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THE RELATIONSHIP BETWEEN BRONZE BIRCH BORER AND BIRCH DIEBACK¹

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Abstract. European white birch (*Betula pendula*) was the species most affected by birch dieback. Grey birch (*B. populifolia*) was occasionally affected. Paper birches (*B. papyrifera*) showing symptoms of decline and dieback were rare. European white birches in good health rarely contained larvae of the bronze birch borer, *Agrilus anxius*. Trees in early stages of decline sustained borer larvae evenly distributed throughout the bole and main stem with lower numbers in the branches near the junction with the main stem. Trees exhibiting dieback symptoms contained high populations of borer larvae evenly distributed throughout the living cambium in the bole, main stem and live branches near the junction with the main stem. adult bronze birch borer beetles emerged only from areas where the cambium had died during the winter and early spring. Emergence did not occur from healthy trees or trees displaying early decline symptoms. Trees died back from branches in the crown; thus, adult beetles emerged in low numbers from branches of trees exhibiting dieback. The largest concentrations of adult beetles emerged from the boles and main stems of trees exhibiting advanced dieback symptoms.

A recent survey of a mid-western city disclosed that one out of every three lawns contained a European white birch *Betula pendula* Roth (Dirr 1975). Another survey of a small Michigan community noted that one out of three European white birches exhibited birch dieback (Ball, 1979). Bronze birch borer, *Agrilus anxius* Gory, is often considered the cause of birch dieback; the gradual decline commencing at the tops of the crown, progressing with dieback of all limbs, and ending in the death of the tree. Due to the threat posed by the bronze birch borer, effective methods of borer control are needed. Current recommendations and control practices, however, may be based on incorrect assumptions about how and when borers attack birch trees.

Reliance on these techniques may give the arborist a false sense of security about the problem and yet do little to actually reduce or manage bronze birch borer numbers.

History of birch dieback. Bronze birch borer was first recognized as an urban pest in the late 1890's. At that time the insect was associated with crown dieback and death of European white birches in Buffalo, New York (Chittenden 1898, Chamberlain 1900). Chittenden identified some of the beetles as *Agrilus anxius*. Since a common name had not yet been provided he named it the bronze birch borer in reference to the color of the adult insect and the tree species it fed on. He mentioned that the insect attacked the top of the tree first.

Larsen (1902), working in southeastern Michigan, noted that European white birch was usually attacked at the top, where limbs were only ¾ to 1½ in. (3 to 6 cm) diameter. Only on badly infested trees were galleries found at the base of the bole. Slingerland (1906) also agrees that infestations began at the top but added that pruning out dead limbs may not be advisable as the entire tree may already be infested. He mentioned that there were no published reports of birch dieback in forests or woodlands.

Swaine (1918) was the first to report bronze birch borer as a forest pest. He observed paper and yellow birch dying in the Ottawa River watershed. Pierson (1927) also reported the borer as a forest problem. He stated that the top of the tree

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was first attacked, with the infestation proceeding downward in later years. Trees usually died in three or four years after the first symptoms of dieback were noticed.

The concern over bronze birch borer and birch dieback was mainly confined to the forests of northeastern North America for the next two decades. During the 1930's and 1940's massive amounts of paper and yellow birch showed symptoms of dieback and subsequent mortality. The populations subsided during the 1950's. Researchers concluded that trees in the early stages of dieback were free of borer and bronze birch borer was not the primary cause of birch dieback (Spaulding and MacAloney 1931, Balch and Prebble 1940, Pomerleau 1944, Hawboldt and Skolko 1948). Abnormally high temperatures and low rainfall during the 1930's and 1940's apparently caused the initial decline with extensive dieback beginning after borer colonization (Hawboldt 1947, Barter 1957).

Present control practices. It is generally recommended that homeowners with declining birch trees should water, fertilize, and control other pest problems such as leaf miner (*Fenusa pusilla*) (Westcott 1973). Other suggestions include pruning limbs a foot or two below the last emergence hole or dead wood (Nielsen 1979). The impression we have received from reading articles and talking with arborists is that borers begin to attack at the top of the tree. As the tree dies back borers gradually attack lower and lower sections of the tree. This idea may have resulted from observing that adults *emerge* from the top of the tree in the initial stages of dieback and then proceed to emerge from lower levels until the tree is dead. We believe however, that borer *attack* begins throughout the main stem of the tree.

Presently chemical control is limited to reducing the adult borer population. Properly timed sprays should be applied to bark and foliage. Lindane is currently recommended (Kennedy et al. 1979).

