Pine weevil feeding in Scots pine and Norway spruce regenerations

Kristina Wallertz
Southern Swedish Forest Research Centre
Alnarp

Doctoral Thesis
Swedish University of Agricultural Sciences
Alnarp 2009

Acta Universitatis agriculturae Sueciae
2009:60

ISSN 1652-6880
ISBN 978-91-576-7407-4

Print: SLU Service/Repro, Uppsala 2009

Pine weevil feeding in Scots pine and Norway spruce regenerations

Abstract

Damage caused by the pine weevil, *Hylobius abietis* (L) feeding on conifer seedlings is a major problem in reforested areas in many parts of Europe. The adult weevil feeds on the stem-bark of young seedlings, frequently killing a large proportion of newly planted seedlings.

The aims of the studies underlying this thesis were to investigate whether additional food supplies could decrease the damage caused by pine weevil to seedlings, and to determine whether access to extra food might explain why seedlings beneath shelter trees receive less damage from pine weevils compared to seedlings planted in a clear-cutting. A survey was conducted to study what effect removing shelter trees has on the level of damage pine weevils cause to seedlings. Finally, the influence of factors including fertilization, establishment and soil scarification on the growth and tolerance of Norway spruce seedlings to pine weevil feeding was studied.

Pine weevil damage to seedlings was significantly reduced when extra food (fresh branches of Scots pine) was regularly provided nearby. Feeding by pine weevils in the crowns of large trees occurred during a limited period following their migratory flight but did not seem to be sufficient enough to explain the lower feeding pressure observed on seedlings in shelterwoods over the entire season. During the first year after cutting, roots in the humus layer seemed to be an important food source but were utilized to similar extent in both clear-cuts and shelterwoods. Thus, findings reported provided valuable knowledge about pine weevil feeding on seedlings and other food sources but could not fully explain why seedlings planted beneath shelter trees receive less pine weevil damage compared to seedlings planted on an open clear-cutting.

Before the removal of shelter trees, Norway spruce and Scots pine seedlings need to have reached diameters of 10-12 mm in order to avoid lethal levels of damage from pine weevil attack.

Loading Norway spruce seedlings with nutrients in the autumn before plantation did not lead to more feeding from pine weevils. Treatments that postpone the start of pine weevil feeding enhanced the ability of seedlings to sustain pine weevil damage later on, probably as a result of reduced stress allowing a more rapid establishment of seedlings.

*Keywords: C*onifer seedling, feeding, fertilization, damage, *Hylobius abietis*, large pine weevil, reforestation, shelter trees, shelterwood, tolerance.

Author's address: Kristina Wallertz, Asa Forest Research Station, Swedish University of Agricultural Sciences, SE 360 30 Lammhult, Sweden.

E-mail: Kristina.Wallertz@esf.slu.se

Contents

List of Publications **5**

1 Introduction **7**
1.1 Biology 7
1.2 *Hylobius* in Europe 8
1.3 Other related *Hylobius* species 9
1.4 Methods to reduce damage 10
1.5 Other methods 11
1.6 Soil scarification 12
1.7 Shelterwoods 13
1.8 Seedling quality 14
1.9 Aims of this thesis 15

2 Materials and methods **17**
2.1 General aspects 17

3 Results and discussion **21**
3.1 Feeding on different kinds of food source (I, II, IV) 21
3.2 Tree species (I, III) 23
3.3 Seedling properties (III, V) 24
3.4 Finding and consuming the food (I,II,IV,V) 26

4 Conclusions **29**
4.1 Conclusions of this study 29
4.2 Practical use and future research 30

References **33**

Acknowledgements **45**

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Örlander, G., Nordlander, G., Wallertz, K. & Nordenhem, H: 2000. Feeding in the crowns of Scots pine trees by the pine weevil, *Hylobius abietis*. *Scandinavian Journal of Forest research* 15, 194-201.

II Örlander, G., Nordlander, G., Wallertz, K. 2001. Extra food supply decreases damage by the pine weevil *Hylobius abietis*. *Scandinavian Journal of Forest research* 16, 450-454.

III Wallertz, K. Örlander, G. & Luoranen. 2005. Damage by pine weevil *Hylobius abietis* to conifer seedlings after shelterwood removal. *Scandinavian Journal of Forest research* 20, 412-420.

