WOUND COMPARTMENTALIZATION POTENTIAL AND BORER DAMAGE IN GREEN ASH

by Frank S. Santamour, Jr.

Abstract. Green ash trees that exhibited strong Wall 2 compartmentalization of chisel wounds made in the trunk had less wood discoloration associated with ash borer activity than did weak compartmentalizing trees. The wood of weak compartmentalizers was extensively colonized by microorganisms (bacteria and stain fungi) and many such trees were declining. Despite the fact that both strong and weak trees were attacked by borers with equal frequency, strong compartmentalizing trees could withstand the attacks and continue to grow normally. The use of vegetatively propagated cultivars, all of which are strong compartmentalizers, is recommended.

Résumé. Les frênes rouges exhibant un mur 2 ce compartimentage très résistant suite à une blessure de ciseau au tronc avaient moins de décoloration du bois associée à l'activité du perceur du frêne qu'avient les arbres faibles compartimenteurs. Le bois des faibles compartimenteurs était colonisé largement par les microorganismes (bactéries et champignons de coloration) et plusieurs de ces arbres dépérissaient. En dépit du fait que tant les arbres faibles que forts étaient attaqués par les perceurs avec une même fréquence, les arbres qui compartimentaient fortement pouvaient résister aux attaques et continuer à croître normalement. L'utilisation de cultivars propagés végétativement, tous de forts compartimenteurs, est recommandé.

In a recent paper (4), it was stated that selection or breeding of green ash (*Fraxinus pennsylvanica*) for resistance to the sesiid ash borers, *Podosesia syringae* and *P. aureocincta,* might be difficult. About 81% of several hundred 9-year-old trees from 41 different geographic origins were attacked by borers, and only a few of the trees not attacked had acceptable growth rates. How, then, can we best combat these insects to reduce the potential damage they might cause? We might also ask whether the damage is of sufficient importance to warrant our attention.

Ash borers make holes in the wood of young ash trees. These holes may cause some downgrading in the quality of lumber sawn from the tree but the holes, *per se,* are not important horticulturally. The holes may reduce the physical strength of the wood but, in a living tree, borer holes in the xylem seldom are so concentrated that a tree will break off near borer-riddled areas.

Before entering the xylem, borer larvae mine or tunnel in the cambial zone, killing small patches of that tissue. However, the degree of borer infestation is seldom so intense that a stem is girdled and killed. The exit holes of the borer (usually about 10 to 30 cm above the entrance) also damage the cambium, but these holes are rather scattered spatially, both vertically and circumferentially. To be sure, some trees are girdled and some trees *do* break off, but these are the exceptions.

In our experience, most trees that are actually suffering from borer infestation exhibit a progressive decline in vigor and growth rate. The leading terminal shoot usually is the first to die back, followed by a few major laterals. The tree, although living, becomes a horticultural eyesore. Actual death of infested trees is likely caused by secondary pathogens and insects.

The basic fact is that all borer activities in a tree are wounding processes. Wounds allow the entrance of microorganisms, and microorganisms can cause wood discoloration and decay. Is the extent and importance of borer damage related to the ability of the tree to compartmentalize wounds? The present study was undertaken to answer that question.

Materials and Methods

The green ash trees used in this study were from the same provenance and progeny tests utilized in our earlier work on ash borers and giant hornets (3, 4). On October 2, 1984, when the trees were 9 years old from seed, 250 trees were wounded by making 2 chisel cuts 12mm wide and 5mm deep into the xylem on opposite sides of the trunk at 1m above ground level. If any tree had 2 or more upright trunks, at least 2 of these were wounded.

Thirty wounded trees, representing only the smaller trunks of 2-trunked trees, were cut down in November, 1985. These harvested trees represented 18 provenances, and included both northern and southern sources. By initially felling only the smaller trunks, we were able to maintain a full complement of trees for longer-term testing. The felled trees were sawn up in various ways to determine their compartmentalization response to chisel wounding and the extent of borer infestation. Later, we were forced to fell the major or only trunks of 17 trees (in spring 1986), including 5 that had not been sampled previously, to check on the constancy of wound response of individual trees and in progenies of the same mother tree.

