CAN TREE SUSCEPTIBILITY TO BORERS BE PREDICTED FROM ROOT STARCH MEASUREMENTS?[1]

by James P. Dunn[2] and Daniel A. Potter

Abstract. The twolined chestnut borer (TLCB) attacks and kills stressed oak trees, especially those that have been weakened by severe drought. We tested the hypothesis that winter root starch reserves of white oak are an indicator of tree vigor, and that trees low in stored starch are especially vulnerable to borer attack during the following summer. Only those trees that were very low in stored root starch were heavily attacked by the TLCB and showed signs of decline or died. A few oaks with high starch reserves were also successfully colonized, but those trees did not show signs of decline and did not die. Thus, winter starch reserves were generally a good predictor of TLCB attacks. Further research is needed to determine if this relationship holds for other hardwood trees and their respective wood borers. Use of root starch ratings to assess tree susceptibility to borers needs further testing in urban settings to determine its practicality for pest management.

L'agrile à deux lignes du châtaignier (TLCB) attaque et tue les chênes sous stress, surtout ceux qui ont été affaiblis par une sécheresse sévère. Nous testions l'hypothèse que les réserves hivernales en amidon racinaire du chêne blanc sont un indicateur de la vigueur de l'arbre et les arbres avec une basse accumulation en amidon sont effectivement spécialement vulnérable à l'attaque de l'agrile au cours de l'été suivant. Seul les arbres qui avaient de faibles accumulations en amidon racinaire étaient lourdement attaqués par l'agrile à deux lignes du châtaignier (TLCB) et montraient des signes de déclin ou mouraient. Quelques chênes avec de très fortes réserves en amidon étaient aussi colonisés avec succès, mais ces arbres ne montraient pas de signes de déclin et ne mouraient pas. Par conséquent, les réserves hivernales en amidon sont un bon prédiseur de l'attaque par l'agrile à deux lignes du châtaignier (TLCB). De plus amples recherches sont nécessaire pour déterminer si cette relation est valable pour d'autres espèces à bois durs et leur perceur respectif. L'utilisation des niveaux d'amidon racinaire pour établir la susceptibilité de l'arbre aux perceurs nécessite de plus amples essais en milieu urbain afin de déterminer sa praticabilité pour la gestion des insectes et des maladies.

Plant health is the most important factor in maintaining the resistance of trees and shrubs to bark and wood boring insects. This premise is based upon a large body of observational evidence that links borer activity and damage to periods following severe drought, defoliation, or to other stresses such as soil compaction (8, 10). Unfortunately, there is little experimental evidence directly relating tree stress to borer attack, nor are the mechanisms of why stressed trees are more susceptible to borers well understood (5). By studying basic interactions between tree stress and insect borers, we hope to develop simple methods by which arborists can predict and control pest outbreaks in the urban forest.

During the drought years of the 1980's, the twolined chestnut borer (TLCB), *Agrilus bilineatus,* attacked and killed many oaks, American beech, and European and American hornbeam throughout the Ohio River Valley and lower Great Lakes Region (4, 11, R.A. Haack, personal communication). This beetle is a pest throughout the eastern United States (3, 7, 8). The TLCB belongs to the family Buprestidae, which includes the bronze birch borer and other flatheaded borers. The female beetle lays her eggs in bark crevices in the branches or on the main trunk of stressed, but living, host trees (2, 3, 6). Mating and egg-laying occur during mid-May through mid-June in Kentucky.

The slender, white larvae of *A. bilineatus* are about 1 inch long when fully grown (7). The region behind the head is broadened and flattened, and there are two small spines at the tail end. The borers feed in the living inner bark, cambium and outer sapwood, leaving meandering tunnels that are tightly packed with frass (wood dust and cellulose-rich feces) (3, 7). Larvae can only colonize living inner bark.

Larval tunneling disrupts transport of water and food, causing the leaves to fade, turn brown and hang from the tree. Sudden wilting of foliage in infested parts of the tree may occur from late July through September. Infestations usually begin in the branches but in following years they occur farther down the branches and into the bole (2, 3, 6). Death of infested trees in urban settings usual-

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ly occurs within three to five years (7).