IV Wallertz, K., Nordlander, G. & Örlander, G. 2006. Feeding on roots in the humus layer by adult pine weevil *Hylobius abietis*. *Agricultural and Forest Entomology*. 8: 273-279.

V Wallertz, K. & Petersson, M. Pine weevil feeding on Norway spruce seedlings: effect of nutrient-loading; scarification and physical protection. *Manuscript*.

Papers I–IV are reproduced with the permission of the publishers.

The contribution of Kristina Wallertz to the papers included in this thesis was as follows:

I Örlander and Nordlander were mainly responsible for writing Paper I and for the inspiration behind it, while Wallertz was responsible for the field work, some writing, and part of the data processing

II Örlander and Nordlander were responsible for the experimental design, and most of the writing, while Wallertz was responsible for the field work, some writing and data processing

III Wallertz and Örlander designed the study and were responsible for the literature search and writing of the paper, Luoranen and Wallertz were both responsible for the data processing and data were collected by Wallertz.

IV Örlander and Nordlander were responsible for the design of the experiment and Wallertz undertook the field work and data processing. Wallertz and Nordlander were responsible for writing the paper and for literature research, assisted by Örlander.

V Wallertz and Petersson were responsible for designing the experiment. Wallertz conducted all the field work, data processing and writing of the paper, assisted by Petersson.

.

1 Introduction

In 1758 Linnaeus described the large pine weevil in his "Systema Naturae", but the insect was not then considered to be a pest as forests were not really managed at that time (Långström & Day 2004). During the 19th century when forests began to be intensively managed, the pine weevil, *Hylobius abietis*, became the major pest of regenerating forests in several European countries (Ratzeburg 1839). Current silvicultural methods, where coniferous forests are predominantly managed by clearfelling, create an environment highly favourable for pine weevil reproduction (Långström & Day 2004). Pine weevils are attracted to clear-cuttings where roots of the stumps are used as a breeding substrate (Eidmann 1974, Nordlander et al. 1997). The major forestry problem is that the adult weevils feed on the stem-bark of young conifer seedlings, causing severe damage and often high mortality rates (Christianssen 1971, Eidmann 1974, Örlander & Nilsson 1999, Wainhouse et al. 2004, Petersson et al. 2004). *H. abietis* is common in most parts of Europe and Asia where conifer trees occur, and some other *Hylobius* species of economic importance occur in both Asia and North America.

1.1 Biology

Pine weevils migrate by flight in the spring or early summer and invade fresh clearcuts, to which they are attracted by odours emanating from newly dead conifer roots: a material in which they can breed (Escherich 1923, Solbreck & Gyldberg 1979, Schlyter 2004). Although adult weevils can fly long distances (Solbreck 1980), the average distance between fresh clearcuts in southern Sweden is short, implying that most sites are within easy reach of swarming pine weevils. Pine weevils build up their flight muscles before leaving their site of emergence (Nordenhem 1989). Some time after migration to their breeding sites, their flight muscles regress and the weevils remain on the ground for the rest of the season.

In August, when days get shorter, the weevils become less active and they hibernate in the soil, emerging in the following spring (Örlander et al. 1997). The generation time (the time it takes to progress from one stage in their development to the same stage in the subsequent generation) is normally two years in southern Sweden (Bejer-Petersen et al. 1962, Nordenhem 1989, Day et al. 2004). However, adult weevils of the new generation often emerge in late summer about 14 months after oviposition (Leather et al. 1999). These weevils often cause severe damage to seedlings in the autumn before they hibernate in the soil (von Sydow 1997, Örlander & Nilsson 1999). Development time depends on the climate and therefore varies between regions and years (Långström 1982). In the UK, when circumstances are favourable, the new generation can emerge in May the year after the egg has been laid, although cold temperatures often delay the completion of development until between July and September (Day et al. 2004).

