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.

* Significantly different from the 71–76 mean at 95% probability level.

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.

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. ☐

LITERATURE CITED

Dale, M. E. 1975. Individual tree growth and simulation of stand development of an 80-year old white oak stand. Pages 46–63 *in* A. R. Ek, J. W. Balsiger, and L. C. Prommitz, (eds). Forest modeling and inventory. Soc. Am. For. and Univ. Wis.-Madison Coll. Agric. and Life Sci., Sch. Nat. Resour.

Tryon, E. H., and R. P. True. 1966. Effect of spring freeze on radial increment of American beech at different elevations. J. For. 64: 625–627.

Tryon, E. H., and R. P. True. 1968. Radial increment response of Appalachian hardwood species to a spring freeze. J. For. 66: 488–491.

US Dep. of Commer. 1971–1982. West Virginia, annual summary. Environ. Data and Inf. Serv. Natl. Clim. Cent., Asheville, NC. p. 2–4. (each year's vol.).

Managing Beech Bark Disease: Evaluating Defects and Reducing Losses

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ABSTRACT. Beech bark disease often produces bark defects that may result in trees being classed erroneously as cull. Because of this, sale overruns occur, and sound trees are mistakenly left uncut in the woods. The disease occurs when Nectria *fungi attack and kill bark predisposed by the beech scale. It results in several types of bark defects on residual trees that do not succumb or on young trees developing in the presence of the causal complex. Defects can be more or less serious depending on the depth of infection. A sawmill study showed that on trees with recognizable, superficial defects, yield is little affected. When the cambium is damaged, however, defects may lead to losses in lumber yield or quality. Understanding how defects develop helps in estimating volume, identifying high risk trees, and making prescriptions that leave stands more resistant to beech bark disease.*

North. J. Appl. For. 4:28–33, Mar. 1987.

As beech bark disease advances westward and southward from its point of origin in Nova Scotia to its current range (Fig. 1), the combined effects of the disease and of landowners trying to minimize losses leave their mark on the forest. Beech is alternately discriminated against, salvaged, or left to stand, often decayed and defective. Sale overruns are common when trees with extensive, but superficial, bark defects are marked as cull. Sometimes, measures designed to reduce losses from beech bark disease take low risk trees and leave a residual stand with the potential for even greater losses in the future. Attempts to eliminate beech altogether have seldom been successful. Many past harvesting practices have preferentially favored beech with its extreme shade tolerance and powerful ability to regenerate vegetatively. The result has been the development, over extensive areas, of forests with an overabundance of highly susceptible beech. In retrospect, eliminating beech altogether probably was not a desirable goal, not only because of its inherent value for specialty timber products, fuelwood, and wildlife, but also because even though it alone is susceptible to beech bark disease, it is not attacked by many other pests of its forest associates.

Although research is continuing to clarify details, many aspects of beech bark disease and the damage it causes are understood. By using what is known to correctly evaluate existing

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[1] We acknowledge the assistance of William Gove in organizing and conducting the mill study and Peter Hannah, William Ostrofsky, Brent Teillon, and James White for reviewing the manuscript.

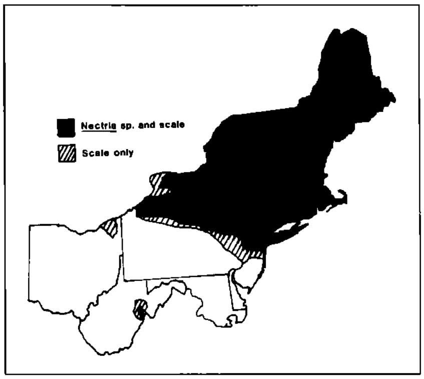

Fig. 1. Distribution of beech bark disease in the United States in 1984 (modified slightly from Miller-Weeks 1985).

defects and reduce the risk of further damage, foresters facing stands stocked with beech can improve quality, maintain diversity, and reduce losses from beech bark disease.

THE BEECH BARK DISEASE ORGANISMS AND HOW THEY ATTACK

Beech bark disease begins when the minute beech scale insect covers the surface of susceptible beech stems with its white, wool-like wax secretions (Ehrlich 1934). The effects of its feeding permit *Nectria* fungi to penetrate and kill the bark. These fungi become visible when their tiny red fruiting structures appear on the stem. Leaves often turn yellow and infected trees may die. On injured, surviving trees, dead patches of bark may lead to decay of underlying wood and to stem breakage. Scales survive best where bark irregularities such as bark crevices, branch stubs, patches of moss and certain lichens, and wounds provide shelter. Protection from winter temperature fluctuations may also be provided on the north sides of trees and in stands where beech stems are shaded by evergreens, especially hemlock (Twery and Patterson 1983). Because trees must be attacked by the scale before *Nectria* can infect them, the factors affecting scale establishment and survival also determine the likelihood of *Nectria* infection and subsequent tree damage or mortality.

