The Integrated Forest Management Programme

by David Wainhouse, Hugh Evans, Roger Moore,
Joan Webber, Katherine Thorpe and Joanna Staley


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1 Adult pine weevils showing natural variation in size; pine needles included for scale


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2 Nylon mesh cages used to enclose adult weevils during feeding experiments


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3 Scots pine seedling with weevil feeding damage on stem

Introduction

One of the principal objectives of the Integrated Forest Management (IFM) programme is the co-ordination and development of research that has the ultimate goal of reducing the use of chemicals in forest management. Chemicals are used to achieve a number of different forest management objectives, although they are used much less extensively than in agriculture. Important uses include applying urea to stumps after felling to prevent establishment of the butt rot fungus *Heterobasidion*, application of herbicides to reduce weed competition in reafforestation sites, applying insecticide to conifer transplants to reduce the impact of feeding damage caused by the pine weevil, *Hylobius abietis*, and using rodenticides to limit the impact of grey squirrel populations in broadleaved forests (Table 1). In addition, fertilisers may also be used to aid tree establishment and promote rapid early growth.

Table 1 Current chemical use in GB forestry (Willoughby, 1999 and personal communication).

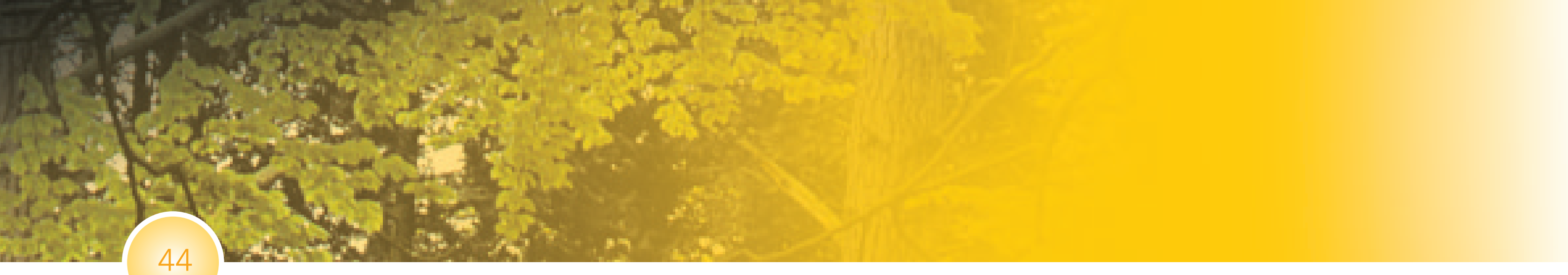
Chemical	**Tonnes**[a]
Urea	420
Herbicides	30
Insecticides	1
Rodenticides	1

[a] Approximate tonnes a.i. in 1994.

The convenience and efficacy of many of these chemicals has been clearly established and much research devoted to selecting appropriate chemicals, optimising timing and target specificity, and minimising risks to operators and the environment. Nevertheless, the development of alternative practices or complementary management techniques that are integrated to allow reduction in chemical use is now regarded as a key component of sustainable forest management (Anon., 1998) and, indeed, is a requirement of the Forest Certification or Woodland Assurance Schemes (Bede Howell, 1999). The development of such methods in forest management will depend to a greater or lesser extent on collaborative research between different disciplines, not only to avoid introduction of conflicting techniques but to ensure that the necessary breadth of expertise is focused on key problem areas. The project on the Integrated Pest Management (IPM) of the pine weevil, *Hylobius abietis*, illustrates this approach.

Integrated Pest Management of pine weevil

The pine weevil is so damaging to young conifer transplants that it is the only UK forest pest against which prophylactic applications of insecticides are used. Adult female weevils are attracted to areas of clearfelled conifers (Plate 1), partly by the odour of ∝-pinene and ethanol released from the cut surface of stumps. The females then lay eggs in the bark below the soil surface and, on hatching, the larvae pass through several growth stages before they pupate and eventually emerge as adults after a period of 1–2 years. The young plants used in restocking are vulnerable to attack by the emerging adults. Both the number of weevils emerging from stumps, as measured by emergence traps (Plate 2), and the timing of emergence in relation to replanting influence the amount of feeding damage on transplants and the period over which it occurs. The tree species present in the forest is one important factor determining the number of weevils emerging from stumps since there is considerable variation both between and within species in their suitability for larval development. In intensively managed forests, emergence of adults from lodgepole pine, *Pinus contorta,* averages 40 to 100 per stump whereas 15 to 30 is more common for Sitka spruce, *Picea sitchensis*. In the forest of Ae, the number of immature *Hylobius* in Sitka spruce varied from 0 to 178 per stump, confirming the