Pine weevils feed on the woody stems of several tree species, but prefer conifers (Manlove et al. 1997, Leather et al. 1999, Löf et al. 2004, Månsson & Schlyter, 2004, Löf et al. 2005). The weevils eat the bark of young seedlings, branches on trees, roots in the humus layer and the bark of shrubs. Several factors affect feeding by pine weevils, including temperature, soil type, surrounding vegetation, and the species on which they feed (Christianssen & Bakke 1971, Pohris 1983, Leather et al. 1994, Örlander & Nordlander 2003, Wainhouse et al. 2004, Petersson et al. 2005, 2006). The optimal temperature for pine weevil activity is about 20°C; their activity is reduced at higher and lower temperatures (Christiansen & Bakke, 1968. Wainhouse et al. (2004) showed weevil size to be an important factor affecting feeding rate, suggesting that variation in size within natural populations may contribute to local variations in feeding on seedlings in the field. Moreover, reproductive females eat about 50% more than males or non-reproductive females (Bylund et al. 2004).

1.2 *Hylobius* in Europe

In addition to the large pine weevil *H. abietis*, three other *Hylobius* species occur in Europe. The lesser pine weevil, *Hylobius pinastri*, is considered to be of less importance, and the few published observations suggest that while its life history is similar to that of *Hylobius abietis* (Eidmann 1974, Långström

1982, Nordlander 1990, Långström & Day 2004), its habitat preferences are slightly different. *H. pinastri* has been shown to be more abundant on moist sites dominated by Norway spruce (Långström 1982, Nordlander 1990 and is moderately abundant in Sweden. In a study in southern Sweden the highest catches accounted for 2.4% of the total *Hylobius* population (Örlander et al. 1997). However, *H. pinastri* occurs in many other countries including Poland, Finland, Estonia and Latvia (Karczewski 1961, Långström 1982, Pitkänen et al. 2008, Ozols et al. 1989). Even less common is *H. piceus*, which is mostly found in moist forests breeding in the root collar of living trees and seldom observed to feed on seedlings, although it is sometimes caught in traps (personal observation). A fourth species, *H. transversovittatus*, differs from the others as far as its host, *Lythrium salicaria*, is a perennial plant not related to conifer trees. Interestingly, this plant is an invasive weed of Eurasian origin that has replaced native wetland vegetation in the United States where *H. transversovittatus* is used as a biological control agent (McAvoy et al. 2002).

1.3 Other related *Hylobius* species

In North America there are several species in the genus *Hylobius* (Cerezke 1994, Day et al. 2004). *H. radicis* and *H. warreni* breeds in the root collar region of healthy hosts (Cerezke 1994, Day et al. 2004) while *H. pales* and *H. congener* are known to breed in roots of dying or recently dead trees, as does *H.abietis* (Welty & Houseweart 1985, Day et al. 2004). Moreover, *H. pales* and *H. congener* are similar to *H.abietis* in that they also feed on conifer seedlings and are therefore described here further.

The pales weevil, *H. pales* is a serious pest in new pine plantations and Christmas-tree plantations throughout eastern North America (Peirson 1921, Lynch 1984). The adult weevils are attracted by the odour of freshly cut pine stumps, logs, and slash, and the weevils feed on the tender bark of mature trees, saplings and seedlings. Pest management tactics vary in different areas but the most common are stump treatments, insecticide treatments and delayed planting (Salom 1998).

H. congener is reported to range from North Carolina to the Canadian Maritimes and west to Alaska (Martin 1964, Welty & Houseweart 1985). Several surveys conducted in Nova Scotia have revealed high mortality among seedlings attacked by the weevil (Lyver 2001). Its biology is not well documented but it seems to be similar to *H. abietis*. The larvae feed on the roots and phloem tissue of the residual stumps and logs, and adults feed on young seedlings. However, in several red pine cuttings where logs and slash remained, stumps were hardly used for oviposition, and when weevils were placed in cages and given a choice of logs and stumps, they ignored the stumps and laid their eggs in the logs (Martin 1964). Generation time is reported to be two years (Welty & Houseweart 1985, Pendrel 1990, Lyver 2001). This species caused less debarking in the interior of plantations, on burned or scarified sites, and where litter had been scraped back from the seedling bases (Welty & Houseweart 1985). Lyver (2001) found that when shelter trees were left, the damage caused by *H. congener* to seedlings decreased in correlation with the percentage of over-storey left standing.

