

19. Silverborg, S.B. and E.W. Ross. 1968. *Ash dieback disease development in New York State*. Plant Dis. Repr. 52:105-107.
20. Tegethoff, A.C. and R.W. Brandt. 1964. *Ash die-back in New Hampshire, Vermont, Massachusetts, Connecticut, New Jersey, and Pennsylvania, 1963*. Plant Dis. Repr. 48:974-977.
21. Tobiessen, P. and S. Buchsbaum. 1976. *Ash dieback and drought*. Can J. Bot. 54:543-545.
22. Wilhour, R.G. 1970. The influence of ozone on white ash (*Fraxinus americana* L.). Ph.D. Thesis, Dept. Plant Pathology, Pennsylvania State Univ. 86 p.

*Research Plant Pathologist
Kitchawan Research Station
Brooklyn Botanic Garden
Ossining, New York
and
Professor of Forest Pathology (retired)
SUNY College of Environ. Science and Forestry
Syracuse, New York*

RESPONSE OF FOREST-GROWN TREES TO TOPPING¹

by Kenneth L. Carvell

Abstract. Mortality of topped trees, four and five years after partial crown removal, was low. Several smaller trees died from exposure after the protection of overhead trees had been removed. Height growth of topped trees was rapid. After topping, dominant trees grew at an annual rate of 0.77 m (2.54 ft) and co-dominants at a rate of 0.68 m (2.22 ft). Height growth of smaller trees was much less. Unless topping removes a major portion of the crown, diameter growth is not seriously affected. Diameter growth of topped trees during the five years after topping was only slightly less than during the five years prior to topping.

Selective clearing of electric transmission line corridors has increased during the past decade. This practice softens the visual impact of corridor establishment and maintenance activities. Basically it entails removing only those trees or portions of trees which interfere now, or will interfere in the near future, with safe and uninterrupted electric current transmission, or with tower erection or inspection.

During selective clearing operations many trees are topped rather than completely removed. The amount of tree crown left after topping is determined primarily by distance from the electric transmission wires rather than by biological considerations of an individual tree's condition. Thus, some trees are cut back severely, even to the

point of removing the major photosynthetic area of the crown.

Tree topping for transmission line construction is not comparable to the tree trimming commonly done in urban areas along distribution lines. Street shade trees are usually open-grown, and have large, deep crowns. During each periodic trimming of shade trees, a relatively small portion of the total crown area is removed. When transmission line corridors penetrate forest land, however, individual trees are closely spaced, and the crown area is restricted to a small percentage of their total height; usually 20 to 40 percent. Topping thus removes a significant percentage of the total photosynthetic surface. Topped trees respond in a number of ways: they may make a vigorous recovery through sprouting, they may remain in a static condition with little immediate change in crown area, or they may decline from the top and eventually die.

The objectives of this study were to determine (1) the growth response of selected tree species after topping, (2) what percentage of the live crown can be removed before decline occurs, and (3) whether such factors as relative crown position prior to topping, and total length of crown

¹Presented at the annual meeting of the International Society of Arboriculture in Toronto, Ontario in August 1978.

prior to topping, can be used to predict a tree's response to topping.

Literature Review

The term "topping" is used to describe the drastic cutting back of tops and limbs (Peace 1962, Pirone 1972). Pirone points out that topping may disfigure a tree by removing the normal canopy and may eventually lead to serious branch decay and sunscalding; however, this practice may be necessary as an invigorating measure, or to eliminate interference with overhead wires. Heavy topping should be done with extreme care and with certain precautions, if the tree is not to be severely damaged.

Pirone (1972) outlines these rules to follow during topping. Branches should be removed with a slanting cut, starting just above a vigorous bud or shoot, and running back across the limb at a 45° angle. A right-angle cut to the long axis of the branch is not likely to heal; those at too sharp an angle will weaken the elbow. All wounds, regardless of size, should be painted with a dressing (McQuilkin 1950). In actual practice, only wounds 5.08 cm (2 in) or more in diameter are so treated, but for low-vigor trees, where healing is slow, decay may develop rapidly even in small branch wounds.

Wounds made in early spring heal most rapidly. Some species, however, such as maples and birches, bleed so profusely when cut at this season that pruning of these trees should be delayed until summer when sap runs less freely. As a rule, American basswood, elms and black locust can be cut-back severely at any time of the year without seriously reducing vigor (Kramer and Kozlowski 1960).

When drastic topping is necessary, careful consideration must be given to species. Although most species when young can tolerate heavy topping, many when older (birch, sycamore, ash and beech) make weak recovery. Mature elms, on the other hand, can withstand heavy topping. Drastic topping of conifers is risky; they should be topped so that at least two whorls of actively-growing branches are left. Those broadleaved trees which produce strong coppice shoots from the stump when felled, such as quaking aspen and yellow-

poplar, usually recover from heavy topping (Peace 1962).

