THE INFLUENCE OF DEFOLIATION ON FLOWERING DOGWOOD[1,2]

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Abstract. Forty flowering dogwood trees were subjected to 1 of 5 defoliation levels (0% , 25%, 50%, 75%, and 100% defoliation). Defoliation impact was assessed by measuring changes in diameter, twig extension growth, and electrical resistance of the cambium. Electrical resistance in the cambium increased for plants that were totally defoliated. Circumference growth of flowering dogwood was reduced 50% by total defoliation when compared to defoliated plants. Twig extension growth of defoliation stressed trees was reduced ⊕ 35% as defoliation levels reached 75% and 100%. Both increases in circumference and twig extension growth are affected by defoliation stress. Twig extension growth is the best measure of defoliation stress because it has the advantage of not requiring wounding when used to assess the impact of defoliation stress after the fact.

Flowering dogwood has been described as the aristocrat of native trees for ornamental purposes (3). The defoliation or death caused by dogwood anthracnose in parts of the United States has not dethroned this plant's popularity, although its continued use will depend on different management strategies being employed. Understanding the effect of various stresses is important as we try to manage this showy ornamental in the urban ecosystem.

Defoliation of plants can result from insect, disease, mechanical, or environmental stresses. The detrimental effects of defoliation are well known (4,6,13). Being able to predict or to understand the effect of a stress such as defoliation is important if we are to manage tree health. Trees often do not have clear and easily discernable signs of stress until vitality has declined significantly (10). Further, there are few standard criteria for defining plant health. Wargo (13) states that tree vigor may be easy to see but is more difficult to define and still more difficult to measure. Standards will vary depending on what is measured. Struve (9) found that leaf size of 2 oaks had recovered 2 years after transplanting, while photosynthetic rates required another year to recover. Clearly there is a real need to discover unequivocal measures of tree health.

Waring et al. (14) studied carbon allocation in trees. They determined that stem wood production has a lower priority for carbon than root or stem extension. Thus, the allocation of carbon to a low priority area such as caliper increase would be a measure of tree vigor. They even went so far as to describe tree vigor as the amount of stem wood produced per square meter of foliage.

Ball and Simmons (1) used a Shigometer to measure resistance to a pulsed electrical current as a measure of tree vitality. Low resistance indicates a high salt content in the cambial area and thus high vitality. Both Ball and Simmons (1) and Shigo (8) define *vigor* as the tree's genetic capacity to resist stress and define *vitality* as the tree's ability to grow in its specific environment.

Materials and Methods

Forty trees were randomly selected from a naturally regenerating population of some 2,000 plants being managed for nursery production on a 1.2 ha old field site in Danville, Ohio. Plants were between 2.5 and 5.0 cm caliper and 1.8 to 2.4 m in height. The trees were between 7 and 10 years old. Single-stemmed trees of similar size and without defects were selected for study.

The soil is a Gilpin silt loam with a pH range of 5.1 to 5.4. Soils are well drained, unglaciated, and located on sloping ridges. The site is an exposed, east-facing hillside, in full sun.

Trees were randomly assigned to 1 of 5 treatment levels: 0%, 25%, 50%, 75%, or 100% defoliation. Defoliation was accomplished by removing every fourth pair of leaves for the 25% defoliation level and every other pair of leaves for the 50% defoliation level. Seventy-five percent defoliation was accomplished by removing 3 of every 4 pairs

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of leaves throughout the canopy. There were 8 replicates per level. Trees were defoliated in July 1984 after full expansion of the primary leaves. At this stage trees were in active growth with twigs extending and no visible terminal buds. The trees had maximum energy demands and limited food reserves (11). Defoliation was repeated in July 1985 for 4 of the original 8 replicates in each level so that the effects of 1- and 2-season defoliation could be evaluated.

During defoliation, 100 leaves were chosen at random, representing top, middle, and lower stratification of the tree, to obtain leaf area and dry weight. Leaf area was measured with a Li-Cor 3000 automatic area meter. Leaf measurements taken in July 1984 served as baseline data.

Stem size was measured annually between 1984 and 1986 at 23 cm above the ground. Measurements of trunk circumference were taken in early April while the trees were still dormant. The change in circumference was determined for each level of defoliation.