The concept of decline and dieback. There is a great deal of misunderstanding on the role the borer plays in dieback. Does the borer attack first or does the tree die back first? We interpret the symptomatology of birch dieback as similar to that studied by Houston (1973). The tree is stressed

which causes an initial decline. Once the stress is removed the tree can improve. However, continual stress will result in physiological changes within the tree. These changes may make the tree a more suitable host for the borer. Once borer attack begins dieback occurs. Repeated borer colonization and further dieback continues until the tree dies.

METHODS

The purpose of our research was threefold: 1) to describe changes in birch tree vigor by species, 2) to determine where borer larvae are distributed within European white birch trees depending upon degree of decline or dieback, and 3) to determine if adult emergence from the lower bole is dependent upon the degree of dieback. A system of classifying trees according to health and vigor was used to place trees into different categories based on the extent of dieback (Figure 1). This classification was applied to individual stems, rather than clumps as birch dieback can affect one stem at a time until the entire clump is dead. Stems were divided into 5 classes. Class 1 stems were healthy with the crown composed of green foliage. Class 5 stems were in the poorest condition, and exhibited the greatest amount of dieback with less than one-half of the crown living.

To determine the extent of dieback and changes in tree condition, surveys of birches were made through three subdivisions in Okemos, Michigan, a Lansing suburb. The initial survey was conducted in August of 1977 with a follow-up in August of 1978 to observe changes in tree vigor. Three species of birches were included in the surveys. The species surveyed were European white birch, grey birch (*B. populifolia* Marshall) and paper birch (*B. papyrifera* Marshall). The address of the home at which the tree was located was recorded to aid in locating the same tree from one year to the next. Tree diameter at 1.37 m height was recorded so individual stems in a clump could be separated.

Between August 18 and September 16, 1978, 28 trees were cut down to examine the bole and branches for larvae of the bronze birch borer. At least 4 trees were selected from each vigor class.

Ten cm strips of bark were removed completely around the bole every 50 cm. The first strip was made at ground level with subsequent strips removed every 50 cm up the tree until the top of the tree was reached. Branches were sampled in a similar manner beginning at the junction with the main stem. This allowed approximately 20 percent of the total inner bark area to be examined.

In the spring of 1979, 20 trees were selected for a study concerned with adult bronze birch borer emergence, to examine differences between vigor classes in the number of adult borers emerging from an area above the base of the bole.

RESULTS AND DISCUSSION

Vigor class changes. Of the three common species of white-barked birches, European white birch exhibited the widest range of dieback symptoms (Figure 2). Only a few grey birches were found below class 2, while practically no paper birch exhibited dieback symptoms or any other sign of bronze birch borer attack. Over half of the European white birch stems changed vigor class in one year (Table 1). Almost half of this change was from class 2 to 1 — the trees improved in ap-

pearance. Only a few class 2 trees declined to class 3.

Class 3 stems did not show any improvement. Forty-five percent of the class 3 European white birch were still class 3 stems one year later; 31 percent declined to class 4 and the remaining stems declined to class 5. Class 4 exhibited the highest percentage of trees declining to a lower class.

The most apparent fact which came out of the class change study was that stems can improve from class 2 to class 1. The only visible difference between these two classes is scattered patches of flagging. This may be due to minor water deficiency, a condition that can be corrected with adequate watering. However, once a stem has reached class 3, further decline appears to be inevitable.

This continual decline may take several years. Barter (1953) showed it took from one to nine

Table 1. Class change of European white birch from 1977 to 1978. Data taken from two neighborhoods in Okemos, Michigan (n = number of trees).

Vigor class (1977)	(n)	vigor class (1978)					dead	re- moved
		1	2	3	4	5		
1	(27)	25	2					
2	(44)	25	10	5	3	1		
3	(16)			7	5	4		
4	(9)				1	4	3	
5	(4)					2	1	

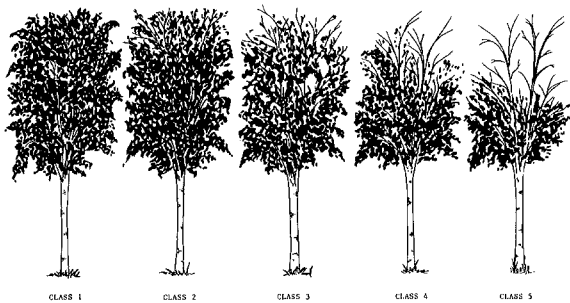


Figure 1. European white birch crown vigor classification.
Class 1 — A healthy, vigorous tree. The crown full and consisting of normal size, green foliage.
Class 2 — Scattered patches of flagging throughout the top of the crown. Dieback of several twigs.
Class 3 — Twig and small branch dieback.
Class 4 — Dieback of at least 3 branches in 1 m in length, however, not more than one-half of the crown bare.
Class 5 — More than one-half of the crown devoid of foliage, but crown must still contain at least several branches with foliage.

