

# Anomalous Dark Growth Rings in Black Cherry

Robert P. Long, David W. Trimpey, Michael C. Wiemann, and Susan L. Stout

## ABSTRACT

Anomalous dark growth rings have been observed in black cherry (*Prunus serotina*) sawlogs from northwestern Pennsylvania making the logs unsuitable for veneer products. Thirty-six cross sections with dark rings, each traceable to one of ten stands, were obtained from a local mill and sections were dated and annual ring widths were measured. One or more dark rings were found in 30 of the 36 cross sections. The most frequent years in which dark rings formed were 1994, on 55% of cross sections, and 1995, on 72% of cross sections. Both years were coincident with widespread cherry scallop shell moth (*Hydria prunivora*) outbreaks. GIS layers and maps obtained from the Allegheny National Forest were used to document cherry scallop shell moth defoliations in these stands. These rings show a darkened discoloration through all or portions of the annual ring without characteristics typical of gum spots or gum defects caused by traumatic injury from bark beetles or cambium miners. Microscopic examination of the rings revealed darkened fiber cell walls, but no other cellular abnormalities. Dark rings are more common in stands with a high proportion of the total basal area composed of black cherry. These stands also are more susceptible to repeated defoliations from cherry scallop shell moth.

Black cherry (*Prunus serotina*) is one of the most valuable eastern hardwood timber species, and some of the highest quality cherry originates in northwestern Pennsylvania (Wiedenbeck et al. 2004). Although black cherry wood has many uses, the best quality logs are used for veneer products. Some recent harvests on private and public land in northwestern Pennsylvania have yielded black cherry logs with an anomalous dark growth ring within one or more annual rings. This defect is not similar to gum spots or gum rings that have been well described previously (Hough 1963, Kulman 1964, Rexrode and Baumgras 1980). Some logs with dark rings were initially identified as veneer logs, but were later rejected by veneer buyers because dark growth rings are an unacceptable visual defect for veneer. Black cherry sawlogs with dark rings can be processed into sawtimber products with a visual defect, but fortunately this does not result in a mechanical defect. However, the financial loss of producing sawtimber products rather than veneer is substantial for the seller.

Anecdotal information provided by foresters and loggers indicates that these discolored rings may be associated with defoliation events and are sometimes referred to as “defoliation rings,” “dry rings,” “green rings” or “Guitonville rings.” Forest managers want to learn what causes these rings so that management actions can be taken to prevent their formation, if possible. We conducted a preliminary study with samples provided by a private industrial landowner in northwestern Pennsylvania. The objectives of this study were to: (1) determine the years associated with the dark rings, (2) describe the macro and micro anatomical features associated with the rings, and, (3) determine intrinsic site and/or stand conditions as well as potential exogenous events that could be associated with the dark rings. Additional research, beyond the scope of this report, will be needed to determine the causal factor(s) and the physiological or biochemical mechanism(s) associated with the ring discoloration.

