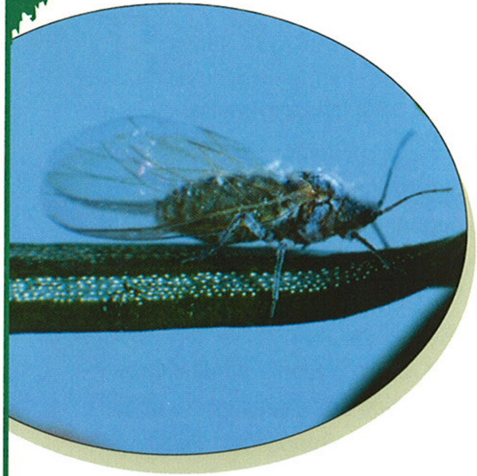
The BALSAM TWIG APHID



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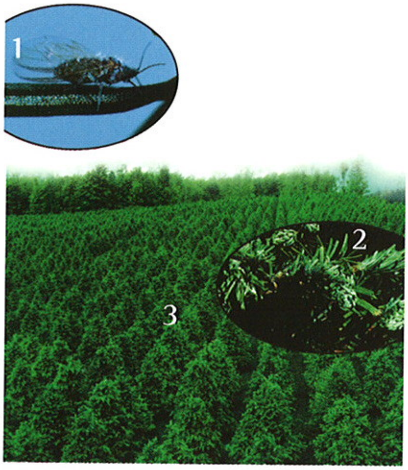

Cover

Photo 1
The balsam twig aphid (*Mindarus abietinus*)
(Photo: *C. Germain*)

Photo 2
Fir shoots infested by colonies of *Mindarus abietinus*
(Photo: *C. Cloutier*)

Photo 3
Christmas tree plantation (Photo: *C. Monnier*)

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Overview

Balsam fir (*Abies balsamea* Mill.) is the basis of an important Canadian industry involving the production of Christmas trees. In Quebec alone, it is estimated that more than 30 million trees are cultivated on a total of 8,000 ha. The balsam twig aphid, *Mindarus abietinus* Koch, is one of the principal pests of fir plantations. This aphid species has a holarctic distribution, extending across Europe and North America. In North America, the insect occurs throughout the range of balsam fir, from the Atlantic to the Pacific Oceans (Varty 1966; Martineau 1985; Rather and Mills 1989).

Like most aphids that use forest tree species as hosts, *M. abietinus* is a minor pest of natural stands, where it causes no mortality or decline in growth and no notable defoliation (Varty 1968; Rose and Lindquist 1994). Balsam twig aphid populations undergo significant but sporadic fluctuations. A few major infestations were recorded in natural stands in New Brunswick and Nova Scotia in 1966 and 1967, and then in Quebec in 1972 and 1978, when the entire region south of the 50th parallel was infested (Martineau 1985). The infestations are usually short-lived (2 or 3 years), although they often affect numerous stands scattered over extensive areas.

In Christmas tree plantations, the balsam twig aphid can cause considerable economic loss by reducing the aesthetic quality of the trees (Renault 1983; Bradbury and Osgood 1986; Kleintjes 1997; Deland et al. 1998). Damage is caused by aphid colonies, which feed on the current year's shoots during their elongation period. This feeding activity leaves distorted needles and stunted shoots on affected balsam fir (Bradbury and Osgood 1986).

Host Plants

Mindarus abietinus is an aphid species with a single-host life cycle. As its scientific name indicates, it attacks mainly conifers of the genus *Abies* (it has been observed on nine species of fir) but it may also feed on certain spruce (*Picea*) and pine (*Pinus*) species (Varty 1966; Bradbury and Osgood 1986; Rather and Mills 1989).

Description of the Different Forms of the Insect

The aphid *Mindarus abietinus* is a member of the order Homoptera, family Aphididae. These aphids undergo incomplete metamorphosis, which means that only minor morphological changes occur between the immature stages of the insect and the adult phase. Hence, except for the presence of wings in some individuals, the adult resembles the nymphs (*Figure 1*). The balsam twig aphid is polymorphic, which means that it occurs in several forms, as described below (*Figure 2*):

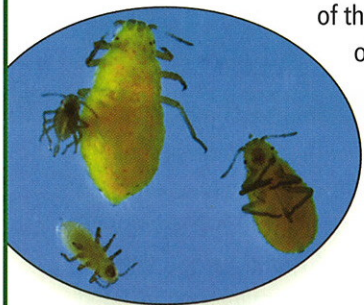

Figure 1

Immature stages of *Mindarus abietinus* fundatrices (Photo: *C. Germain*)