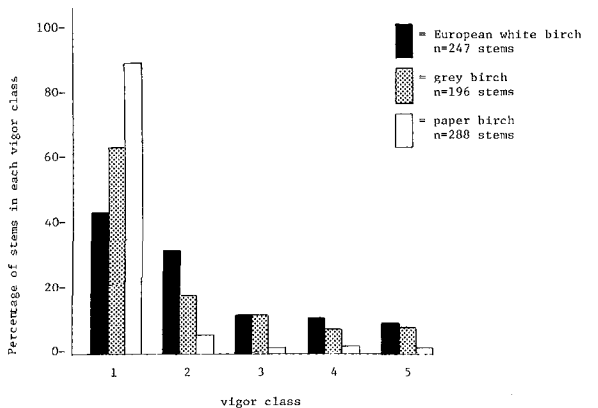


Figure 2. Percentage of birch stems in each vigor class. Data taken in 1978 from three subdivisions in Okemos, Michigan.

years for a paper birch to decline from a healthy to a dead state. He also noted dieback progressed slower in the beginning than towards the end. His interpretation can probably be applied to our data on European white birch from this study, although it will take a few more years of class change studies to develop a more precise prediction capability.

Larval distribution. Class 1 and 2 trees had only a few bronze birch borer larvae (Table 2), and these were only in the bole. The situation with class 3 trees was quite different. Each tree sampled had larvae throughout the bole and branches, though there were fewer larvae in the branches than in the bole. The majority of the larvae in the branches were near the junction with the main stem. The large larval population density of class 3 trees compared to the first two classes indicates that class 3 trees are much more susceptible to bronze birch borer attack. Larval density is still lower in the branches as compared to the bole.

Table 2. Comparison of average number of *Agrilus anxius* larvae per 100 cm² (\pm SE) of inner bark between European white birch bole and branches for each vigor class (n = number of 10 cm wide sample strips).

vigor class	average number of larvae			
	bole	n	branches	n
1	0.5 \pm 0.02	67	0.00 \pm 0.00	179
2	0.05 \pm 0.02	61	0.00 \pm 0.00	184
3	0.74 \pm 0.09	69	0.45 \pm 0.08	165
4	0.9 \pm 0.19	35	0.30 \pm 0.09	85
5	1.05 \pm 0.33	22	0.17 \pm 0.08	40

In addition to branches in the upper crown being dead, class 4 trees had small pockets of dead inner bark throughout the bole. The dead areas did not show outwardly as the boles appeared healthy. Class 4 trees had higher larval populations than class 3 trees. Little of the living inner bark on the bole remained uninfested. There were fewer larvae in the crown of class 4 trees than in class 3 trees.

Class 5 trees exhibited large pockets of dead inner bark. Since larvae cannot survive in dead inner bark (Balch and Prebble 1940), the area they can live and feed in is substantially reduced compared to other vigor classes. Though the total area

the larvae can feed in was reduced, class 5 boles had the highest larval density. Larval density in the remaining live portions of the crown, however, was less than that found in class 3 and class 4 crowns.

Class 5 was the last stage before death. The majority of branches were dead and the remainder in a state of low vigor. The larvae were concentrated in the few sections of inner bark that remained alive.

Adult emergence holes distribution. A difference in the number of emergence holes in the one meter strip 50 cm from the base of the bole was noted between class 5 trees and trees of the remaining four classes (Table 3). One hundred sixty-five new emergence holes were counted on the bark area of class 5 trees; only two were noted on the class 4 trees. No emergence holes were found on the lower bole of class 1, 2 or 3 trees.

Table 3. Average number of *Agrilus anxius* emergence holes per 100 cm² (\pm SE). Data taken between 0.5 and 1.5 m in European white birch boles (n = number of trees).

vigor class	emergence holes/ 100 cm ²	n	bark area examined (cm ²)
1	0.00 \pm 0.00	6	24,239
2	0.00 \pm 0.00	6	29,463
3	0.00 \pm 0.00	6	27,154
4	0.00 \pm 0.00	6	31,450
5	0.06 \pm 0.14	6	30,160

No emergence holes would be expected on a class 1 or 2 tree since few larvae were present in the bole. However, for class 3 and 4 trees large numbers of larvae were located throughout the lower bole. It was assumed that adult borers should be emerging from this general area, but this was not the case. Only the boles of class 5 trees near death exhibited large numbers of emerging adult bronze birch borers. Balch (1946) stated that larvae need living inner bark to feed on, but adults can only emerge from dead wood. Such optimum conditions were provided by class 5 trees.