The thin, living bark of beech is particularly vulnerable to injuries and to attack by sucking insects like the beech scale (Houston 1981). In the bark of most tree species, many layers of cork cells build up and provide a thick protective cover for the living cells inside. But, in beech, only a few layers of cork cells are produced. The scale's probing mouthparts penetrate this outer bark layer to feed from living thin-walled cells beneath.

Although the insects rarely probe deeply enough to injure the cambium, heavy infestations can kill living bark cells causing the bark to dry out Damaged bark will crack and fissure as the tree grows, providing added refuges for the scale and points of entry for *Nectria*. Once established, *Nectria* may penetrate the inner bark, sometimes deep enough to kill the cambium. It is the infection and death of the cambium that leads to growth loss, internal defect, decay, and tree death.

DEFECTS CAUSED BY TREE RESPONSES TO ATTACK

How much defect results from beech bark disease is often determined by how trees respond to injury or invasion (Fig. 2). In the inner bark of beech, wounding triggers the development of "barrier" layers of cells with dense, thick walls, impervious to air and moisture, that wall off injuries (Ostrofsky and Blanchard 1983). When the beech scale wounds the bark, it secretes materials that inhibit barrier formation as long as it is actively feeding. *Nectria* takes advantage of wounds where barrier formation is inhibited. When scale infestations are scattered and localized, trees respond to *Nectria* infection and develop barriers beyond the feeding zones. These barriers limit the further spread of *Nectria* within the bark, and small, discrete cankers result. Vigorous trees with thick inner bark may do this quickly before the cambium is invaded and killed. The steps in defect development are outlined in Fig. 3.

Bark defects can be separated into four different types: discrete lesions, which may be either raised from the bark surface or sunken, large dead patches, and blockiness. The presence of discrete lesions indicates a tree with isolated scale infestations at the time it was infected by *Nectria*. Where lesions are raised from the bark surface (Fig. 4), *Nectria* was successfully walled off and the cambium was not killed. The wood behind raised lesions is sound. Sunken lesions result when bark is unable to wall off *Nectria* before it reaches and kills the cambium. Since dead cambium can not produce new wood, the dead patches are "left behind" and become sunken as the tree increases in diameter (Fig. 5). Recently formed sunken lesions generally come off in the slab when logs are milled. With time, however, trees will callus over this defect. Although they become less visible from the outside, these buried defects may cause substantial lumber degrade, especially if they are abundant and occur repeatedly (Fig. 6).

The two other types of defect occur when heavy scale populations develop over extensive areas of the bark. Where there are large dead patches, *Nectria* was not walled off and the cambium was killed. Because large wounds take more time to close over, extensive decay can develop behind them (Fig. 7). Affected trees often break off or stand as hollow culls in the woods.

Where bark is thick and blocky, *Nectria* is successfully walled off. This symptom results when heavy scale feeding kills cells near the bark surface. Because dead cells can no longer divide, bark fissures develop as the tree grows and expands. Wood under such "blocky" bark is usually sound The craters in the center of some of the "blocks" result when the outer tissues are invaded by *Nectria* and become partially decayed (Fig. 8).

Trees may be undamaged by beech bark disease even though all nearby beech are heavily affected. Some individuals are genetically resistant to scale infestation and remain free of insect attack (Houston 1983). Other trees, although infested, never build large populations and remain relatively free of damage. These trees may owe their "partial resistance" to bark structure. Bark of some relatively resistant European beech trees contain many thick-walled cells relative to thin-walled food cells, which allows only limited numbers of scales to develop (Lonsdale 1983).

EVALUATING HOW DEFECTS ON STANDING TREES AFFECT LUMBER QUALITY AND YIELDS

Although mortality from beech bark disease can be extensive, many trees with bark defects survive (Houston 1975). By understanding the origin of these defects and what lies underneath them, standing timber can be inventoried more accurately and high risk trees can be distinguished from those with superficial damage only.