## Methods

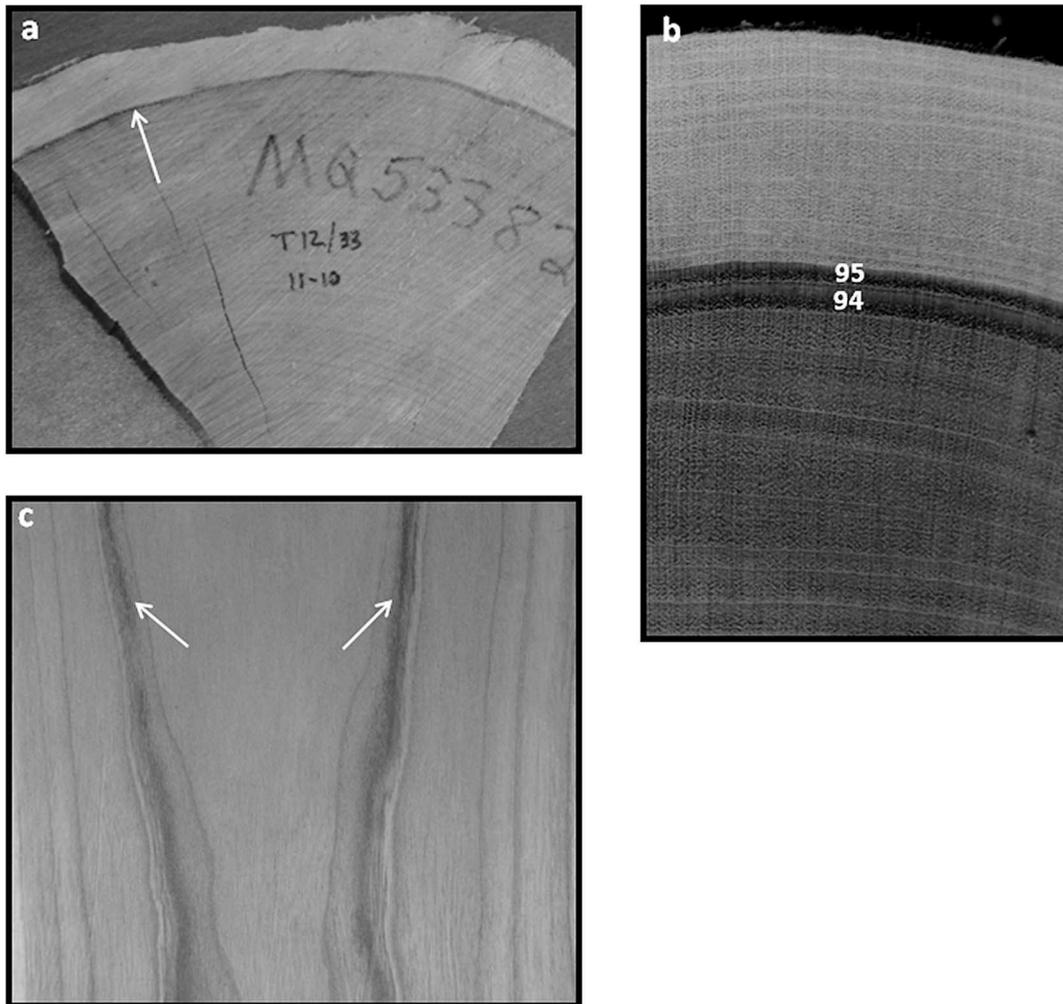
Thirty-six cross sections or partial cross sections from nine different stands were obtained from a private industrial landowner in northwestern Pennsylvania. All sections were from trees cut in fall or winter 2010–2011, and were selected based on the observation of a dark ring in logs delivered to the mill. All logs were traced to their stand of origin and all were from holdings in Forest (7 stands with 29 cross sections), McKean (2 stands with 5 cross sections), and Warren (1 stand with 2 cross sections) Counties. The cross sections were sanded first with 80 grit sandpaper and progressing through 120, 220, and 300 grits to enhance visibility of ring boundaries and facilitate dating. The sections were cross-dated under a dissecting microscope using skeleton plots and the list method (Speer 2010). The dated sections were subsequently measured using WinDENDRO (Regent Instruments, Quebec City, Canada). The measurement quality control program COFECHA was used to validate measurements and cross-dating (Holmes 1983). Each section was examined for the presence of a dark ring or rings and the calendar year associated with the ring was noted. The measured ring-width series were standardized using the ARSTAN (Cook and Holmes 1996) program and the standardized ARSTAN chronologies from the three best replicated stands were compared graphically. Raw ring-widths were standardized by fitting a negative exponential curve or linear regression line and dividing the actual ring width value by the curve-fitted value (Cook and Holmes 1996).