While small numbers of adults emerged from the crowns of class 3, 4 and 5 trees, only class 5 trees exhibited significant emergence from the lower portion of the bole. A few adults emerged from the necrotic spots along the boles of class 4

trees. Since class 5 trees sustained the highest larval densities and also allowed adult emergence from the main bole, they likely provided the greatest source of adult beetles in the spring.

Progression of borer attack. Trees begin in class 1 or 2, moving between the two classes as environmental stresses dictate. The trees may be lightly attacked by the bronze birch borer, with the first successful larval penetration beginning in the main stem rather than in the branches of the crown. Larvae are unable to develop into adults due to the vigor of the tree. At some point, physiological changes occur within the birch tree. These changes may be induced by environmental stresses or possibly by repeated unsuccessful though damaging attacks from the borer. At this time dieback begins in the upper crown and the tree enters class 3. A class 3 tree contains larvae throughout the bole and into the branches of the crown. The larvae are not significantly concentrated at any particular height within the main stem. Larvae in the branches are equally distributed with respect to height. The following spring adult borers emerge from inner bark which has died over the winter. Since the tree is dying back from the extremities the majority of freshly killed phloem is in the branches of the upper crown, hence this is the area of adult borer emergence.

Within several years the progression of girdles from galleries results in additional dieback of the branches in the crown. The tree now enters class 4. As living cambium and phloem in the crown decreases, the number of larvae in the branches also decreases. Within the bole the number of larvae increases, further stressing the tree through additional girdling. Internally, the inner bark of the upper third of the main stem is dead. The remainder of the bole contains small areas of dead inner bark. This increase in recently dead phloem increases the potential for adult borer emergence. Though adult emergence is still concentrated in portions of the crown, an occasional emergence will occur from the necrotic tissue in the bole.

Finally, the tree has less than half of a living crown. The upper half of the main stem is dead with the basal portion containing many areas of dead cambium. These areas range from large

spots several centimeters in diameter to bands ten cm or more wide. The larval population continues to decrease in the branches of the crown while increasing in the lower bole. Due to the large amount of bole cambium which dies during the winter, adult beetle emergence peaks. Within a year or two the tree is completely dead.

Area management. Based on our research results, we recommend the development of a prevention program centered around *minimizing* the number of adult beetles available to lay eggs on any birch tree. Our premise is that even though adult beetles cannot emerge from living portions of trees, their larvae can still develop creating stress response within healthy trees. If we minimize the number of adults laying eggs over a manageable geographic area such as a subdivision, golf course, city park, etc., then we can effectively minimize bronze birch borer as a stress-causing agent from the locality.

To institute such a plan will first require an inventory and classification of all birch trees within the management area. This should be done in mid summer after trees have become fully leafed.

Next, remove all class 5 trees during late fall, later winter or early spring as is convenient with work plans and manpower availability. Additionally, all branches on class 4 and class 3 trees displaying dieback should be pruned below the dead wood in late fall. While springtime is the traditional time for pruning, we are concerned that the fresh wounds might attract borers to the trees. Both trees and branches removed in this manner will contain larvae that can pupate and emerge as adult beetles. For this reason, all material should be incinerated, chipped, or removed from the area so that the potential source of beetles is withdrawn from the area.

Next, every effort should be extended to keep the remaining trees healthy. Mulching, fertilizing, watering and attention to defoliating insects is of paramount importance. Continued care of this nature, year after year, will assure a minimum impact by the bronze birch borer and a maximum enjoyment of white-barked birches in ornamental plantings.

Individual tree care. Even though we present area management as a method of reducing the in-

vidence of bronze birch borer, we realize that not all situations can be practically handled through area management. In your work as an arborist you may be required to provide tree care for trees with surroundings that are not under your control. For these situations we make the following suggestions: We again recommend that all class 5 trees be removed, whether they occur singly or in a clump with more vigorous trees. This practice may also be extended to class 4 trees. However, the usefulness of this practice in reducing the local adult borer population is influenced by the condition of neighboring birch trees. If a lawn is adjacent to class 5 trees, the overall adult borer population will not be greatly decreased.

In addition, we recommend pruning branches to below the dead wood or last emergence hole. Pruning should be limited to class 3 and lightly damaged class 4 trees. The wood from the pruning should not be stored near the trees as the borers are still capable of emerging from it. However, since the wood is dead it will not be reinfested.

Trees in this condition would not be aesthetically altered by pruning. The tree would still be pleasing to the eye and recovery is likely. However, cultural controls should extend beyond pruning. Class 3 and 4 trees are still susceptible to borer colonization from other sources. To reduce the susceptibility of these trees improve their vigor by proper watering and fertilizing. Properly timed pesticide sprays to control adult bronze birch borers may also be included in the recovery program.

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