Not all portions of a tree crown are equally important in terms of photosynthesis. Lower crown branches, for instance, usually have relatively little leaf tissue and a large respiring surface. The natural death of lower branches is preceded by an extended period of retarded branch growth (Kramer and Kozlowski 1960). Pruning live branches decreases the amount of photosynthetic surface, and also the respiratory surface. Because many shaded basal branches have a small photosynthetic surface, they may consume most of the carbohydrates in respiration which they produce in photosynthesis. Consequently they do not contribute to stem growth (Labyak and Schumacher 1954).

Location and Description of Study Areas

Calvert Cliff Line, Maryland. This transmission corridor contains two 500 kV lines, and was constructed by Baltimore Gas and Electric Company between 1970 and 1972. The corridor extends from the Calvert Cliff thermonuclear plant in southern Maryland north to Baltimore, a distance of 128 km (80 mi). The section of corridor used in this study is located in Anne Arundel County.

The major hardwood forest type on mesic and xeric sites within the study area is white oak-northern red oak-hickory. Associates of these stands include red maple, American beech, chestnut oak and black gum. On upland sites wherever abandoned fields have recently been invaded by trees, young stands of Virginia pine often form the forest cover. On hydric sites the river birch-sycamore type is the predominant cover. Black gum, sweetgum and red maple are associated species.

In the spring of 1972, the power company selectively cleared the study area with topping of many "leave" trees. Where possible, trees were topped rather than felled. Topping ranged from light, removing 10 percent or less of the total crown length, to severe, where up to 70 percent of the crown length was removed.

Plymouth Meeting House-Conowingo Dam Line, Pennsylvania. This transmission corridor contains two 230 kV lines. The section of corridor used for

this study is located in Montgomery County, Pennsylvania, and is owned and operated by the Philadelphia Electric Company.

The major forest type on hydric sites is the black ash-red maple-American elm type. Red maple is the most abundant component of this type. On mesic sites the yellow-poplar-white oak-northern red oak type is the dominant cover. Black oak is a common associate of this type. On xeric sites the white oak-northern red oak-hickory type is the predominant cover, and chestnut oak is an abundant associate.

The power company initially cleared this corridor in 1927; however, they did not top the trees in the immediately adjacent stand until 1956. Topping was done to taper the profile of the adjacent stand towards the corridor edge, and thus eliminate the pronounced vertical line of the corridor margin. The company also did some topping in 1968. A later topping, which included all trees within 30 m (100 ft) of the corridor margin, was completed in January 1973.

Field Procedure

On the two study corridors the most abundant topped tree species were determined by sampling. From this tally the three most abundant species on the Pennsylvania study corridor were chosen for study. Because of the greater species diversity on the Maryland corridor, six species were selected for study.

Study plot locations on each corridor were established by selecting six potential study locations based on species diversity and accessibility. Using random numbers, three of these corridor sites were selected as study plots.

For each topped tree the following information was recorded: species, diameter breast high, height to base of live crown, height growth or dieback since topping, diameter growth before and after topping (from increment cores), and vigor of present crown (a subjective evaluation based on color and density of foliage). From the study plots on each corridor approximately 30 topped trees of each species were studied with the exception of sycamore, which proved scarcer on corridor study plots than the original tally had indicated.

In addition, for each species an equal number of untopped control trees was studied. Untopped trees were located in the woods immediately adjacent to the corridor. Control tree measurements included: species, total height, height to lowest live branch, relative crown position (dominant, co-dominant, intermediate or overtopped), diameter growth since corridor trees were topped (from increment cores), and vigor.

Results

Table 1 presents a list of species used in this study, the number of study and control trees, location, and average diameter breast high. Table

Table 1. Species, number of study trees and control trees, location, average diameters and percent of crown left after topping.

Species	Study area	Number of topped trees	Number of control trees	Average diam. of topped trees	Average diam. of controls	Percent of crown left after topping
				cm	cm	
Beech, American	Maryland	30	30	19.6	23.9	50.4
Hickory	Maryland	28	28	20.5	16.9	69.2
Oak, chestnut	Pennsylvania	30	30	30.5	30.0	52.4
Oak, northern red	Pennsylvania	30	30	37.4	38.9	57.2
Oak, white	Maryland	30	30	24.3	21.3	48.3
Pine, Virginia	Maryland	30	30	18.4	18.0	62.7
Sweetgum	Maryland	24	24	19.7	26.2	39.3
Sycamore	Maryland	7	7	43.2	52.7	36.1
Yellow-poplar	Pennsylvania	30	30	34.5	29.0	45.3

2 gives annual height growth for each species since the topping operation. Annual height growth is presented by crown classes to illustrate the effect of relative crown position on subsequent height growth. Table 3 presents the basal area growth by species for the five growing seasons before and after topping for the Maryland study area. For comparisons, this table also contains average basal area growth for control trees during the same time periods. Table 4 presents the basal area growth for the four growing seasons before and after topping for the Pennsylvania study area, and basal area growth of control trees during the same intervals.