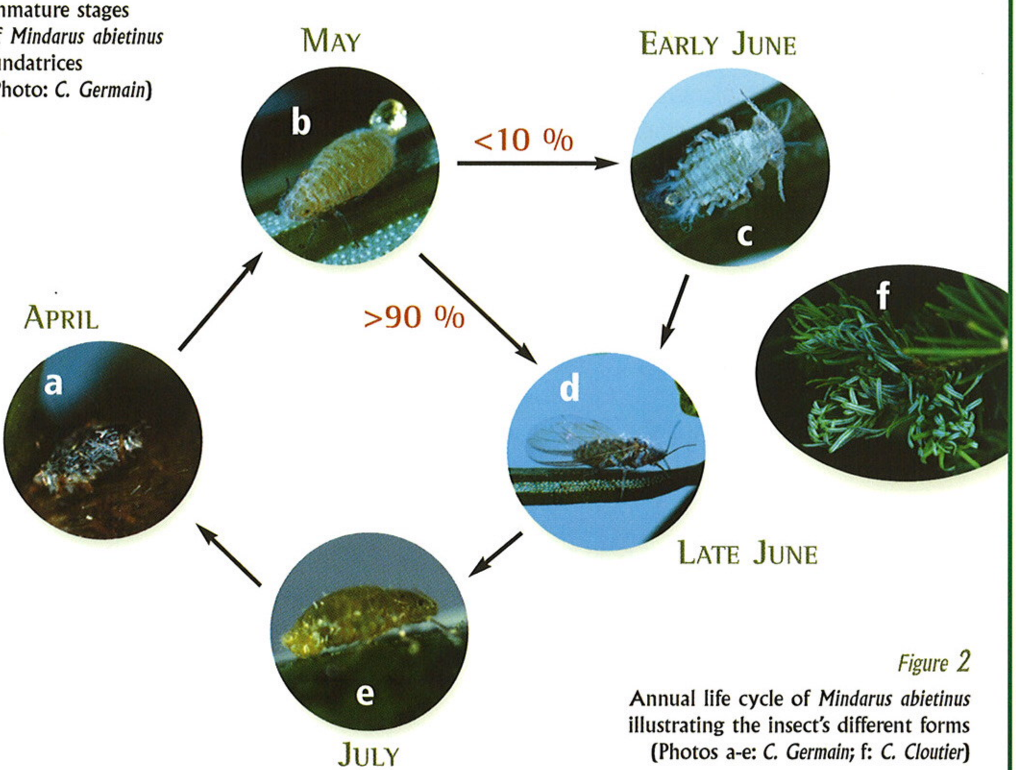

Figure 2

Annual life cycle of *Mindarus abietinus* illustrating the insect's different forms (Photos a-e: *C. Germain*; f: *C. Cloutier*)

a Egg

The oval-shaped egg is about 0.5 mm long. Although yellowish in colour at oviposition, the egg turns black a few days later. The eggs, which are deposited on young shoots, are covered with small white rods of wax that have a silverish tint.

b Fundatrix (stem mother)

This is the first form to appear during the season. Fundatrices are female aphids that go through four immature stages before reaching the wingless adult stage. The adults are 1.2 to 2.0 mm long and range in colour from beige to green. Adult fundatrices can be recognized by their greatly reduced cornicles, which are basically orifices, and by their simple eyes.

c Apterous viviparae (fondatrigenia)

Like fundatrices, aphids of this form are female; they, too, go through four immature stages before reaching the apterous adult phase. These adults are slightly larger (1.5 to 2.8 mm) than the fundatrices, but their colouring is similar. They can be distinguished from the latter by their compound and better developed eyes and by the presence of cornicles.

d Winged viviparae (sexuparae)

Winged viviparae are female only and resemble apterous viviparae in terms of the number of instars they go through and their colouring and size. However, the adult stage of this form has wings with reduced venation, and the third and fourth instars have wing pads, a feature that can be used to differentiate them from apterous viviparae.

e Sexuales

Sexuales are the last generation of the season out of a total of three or four. This is the first form comprising males; the males are smaller than the females and go through one less instar (three versus four for females). Sexuales have the same colouring as the preceding forms, but they are wingless and much smaller (about 1 mm).