wide variability in colonisation and breeding success. Emergence traps placed over these stumps also revealed that weevils emerged over a protracted time period. Most emergence occurred within 33 months of felling, but in some stumps, emergence occurred over a period of 52 months. More detailed examination of the development of larvae revealed some interesting findings that suggest limitations in the effective exploitation of stumps that could have significant effects on weevil abundance and population dynamics and which therefore may be of importance in the management of this pest.

PLATE 1

Stumps utilised for weevil breeding in a clearfell area. (D. Wainhouse)

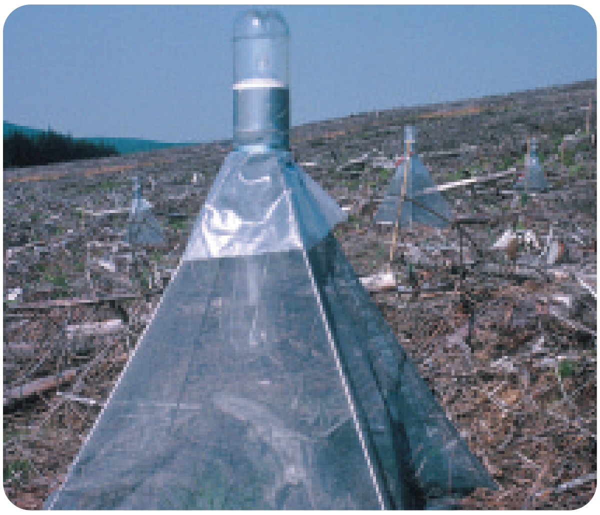


PLATE 2

Weevil emergence trap placed over conifer stump. (R. Moore)

Effects of competition and stump quality on performance of weevil larvae

When weevil eggs or larvae are inoculated into logs of Douglas fir, Scots pine, Sitka spruce and hybid larch in laboratory experiments, larval survival varies considerably between species and is also influenced by the size of larvae inoculated (Figure 1). The size differences among larvae are related to differences in the size of eggs laid by weevils (Figure 2) which appear to be caused by variation both in the size of adult weevils themselves and in the species of transplant on which they have been feeding. These so-called maternal effects on offspring 'quality' and survival can arise where size or competitive ability of offspring are important in survival and development (Wainhouse *et al.*, 2001). This suggests that mortality of *Hylobius* larvae in stumps can be high, depending on the conifer species, degree of resistance in 'fresh' stumps and the extent of previous colonisation by weevil larvae. As well as *Hylobius* larvae, stumps can be colonised by other organisms such as *Hylastes* bark beetles, other saproxylic invertebrates and fungi that may be effective competitors. Their activity may further restrict the availability of bark during the larval development period which typically extends over 1–2 years (Plate 3).

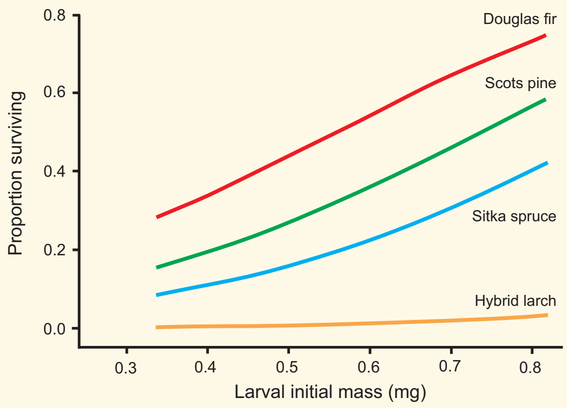


FIGURE 1

The effect of larval size on survival on different conifers.