Portions of five representative cross sections were sent to the US Forest Service, Forest Products Laboratory, Madison, WI, for an anatomical examination. Low power magnification (7× to 45×) was used to inspect the sections and small pieces were excised with a scalpel from areas with and without dark rings to examine under a

Manuscript received October 20, 2011; accepted May 21, 2012. <http://dx.doi.org/10.5849/njaf.11-043>.

Robert P. Long (rlong@fs.fed.us), US Forest Service, Northern Research Station, 335 National Forge Road, Irvine, PA 16329; Phone: (814) 563-1040. David W. Trimpey (DTrimpey@CollinsCo.com), Collins Pine Co., Kane Hardwood Division. Michael C. Wiemann (mwiemann@fs.fed.us), US Forest Service, Forest Products Laboratory. Susan L. Stout (sstout@fs.fed.us), US Forest Service, Northern Research Station. The authors wish to thank Kurt Sherrard, Gregory Sanford, Eric Baxter, and Timothy Fox for assistance in surfacing samples and measuring cross sections. Dr. J. Wiedenbeck, Dr. G.B. Williamson, and Dr. T.E. Ristau reviewed earlier versions of the manuscript and provided useful comments that improved the manuscript.

This article was written and prepared by a US Government employee on official time, and it is therefore in the public domain and not copyrightable.



**Figure 1.** (a) partial cross section from log end showing a conspicuous dark ring at the heartwood/sapwood boundary; (b) close-up showing the dated dark rings in 1994 and 1995, (c) a tangential section showing the dark rings in a board.

microscope. Alterations in xylem cellular characteristics and color were described and documented with digital photos.

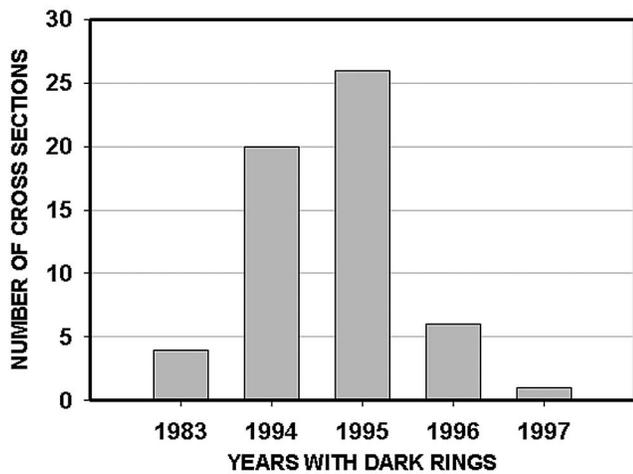
We queried foresters managing these stands and visited the post-harvest stands to qualitatively assess site and stand conditions. Mill personnel estimated the approximate percentage of black cherry logs with dark rings from the respective stands. Stand-level preharvest data were not available, but adjacent areas with similar composition were sampled using a 10 BAF prism. Species composition was estimated from the prism plots for two areas from which most of the cross-section samples originated. All cross section samples came from stands located within or immediately adjacent to the Allegheny National Forest proclamation boundary. Historical defoliation records were obtained from published literature and a GIS defoliation layer provided by the Allegheny National Forest (ANF). Mean monthly Palmer drought severity indices (PDSI) for Pennsylvania climate division 10 were examined to assess whether drought could have played a role in formation of the dark rings (National Oceanic and Atmospheric Administration 2011). The mean growing season PDSI was calculated by averaging the values from April through September.

## Results

Dark rings were conspicuous and readily identifiable on fresh, rough cut cross sections and, according to sawmill managers, were

always present at both ends of the log (Fig. 1a). The dark rings were always within the heartwood and were frequently located immediately at or within the heartwood/sapwood boundary. Dark rings become less obvious as the rough cut surface weathers and veneer buyers frequently ask to examine a fresh-cut surface. Some of the dark rings in the sanded cross sections became faint in appearance after sanding, probably from sanding dust accumulating in the vessels. In most cases this was remedied by use of high pressure air to remove the dust. Of the 36 cross sections, 30 sections showed a readily identifiable, characteristic dark ring or rings (Fig. 1b). Radial and tangential (Fig. 1c) sections also show the dark zones as dark lines. Six cross sections showed some evidence of dark rings in the rough cut section, but when sanded the dark ring was faint and/or inconsistently dark in the portion of the cross section available for examination. These rings were not considered characteristic dark rings and were not counted in dark ring frequency analyses.