Following periods of widespread drought it has been observed that not all trees are attacked and killed by borers. Apparently, some trees are more resistant or less attractive than others to attacks by borers and disease. One explanation for this variation in susceptibility is that individual trees differ in their vigor *before* the onset of stress, and that further stress renders only the less vigorous trees susceptible to attack (13). Predicting which trees are most likely to be attacked by borers would be useful for arborists and foresters concerned with making pest management decisions.

Starch is the major form of stored food in most hardwood trees. Concentrations can be high in leaves, twigs, and fine roots, but most of the starch is stored in the living cells (parenchyma) of the outer sapwood and innermost bark of the bole and large diameter roots (9). Starch is a complex form of carbohydrate that when broken down to glucose supplies the energy for tree physiological processes, which include growth of the bole, stems, foliage and roots, respiration, and the synthesis of defensive chemicals in the bark and leaves that may protect the tree from attacks by insects or pathogens (5, 15). Starch reserves are particularly important in deciduous trees since this stored energy is needed to maintain tree life over the winter when there are no leaves to manufacture sugars, and most importantly for radial growth and refoliation in the spring (9). Trees with low winter starch reserves may have insufficient energy reserves to resist borer attack in late spring and early summer (5).

Dr. P.M. Wargo (USDA Forest Service) proposed that the levels of stored starch in the root systems of temperate deciduous trees (e.g. oaks and maples) may be a good general measure of tree health (13, 14). By this criterion trees high in stored starch would be considered more vigorous than those low in stored starch. Wargo (13) showed that oaks low in stored root starch were more likely to die in the following years than oaks that were high in stored starch. Tree death was assumed to be caused by the TLCB and/or the shoestring root rot fungus, *Armillaria* species. Results of another study suggested that oaks subjected to three years of mechanical defoliation were killed by *Armillaria* species and the TLCB (13), although beetle attacks and/or fungal infestations of dead trees apparently were not quantified. Others (6) found that oaks infested with TLCB larvae were also low in root starch, but it was unclear if the low starch was the result of borer colonization, or was low prior to colonization.

We tested Wargo's hypothesis that winter root starch reserves of oak are an indicator of tree vigor and that trees low in stored starch over the winter would be attacked by the TLCB the following summer. Detailed results of this research have been reported elsewhere (4, 5). This work was supported in part by a grant from the International Society of Arboriculture Research Trust.

More than 500 co-dominant white oaks, about 50 years old, with healthy crowns showing no signs or symptoms of previous borer attack (e.g. emergence holes or declining upper branches) were sampled for winter root starch in January and February in two successive years. This area had experienced below average precipitation in 5 of the 6 years preceding the study (11). We used methods developed and described by Wargo (12), except that wood samples were collected from two roots per tree. Due to the large number of trees sampled and to the destructive nature of root and bole wood sampling, the work was carried out at the University of Kentucky's Robinson Experimental Forest, Quicksand, Kentucky.

In our 1986 studies, about 10 times as many adult TLCB were attracted to the low starch trees as compared to trees high in stored root starch. Furthermore, trees that were low in stored starch that we additionally stressed by bark wounding attracted 3.7 times as many beetles as did non-wounded trees that were low in starch (although non-wounded, low starch trees were also attacked). Heavy attacks occurred only on oaks that were extremely low in winter root starch reserves, and these trees were the only ones that showed symptoms of decline (e.g., dieback, dead foliage) or that died. In 1987, we obtained similar results, i.e., beetles were significantly attracted to the low starch trees. However, about 10% of white oaks that were high in stored starch were also successfully colonized by the TLCB. This indicates that under some circumstances borers may also successfully attack high starch trees. The summer of 1987 was extremely hot and dry during the time that TLCB eggs were being laid; we suspect that these extremes in environment may have restricted the utilization of available sugars for tree defense even in some high starch trees.