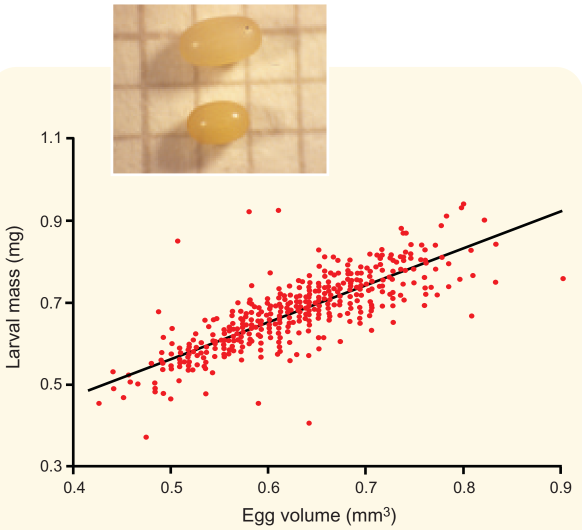


FIGURE 2

Relationship between larval and egg size. Inset illustrates variation in egg size (scale: grid = 1mm). (J.Staley)

It is possible that some of the most effective strains of fungi already applied as stump treatments for the biological control of the root and butt rot pathogen *Heterobasidion* (Pratt, 1999) may be effective colonisers of bark, with the potential to limit the amount of bark resource available for exploitation by *Hylobius* larvae. Preliminary studies using a range of fungi inoculated into freshly felled logs show that *Hylobius* larvae actively avoid already established fungal lesions (Plate 4), suggesting that competitive exclusion may be a promising line of research with the potential to unify elements of the control of *Heterobasidion* and *Hylobius*.

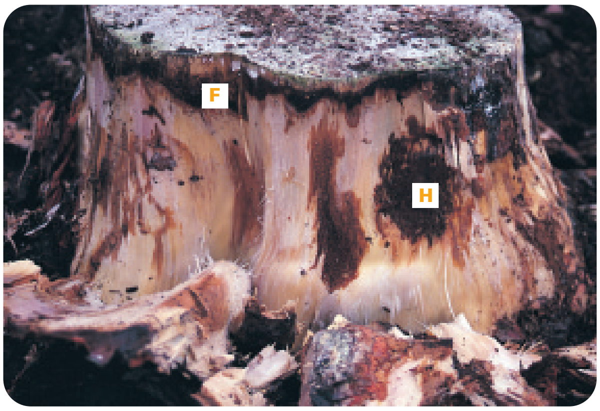


PLATE 3

Scots pine stump colonised by fungi (F) and *Hylastes* sp. (H) as well as *Hylobius* larvae. (D. Wainhouse)

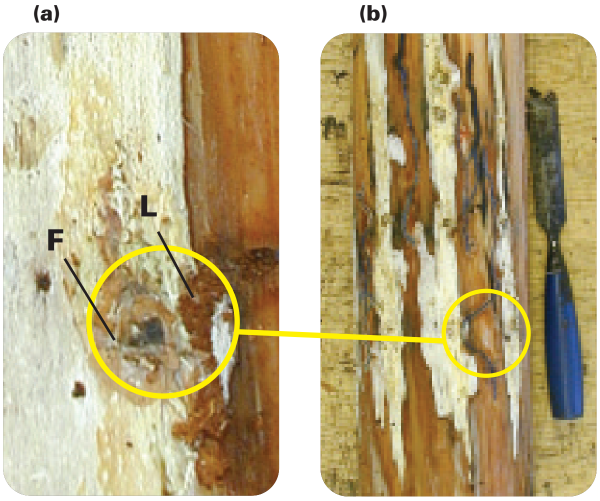


PLATE 4

(a) Enlarged section of log showing *Hylobius* larval gallery (L) avoiding fungal lesion (F). (b) Large pale coloured fungal lesions on log restrict lateral movement of *Hylobius* larvae. (K. Thorpe)

Reducing populations of *Hylobius* emerging from stumps is only one element of an integrated approach to control. Even at relatively low densities, feeding by adult weevils can kill or severely damage transplants. The behaviour of weevils once they emerge from stumps, how long they remain on site and how effective they are at finding seedlings will be important determinants of the relationship between weevil population size and damage to seedlings, and is the subject of ongoing research. The damage that is inflicted on transplants is assumed to be part of maturation feeding without which female weevils would be unable to lay eggs. Although transplants are assumed to represent a high quality food, there are nevertheless large differences in the number of eggs laid by females when thay feed on different tree species (Figure 3). Such differences could affect population dynamics and management in forests dominated by different conifer species. Replanting forests with conifers that have the ability to resist or recover from weevil attack is an important element of IFM and is currently the subject of intensive research.