For the cross sections with dark rings, the oldest section dated to 1900 and the most recent to 1981, although this latter section was only a partial and did not include the pith. The most frequent years displaying dark rings were 1994 and 1995 (Fig. 2). Twenty-six (72%) cross sections showed dark rings corresponding to one or both of these years. In six cross sections, the 1996 ring was characteristically dark, but faded in some portions of the cross section. In



**Figure 2.** Frequency of dark rings by year of occurrence. No other dark rings were present in the sampled cross sections.

cross sections with the dark rings, the narrowest ring was in 1995 or 1996, or rarely 1997. In six sections, only the 1995 ring was dark, while all 20 of the cross sections with a 1994 dark ring also had a dark ring in 1995. Four cross sections from McKean County had dark rings in 1983 including one section with a dark ring in 1983 and dark rings in 1994 and 1995. No other characteristic dark rings were present on these cross sections.

The location of the dark cells within the dark rings varied by year (Fig. 3a), but only because the amount of earlywood produced in 1994 was much greater than in 1995. In 1994, the first cells in the earlywood are normal, but then the earlywood transitions to a dark brown color. The ring is then dark for about the next quarter to third of the ring width and then the color turns lighter, though not normal, in the last portion of the latewood. The 1995 dark ring was much narrower than the 1994 ring. Within the 1995 dark ring there is less earlywood produced and a rapid transition to darker colored cells. A 1983 dark ring was only present on four of the cross sections examined and was generally in a narrow growth year. Macroscopically it looked quite similar to the 1995 dark rings with a rapid transition to darkened cells.

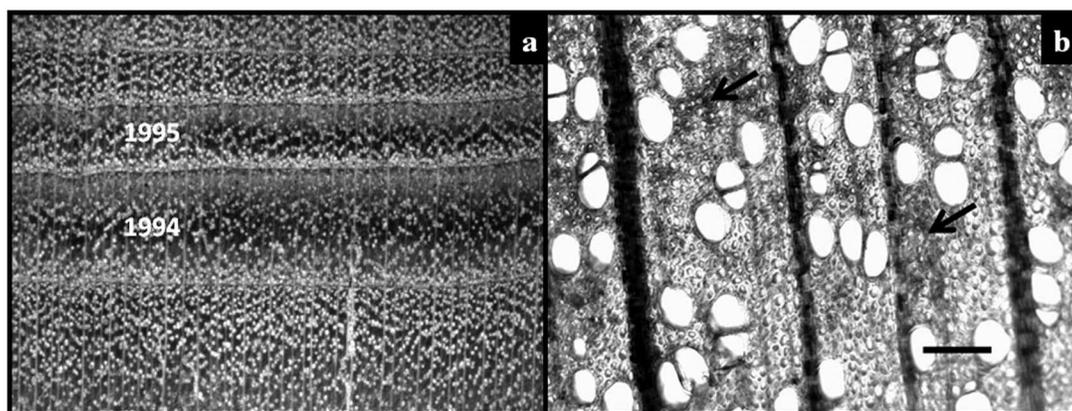
Under higher power magnification (Fig. 3b), the cellular structure of the 1994 and 1995 dark rings shows normal colored fiber cells in the earlywood transitioning to fiber cells with darkened walls

that formed later in the growing season. In the sections examined, there was no cellular deformation, just a darker coloration of the fiber cell walls that gives the ring its dark appearance.