Hylobius xiaoi (Zang) is native to south-eastern China where it has become a major pest, mainly attacking two exotic pines: slash pine, *Pinus elliotti,* and loblolly pine, *P. taeda;* and the native masson pine *P. massoniana* (YongSong et al. 2004). The larvae feed on the inner bark of the lower stem and root collar causing severe damage and mortality. Methods to control the insect are spraying with insecticides or removing branches, litter, vegetation and soil from around the tree base (Wen et al. 2006).

1.4 Methods to reduce damage

Several measures can be used to protect seedlings from pine weevil damage, but the most common approach in Europe since the 1950s has been to use insecticides (Leather et al. 1999, Långström & Day 2004). However, because of the environmental and health risks associated with insecticides, their use has been questioned in many countries (Mian & Mulla 1992, Swedish Chemicals Inspectorate 2005). Moreover, the process of forest certification might further reduce the utilization of insecticides (Hansen 1998). Feeding barriers that physically prevent the pine weevil from reaching the seedlings have been developed and tested in Sweden for a long time (Lindström et al. 1986, Eidmann et al. 1996, Petersson et al. 2004, Nordlander et al. 2009). There are two main types: shields - with or without a collar (made of paper, plastic or other materials); or various types of coating applied to the lower part of the stem (Petersson et al. 2004).

Silvicultural measures that can reduce pine weevil damage include scarification and planting under shelterwoods (Söderström et al. 1978, von Sydow 1997, Örlander & Nilsson 1999). Scarification is widely used in Scandinavia and is beneficial both for promoting the establishment of newly planted seedlings (Örlander et al. 1990, Nordborg & Nilsson 2003) and for reducing pine weevil damage to conifer seedlings (Söderström 1978, Björklund et al. 2003, Petersson & Örlander 2003, Petersson et al. 2005). It has been proved that planting under shelter trees reduces damage to conifer seedlings compared to planting in clear-cuttings (von Sydow & Örlander 1994, Nordlander et al. 2003a, 2003b). An additive effect can be achieved if different methods are used (Petersson & Örlander 2003), and combinations of silvicultural measures and seedling protection are commonly applied in practical forestry in Sweden today.

1.5 Other methods

Antifeedant compounds might be a potential alternative to insecticides. Bark extracts from *P. contorta* deter feeding more than extracts from *P. sylvestris* (Bratt et al. 2001). Månsson & Schlyter (2004) found that linden (*T. cordata*) was rejected as a food source by the pine weevil. The bark contains nonanoic acid, a chemical constituent which has a strong antifeedant activity against the pine weevil (Månsson et al. 2005). During oviposition, female weevils defecate on their eggs which causes other females to avoid ovipositing in the same place. Weevil excrement has thus been found to act as a deterrent (Borg-Karlson et al. 2006). The active substance has been identified but finding a suitable carrier has proved to be more difficult than expected. Carvone (Schlyter et al. 2004, Kleipzig & Schlyter 1999) and neem (*Azadirachta indica*) oil (Bryan 2003, Thacker et al. 2003) are other substances that have been shown to have a deterrent effect on pine weevil feeding,

Another approach to reduce pine weevil damage to seedlings is to suppress the pine weevil population. In the UK and Ireland there is great interest in the use of entomopathogenic nematodes and the method has been shown to increase mortality to larvae and pupae of *H. abietis* (Dillon et al. 2007). In Sweden, there are at least two indigenous parasitoid species which attack *H. abietis: Perilitus areolaris* (Gerdin & Hedqvist) (Gerdin & Hedqvist 1985) and *Bracon hylobii* (Ratzeburg) (Henry & Day 2000); the former attacks the adult weevil while the latter attacks the larvae. *P. areolais* may cause high mortality rates, sometimes up to 40% (Bylund et al. unpublished) and the mortality caused by *B. hylobii* has been estimated to be almost 50% (Henry 1995), indicating that these two parasitoids might be potential bio-control agents if the approach of suppressing the populations is considered to be a realistic alternative to other methods.

Removal of stumps is a method that has been reintroduced in Sweden and in Finland during the last few years. Theoretically this method might reduce the breeding potential of the pine weevil and thus in the long run suppress the population. Research in the matter has recently started. However, earlier results indicated that there might be enough amount of roots left in the ground to support a substantial weevil population (Långström and Day 2004).