These results indicate that winter starch reserves are generally a good predictor of TLCB attack. Maintaining tree vigor through cultural practices such as watering, fertilizing, or vertical mulching may alleviate borer problems. Moreover, concentrating control tactics on "high-risk" trees (i.e., those low in stored starch but without signs of decline) may be a viable pest management approach. Relative levels of starch reserves can be easily measured by cutting thin sections of root tissue with a razor blade or an inexpensive microtome and staining them with potassium iodine as described by Wargo (7, 8). It is important to realize, however, that once a tree is showing symptoms of borer attack it may be too late to save it from continued borer colonization and death.

Additional research in urban settings is needed to see if this relationship holds with other hardwood trees (e.g., birch, honeylocust) and their respective flatheaded borers. Starch measurement by the iodine staining technique may be difficult to interpret for some hardwood species such as honeylocust that do not have large ray cells in which most of the starch is stored. Also, some trees such as pines and basswood store both fats and starch, and the iodine would not stain the stored fats (9). Deciduous trees normally store high amounts of starch in the winter, so that under favorable conditions one would not expect to find many low starch trees. Our studies were carried out under extremes of drought on a dry, southwest-facing slope. Nevertheless, the 517 mature white oaks without signs or symptoms of previous borer attack that were sampled, only 46 trees were low in stored starch at the onset of the experiment. This suggests that white oaks are very resistant to drought, since low starch trees were uncommon even after 5 to 6 years of below average precipitation. Trees in the urban landscape are often under constant stress, so that low starch trees may be more common there than in the forest (1).

Targeting low starch trees in urban situations during normal environmental conditions may be impractical due to the time required to sample roots. Use of a standard forestry increment hammer to collect samples of lower bole wood for starch staining would be a more practical means of sampling trees. However, starch content of bole sapwood may be much more variable than rootwood due to the conversion of starch to free sugars, which cannot be measured by iodine staining, so the utility of this approach needs to be tested. Wargo (14) has explored the use of an increment borer as a more efficient way to sample root wood for starch analysis.

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EUONYMUS SCALE PATTERNS OF DAMAGE TO WOODY PLANTS[1]

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Abstract. Armored scale insects include species which feed primarily on stems and those which feed on both leaves and stems. The euonymus scale is an example of the latter. Scales which feed on leaves produce a chlorotic halo that is deficient in chloroplasts. Infested leaves have impaired photosynthesis and are prone to abscission. Healthy plants may tolerate and outgrow injury from scale insects, but infested plants that experience additional environmental stress may suffer severe leaf abscission and branch dieback. Early detection of infestations and management to minimize plant stress are helpful in maintaining woody landscape plants that are susceptible to scale insect infestations.

Les cochenilles incluent des espèces qui s'alimentent principalement sur les tiges et d'autres qui s'alimentent à la fois sur les feuilles et les tiges. La cochenille du fusian est un exemple du dernier groupe. Les cochenilles qui s'alimentent sur les feuilles produisent une chlorose auréolée qui est déficiente en chloroplastes. Les feuilles infestées ont une photosynthèse réduite et sont encleintes à l'abscission. Les plantes en bon état de santé peuvent tolérer et surmonter les dommages causés par les cochenilles, mais les plantes infestées qui subissent des stress environnementaux additionnels peuvent souffrir de sévères chutes de feuilles et de dépérissement sur les branches. Une détection précoce des infestations et une gestion qui minimise les stress sur la plante sont utiles pour le maintien de plantes ligneuses ornementales qui sont susceptibles aux infestations de cochenilles.

Armored scales are tiny insects that are highly specialized to feed on the sap of woody plants. They live most of their lives under a shell of wax, snugly attached to the bark of twigs or branches, or to the leaves of their hosts. As a group, they include some of the most pernicious and difficult to control pests of woody landscape plants (1, 9).

Species of armored scale insects can be divided into two groups: those which feed on both leaf and stem tissue, and those which feed primarily on stems and rarely settle on leaves. The euonymus scale, *Unaspis euonymi*, feeds on both leaves and stems of *Euonymus* spp. and a few other landscape plants. Other armored scales with similar feeding habits include the California red

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