Tree-ring chronologies were developed by combining data from nearby stands (Table 1). Standardized tree-ring chronologies from the three best replicated areas show a general synchronicity in growth among the three areas (Fig. 4). Cross sections from nearby or adjacent stands were combined so that the Forest 1 chronology includes sections from three adjacent stands ( $n = 21$  trees) and the Forest 2 chronology combines sections from four adjacent stands ( $n = 8$  trees). The pith year for Forest 1 trees ranged from 1921 to 1945 and average tree age was 72 years. For Forest 2 trees, the pith year ranged from 1928 to 1944, and average tree age was 60 years. Since we do not know exactly where on the bole the cross sections were sampled, these are likely conservative estimates of tree age. The McKean chronology includes just four cross sections from a single stand. The standardized chronologies show a few conspicuous differences. The McKean chronology, with the oldest trees (pith years 1903, 1903, 1900, and 1912; mean age = 106 years), shows much lower growth in the 1960s and 1970s compared with the other two chronologies. The McKean chronology also shows a possible release with greatly increased growth after the mid-1990s. While all three chronologies show reduced growth in the early and mid-1990s, only the McKean chronology shows a sharp decrease in growth in 1983 and 1984.

Susceptibility to defoliation by cherry scallop shell moth (*Hydria prunivorata*) (CSM) has been shown to be related to the amount of black cherry in affected stands (Morin et al. 2006). Stands with a higher percentage of stand basal area composed of black cherry received significantly ( $P < 0.001$ ) more years of defoliation. Stand level data were not available for the harvested areas in our study. However, buffer areas around the harvested stands were similar in composition to the harvested stands according to forest managers. Prism plots taken adjacent to the Forest 1 harvest area indicated that 52% of the stand basal area was black cherry (94 ft<sup>2</sup>/acre) and 42% of the stand basal area was red maple (*Acer rubrum*) (76.0 ft<sup>2</sup>/acre). At the buffer area around the Forest 2 harvest area, 50% of the stand basal was composed of black cherry (87.5 ft<sup>2</sup>/acre) and 25% of the basal area was red maple (43.8 ft<sup>2</sup>/acre).

Anecdotal information has linked the dark rings in black cherry to defoliation events. Historical defoliation records (Bonstedt 1985; Morin et al. 2006) indicate the McKean stand was heavily defoliated



**Figure 3.** (a) close-up showing dark rings in 1994 and 1995; (b) microscopic view of vessels and fiber cells; note the arrows pointing to the darkened fiber cell walls; black scale bar shows distance of 0.1 mm.

**Table 1. Tree-ring chronology characteristics.**

Chronology	Forest 1	Forest 2	McKean	All Samples
Number of stands	3	4	1	10
Number of cross sections	21	8	4	36
Mean ring width (mm)	2.76	2.84	2.27	2.69
Chronology period	1921–2010	1928–2010	1900–2010	1900–2010
Correlation with master	0.589	0.558	0.494	0.521
Mean sensitivity	0.231	0.248	0.272	0.244
Percent black cherry <sup>a</sup>	52	50	—	—

<sup>a</sup> Stand level pre-harvest data were not available. Percent black cherry basal area was calculated from prism plots located in buffer areas around the cut stands.

by CSM in 1982 and 1983, and was defoliated once by CSM in 1995. The ANF defoliation maps also indicate that trees in the Forest 1 chronology were defoliated once by CSM during 1995 and were just adjacent to an area defoliated a second time in 1996. The maps available for Forest 2 sites require interpolation but these stands were adjacent to areas defoliated in 1994 and 1995 by CSM.