Life Cycle and Behaviour

The balsam twig aphid has a life cycle comprising three to four generations (multivoltine cycle) occurring between April and July (*Figure 2*) (Varty 1966; Bradbury and Osgood 1986). On balsam fir, the cycle begins before budbreak and ends at an advanced stage of shoot growth. Temperature and hence climatic conditions play a key role in determining how fast the aphids develop and move through their life cycle (Varty 1968). In southern Quebec, the eggs generally hatch between mid-April and mid-May (Deland et al. 1998). Young fundatrices (nymphs), which represent the first generation, begin feeding on the needles from the previous year before migrating to the newly opened buds (*Figure 3*), and then feed on new foliage to complete their development (Varty 1968; Stary 1975; Rather and Mills 1989). When these aphids reach the adult stage, parthenogenetic reproduction (not requiring mating with males) begins; each fundatrix produces 40 to 60 nymphs of the second generation, the winged or apterous viviparae (Varty 1966, 1968).

Figure 3

Adult fundatrix inside a newly opened bud (Photo: *C. Germain*)

The fundatrix and her progeny form a rapidly expanding colony (*Figure 4*) which feeds on young growing shoots, causing the distinctive damage that is characteristic of this pest's presence (Nettleton and Hain 1982; Renault 1983; Rather and Mills 1989). The affected shoots, or pseudogalls, provide shelter for the aphid colony. Most of the viviparous offspring of the fundatrix develop into winged viviparous individuals (about 90%), enabling the pest to disperse by air (Varty 1966, 1968; Rather and Mills 1989). Upon completing the fourth instar, the viviparous nymphs (with wing pads) leave the colony, climbing on pseudogalls or higher up on the shoots as they continue their development to the adult winged stage. Dispersal of these individuals may occur locally, from tree to tree within a given plantation, or reach more distant hosts in other plantations or in natural stands (Deland et al. 1998).

Figure 4

Shoot infested by a colony of *Mindarus abietinus* and honeydew secretion (Photo: *C. Germain*)

Apterous viviparae reproduce but do not disperse. Their progeny is composed exclusively of winged viviparae, which increase both the duration and extent of the balsam twig aphid's dispersal and the production of sexuales (Varty 1966, 1968; Deland et al. 1998). The winged viviparous individuals fly to other trees and give birth to the last generation, the sexuales (third or fourth generation as the case may be) (*Figure 5*). Their male and female progeny, which are roughly equal in number, are wingless (Varty 1966). Following mating, the female sexuale lays one or two eggs; these are usually deposited on new shoots at the base of needles or on buds (Varty 1966; Nettleton and Hain 1982; Deland et al. 1998). The balsam twig aphid then overwinters as an egg.

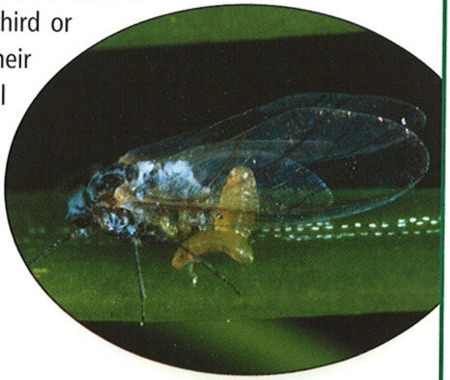

Figure 5

Winged viviparous individual giving birth to sexuales (Photo: *C. Germain*)

Damage

The fundatrices (first generation), which initially feed on needles of the previous year's shoots, and the sexuales (last generation) which do little or no feeding, do not cause noticeable damage (Varty 1966; Renault 1983). The aesthetic damage that can be seen on new growth is caused by the aphid colonies (fundatrix and its apterous and winged viviparous progeny), which feed on the elongating shoots (Varty 1966; Rather and Mills 1989). The main signs of damage are needle distortion and shoot stunting (*Figure 6*) (Renault 1983; Bradbury and Osgood 1986; Rather and Mills 1989). The abundant honeydew secreted by aphids also favours the appearance of a fungi, the sooty mould, further reducing the aesthetic quality of the infested shoots (Renault 1983). Light damage caused by a short-lived colony at an early stage may disappear as the shoot grows (Nettleton and Hain 1982). Severe damage remains visible for several years, but disappears with the eventual fall of the damaged old foliage.

Figure 6

Characteristic damage showing distorted needles (Photo: *C. Cloutier*)

Aside from aesthetic damage, in severe infestations, height growth and annual shoot elongation may be reduced by 10 to 30% (Amman 1963; Berthiaume 1998; Desrosiers 1998). The economic impact of such reductions at harvest depends on such factors as annual pruning that removes the current year's growth and improves the trees' appearance.

The severity of aphid infestations may vary from year to year and from tree to tree. During major infestations, the percentage of shoots that are damaged in the absence of control may exceed 80% on some trees (*Figure 7*). The economic consequences of such infestations include a reduction in the monetary value of trees nearing harvest and a possible delay in marketing of affected trees.