The effect of beech bark disease defects on the volume and grade yield of lumber was examined in Vermont as part of a routine sawmill yield study The study involved over 200 logs from eastern New York. They had been cut from trees exposed to beech bark disease for at least 10 years. The logs were scaled, and graded according to USDA Forest Service guidelines (Rast et al. 1973). Defects from beech bark disease were not considered in log grading. Logs were rated separately for presence of raised or sunken lesions, large dead patches, and blocky bark on each of four faces. Often, several types of defect occurred on the same face, and no attempt was made to quantify the relative amount of each type. Final lumber volume and grade was tallied for each log.

As logs went through the mill, most defects were removed with the slab Where lumber was affected, defects reduced grade rather than volume (Fig. 9). Usually, this was from bark

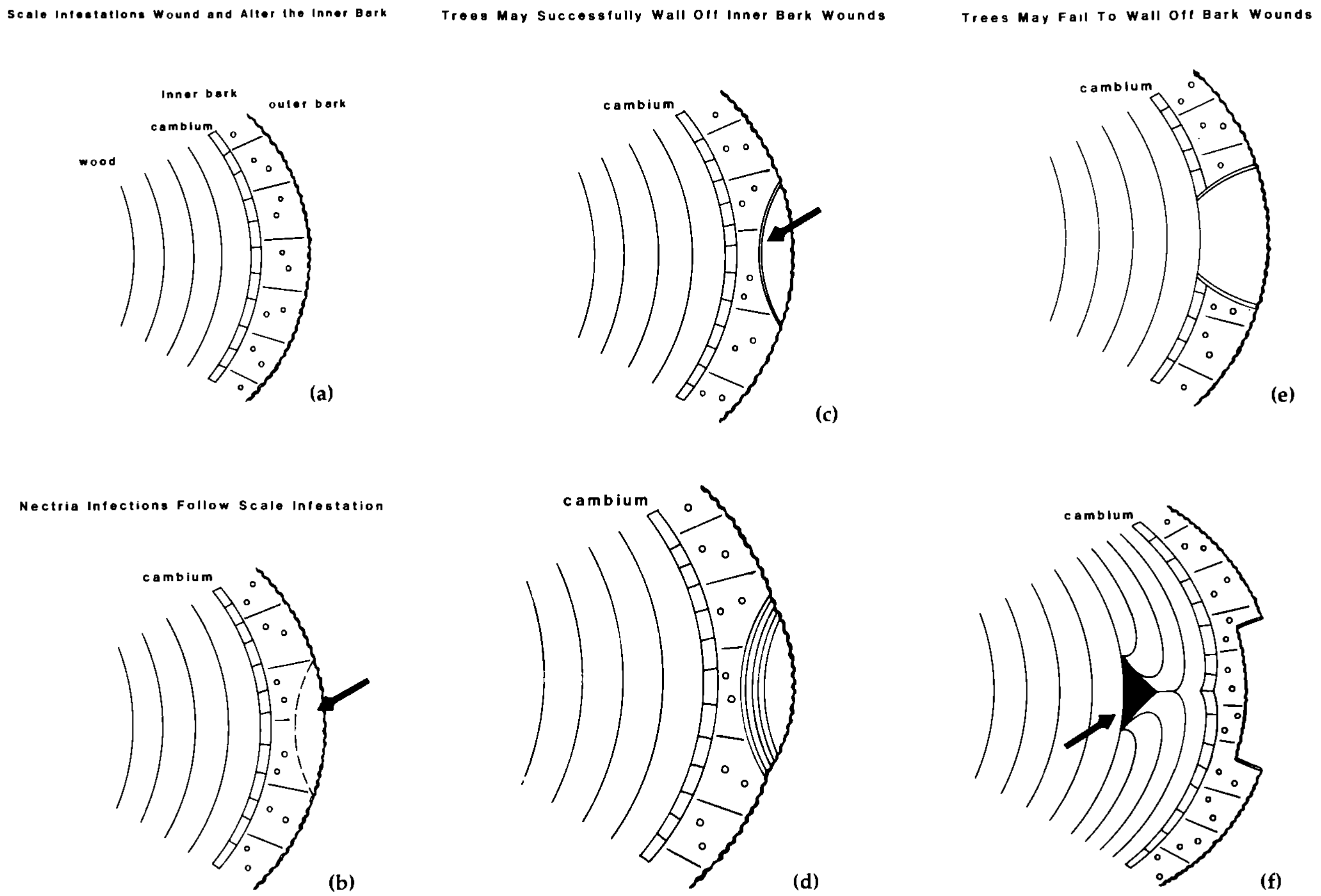

Fig. 2. Tree response to attack by beech scale/*Nectria.* (a) The thin outer bark of beech provides little resistance to scale, which uses the contents of thin-walled living cells of the inner bark for food. (b) Scale insects chemically alter