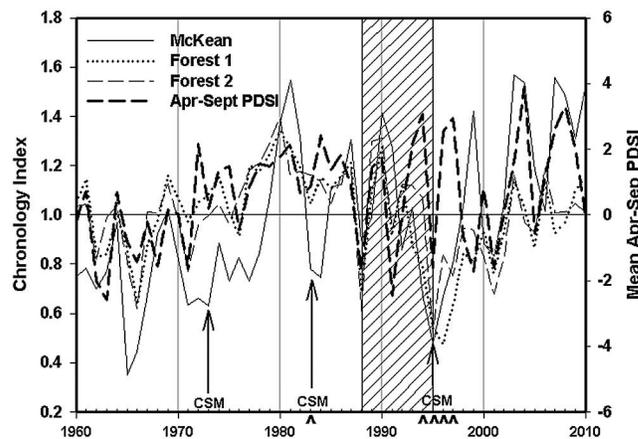
The late 1980s and early 1990s were periods of unusual events affecting forest health in northern Pennsylvania (Morin et al. 2006). Moderate drought prevailed in 1988 (June PDSI = -2.21 for PA climate division 10), and was followed by severe drought (PDSI between -3 and -4) in July, August, and September of 1991 (National Oceanic and Atmospheric Administration 2011). Additionally, an unprecedented outbreak of elm spanworm (*Ennomos subsignarius*) occurred from 1991 to 1993, although the population collapsed in 1994 (Morin et al. 2006). Elm spanworm defoliated American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), red maple, and black cherry. Elm spanworm defoliated all of the stands in our study at least once, and this defoliation(s) was followed by the CSM outbreak from 1993 to 1996, which is more closely associated with the year that dark rings occurred in black cherry.

## Discussion

The dark rings in black cherry sawlogs have been observed for a number of years by loggers and sawmill operators. However, while the rings were within the sapwood portion of the log, particularly those formed in the mid-1990s, they did not substantially affect the value of veneer logs. Now that the 1994 and 1995 dark rings are transitioning to the heartwood, they are a serious defect for veneer products. Although there is some evidence for linkage of defoliation events with formation of these rings, more thorough analyses are required to confirm this relationship.

A similar defect in European wild cherry (*Prunus avium*) has been documented in Italy where “vena verde” or green vein has been shown to occur in association with tension wood (Nocetti 2006). The growth rings have a distinct olive or green coloration but occur within the gelatinous fibers characteristic of tension wood. Examination of a subsample of our cross sections did not reveal any association of gelatinous fibers with the darkly colored rings in black cherry.

Defoliation events have been shown to affect ring color in trembling aspen (*Populus tremuloides*) (Hogg et al. 2002a). Pale-colored “white” tree rings have formed in response to defoliation from forest tent caterpillar (*Malacosoma disstria*) and white ring formation has been induced with artificial defoliation experiments (Hogg et al. 2002a, 2002b). White rings in aspen have much thinner fiber cell walls, and the cell walls have little secondary thickening giving them a pale appearance (Sutton and Tardif 2005). The dark rings in black cherry only show a discoloration of the fiber cell walls; the cell wall



**Figure 4. Standardized tree ring chronologies from three different areas and the April through September mean Palmer Drought Severity Index (PDSI) (heavy dashed line, scaled to the right Y-axis). Chronologies are from McKean County ( $n = 4$ ), and two from Forest County, as Forest 1 ( $n = 21$ ) and Forest 2 ( $n = 8$ ). Documented cherry scallop shell moth outbreaks are noted as CSM and A symbols beneath the X-axis indicate a year in which one or more dark rings were observed. The cross-hatched area highlights the period from the late 1980s to mid-1990s when multiple drought and defoliation events occurred in the region.**

thickness does not appear to be affected, based on this preliminary assessment.

Forest tent caterpillar is an early season defoliator as is elm spanworm; however, cherry scallop shell moth is a mid-season defoliator affecting cherry in late July or August (Schultz and Allen 1975, Allen 1993). This difference in timing of defoliation and the combination with drought may interact to produce conditions favoring dark ring formation, although the precise mechanism is unknown. More experimental work and field research will be needed to determine the causal factors associated with dark ring formation in black cherry. While the association of defoliation with dark ring formation is strictly correlative, forest managers may want to consider suppressing CSM in stands in where stand basal area is dominated by black cherry.