To determine the influence of various degrees of topping on basal area growth, regression analyses were made for each species using the model:

$$G = b_0 + b_1D^2 + b_2H$$

where:

G = basal area growth since topping,

D = diameter breast high,

H = percent of original crown length remaining after topping.

Table 5 presents the results of these multiple regression analyses.

Discussion

It was not possible to obtain precise data on mortality of topped trees because some of the smaller trees on the Maryland study area had been felled subsequent to the time of selective clearing and topping. The small diameters of these stumps suggested that these trees had died from exposure rather than from topping. Trees of the size indicated by these stumps would have been from the intermediate and overtopped crown classes; trees of these crown classes were rarely tall enough to require topping. Of the topped trees present at the time of this study, only one was dead. This was a co-dominant Virginia pine that had been topped so severely that only two whorls of branches remained.

Annual height growth since topping varied with species (Table 2). Dominant and co-dominant trees generally recovered from topping more rapidly than intermediate or overtopped trees.

Virginia pine, a relatively short-lived tree, exhibited the least annual height growth of the nine study species. Northern red oak, chestnut oak and yellow-poplar, species on the Pennsylvania study area, had the largest annual height growth after topping. This was attributed to the better site conditions along this corridor. Sweetgum and sycamore, fast-growing species on the hydric sites on the Maryland corridor, recovered very rapidly from topping.

Table 2. Annual height growth of study trees after topping by crown classes (in cm).

Species	Crown Class			
	Domi- nant	Co-domi- nant	Inter- mediate	Over- topped
Beech, American	50	37	37	—
Hickory	43	53	37	18
Oak, chestnut	116	102	107	76
Oak, northern red	110	107	99	—
Oak, white	56	56	27	35
Pine, Virginia	41	30	12	—
Sweetgum	64	63	26	05
Sycamore	85	43	—	—
Yellow-poplar	131	120	79	114
Average	77	68	47	28

For the Maryland study area the basal area growth for all species combined indicates that topped trees grew only slightly less than they had in the period prior to topping (Table 3). The greater basal area growth of sycamore, when compared with other Maryland species, is attributed to the fact that all of the sycamore study trees had much larger diameters than those for other study species (Table 1). It has been shown that trees of larger diameters produce a larger basal area increment than do trees of smaller diameters (Loetsch *et al.* 1973).

The influence of topping on basal area growth is less apparent in the Pennsylvania study tree data (Table 4). Northern red oaks increased less in basal area after topping than they had in the preceding four growing seasons. Their growth after topping was less than that of the controls. Basal area growth of topped chestnut oaks actually increased in the years after topping and was superior to the basal area growth of controls during this period.

Multiple regression analyses to identify the rela-

tionships between diameter, percentage of crown remaining after topping, and basal area growth since topping showed a strong relationship between diameter and basal area growth (Table 5). Surprisingly, for most species there was no significant correlation between percentage of crown remaining after topping and subsequent basal area growth. This relationship, however, was significant for chestnut oak and yellow-poplar. The fact that few of the study trees had received such severe topping that one-third or less of their original crown length was left intact, may explain why the relationship between percentage of crown remaining after topping and subsequent basal area growth was not significant for all species.

Conclusions

Mortality of topped trees, four and five years after partial crown removal, was low. Few of the topped trees on the study areas, however, had more than 60 percent of their crown length removed in the topping operations. Only one of the 231 topped trees died from excessive crown removal. Several overtopped and intermediate crown class trees died from exposure after the protection of overhead trees had been removed.

Height growth of topped trees was rapid. Dominant trees grew at an annual rate of 0.77 m (2.54 ft) and co-dominants at an annual rate of 0.68 (2.22 ft). Height growth of intermediate and overtopped trees was much less. Chestnut oak, northern red oak, sweetgum, sycamore and yellow-

Table 3. Average basal area growth (in cm²) by species for five-year period before and after topping for Maryland study area.

Species	Topped trees		Control trees	
	1967-1971	1972-1976	1967-1971	1972-1976
Beech, American	40	50	70	60
Hickory	40	40	30	30
Oak, white	60	60	60	70
Pine, Virginia	50	40	50	40
Sweetgum	50	40	70	80
Sycamore	170	190	160	190
Average	50	50	60	60

Table 4. Average basal area growth (in cm²) by species for four-year period before and after topping for Pennsylvania study area.

Species	Topped trees		Control trees	
	1969-1972	1972-1976	1967-1971	1972-1976
Oak, chestnut	80	80	70	70
Oak, northern red	120	110	120	130
Yellow-poplar	240	210	220	180
Average	170	130	130	130

Table 5. Multiple regressions and coefficients relating basal area growth since topping (G) with percent of crown remaining after topping (H) and diameter breast high (D), and levels of significance.