Annual twig extension growth from 1984 and 1985 was taken in March 1986. Measurements were taken in the top third of the tree. Twig extension was determined for the first, second, and third whorls. The terminal whorl consisted only of 1985 growth. Data were collected for the 4 cardinal quadrants (N, E, S, and W) for each of the 3 whorls.

Electrical resistance of the cambium zone was measured using a Shigometer Model OZ-67. This instrument has been used as a measure of plant stress and to predict vulnerability to insect attack (1). Measurements were taken in September of 1984 and 1985. Vitality was measured using the needle probe technique. The 2 probes were vertically aligned and inserted through the bark and cambium and into the xylem. Two readings were taken per tree with 1 reading at 30 cm and 1 reading at 46 cm above the ground. The 2 readings per tree were averaged for analysis. All Shigometer readings were taken on the same day. The first set of resistance readings was made only 5 weeks after the trees were defoliated on July 10, 1984.

An analysis of variance was performed for each parameter. Mean separations were made using the least significant difference (LSD). Regression analysis was further used to evaluate data.

Results and Discussion

Change in circumference. The increase in circumference of trees with 50%, 75%, or 100% defoliation was less than for the trees receiving 0% or 25% defoliation (Table 1). During the first year of the stress, the circumference growth for the 1984 growing season declined from 2.8 cm for undefoliated trees to 1.4 cm for trees that had been totally defoliated. The trees averaged a 8.9 cm trunk circumference (2.8 cm diameter) at the beginning of the trial (ranging from 7.6 cm to 12.2 cm). Growth, after 1 year, would then would result in a 9.3 cm circumference (2.9 cm diameter) totally defoliated tree and a 11.7 cm circumference (3.7 cm diameter) undefoliated tree. Stating the size as cross-sectional area, the undefoliated tree would have an area of 10.8 cm^2 as compared to an area of 8.4 cm^2 for a tree that had been totally defoliated. Thus, the cross-sectional area of the undefoliated tree was 28% larger than the defoliated tree after 1 year. After 2 years of growth in the field, the trees were 4.2 cm in diameter if defoliated and 5.0 cm in diameter if undefoliated. Undefoliated trees had a 41% larger cross-sectional area. The impact of defoliation was therefore apparent for more than a single year in this trial.

These results are consistent with the work of others, although the terms used to describe the plant condition would vary. Waring et al. (14) describe the undefoliated trees as *more vigorous,* while Shigo (8) uses the term *higher vitality* in this situation. We prefer the term *higher vitality* because we believe that the more rapid growth rate is an

Table 1. Influence of percent defoliation on trunk circumference, electrical resistance, leaf weight, leaf area, and leaf specific weight during the 1984 and 1985 growing seasons.

	Circumference increase (cm)		Electrical resist. (kΩ)		1985		
% Defol.	'84-85	'84-86	'84	'85	Weight per leaf (mg)	Area per leaf (cm^2)	Specific weight of leaf (mg/cm^2)
0	2.8	6.9	9.3	15.7	221	44.0	5.0
25	2.6	7.3	9.4	16.2	242	38.7	6.4
50	2.5	5.4	9.5	18.4	213	39.5	5.5
75	2.0	4.8	10.2	20.0	174	35.5	4.9
100	1.4	4.3	12.2	19.7	163	31.2	5.2
$LSD_{0.05}$	0.5	1.1	1.4	3.9	5.3	5.3	1.6

indication that the undefoliated plants are likely to survive under poorer conditions—although long-term survival was not measured.

More than 50% defoliation of flowering dogwood results in reduced vitality for more than 1 growing season, even when the trees are growing in a native site. The impact of the defoliation stress was clearly identified for both 75% and 100% defoliation levels by using change in circumference (diameter) as a measure of growth. A problem with using changes in circumference (diameter) after the fact to determine changes in growth or vitality is that an increment borer is used to remove a core of xylem to measure the change in diameter. Core removal damages the subject. Changes in circumference measure the change in diameter without damage, but can be used only when the diameter or circumference is known before the stress is delivered.

Electrical resistance. Electrical resistance readings were able to detect differences between various defoliation levels rapidly (Table 1). Cambial resistance to a pulsed electrical current increased for trees that were totally defoliated. By 1985, the electrical resistance was higher for trees suffering both 75% and 100% defoliation than it was for undefoliated trees. Increased cambial resistance to an electrical current following defoliation was also noted by Wargo and Skutt (12).