Figure 7

Infested fir showing significant aesthetic damage (Photo: *C. Hébert*)

Natural Enemies

A wide diversity of natural enemies is active in fir plantations, provided the ecosystem has not been disrupted by insecticide treatments. Ladybird beetles, syrphid fly larvae, cantharids and, to a lesser extent, lacewings and spiders are active predators of the balsam twig aphid (Varty 1966, 1969; Nettleton and Hain 1982; Kleintjes 1997; Berthiaume 1998). The ladybird beetle *Anatis mali* (*Figure 8*), which is exceptionally voracious, has a very close association with the balsam twig aphid (Berthiaume 1998). It has adapted to laying its eggs on infested trees and exploiting aphid colonies to promote the development of its own larvae. Other species such as the seven-spotted beetle, *Coccinella septempunctata*, the Asian ladybird beetle *Harmonia axyridis* (recently

Figure 8

Adult ladybird beetle, *Anatis mali*, searching for aphids (Photo: *C. Cloutier*)

Figure 9

Adult ladybird beetle, *Harmonia axyridis*, exploring a fir shoot (Photo: *C. Cloutier*)

introduced into Quebec) (*Figure 9*), as well as *Coccinella trifasciata* and two species of *Mulsantina* are also associated with the balsam twig aphid. Adult ladybird beetles, particularly *A. mali*, appear quite early in the spring and feed on the fundatrices before they have a chance to penetrate buds that are opening up (Berthiaume 1998). By reducing the survival of fundatrices before colonies are formed, adult ladybird beetles may play a key role in preventing damage to trees (Berthiaume 1998). Larvae (*Figures 10 and 11*) that hatch from ladybird beetle eggs laid on the trees emerge too late to kill the fundatrices before colony establishment. Nonetheless, they are beneficial since they reduce the number of active colonies, the pest density within persisting colonies and the density of overwintering eggs, thereby permitting greater elongation of new shoots (Berthiaume et al. 2000).

Figure 10

Larva of the ladybird beetle, *Anatis mali*, looking for aphids (Photo: *C. Germain*)

The larvae of several syrphid fly species are also important predators of the balsam twig aphid in Quebec (*Figure 12*). They have been credited with ending a balsam twig aphid outbreak that occurred in natural stands in 1978 (Martineau 1984). Adult syrphids are active early in the season but do not prey on aphids (*Figure 13*). Since these insects visit flowers to feed on their nectar and pollen, they are attracted by the presence of plants with flowers, including certain weeds. Syrphid fly larvae are less mobile and their presence is synchronous with that of aphid colonies, which they are likely to inhabit and exploit just as ladybird beetle larvae do (Nettleton and Hain 1982; Kleintjes 1997).

Figure 11

Larva of the ladybird beetle, *Harmonia axyridis*, looking for aphids (Photo: *C. Germain*)

Figure 12

Syrphid fly larva searching for prey near an aphid colony (Photo: C. Germain)

Recent studies have revealed predation by the cantharid *Podabrus rugosulus* (Figure 14) on the winged viviparous forms of the balsam twig aphid when they leave the colony during the aerial dispersal phase (Berthiaume et al. 2001). Since these cantharids interfere with the production of sexuales, they represent a useful tool for preventive control throughout the Christmas tree production cycle. Unpublished research also reports the low-density presence of an as-yet unidentified wasp (family Braconidae) that is a parasitoid of *M. abietinus* (Figure 15). Only one known parasitoid species, *Pseudopraon mindariphagum*, has been reported to attack *M. abietinus* in Central Europe (Stary 1975). While fungal diseases occasionally affect the balsam twig aphid, they do not appear to have a significant impact on the populations studied in Quebec.

Figure 13

Adult syrphid fly feeding on a flower (Photo: *C. Germain*)

Figure 14

Podabrus rugosulus searching for aphids (Photo: *C. Germain*)

Figure 15

Parasitoid (Braconidae) that attacks balsam twig aphids (Photo: *C. Germain*)

Susceptibility of Plantations

The timing of budbreak has a direct influence on the extent of fir damage caused by balsam twig aphids and on the number of deformed needles found on damaged shoots (*Figure 16*) (Desrosiers 1998). At the end of the growing season, trees that have undergone late budbreak show less damage than those characterized by early budbreak (Desrosiers 1998). Although trees with later budbreak have slower shoot growth as measured at the end of the season, the selection of breeding lines with this trait would help to limit the detrimental effect of the aphid on Christmas trees and reduce the need for insecticide applications (Desrosiers 1998).