portions of the inner bark as they feed (arrow); *Nectria* may infect these areas. (c) The patch of injured (invaded) bark is walled off from the cambium by a barrier of thick-walled cells called the wound periderm (arrow). (d) The dead area is "pushed" or raised as the wound periderm increases. The wood underneath is not affected. (e) When wound periderm is not able to wall off the dead area, *Nectria* can infect and kill the cambium. (f) As new wood produced by the cambium closes over the wound, a buried defect results (arrow). See also Fig. 6.

inclusions left when older sunken lesions were buried in the wood. Occasionally, boards were discolored where the wood behind dead bark patches was beginning to decay. Where lumber from logs with blocky bark or raised lesions was degraded, these symptoms were associated with other defects. Although the lumber grade yields from defective logs were lower than from defect-free logs, no differences were significant. Lumber

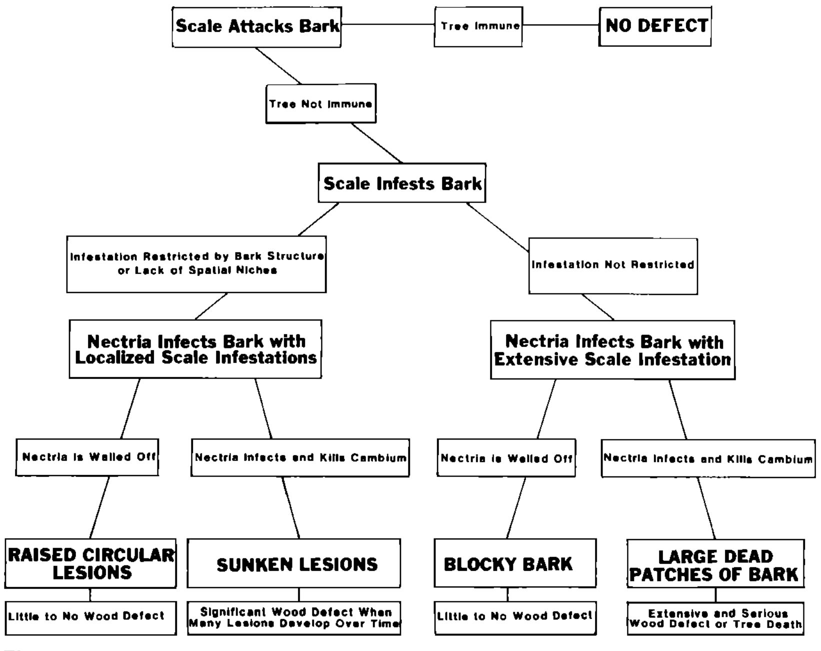

Fig. 3. Development of defects caused by beech bark disease.

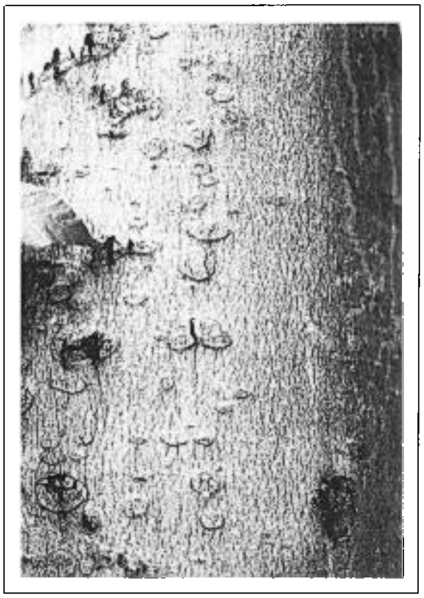

Fig. 4. Raised lesions indicate little or no wood defect. *Nectria* has infected the bark only.