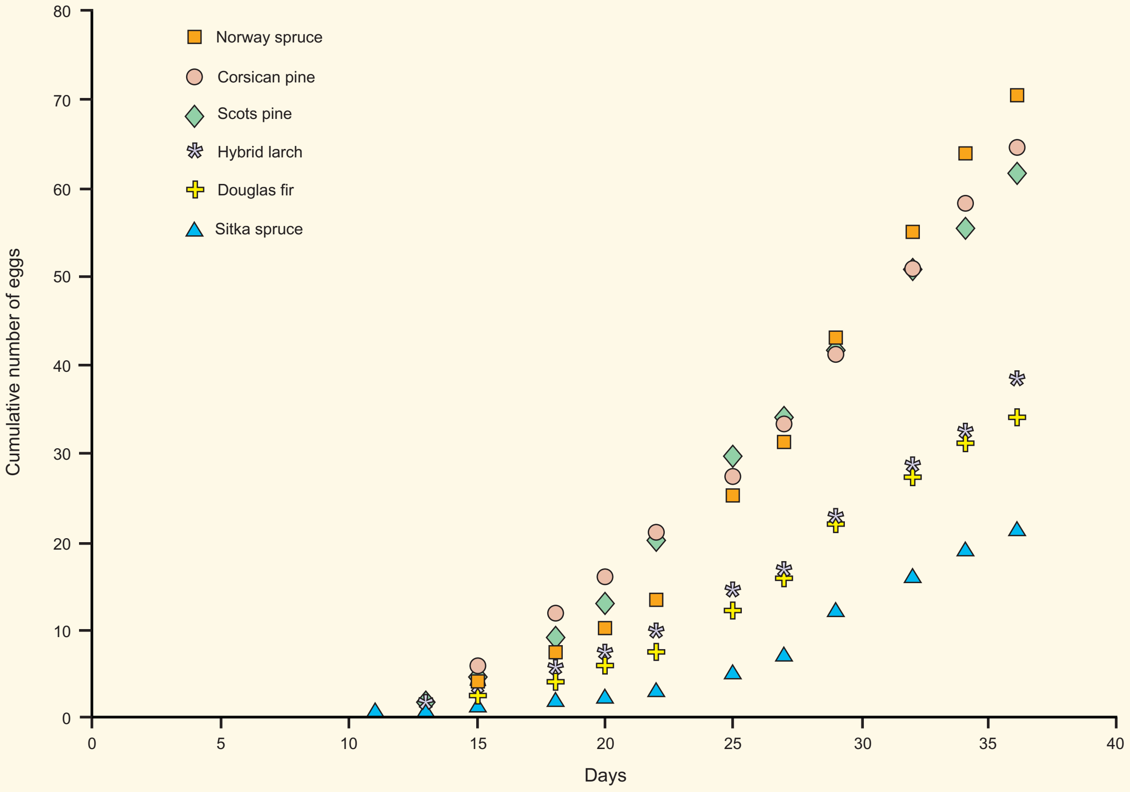


FIGURE 3

The fecundity of weevils when feeding on current year stem bark of different species of conifer transplant.

Some of the main factors likely to influence risk of damage to transplants and therefore of value in a decision support system have been discussed in a recently published information note (Heritage and Moore, 2001). An important consideration will be how the various factors interact to drive down *Hylobius* populations below the level that leads to plant damage. In the medium term, the results described here, together with data on population dynamics, weevil movement and the application of insect parasitic nematodes for the biological control of *Hylobius* larvae (Brixey, 1997), will be used to develop a practical IFM approach to management of this important pest.

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