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Balsam Woolly Adelgid

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The balsam woolly adelgid, *Adelges piceae* (Ratzeburg), is a tiny sucking insect that was introduced into North America from Europe. It probably first entered the Northeastern United States and Southeastern Canada around 1900. Later, it appeared on the West Coast (1929), and in the Southeastern United States in the mid 1950's. Infested nursery stock is the presumed source of introduction.

In Europe, host trees are relatively insensitive to attack and the insect is not considered a significant forest pest. In North America, however, it has caused significant damage and mortality to true firs (*Abies* spp.) in both eastern and western forests. In some localities, firs are slowly being eliminated from the ecosystem; and adelgid populations continue to spread to previously uninfested areas.

Hosts and Distribution

True firs are the only known hosts of the balsam woolly adelgid. Susceptibility ranges from highly sensitive to resistant, with North American species being the most sensitive to attack. European firs, especially European silver fir (*Abies alba* Miller), support large adelgid populations and yet remain relatively unharmed. Asian firs seem intermediate in sensitivity; some are damaged and some are not.

Figs. 1a and 1b. Gouting caused by the balsam woolly adelgid.

In North America, infestations occur on balsam fir (*Abies balsamea* (L.) Mill.) in the northeastern United States and the Maritime Provinces of Canada; and bracted balsam fir (*A. balsamea* var. *phanerolepis* Fernold) and Fraser fir (*A. fraseri* (Pursh) Poir.) in the mountainous regions of Virginia, North Carolina and Tennessee. In the West, it occurs primarily on subalpine fir (*Abies lasiocarpa* (Hook.) Lindl), Pacific silver fir (*A. amabilis* (Dougl.) Forbes) and grand fir (*A. grandis* (Dougl.) Lindl.) in Oregon, Washington, Idaho and British Columbia. Subalpine fir and Pacific silver fir are infested in the mountainous areas and grand fir in the lowland valleys. See the map for the distribution of balsam woolly adelgid in North America (pg. 6 & 7).

Several other North American fir species, such as white fir (*A .concolor* (Gord and Glend.)Lindl.), noble fir (*A. procera* Rehd.) and Shasta fir (*A. magnifica* A. Murr) have shown signs of resistance in natural stands, but have been reported as being attacked by the adelgid in exotic or off-site plantings.

Fig. 2: Crown symptom shows crown decline and "fiddle-shape".

Symptoms

"Gouting" is a symptom of balsam woolly adelgid attack that occurs on North American firs. It appears as stunting of the terminal growth with distinct swellings around the buds and branch nodes (Figures 1a and 1b). The larger swellings occur in the fastest growing parts of the crown, and on trees that have been lightly infested for a long time. Trees with this kind of injury decline slowly, often persisting for years. Growth is retarded and tree crowns often take on a "fiddle-shaped" appearance (Figure 2) or experience "top curl" (Figure 3). The dead, or dying, upper stem is often invaded by wood-destroying fungi.

Another, more serious, type of attack is

Fig. 3: Crown symptom showing "top curl".

the mass infestation along the main bole (Figure 4). Populations frequently reach densities of 100 to 200 adelgids per square inch of bark surface. Symptoms of decline vary somewhat with the tree species infested, but generally the foliage in a dying tree turns yellow, then deep red or brown. This sequence is particularly characteristic of infested balsam, Fraser, and subalpine fir.

The habits of the insect and the response of the infested trees also appear to vary by region. In the West, stem-infested grand and Pacific silver firs generally have needle loss, followed by a change in color to a grayish-green and, ultimately, death. These trees often die quickly, sometimes after only 2 or 3 years of heavy infestation. Symptoms of gouting are seldom conspicuous in conjunction with stem infestations because of the trees' weakened condition and the short period of infestation before tree death. In the Northeast, both gouting and stem attacks can be seen on the same tree, and trees with stem attacks can often survive for a decade or more.

All sizes of trees are attacked, although trees that are pole-sized or larger seem most susceptible. In the West, stem infections are most abundant on the best sites, and crown attacks occur more often on poorer sites. In the Maritime Provinces of Canada, it appears that stem infestations are more abundant in the inland areas and crown attacks occur more often on the coastal areas. In New England, there does not appear to be a geographic pattern to the occurrence of the gout phase or the stem infestation. Bracted firs generally have gout infestations and Fraser fir has primarily sustained stem attacks.

Fig. 4: Heavy stem infestion of balsam woolly adelgid along the stem of sub-alpine fir.

Effect on Host Trees

Stem and twig injury is a result of the insect feeding on the host. The adelgid injects a substance into the bark that apparently affects the hormonal reaction of the tree and causes abnormal cell division and differentiation in the bark and newly formed wood. Giant parenchyma cells develop in the bark, and the cambium is stimulated to produce an abnormal number of phloem and ray cells. At the same time, an abnormally wide annual ring composed of cells with unusually thick walls is produced in the woody tissue.

On twigs and branches, the abnormal cells cause a swelling, or gouting, at the nodes. These trees may live for many years, but growth is curtailed. Slowly, old needles drop and are not replaced by new ones. Cone and seed production is considerably reduced.