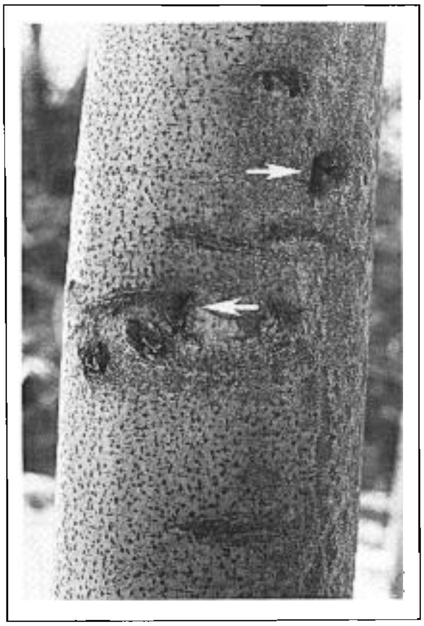

Fig. 5. Sunken lesions (arrows) result when *Nectria* infections reach and kill the cambium. Recently formed lesions usually come off in the slab, but older lesions that become buried may cause substantial degrade.

Fig. 7. When large patches of bark are killed, extensive wood decay may develop that leads to stem breakage or significant losses in yield. This stem may be cull, especially if other decay indicators, such as fungus conks or open branch stubs, are present.

quality is also influenced by factors such as prior wounding and branch healing. These led to large variations in the grade of lumber sawn, masking some of the impact of disease-related defects. Had the trees been left longer in the woods, the relative importance of the defects from beech bark disease would have been greater.

Time is critical to the development of serious defects on beech stems. As the tree grows around them, sunken lesions will close over. When logs from trees with sunken lesions are sawn, outside boards, which are usually clear, will be degraded by bark inclusions, distorted grain, and discolored areas. Volume and grade loss behind dead patches can be extensive because beech wood decays quickly once the bark is dead. Trees with blocky bark or circular raised lesions, however, will continue to grow normally with little effect on lumber yield.

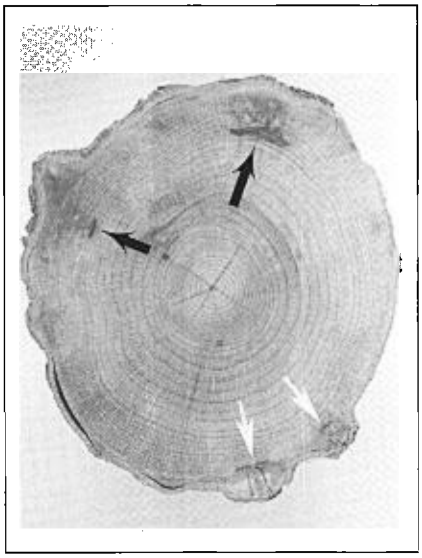

Fig. 6. With time, sunken lesions become buried defects (black arrows) and can cause substantial lumber degrade. Sometimes, irregular raised "bumps" caused by continued callus development indicate the presence of buried defects (white arrows).

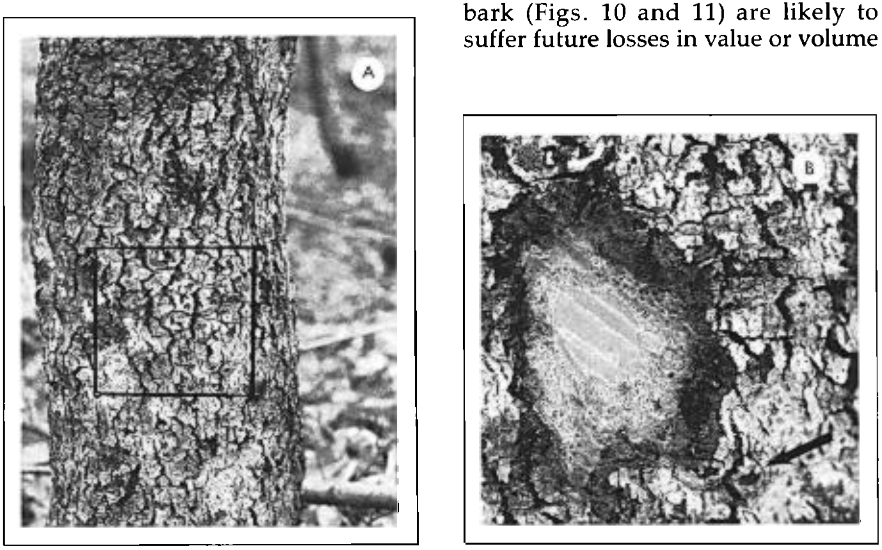

Fig. 8. Thick, blocky bark (A) results when heavy infestations kill bark cells, and when extensive *Nectria* infections do not reach the cambium to cause wood defect (B). The craters (arrows) develop when outer bark, killed by *Nectria* and degraded by other fungi, erodes away.