Species	Multiple regression equation	Multiple regression coefficient	Simple correlations (r-values)		
			H,G	D ² ,G	D ² ,H
Beech, American	$G = 0.0242 + 0.00032D^2 + 0.00008H$	0.69**	0.004	0.685**	-0.048
Hickory	$G = 0.0286 + 0.00018D^2 - 0.00002H$	0.62*	-0.049	0.624**	-0.071
Oak, chestnut	$G = 0.0035 + 0.00019D^2 + 0.00086H$	0.59**	0.458**	0.514**	0.347
Oak, n. red	$G = 0.0324 + 0.00034D^2 + 0.00068H$	0.54**	0.146	0.545**	0.248
Oak, white	$G = 0.0425 + 0.00012D^2 - 0.00007H$	0.48*	0.012	0.483*	-0.040
Pine, Virginia	$G = 0.0431 + 0.00049D^2 - 0.00039H$	0.76**	-0.179	0.690**	0.206
Sweetgum	$G = 0.0198 + 0.00037D^2 - 0.00003H$	0.77**	-0.057	0.775**	-0.034
Sycamore	$G = -0.083 + 0.00054D^2 + 0.00179H$	0.95*	-0.175	0.935**	-0.353
Yellow-poplar	$G = 0.0365 + 0.00031D^2 + 0.00339H$	0.57**	0.521**	0.256	0.051

r = simple correlation coefficient

* = significant at 0.05 level

** = significant at 0.01 level

poplar grew most rapidly in height. American beech and white oak were intermediate in rate of height growth. Hickory and Virginia pine grew comparatively slowly.

Unless topping removes the major part of the crown, basal area growth is not seriously affected by topping. Basal area growth of topped trees during the five years after topping was only slightly less than that during the five years prior to topping.

For many of the species included in this study, there was no significant relationship between the intensity of topping and subsequent basal area growth. This relationship, however, was significant for chestnut oak and yellow-poplar. Evidently topping of the intensity used on the two study areas (averaging no more than 60 percent crown removal per species) is not severe enough to cause a major depression in basal area and

diameter growth.

Literature Cited

- Kramer, P.J. and T.T. Kozlowski. 1960. *Physiology of Trees*. McGraw-Hill Book Co., Inc., New York. 624 pp.
- Labyak, L.F. and F.X. Schumacher. 1954. *The contribution of its branches to main stem growth of loblolly pine*. *J. Forestry* 52:333-337.
- Loetsch, F., F. Zohrer and K.E. Haller. 1973. *Forest Inventory (Vol. II)*. BLV Verlagsgesellschaft, Munich. 469 pp.
- McQuilkin, W.E. 1950. *Effect of some growth regulators and dressings on the healing of tree wounds*. *J. Forestry* 48:423-428.
- Peace, T.R. 1962. *Pathology of Trees and Shrubs*. Oxford Press, New York. 753 pp.
- Pirone, P.P. 1972. *Tree Maintenance (4th ed.)*. Oxford Press, New York. 574 pp.

*Division of Forestry
West Virginia University
Morgantown, West Virginia*

ABSTRACTS

Peterson, G.W. 1978. **Effective and economical methods for controlling *Diplodia* tip blight**. *Am. Nurseryman* 147(1): 13, 66, 70, 72.

The fungus *Diplodia pinea* is causing increasing damage to pines in the U.S. The fungus, which infects more than 20 pine species has been reported in 29 states. Damage is severe on pines over 30 years old in the Midwest. Research revealed when spores of the fungus are dispersed and initial infection occurs, which tissues are susceptible, and the number and timing of fungicide applications necessary to control the fungus.

Cathey, H.M. & L.E. Cambell. 1977. **Light frequency and color aid plant growth regulation**. *American Nurseryman* 146(10): 16-18, 108-114.

In the 1920's and 1930's scientists determined that the length of the day regulates the growth cycles of many kinds of plants. Through the intervening years, we have learned that the type of light, its color content and intensity, and the frequency of light and dark periods strongly influence responses of various plants. Our ability to regulate plant growth has been increased by application of additional knowledge, as follows:

- (1) Interruption of the dark period rather than extension of the day, cutting the required lighting time from 12 to 4 hours, and intermittent lighting for the 4 hours; lamps on 6 to 12 seconds every minute.
- (2) Increased use of long-lived incandescent lamps, which can burn for 2,500 rather than 600 hours, and 230- to 240-volt lamps, which lower wiring costs.
- (3) Determination of special requirements for photoperiod response.
- (4) Development and general use of various light sources — fluorescent, mercury, metal halide, high-pressure sodium and low-pressure sodium — all more efficient than incandescent.