



## Defoliation and growth loss in young Sitka spruce following repeated attack by the green spruce aphid, *Elatobium abietinum* (Walker)

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### Abstract

Green spruce aphid, *Elatobium abietinum* (Walker), is a serious defoliator of Sitka spruce (*Picea sitchensis* (Bong.) Carr.). In a field experiment in Hafren Forest, mid-Wales, different population densities of *E. abietinum* were created amongst plots of P91 Sitka spruce by applying insecticides and artificially infesting trees with aphids. Trees subjected to high aphid populations (HP treatment) lost 51, 29 and 15% of their older needles because of infestation in 1994, 1997 and 1999, respectively, whereas trees with low aphid populations (LP treatments) suffered only 15% defoliation in 1999. Aphid numbers, defoliation rates and tree growth were monitored from 1993 to 2000, to determine: (1) relationships between defoliation and aphid density, (2) the impact of repeated infestations on spruce growth, and (3) whether previous defoliation influenced subsequent infestation and damage. Defoliation rate showed an asymptotic relationship with *E. abietinum* density in each year, and was higher relative to aphid density for older age-classes of shoots. Relationships obtained in 1997 and 1999 confirmed previous observations that low *E. abietinum* densities cause relatively high rates of needle loss. Repeated defoliation in the HP treatment reduced height and volume growth by 8 and 6%, respectively, by the end of the experiment. Reductions in volume increment were related to changes in total needle DW per tree. In 1999, all trees in the experiment were colonised by *E. abietinum* because of a natural increase in aphid populations, but significantly fewer aphids were recorded on the previously defoliated trees in the HP treatment ( $P = 0.007$ ). However, despite lower aphid densities, defoliation rates were similar and growth losses were higher in the HP treatment, suggesting that the differences in aphid density were primarily a reflection of changes in general tree vigour, rather than a result of induced changes in host quality.

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## 1. Introduction

Green spruce aphid, *Elatobium abietinum* (Walker), is one of a number of conifer-feeding aphids that induce chlorosis in the needle leaves of their host, leading to premature needle abscission and defoliation (Bliss et al., 1973; Parry, 1974a; Thompson, 1977; Odendaal, 1980; Skarmoutsos and Millar, 1982; Simpson and Ades, 1990; Murphy, 1996; May and Carlyle, 2003). Several of these aphids are serious pests of commercial forest plantations, and the damage and loss of foliage that they cause has been related to reductions in shoot and height growth (DeBoo et al., 1964; Thompson, 1977; Madoff and Austarå, 1990; Straw et al., 1998), smaller radial and volume increments (Zwolinski, 1990; Day and McClean, 1991; Thomas and Miller, 1994; Straw et al., 2000), and decreases in stand productivity (May and Carlyle, 2003).

*E. abietinum* is one of the most damaging species. It feeds on spruce (*Picea* spp.), and is particularly damaging to spruce species of North American origin (Nichols, 1987). This includes Sitka spruce (*Picea sitchensis* (Bong.) Carr.) which has been planted extensively in regions with a mild, maritime climate, such as the west and northern parts of Britain (Allison et al., 1994; Ray et al., 2002). In these areas, Sitka spruce is often the most productive conifer species (Savill and Evans, 1986; Gill and McIntosh, 2001). However, the climate that suits Sitka spruce also favours *E. abietinum*. Mild winters and relatively cool and wet summers, characteristic of maritime areas, allow *E. abietinum* to persist on spruce throughout the year as anholocyclic, parthenogenetic populations. These populations comprise continuous, overlapping generations of adult aphids and nymphs. Populations peak during the spring or early summer (Parry, 1969, 1974b; Day, 1984; Day and Crute, 1990), or where the climate is cooler, as in Iceland, during the autumn (Day and Kidd, 1998; Halldórsson et al., 2003).

Foliage yellowing and defoliation are caused by material injected into the needle tissues as the aphids are feeding (Kloft and Ehrhardt, 1959; Parry, 1974a). The defoliation of Sitka spruce by *E. abietinum* has been shown to reduce annual increment for one or up to several seasons (Carter, 1977; Carter and Nichols, 1988; Seaby and Mowat, 1993; Thomas and Miller, 1994; Orlund and Austarå, 1996; Straw et al., 2000, 2002b; Halldórsson et al., 2003). Trees are rarely

killed, at least in Europe, and the main impact of the aphid on Sitka spruce is to reduce growth and productivity. The extent to which total timber production is reduced by the end of the rotation depends on how often and how severely trees are attacked. Consequently, estimating long-term impacts requires integrating the effects of successive defoliations over the life of individual forest stands. This in turn requires a knowledge of the defoliation history of individual stands, or records of insect abundance over time, and information on how defoliation or infestation affects tree growth (Alfaro et al., 1982; MacLean et al., 1996; Straw et al., 2002a).

For *E. abietinum*, the information required to undertake an empirical analysis of long-term impacts is not yet available. There are no long-term records of defoliation by *E. abietinum* in individual spruce stands, and estimates of growth loss following *E. abietinum* infestation are largely restricted to trees younger than 15 years of age. The longest continuous record of *E. abietinum* populations in a single stand covers 8 years (Day and Crute, 1990; Day and McClean, 1991), and although retrospective analyses of previous outbreaks suggest that severe defoliation by *E. abietinum* occurs on a regional basis every 3–6 years, or at longer intervals (Bejer-Petersen, 1962; Carter, 1977; Lewis et al., 1999), this may not apply to individual stands within a region.

Without long-term population data and estimates of impact on older trees, calculating the effect of *E. abietinum* on total productivity is dependent on developing population models that predict fluctuations in aphid populations from year to year (Day and Kidd, 1998), and combining these models with simulations of plantation growth that incorporate the effects of defoliation (Randle and Ludlow, 1998). Crucial to linking these two types of model, and for identifying economically important aphid densities, is a clear understanding of aphid density–defoliation relationships. However, only a small number of studies have quantified defoliation rates in relation to *E. abietinum* density, and the relationships obtained vary considerably (Hussey, 1952; Day and McClean, 1991; Straw et al., 1998).

This study analyses a larger dataset on aphid–needle loss relations for *E. abietinum* than has hitherto been available, and establishes needle loss relationships for different age-classes of Sitka spruce shoots.

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