In regions like southern Sweden, most conifer forests are managed by clear-cutting followed by replanting with conifer seedlings. The short distances between the clear-cuts, and their even geographic distribution, make it possible for weevils to invade most fresh clear-cuts in an area. Therefore, to prevent pine weevil damage to seedlings, methods other than suppressing the weevil population have generally been more favoured in Sweden.

1.6 Soil scarification

Directly after planting, the development of seedlings depends to a great extent on their ability to take up water (Örlander 1986, Grossnickle 1988, Örlander et al. 1998). However, field vegetation competes with the seedlings for water, and other resources such as light and nutrients (Imo & Timmer 1999, Nordborg & Nilsson 2003). Soil scarification is a method whereby the organic layer is removed and the mineral soil surface becomes exposed, although the technique might also result in a mixing of humus and mineral soil. The aims are to improve seedling establishment and growth and reduce the risk of frost injuries, and damage from voles and insects (Örlander et al. 1990). Soil scarification is well known to reduce pine weevil damage to conifer seedlings (Söderström et al. 1978, Lindström et al. 1986, Örlander & Nilsson 1999, Örlander & Nordlander 2003). The reduction is usually most evident in the first year after planting (Örlander & Nilsson 1999) and the best effects are achieved if the seedling is surrounded by pure mineral soil (Björklund et al. 2003, Petersson et al. 2005). According to Långström and Day (2004) scarification as a counter-measure against pine weevil is mainly used in the Scandinavian countries.

Pine weevils move faster and straighter on mineral soil compared to humus and consequently spend less time there (Kindvall et al. 2000). However, Björklund et al. (2003) found that the same number of weevils were caught in traps placed on mineral soil and humus, suggesting that, for some reason, pine weevils do not feed on seedlings planted in mineral soil, even if they pass very closely to them. Some suggested explanations of this behaviour include a lack of hiding places, risk of overheating due to solar radiation, and greater risks of predation while exposed on a mineral soil substrate (Björklund et al. 2003, Örlander & Nordlander 2003).

The dominant soil preparation methods in Sweden are disc trenching and patch scarification/mounding (Strömberg et al. 2001). Soil inversion, where inverted humus is covered with the underlying mineral soil, is a method still under development. Experiments have shown that soil inversion creates a favourable environment for seedling growth and has at least the same effect on pine weevil damage as patch scarification or disc trenching (Örlander et al. 1998). Soil inversion was used as the scarification method in paper V.

1.7 Shelterwoods

When harvesting an old forest, the area can either be completely cleared of trees, or some trees can be left as seed trees or shelter trees. The purpose of a seed tree stand is to produce and distribute seeds, while a shelterwood also provides a sheltering purpose (Hagner 1962, Karlsson 2000). Shelter-woods are used in Scandinavia but also in other parts of Europe and North America (Smith 1986, Matthew 1991, Lyver 2001). Shelter trees not only reduce the risks of damage from frost, they also promote a greater diversity of field vegetation than is normally found in clearcuts (Langvall & Örlander 1991, Hannerz & Hånell 1997). Moreover, in Sweden shelterwood is sometimes used to promote mixed conifer forests, i.e. naturally regenerated pine seedlings derived from the shelter trees are allowed to grow together with planted seedlings of spruce (Nilsson et al. 2006). Several studies in Scandinavia have demonstrated that planting beneath shelter trees reduces damage caused by *H. abietis* to conifer seedlings (von Sydow & Örlander 1994, Nordlander et al. 2003a, Pitkänen et al. 2005) but the reason why is not yet fully understood.

Pine weevils are attracted to new clear-cuts by odours emanating from fresh stumps and fresh slash (Escherich 1923, Nordenhem & Eidmann 1991, Schlyter 2004). The hypothesis that fewer weevils should be attracted to areas with a shelterwood than to clear-cuts, because there are fewer stumps in the former, therefore seems plausible. However, trap catches of pine weevils have shown the sizes of pine weevil populations in shelterwoods and clearcuts to be similar, although the damage to seedlings was considerably more intense in the latter (von Sydow & Örlander 1994, Nordlander et al. 2003a). Similarly, Pitkänen et al. (2008) caught higher numbers of pine weevils among groups of retained trees than in open areas. Thus, reasons