The response of electrical resistance to stress was rapid but required extreme stress (100% defoliation) to be detectable. Changes in cambial growth were more sensitive to stress levels than was electrical resistance of the cambium in this study.

Leaf size. Both leaf size and leaf weight decreased as defoliation stress increased (Table 1). Leaf size decreased 26% from 221 mg for undefoliated leaves to 163 mg for plants that had been totally defoliated. Leaf area declined 29% from 44 cm^2 to 31 cm^2. There appears to be no compensation for the stress of defoliation in increased leaf size. The specific weight of the leaves did not increase to compensate for increasing defoliation levels.

Twig extension growth. During the first season of defoliation, shoot growth in the terminal or first whorl was unaffected by the treatments (Table 2). Twig extension in the second whorl was reduced significantly for defoliation levels greater than 75%. Some shoot extension growth occurred following the defoliation treatments in July. Kozlowski and Ward (5) also noted the ability of *Cornus florida* shoots to elongate in midsummer. Differences were evident in the first and second whorls by 1985. As noted before, the second whorl was more responsive than the first to defoliation stress. The fact that the second whorl is below the apex in the hierarchy for energy allocation makes it a more responsive measure of defoliation stress (2,7). The impact of the defoliation stress was evident for single incident defoliation levels above 25% during the second year. Interestingly, consecutive defoliation levels of 25% for 2 years also caused a decrease in the growth of the first and second whorls and was similar in impact to a single defoliation of 50% for a single year. Defoliation levels ⊕ 50% were required to reduce twig growth rates in a single incident.

The impact of the second year of defoliation was most clearly noted at the 25% defoliation level. Here, the second defoliation reduced growth by 68% compared to trees defoliated once. The second 25% defoliation was similar to the impact caused by a single defoliation of 50%.

Trees defoliated 50% or more had less twig extension growth than plants defoliated to a lesser extent. Curiously, the second defoliations of 50% or more did not seem to reduce the growth beyond

Table 2. Influence of percent defoliation in 1984 and 1985 on mean shoot growth in the first and second whorl of flowering dogwood.

Treatment defoliation		Growth increase (cm)		
1984	1985	1984 2nd whorl	1985 1st whorl	1985 2nd whorl
0	0	39.0	39.3	35.2
25	0	33.0	39.7	35.0
25	25	n/a	26.2	23.7
50	0	28.5	23.5	27.5
50	50	n/a	26.2	23.7
75	0	25.0	22.5	18.0
75	75	n/a	22.0	20.2
100	0	23.7	11.7	9.8
100	100	n/a	14.7	8.3
$LSD_{0.05}$		10.5	12.1	9.5

the initial impact caused by a single defoliation. Perhaps the second defoliation would principally extend the time to recovery for trees 50% or more defoliated.

Changes in caliper, increases in electrical resistance, and twig extension growth all are impacted by defoliation stress. Both changes in caliper and twig extension growth are reasonably sensitive to the stress. Twig extension growth has the advantage of being a nondestructive technique when used to assess the impact of the stress after the fact.

Defoliation is a common result of urban stress and a concern for dogwood because of the additional anthracnose threat. While cambial resistance as measured by the Shigometer, change in circumference, and twig extension are all means of measuring the impact of defoliation, changes in caliper and twig extension are more sensitive measures. Twig extension is more easily measured by arborists and causes less plant injury than change in circumference or caliper and is more likely to be used in the industry. Fifty percent defoliation in a single incident or two 25% defoliations cause measurable reductions in the growth rate of flowering dogwood.

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Résumé. Quarante arbres provenant d'un groupe de cornouillers de Floride produits en pépinière et qui se sont reproduits naturellement ont été sélectionnés sur une base aléatoire.Les arbres ont été défoliés selon cinq intensités différentes variant de 0 à 100%. Le stress causé par la défoliation affectait à la fois la croissance en diamètre et en longueur des tiges. La croissance en diamètre était réduite d'un facteur de 50% lorsque les arbres étaient entièrement défoliés par rapport aux arbres non défoliés. La croissance en longueur des tiges des arbres défoliés était diminuée d'un facteur de 35% ou plus lorsque le degré de défoliation atteignait les 75%. La résistance électrique du cambium était accrue pour les végétaux entièrement défoliés.