Fig. 5: Compression-like wood in irregular outer rings caused by the trees reaction to feeding by the balsam woolly adelgid.

Reddish, irregular growth rings, similar to compression wood, referred to as "rotholz" in the literature, occur in the stems of the trees that have heavy bole attacks (Figure 5). This disrupts water conduction to the crown and often results in tree death within 2-3 years after the attack.

Fig. 6: Ventral view of balsam woolly adelgid.

Life History and Behavior

Balsam woolly adelgid populations in North America are composed entirely of females; as a result, reproduction is parthenogenetic (i.e. without mating and fertilization). Adults are tiny (about 1mm. long) dark purple to black, nearly spherical and wingless (Figure 6). They produce a thick mass of a waxy wool-like material that covers the body and protects the adult and her eggs (Figure 7). Some 100 - 250 amber colored eggs are laid under this wool-like coat. An amber colored crawler hatches from the egg. The newly hatched crawler is the only stage capable of directed movement or dispersal. Long range spread is accomplished mainly by wind, although contact with birds and other animals may also contribute to natural dispersion. The crawler disperses and seeks a feeding site – most often bark lenticels and other roughened areas of the main stem, around branch and twig nodes, and the base of buds in the crown. It inserts its mouthparts into the bark and transforms, without molting into a flattened wax-fringed resting stage known as neosistens. In the mountains, the neosistens is the only stage that will survive winter temperatures. Two immature forms closely resembling

the adult follow the neosistens. These two forms, plus the adult are called the sistentes.

A rare stage, known as the progrediens has been observed in Europe and the Maritime Provinces of Canada. In one form, it is wingless and in another, winged. The wingless form is very similar to the sistentes. The winged form has membranous wings, five-segmented antennae, and generally lack wax pores.

Fig. 7: Balsam woolly adelgid eggs and crawler. Wool pushed aside for photographic purposes.

The balsam woolly adelgid has 2 to 4 generations per year, depending on locality and elevation. Two generations are most common in mountainous areas of the West and throughout New England and the Maritime Provinces of the East. Spring development begins in late April or early May; by the end of June, most are in the adult stage. This is followed by an egg-laying period of about 6 weeks. In warm weather, eggs hatch within a few days, and the crawlers settle on the bark and transform into the resting, neosistens stage, which lasts from 2 to 8 weeks. Adults of the second generation become abundant in late September and early October, and egg laying continues until about mid- November.

In some areas where temperatures are warmer and there are extended warm seasons, additional generations can occur. A partial third generation usually develops in North Carolina, and three generations with a partial fourth occur in the lowland areas of Oregon and Washington.

Likewise, the extended months of colder winter temperatures and the shortened season of warmer temperatures that characterize some of the higher elevations, especially in the northern latitudes, can either result in fewer generations per year, or possibly limit the distribution of the adelgid entirely.

Effects and Impacts

In initial, intense infestations, when the adelgid first colonizes a stand, it encounters a reservoir of susceptible trees that has accumulated over many years. Since all adelgids are females, all individuals have the ability to reproduce, and population

increases are exponential. These factors result in considerable spectacular tree mortality for several years (Figures 8a, 8b, and 8c), and are characterized by stem attacks. After the initial wave of tree mortality, the effects of the adelgid become rather unspectacular because host is limited, populations fluctuate, it takes time for new trees to grow into a susceptible state, and environmental factors exert an influence on lower populations. It appears that once the adelgid colonizes a stand, it is there

Extensive tree mortality from balsam woolly adelgid following initial infestation.

Fig. 8a: Individual tree mortality and fading trees.

Fig. 8b: Extensive tree mortality.

Fig. 8c: Older mortality with scattered dying trees.

permanently, and mortality continues on individual trees many years after the initial infestation.

In areas where site, host, and environmental factors are not conducive to large population increases, chronic low-level infestations occur. These are more often characterized by gouting. New growth is halted in the crown, and cone and seed production is curtailed. These infestations can kill trees over time and decline is usually evidenced through varying degrees of top kill, poor crowns, and reduced reproduction (Figure 9). Trees that are weakened and have a poor live-crown ratio are more susceptible to the effects and impacts of other insects and disease agents. For example, moderate defoliation from western spruce budworm may result in significantly more mortality in stands infested by balsam woolly adelgid, than would be expected to occur in an uninfested stand.

Although it is unlikely that the balsam woolly adelgid will eliminate its hosts entirely, it does present some local ecological problems. In harsh or disturbed environments, such as old lava flows, avalanche tracks and marshy meadows, subalpine fir acts as a pioneer species. By killing trees and inhibiting cone production, the balsam woolly adelgid has removed the subalpine fir from some of these local areas. In the lower Willamette Valley in Oregon, and the Puget Sound Trough in Washington State, long-time infestations in the bark cracks and along branches of large old grand firs, have gradually destroyed crown characteristics, cone crops are rare, and new reproduction is non-existent. As a result, grand fir is slowly disappearing from these ecosystems. In the East, balsam fir reproduction within infested fir stands is very good. However, much of the regeneration is heavily infested with the gout phase, and the future of that regeneration is uncertain.