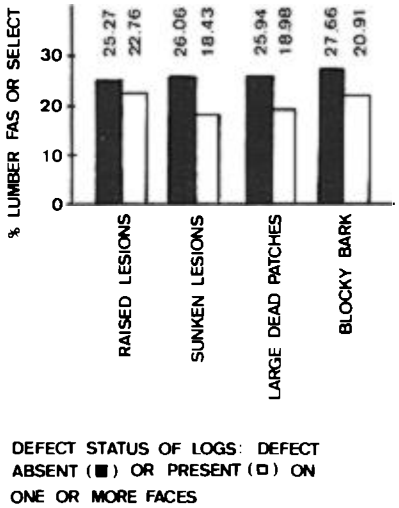

Fig. 9. Percentage of lumber yield in FAS or select grades according to the type of defects present on log faces from 166 USFS Grade 2 logs recently affected with beech bark disease. No differences were significant. Degrade would have been greater had trees been left to callus over and bury sunken lesions or to decay behind dead patches of bark.

MANAGING BEECH IN LONG-AFFECTED STANDS

The objective in managing stands affected by beech bark disease is to avoid situations where *Nectria* successfully invades the cambium. Successful attacks by *Nectria* are either directly or indirectly responsible for the volume and grade loss due to reduced growth, internal defect, decay, and mortality from the disease. These losses can be reduced by recognizing and removing trees with a high risk of further damage, maintaining vigor, and selecting resistant individuals for the residual stand.

Trees with significant numbers of sunken lesions or patches of dead bark (Figs. 10 and 11) are likely to suffer future losses in value or volume

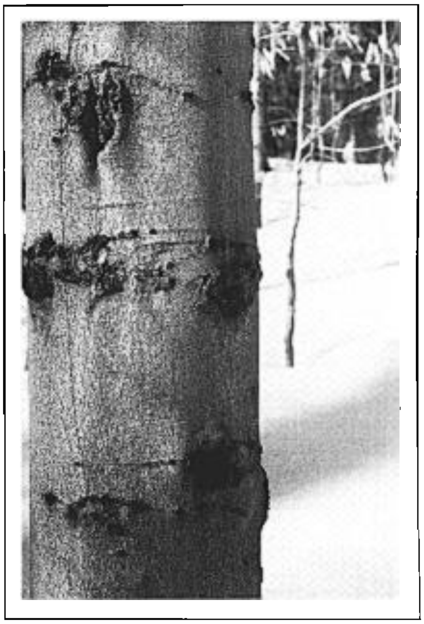

Fig. 10. Shallow defects like these are not important now because they come off in the slab. They will degrade the lumber if the tree is left to grow around them.

from buried defects. These trees should be identified and removed. If existing bark defects are deep (Fig. 12), or if decay indicators are present, volume loss should be accounted for on the timber tally.

Trees with only raised lesions or blocky bark can be maintained in the stand because the wood behind these bark defects usually is sound (Fig. 13). If cut, no volume loss from these defects should be tallied. If left in the stand, such trees will continue to grow normally with little or no loss of wood volume. Such trees may, of course, be reinfested by scale.

Fig. 11. Extensive defects may become hidden as trees close over them.

Fig. 12. When defects are deep, lumber grade and volume are seriously affected.

Overall tree vigor should be enhanced by maintaining proper stocking and favoring trees with full crowns. Vigorous trees, because they usually have smooth bark and close wounds quickly, provide relatively little shelter for the beech scale. And, since most rapidly growing trees have thicker inner bark (phloem) than suppressed or slow-growing ones (e.g., Carter and Blanchard 1977, Cole 1980, Shortle et al. 1979) vigorous trees may be better able to prevent *Nectria* from reaching the cambium.

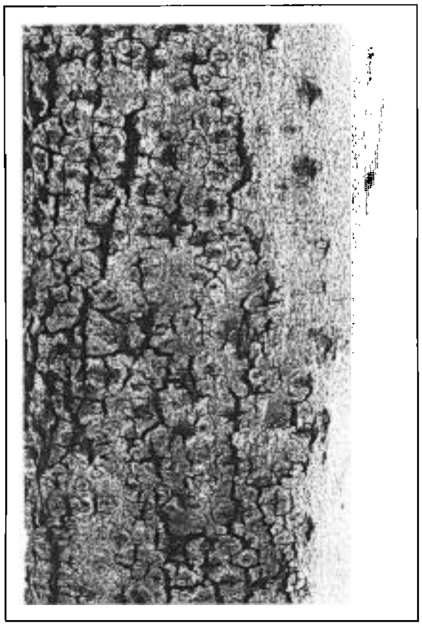

Fig. 13. Raised lesions and blocky bark occur where *Nectria* is walled off before the cambium is infected. Trees with these symptoms will continue to grow normally if left in the stand.