Results and Discussion

Some of the study trees were strong wound compartmentalizers and some were weak. A strong compartmentalizing tree is capable of forming a Wall 2 (CODIT,5), interior to the chisel wound, that is not penetrated by microorganisms, and the zone of discolored wood is virtually confined, in cross-section, to the cells killed at the time of wounding (Fig. 3, 4, 5). In weak compartmentalizers, the new Wall 2 is not sufficiently impenetrable to prevent microorganisms from discoloring cells internal to the wound, frequently all the way to the pith (Figs. 1, 2).

Because of the limited sampling, but also because of the variable number of parent trees represented in each provenance (4), it was not possible to make any correlations between provenance and compartmentalization potential. We know that the potential for strong compartmentalization is a characteristic of individual trees and is under moderate to strong genetic control, and is independent of growth rate. Thus, differences attributable to provenance might not occur. We did find both strong and weak compartmentalizers in 5 provenances and in the progenies of 4 individual mother trees. The trees of 3 seedlots, one each from Nebraska, Quebec, and Vermont, appeared to be suffering from borer attack to a greater degree than others and were showing reduced growth and dying tops. Trees of other progenies from similar localities were more vigorous.

Figure 1. Cross-sections through weak compartmentalizing tree. Upper left section showing wound-induced wood discoloration into center of tree and no Wall 2 formation. Other cross-sections showing various patterns of wood discoloration associated with borer activity. Borer exits shown in upper left and center sections.

Figure 2. Cross-sections through a weak-compartmentalizing tree (wounded section, lower right). Considerable wood discoloration was associated with borer activity. Note also discolored flecks in most annual rings, probably denoting fungal infection.

The most significant observation was that weak compartmentalizing trees (Figs. 1, 2) exhibited considerably more wood discoloration associated with borer activity than did strong compartmentalizers (Fig. 3, 4, 5). This was especially evident in the amount of discoloration contiguous to vertical tunnels, but was also noted in the vertical extent of discoloration caused by borer entry and exit. It was not possible to quantify these differences because of repeated borer attacks and overlapping discoloration patterns.

There were also marked differences between strong and weak compartmentalizers in what appeared to be microbial discoloration in the springwood regions of annual rings. In weak compartmentalizing trees, discoloration or "flecking" occurred in most annual rings, frequently totally around the tree, even in areas where the surrounding wood was not discolored (Fig. 1, 2). Sometimes, "flecking" was found in a limited segment of an annual ring in strong compartmentalizing trees (Fig. 4, bottom right). Such patterns could usually be traced to vertical extensions of discoloration emanating from cambial wounds made at the time of borer entry. Solomon and Toole (6) investigated the various microoganisms in "stained" and decayed areas of wood associated with galleries made by carpenterworms (*Prionoxystus robiniae*). Bacteria and stain fungi of the genus *Fusarium* were the most commonly isolated microorganisims from all tree species—green ash, American elm (*Ulmus americana*), and Nuttall oak (*Quercus nuttallii*)—10 months after infestation. Several non-stain fungi, including *Cephalosporium*, were isolated occasionally. After 22 months, *Ceratocystis* was common in all trees and decay fungi were found in oak.

We were able to isolate bacteria and fungi from both discolored wood and "flecked" portions of annual rings. With the kind assistance of Dr. R. J. Stipes (VPI & SU, Blacksburg, VA) the most common fungus was identified as a *Fusarium*, and *Cephalosporium* was occasionally found. Our studies were not exhaustive, but it is of interest that marked similarities did exist in the microflora associated with the activities of different borers.

The logistics of carpenterworm attack differs from those of the ash borers in several ways that may allow more extensive colonization by microorganisms. The carpenterworm makes only 1 hole in the trunk, which is used by the larva as both an entrance and an exit. With continual "reaming out", this hole may eventually be as large as one-half-inch (13mm) in diameter and remain "open" for nearly 2 years. The entrance "hole" of the ash borers is nearly indistinguishable after a few weeks and the exit hole is only 3 to 5 mm in diameter and it is callused over fairly rapidly.