Fig. 9: Gradual tree decline evidenced through varying degrees of poor crowns, top kill and eventual mortality.

In areas where host is limited or confined, such as the Fraser fir on scattered mountain- tops in the Appalachians, significant initial mature tree mortality occurred; however, Fraser fir regeneration is extensive (Figures 10a and 10 b). Stand characteristics have been changed, by changing the patterns of age and distribution of the fir. The effect of balsam woolly adelgid on this regeneration as it matures, remains to be seen, and it is possible that successive cycles of regeneration-mortality will result in decreasing numbers of trees over time.

Figs. 10a and 10b: Fraser fir second-growth following extensive mature tree mortality from balsam woolly adelgid on Mt. Mitchell in North Carolina.

Management and Control

Natural Predators and Parasites

No parasites of the balsam woolly adelgid are known, but many predaceous enemies have been observed. Most North American predacious insects or spiders are general feeders and unreliable as control factors. They do not seem to concentrate on adelgid populations or fluctuate with adelgid population levels.

Several species of insect predators have been introduced into North America from other parts of the world, primarily Europe. These include 3 beetles - *Laricobius erichsonii* (Rosenhauer) (Derondontidae); *Pullus impexus* (Mulsant) (Coccinellidae), and *Aphidecta obliterata* (L.) (Coccinellidae); and 3 flies - *Aphidoletes thompsoni* Mohn (Cecidomyiidae), *Cremifania nigrocellulata* (Czerny) (Chamaemyiidae), and *Leucopis obscura* Haliday (Chamaemyiidae). As yet, none of these predators have affected any detectable level of adelgid population control. They appear to feed on stages of the adelgid that are unimportant in determining trends in the adelgid populations. In initial stages of infestation, expanding adelgid populations increase so rapidly, and some tree species are so sensitive to attack, that predators have little chance of affecting any control before irreversible damage has been done.

Environmental and Cultural Management

The populations and effects of the adelgid may be limited on individual trees by the response of the tree itself. Stem-attacked trees that survive more than 1 or 2 years may form patches of a wound layer in bark that is still living, but impermeable to insect attack. Over time the adelgid populations are increasingly restricted to a smaller and smaller area until most adelgids die. Eventually, though, because the tree continues to grow and the protective layer becomes cracked, the tree is subject to re-infestation.

Weather is also an important factor in affecting insect survival, particularly in the northern latitudes and higher elevations. In cold winters, only adelgids below the snowline will survive temperatures of below 30 degrees F. Subalpine firs growing close to timberline may not be as affected as trees at a lower elevation, because during short spring and summer seasons there is rarely enough heat accumulation for the insects to complete a second generation and allow good winter survival (only the resting 1st instar can survive the winter in the mountains).

Stand and host susceptibility also appear to be related to other environmental factors such as elevation, stand age, and site condition. Some hosts such as grand fir are susceptible at low elevations, but rarely attacked at higher elevations. Pacific silver fir and subalpine fir also experience severe infestations at low elevations. At higher elevations subalpine fir experiences heavy infestations, but adjacent Pacific silver fir is rarely attacked. Mature Fraser fir is very susceptible, while younger trees do not appear to be as affected in natural conditions, but can be heavily infested in plantations. Species such as noble and red firs, that are resistant under natural conditions, can be attacked when planted in off-site and ornamental situations.

The combination of host, site, and other environmental factors makes this a difficult insect to manage. For some tree species, reducing stocking and improving site conditions may reduce susceptibility; however, with other species, good site conditions make a species more susceptible to this insect. Hazard/Risk rating systems using site variables such as elevation, soil and site conditions, and stand conditions, developed for each individual tree species, can help identify those instances where a particular species would be most susceptible, and those situations where other species may survive. Where possible, the land manger should select against susceptible or infested individuals and favor more tolerant, or non-host species, either through selection harvest or planting.

In Christmas tree plantations or other high-value situations removing infested trees (if there are only a few individuals) and/or direct control can reduce the impact of the balsam woolly adelgid.

Direct Control

The adelgids are hidden in protective niches of the bark and branches of trees and are individually protected by their wool-like waxy exudation. Applying contact insecticides effectively by aerial spraying over large areas is not possible. However, spraying individual trees from the ground with an approved insecticide has proved effective for control.

Contact insecticides are most effective against the exposed crawler stage and are applied as a bark drench with a hydraulic sprayer in May through June and September through October. Some of the insecticidal soaps and oils can penetrate the waxy coating of the adult adelgids, however, timing of application is important, in order to avoid burning the foliage on the tree. Treatment will reduce populations to below the tree-killing level, and some treated trees may remain generally free from adelgids for several years.

Spraying is warranted only in accessible areas supporting relatively high-value trees. Some systemic insecticides are registered for adelgid control and may be effective on balsam woolly adelgid. Contact local extension agents or forest entomology experts for the currently registered and most effective insecticides.

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