## Literature Cited

- ALLEN, D.C. 1993. *Cherry Scallop Shell Moth*. New York Forest Owner Association, Lima, NY.
- BONSTEDT, S.M. 1985. *A twenty-year history of forest insect and disease management on the Allegheny National Forest, Pennsylvania, 1965–1985*. USDA Forest Service, Northeastern Area State and Private Forestry, Morgantown, WV. 59 p.
- COOK, E.R., AND R. HOLMES. 1996. Guide for computer program ARSTAN. P. 75–87 in *The International Tree-Ring Data Bank Program Library Version 2.0 User's Manual*, Holmes, R., and H. Fritts (eds.). University of Arizona, Tucson, AZ.
- HOGG, E.H., J.P. BRANDT, AND B. KOCHUBAJDA. 2002a. Growth and dieback of aspen forest in northwestern Alberta, Canada, in relation to climate and insects. *Can. J. For. Res.* 32:823–832.
- HOGG, E.H., M. HART, AND V.J. LIEFFERS. 2002b. White rings formed in trembling aspen saplings following experimental defoliation. *Can. J. For. Res.* 32: 1929–1934.
- HOLMES, R.L. 1983. Computer-assisted quality control in tree-ring dating and measurement. *Tree-ring Bull.* 43:69–78.
- HOUGH, A.F. 1963. Gum spots in black cherry. *J. For.* 61(8):572–579.
- KULMAN, H.M. 1964. Defects in black cherry caused by barkbeetles and Agromizid cambium miners. *For. Sci.* 10(3):258–266.
- MORIN, R.S., A.M. LIEBHOLD, K.W. GOTTSCHALK, C. WOODALL, D.B. TWARDUS, R.L. WHITE, S.B. HORSLEY, AND T.E. RISTAU. 2006. Analysis of forest health monitoring surveys on the Allegheny National Forest (1998–2001). USDA Forest Service, Northeastern Research Station, Newtown Square, PA. Gen. Tech. Rep. No. NE-339. 102 p.

- NATIONAL OCEANIC, AND ATMOSPHERIC ADMINISTRATION. 2011. NOAA, Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina. Available online at: [www1.ncdc.noaa.gov/pub/data/cirs/](http://www1.ncdc.noaa.gov/pub/data/cirs/); last accessed Aug. 5, 2011.
- NOCETTI, M. 2006. *Produzione legnosa e miglioramento genetico: variabilità delle caratteristiche del legno in cloni di ciliegio (Prunus avium L.)*. Università degli studi della Tuscia di viterbo, Viterbo, Italy.
- REXRODE, C.O., AND J.E. BAUMGRAS. 1980. Gum spots caused by cambium miner in black cherry in West Virginia. USDA Forest Service, Northeastern Forest Experiment Station, Broomall, PA. Forest Service Research Paper No. NE-463. 9 p.
- SCHULTZ, D.E., AND D.C. ALLEN. 1975. Biology and descriptions of the cherry scallop shell moth, *Hydria prunivorata* (Lepidoptera: Geometridae), in New York. *Canadian Entomol.* 107(1):99–106.
- SPEER, J. 2010. *Fundamentals of Tree-ring Research*. The University of Arizona Press, Tucson, AZ. 333 p.
- SUTTON, A., AND J. TARDIF. 2005. Distribution and anatomical characteristics of white rings in *Populus tremuloides*. *IAWA J.* 26(2):221–238.
- WIEDENBECK, J., M. WIEMANN, D. ALDERMAN, J. BAUMGRAS, AND W. LUPPOLD. 2004. Defining hardwood veneer log quality attributes. USDA Forest Service. Northeastern Research Station, Newtown Square, PA. Gen. Tech. Rept. No. NE-313. 36 p.