Figure 16

Comparison of shoot development on a balsam fir with early budbreak (foreground) versus late budbreak (background) (Photo: *N. Desrosiers*)

Detection, Monitoring and Chemical Control

To minimize insecticide applications and thus limit the negative repercussions on the environment as a whole and on non-target fauna (Nettleton and Hain 1982; Rondeau and DesGranges 1991; Kleintjes 1997; Deland et al. 1998), a preventive monitoring system is proposed for controlling balsam twig aphid infestations. This approach permits forecasting of the infestation risk on an annual basis.

Detection may be done in three steps. The size of winged aphid populations is estimated by means of yellow sticky traps (*Figure 17*). Based on this information, a risk index can be established for the following year as early as July. Aphid flights are widespread and involve huge numbers of individuals. Even in a plantation where the insect pest is under control in the spring, there is a high risk of invasion by winged viviparae from elsewhere (Deland et al. 1998). Following trap monitoring, observations are carried out during the season by using a magnifying glass to assess egg densities on new shoots; this helps to identify the plantations that will be at greatest risk during the next season. Finally, where warranted by the risk level estimated in the previous steps and where trees are near maturity, it is strongly recommended that fundatrices be monitored in plantations during the month of May, at least two weeks prior to colony formation (Kleintjes et al. 1999). This final monitoring step involves determining the percentage of shoots infested by immature fundatrices (*Figure 18*). As the damage threshold acceptable to buyers (5% shoot injury) will be reached when 9% of current-year shoots are infested by fundatrices in May (Deland et al. 1998), an insecticide application may be recommended. Therefore, any insecticide application below this 9% threshold is unnecessary. In Canada, Diazinon 500 EC is the only insecticide authorized for balsam twig aphid control in balsam fir plantations.

Figure 17

Yellow sticky trap used to detect the presence of winged aphids (Photo: *C. Moffet*)

To prevent aesthetic damage to shoots, the insecticide treatment must be carried out before the aphid colonies are established. A forecasting model based on the degree-days accumulated above a base of 2°C can be used to predict egg hatch along with the fundatrices' development and attainment of maturity. In the spring, it takes an estimated 95, 160, 200, 255 and 280 accumulated degree-days (base 2°C) before 50% of fundatrices reach instars 1, 2, 3, 4 and the adult phase, respectively (Deland et al. 1998). No insecticide spraying should be done before reaching 95% egg hatch, which occurs after the accumulation of 125 degree-days above the base temperature. Since the aphid is difficult to detect before the second instar, visual inspection of shoots with a magnifying glass to detect fundatrices is more effective when performed beginning around 160 degree-days. Insecticide treatments carried out after 5% of fundatrices have reached the adult stage, namely at 255 accumulated degree-days above 2°C, are unlikely to prevent shoot damage.

As part of an integrated management approach spanning several years of the production cycle, it is crucial to consider plantation age, because the aesthetic damage caused by aphids is not visible after a few years due to the rapid growth of young fir and the effect of annual pruning (Nettleton and Hain 1982). There appears to be no need to treat a plantation before the trees are within two or three years of commercial maturity. This management strategy would allow beneficial organisms, especially natural enemies of the balsam twig aphid, to become established and multiply in the plantations, thereby limiting the magnitude of aphid infestations and the need to use insecticides.

Figure 18

Visual monitoring to determine the percentage of shoots infested by *Mindarus abietinus* (Photo: *C. Moffet*)

Impact of Chemical Control and Alternatives

At present, control of the balsam twig aphid is based primarily on the use of insecticides, particularly Diazinon (Kleintjes 1997; Deland et al. 1998). Chemical treatment should not be initiated until the economic threshold is reached, as ascertained through monitoring (the threshold is 9% of shoots infested by fundatrices). Like other broad-spectrum insecticides, Diazinon has been shown to have negative effects on birds that nest in plantations (Rondeau and DesGranges 1991) as well as on soil arthropods and the natural enemy complex (Nettleton and Hain 1982; Kleintjes 1997; Deland et al. 1998). Further research is required so that an environmentally sound and more comprehensive control strategy can be developed, combining the use of trees that have later budbreak, augmenting the effectiveness of natural enemies (*Figure 19*) and better knowledge of the relationship between the balsam twig aphid and economic tree damage. In the meantime, insecticide treatment should not be considered until the final growing seasons before harvest and only when the economic threshold is reached. A single application that kills fundatrices before colonies are established should be sufficient to eliminate the risk of damage. Later applications may reduce aphid populations but will have no effect on already damaged shoots.

Figure 19

Plantation managed with a minimum of chemical inputs, thereby promoting the presence of herbaceous plants that are important for many natural enemies (Photo: *C. Hébert*)

For Further Information

Anyone with comments or suggestions regarding the information provided in this leaflet is invited to contact the authors by e-mail at

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