Trees with little or no scale populations or defects *may* be immune or resistant and should be favored. Their genetic traits may ensure that they will remain disease-free, even if additional outbreaks occur. When the stand is regenerated, resistant trees should be favored as a seed source. Even though the numbers of highly resistant progeny may be quite low, there will probably be higher numbers from resistant parents than from susceptible ones.

Research now underway to clarify the genetic relationships of resistant trees may help determine whether resistance can best be maintained or enhanced by techniques that favor sexual (seedling) or asexual (root sprout) regeneration. Where advance beech regeneration is present among highly susceptible parent trees, or where existing regeneration is mostly of sprout origin from trees killed or damaged by beech bark disease, it may be desirable to eliminate it using herbicides. Use of herbicides in this way followed by a two-step shelterwood cut has been employed successfully to produce a forest of desirable composition and reduce the amount of susceptible beech (Kelty and Nyland 1981).

Although it has taken its toll, beech bark disease has not wiped out beech in long-affected regions (Shigo 1972). It has, instead, left trees whose scars tell the story of how they responded to the disease, how much damage was done to the wood, and how well they might survive a future outbreak. By favoring those trees whose vigor, structure, and genetic makeup provide them with a good ability to avoid heavy infestation and infection, better quality beech can be grown while reducing the threat of losses in the future.

IN SUMMARY, TO MANAGE BEECH AFFECTED BY BEECH BARK DISEASE:

- Maintain proper stocking and discriminate against trees with wounds and other stem irregularities. Enhancing overall tree vigor and stem quality will reduce shelter for scale and improve ability of trees to resist scale and *Nectria*..
- Remove trees with sunken lesions and dead patches to minimize buried defect in later years. Make a volume loss deduction if the wounds are deep.
- Trees with raised lesions or blocky bark are susceptible to scale, but will grow normally if left in the stand. If harvested, a deduction for defect is not necessary.
- Retain trees which have smooth

bark and no evidence of lesions as final crop trees and for regenerating the stand by seeding or sprouts. These trees may be genetically resistant.

- Discourage monocultures by encouraging species diversity. ☐

LITERATURE CITED

Carter, K. J. and R. O. Blanchard. 1977. Electrical resistance related to phloem width in red maple. Can. J. For. Res. 8:90–93.

Cole, D. M. 1980. Within-stand comparisons of inner bark electrical resistance in lodgepole pine—the bark moisture factor. For. Sci. 26:309–312.

Ehrlich, J. 1934. The beech bark disease. A *Nectria* disease of *Fagus*, following *Cryptococcus fagi* (Baer.). Can. J. Res. 10:594–692.

Houston, D. R. 1975. Beech bark disease: the aftermath forests are structured for a new outbreak. J. For. 73:660–663.

Houston, D. R. 1981. The trouble with beech is . . . Conn. Woodlands XLVII(1): 12–15.

Houston, D. R. 1983. American beech resistance to *Cryptococcus fagisuga*. P. 38–42 *in* Proc. IUFRO beech bark disease working party conf. USDA For. Serv. Gen. Tech. Rep. WO-37.

Kelty, M. J. and R. D. Nyland. 1981. Regenerating Adirondack northern hardwoods by shelterwood cutting and control of deer density. J. For. 79:22–26.

Lonsdale, D. 1983. Wood and bark anatomy of young beech in relation to *Cryptococcus* attack. P. 43–49 *in* Proc. IUFRO beech bark disease working party conf. USDA For. Serv. Gen. Tech. Rep. WO-37.

Miller-Weeks, M. 1985. Forest pest conditions report for the Northeastern area. USDA For. Serv., Northeastern Area, NA-FR-32. 22 pp.

Ostrofsky, W. D., and R. O. Blanchard. 1983. Characteristics and development of necrophylatic periderms in mature bark of American beech. P. 69–79 *in* Proc. IUFRO beech bark disease working party conf. USDA For. Serv Gen. Tech. Rep. WO-37.

Rast, E. D., D. L. Sonderman, and G. L Gammon. 1973. A guide to hardwood log grading (revised). USDA For. Serv. Gen. Tech Rep. NE-1.

Shigo, A. L. 1972. The beech bark disease today in the northeastern United States. J. For 70:286–289.