The inescapable conclusion was that weak compartmentalizing green ash trees were more likely to *suffer* from ash borer attack than were strong compartmentalizing trees. All of the "sick" trees in the aforementioned provenances were weak compartmentalizers., as were 2 other trees that did not yet show any external symptom of "in-

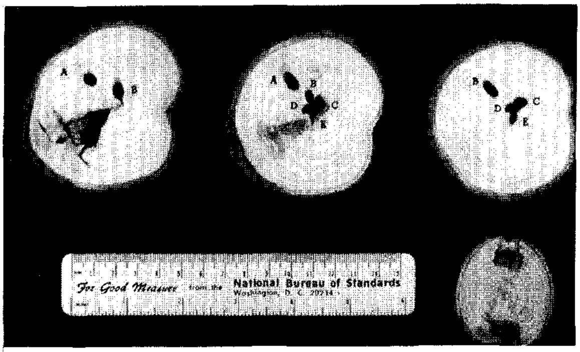

Figure 3. Cross-sections through a strong compartmentalizing tree (lower right, chisel wound made on smaller of 2 trunks). Borer tunnels of A and B were present in the tree when massive attack of 3 borers (C, D, E) occurred at roughly the same entrance site, causing considerable wood discoloration. However, this discoloration was not evident 4 cm above entrance (upper right disk) and no discoloration was associated with the borer tunnels.

Figure 4. Cross-sections through what must be considered as a strong-compartmentalizing tree, even though borer attacks at chisel-wound site (2nd section from left, upper row) might indicate otherwise. Upper 8 disks, *ca.* 2 cm thick, sawn sequentially up stem. At time of wounding in October, 1984, tunnels made by 2 borers (A and B) were present in the stem. The borers had exited, but the tunnel of B extended into the next section. Borers C and D attacked at wound site in the autumn of 1983, and were probably *P. aureocincta*, exiting during autumn of 1985. Borer E entered in summer of 1985 and larva was still present in the tunnel when the tree was felled in the spring of 1986. Lower left section shows typical wood discoloration pattern associated with single borer entrance sites, 2 borers entered at roughly the same level in 2 different years. In all sections, note minimal wood discoloration associated with borer activity. "Flecking" in a protion of the annual ring in bottom right section probably caused by cambium damage upon borer entry, similar to lower left.

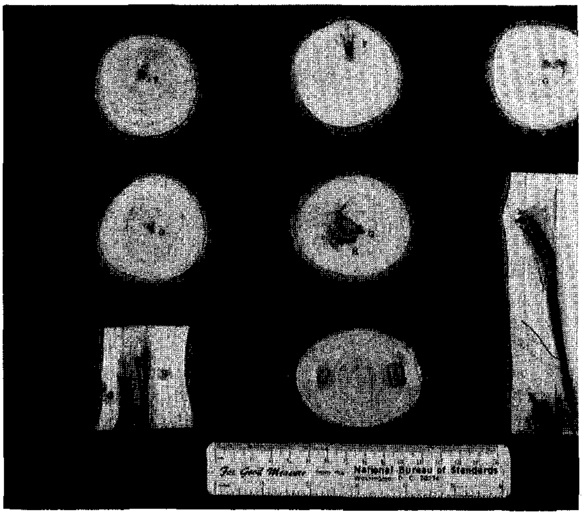

Figure 5. Cross- and longitudinal sections of strong-compartmentalizing tree (wound section, bottom center). Typical old exit hole at top row, center; entrance pattern, top right; entire 1-yr. disruption from entrance to exit at bottom right, wire inserted to show continuity of tunnel. Lower left: vertical discoloration resulting from borer tunnels of G (exited near letter "G") and H (larva present). Minimal wood discoloration associated with borer activity.

fection". Weak compartmentalizing trees were characterized by the extensive invasion of microorganisms in their trunk wood. Strong compartmentalizing trees, even though attacked by ash borers with the same frequency as weak compartmentalizers, did not exhibit more than incidental local wood discoloration as a result of borer-inflicted wounds.

Recent research (1, 2) has shown that cultivars of landscape trees propagated by budding or grafting (including green ash 'Marshall Seedless' and 'Summit') were strong compartmentalizers. With the current trend toward the use of such selected male cultivars of green ash we are at least assured that these trees will probably be more able to cope with attacks by the ash borers than run-of-the-nursery seedlings.

The nagging questions that could not be resolved were: 1) Was the weak compartmentalization response of some trees the result of previous infection of the tree by borer-associated microorganisms? 2) Was the extensive colonization of some trees by borer-associated microorganisms the result of the inability of the tree to compartmentalize wounds? It is entirely possible that both questions can be answered in the affirmative, and that weak-compartmentalizing trees will, through continued wounding and borer attack, become progressively weaker and die. This "chicken or egg" situation may soon be resolved by wounding studies on vegetatively propagated trees of both weak and strong compartmentalizers—if we can keep the borers away.

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