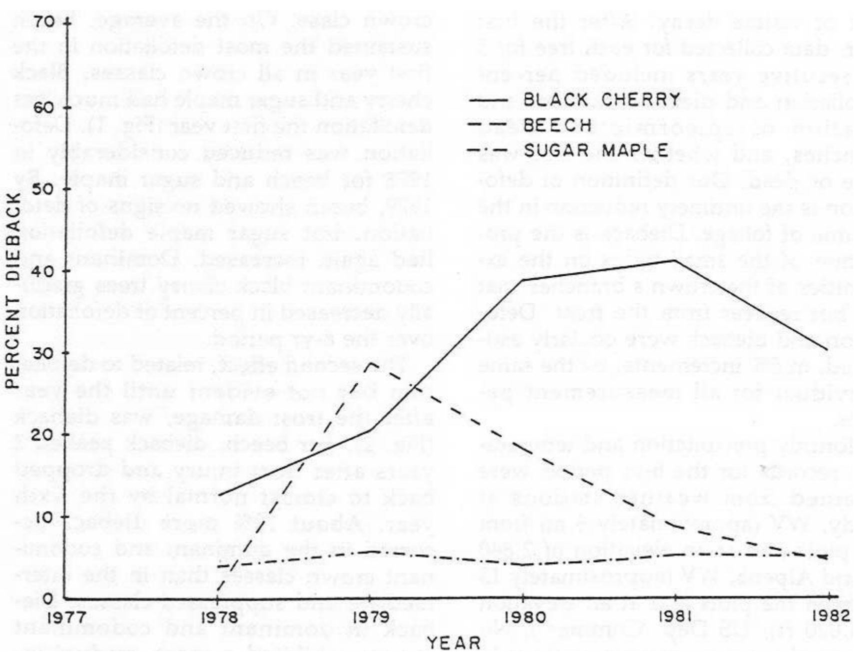

Fig. 2. Average percent dieback for dominant and codominant crown classes by species for all plots.

The third obvious change was the dramatic increase in epicormic branching below the crown, particularly for beech and black cherry. In 1977, only 12% of the dominant and codominant beech trees had epicormic branches, but by 1982; 32% had epicormic branching. Only 5% of the cherry trees had epicormics in 1977; 32% did in 1982.

Because the beech was so severely defoliated in 1977, we expected an abnormally high amount of mortality. However, only one codominant beech tree died in the 6-yr period. Eight intermediate and suppressed beech died in the same period. Mortality was low in the intermediate and suppressed crown class of the other species: black cherry, 5; sugar maple, 1; black birch, 1; and striped maple, 1. According to Dale (1975), normal mortality is approximately 1.5 trees/ac/yr for a typical stand of this age. In the 6-yr period of this study, 1977-82, the loss was 1.1 trees/ac/yr.

Radial growth increments over the 6-yr period following the frost were different for the three major species (Table 2). In dominant and codominant beech, the first year's increment was about 70% of the annual average for the previous 6-yr period. Growth did not return to normal until the sixth year. Even though substantial defoliation occurred in the intermediate and suppressed crown classes for this species, radial growth was not substantially reduced. An increase in epicormic branching in the intermediate and suppressed trees coupled with a thinning of the upper crown canopy due to defoliation and dieback may account for this relatively normal growth for beech trees in these lower crown classes. The average annual growth increment of dominant and codominant beech for the 6-yr period after forest was significantly less (*p*$\leq$ .05) than the before frost period (Table 2). Tryon and True (1968) found similar results for beech at higher elevations.

Radial growth for dominant and codominant black cherry and sugar maple followed a more complex pattern. Initially the growth of cherry was reduced to 85% of the previous 6 years annual increment. This was a significant reduction (p$\leq$ .05). By the second year, it was 1.2 times more. Growth then generally decreased until the sixth year, when it again increased. This may be the result of the prolonged low-level defoliation and increasing dieback throughout the greater portion for the 6-yr period. This variation in growth rates at elevations above 3,200 ft may reduce the value of black cherry for face veneer, particularly if frosts recur at varying times throughout the rotation period. Uneven ring width affects drying consistency and therefore the quality of the veneer produced.

Table 2. Mean annual radial growth (mm) by species for dominant and codominant trees (top of the first 8-12 ft log).

Year	Beech	Sugar maple	Cherry	Other
71–76	0.82 ± 0.10[a]	1.57 ± 0.16	1.30 ± 0.06	1.54 ± 0.15
77	.60 ± .11*	1.39 ± .20	1.11 ± .08*	1.35 ± .10*
78	.70 ± .13*	1.68 ± .28	1.56 ± .10*	1.37 ± .16
79	.70 ± .12*	1.51 ± .24	1.16 ± .07*	1.78 ± .16*
80	.83 ± .17	1.37 ± .22	1.37 ± .15	1.70 ± .19
81	.74 ± .13	1.25 ± .18*	1.19 ± .06*	1.51 ± .17
82	.84 ± .14	1.95 ± .24*	1.37 ± .07	1.91 ± .22*
77–82	.74 ± .12*	1.52 ± .20	1.29 ± .07	1.66 ± .14

[a]Standard error of the mean.
[8]Significantly different from the 71-76 mean at 95% probability level.

The growth of dominant and codominant sugar maple was reduced to only 88% of the previous 5-yr average during the first year after the frost. This is slightly more than Tryon and True (1968) found. The variability in growth rate for sugar maple was significantly higher than for cherry even through the distribution of tree size for both species was similar. Because of the high within-species variability, none of the annual growth increments after frost were significantly different than the before-frost average except for years 5 and 6. The intermediate and suppressed sugar maple had lower growth rates and significantly less between-tree variation than the dominant and codominant trees.

MANAGEMENT IMPLICATIONS

While management cannot control the weather, forest managers can do some things to minimize the effects of abnormal frost occurrences. While we realize that one study does not provide sufficient data to develop any firm management guidelines, we believe this information can provide useful suggestions.

First, if production of quality timber at normal growth rates is an objective for stands at elevations above 3,200 ft in the Appalachian Mountains, beech regeneration should be discouraged. After the second year, it appeared that almost all the beech would die. Even though only nine beech trees died, this was more than 50% of the tree mortality. But more importantly, 38% of the beech trees had epicormic branches spread over the entire bole, whereas for all the other species combined the figure was only 22%.

Secondly, if thinnings are planned for an area with the potential for severe frost damage, the removal of beech should be considered in the thinning guidelines. However, one must take into consideration any wildlife management objectives.

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