Shortle, W. C., J. Abusamra, F. M. Laing, and M. F. Morselli. 1979. Electrical resistance as a guide to thinning sugar maples. Can. J. For Res. 9:436–437.

Twery, M. J., and W. A. Patterson, III. 1983 Effects of species composition and site factors on the severity of beech bark disease in western Massachusetts and the White Mountains of New Hampshire: a preliminary report P. 127–133 *in* Proc. IUFRO beech bark disease working party conf. USDA For. Serv. Gen Tech. Rep. WO-37.

Hooking Rules Increase Cable Yarder Productivity

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ABSTRACT. Hooking rules designed to increase average turn volume by limiting the minimum volume yarded per turn were tested with a small skyline cable yarder. The test was conducted on a steep-slope Appalachian hardwood site, harvesting fuelwood from logging residue. Average volume per turn yarded increased from 10.0 to 12.3 ft^3, increasing yarder production from 121 to 156 ft^3 per hour, and reducing yarding cost from $22.74 per hundred ft^3 to $17.75 per hundred ft^3. These results demonstrate the feasibility of applying a simple set of hooking rules to improve the efficiency of smallwood harvesting operations.

North. J. Appl. For. 4:33–35, March 1987.

Although cable yarding is an environmentally sound method of harvesting timber on steep slopes, yarding costs will determine the application of this technology in the Appalachian hardwood region. This is particularly true for the harvesting of small trees or logging residue, because costs generally increase with decreasing piece size, and unit revenues are lower for small wood than for sawlogs.

Balanced harvesting operations using small cable yarders, and small crews have been shown to reduce the cost of yarding small trees significantly (Kellogg and Olsen 1984). With an efficient mix of workers and machines, log hooking strategy can also help keep costs in line with the value of the wood harvested. To maintain residue yarding costs at or below break-even levels, LeDoux (1984) recommended establishing minimum piece sizes by yarding distance zone.

This report presents results of implementing hooking rules designed to increase average turn volume and reduce yarding cost. The objective of the test was to determine the feasibility of applying piece size limits to residue or small-tree yarding operations, and to assess the effectiveness of these limits on productivity and cost.

TEST CONDITIONS

The test site located on the Daniel Boone National Forest in Kentucky had been harvested previously for hardwood sawlogs. Most remaining trees had been felled to promote the regeneration of desirable tree species. The predominant tree species were white oak, chestnut oak, and yellow-poplar. Only bolewood material was yarded during the test, including the unmerchantable bole sections of large sawtimber trees, and bole length sections of the poletimber and small sawtimber trees felled during site preparation. All boles were limbed and topped at 3 to 5 in diameter outside bark (dob). Utilized for fuelwood, much of the material yarded was also suitable for roundwood pulpwood or low grade sawlogs.

The test was conducted yarding uphill on two adjacent units 550 ft long and 120 ft wide. Slopes averaged 30%, ranging from 21 to 43%. Unit 1 contained 221 pieces with a large end dob $\geq$ 6.0 in that totaled 1,585 ft^3 of wood and bark. Unit 2 contained 226 pieces with a large end dob $\geq$ 6.0 in, that totaled 1,679 ft^3 of wood and bark. Average piece volume was 7.17 ft^3 on Unit 1 and 7.42 ft^3 on Unit 2. The distribution of the pieces by volume classes shows similar piece sizes on both units, with more than 80% of the pieces less than 12 ft^3 (Table 1).

The logging residue was yarded with a Bitterroot Miniyarder—an 18 horsepower, live skyline cable yarder (USDA For. Serv. 1983). Production time, delay time, and piece sizes were recorded for each yarding cycle. The Forest Service yarding crew consisted of two persons—one operating the yarder and unhooking, the other hooking chokers. The crew had prior experience with this machine and showed excellent motivation throughout the study.

RESULTS

Unit 1 Results

On the first unit the crew was instructed to yard all pieces with a large end dob $\geq$ 6 in, hooking as many pieces as possible each turn. Results were used to develop hooking rules for the second unit and to provide baseline results to gauge the effectiveness of the hooking rules.

Summary yarding production statistics from Unit 1 were:

Table 1. The distribution of residue pieces by volume class.

Piece volume class (ft^3)	Unit 1	Unit 2
	............%	....
0.1–3.9	27.5	26.9
4.0–7.9	33.3	31.4
8.0–11.9	23.6	25.1
12.0–15.9	12.9	10.3
16.0–19.9	2.7	4.5
20.0+	0.0	1.8