

Interim guidance on the integrated management of *Hylobius abietis* in UK forestry



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Summary

The large pine weevil (*Hylobius abietis* L.) is probably the most serious pest of newly planted or naturally regenerating woodland trees on restocking sites in the UK. On affected sites, in the absence of protective measures, losses of replanted trees will average around 50%, but in the worst cases all trees can be killed. Both conifers and broadleaves are attacked and in some circumstances it can become impossible to establish trees and sustainably regenerate forests.

It is recommended that an integrated approach to the management of this pest is adopted. As described in this Note, this involves firstly understanding the life cycle and likely impacts of *Hylobius*, and then considering the full range of potential approaches available to prevent the insect damaging young trees, if necessary by using different techniques in combination with each other.

Although research into non-chemical approaches is ongoing, currently on many sites in the UK and Ireland it is likely that insecticides will still need to be used as part of the integrated management of *Hylobius*. Where insecticide use is unavoidable, pre-treatment of young trees in an off-site horticultural tree nursery with alpha-cypermethrin or acetamiprid, possibly combined with later post-planting top-up sprays in the forest of those trees with acetamiprid, when used as described on the Health and Safety Executive approved pesticide product labels, and when combined with the additional precautionary measures in place as described in this Note, should not pose any unacceptable risk to consumers, operators, bystanders, neighbours or the wider environment.

1. Aims

The purpose of this Note is to provide updated guidance on the integrated pest management of the insect *Hylobius abietis*. Guidance on the integrated management of all major pest, weed and disease issues facing UK forestry, along with advice on pesticide minimisation and reducing the risk of damage to the environment, is provided in Forestry Commission Practice Guide 15 : *Reducing pesticide use in forestry* (Willoughby *et al.*, 2004). This Note provides a summary of the main changes affecting integrated management of *Hylobius*. In doing so it draws on some of the key findings after 7 years of an ongoing programme of collaborative forest industry research on alternatives to the use of the insecticide cypermethrin for protecting trees from *Hylobius* damage (Moore *et al.*, unpublished). In addition, as a separate Appendix, it summarises knowledge and guidance on the safe use of the insecticide acetamiprid, which is increasingly being phased in across the UK forest industry as an alternative to cypermethrin.

2. Background

The large pine weevil (*Hylobius abietis* L.) is probably the most serious pest of newly planted or naturally regenerating woodland trees on restocking sites in the UK. Adult pine weevils are large insects - up to 12 mm long - and can live for up to 4 years in upland areas, or can complete their life cycle in as little as a year on lowland pine sites. The adult weevils migrate onto felled sites, either in low numbers if the felling is entirely new within a given forest area, or in high numbers if it is in close proximity to an existing clearfell. Eggs are laid below ground level in the bark of stumps of recently felled conifers or in fallen / felled conifer stems and branches in direct contact with the ground. Depending on the tree species, stumps can remain suitable for weevil reproduction for up to 5 years after felling. Larvae feed in the cambial layer inside the outer bark and pass through several moults before finally pupating in a pupal chamber. Adults usually emerge in the autumn and concentrate their feeding on the bark of exposed lower stems of transplanted or naturally regenerated conifer seedlings and the upper part of the stem of broadleaved trees. This often leads to girdling of the stem and results in plant death. Feeding is non-specific in the sense that adult weevils are known to browse on many available plant food sources including the branches of mature standing trees, seedlings and woody weeds on site.

Adult *Hylobius* feed at any time of year when it is warm enough for insect activity, generally between early March and November. However, there is a tendency for two peaks of damage to occur, one in spring before egg laying and the other in late summer soon after a new generation emerges from the stumps but before the adults hibernate underground. The timing of these feeding periods depends on both the physiological condition of the insects and the ambient temperature. The relative magnitude of these peaks will vary from forest to forest and from year to year. When sites are clearfelled

the availability of alternative food sources for adult beetles is restricted, hence newly planted or naturally regenerating trees tend to be favoured by the weevils, giving rise to extensive browsing.

On affected sites, in the absence of protective measures, losses of replanted trees will average around 50%, but in the worst cases all trees can be killed. Both conifers and broadleaves are attacked and in some circumstances it can become impossible to establish trees and sustainably regenerate forests (Willoughby *et al.*, 2004).

3. Management options

3.1. Integrated Forest Management

Pesticide use in forestry is on a very small scale compared to agricultural, horticultural and amenity use. It has been estimated that despite forests covering over 11% of the land area of Britain, they account for less than 0.1% of all pesticides used (Willoughby *et al.*, 2009; McCarthy *et al.*, 2011).

Rather than using pesticides as a first resort, Forest Research recommend that an integrated approach to pest, disease and weed management is always adopted, based on an understanding of the nature and impacts of the damaging agent, and after consideration of the full range of potential solutions, if necessary in combination with each other. Only if all non-chemical control options have been considered and shown to be impractical, ineffective, excessively costly, or likely to carry the risk of causing more harm to people and the environment, should the use of pesticides be countenanced. Often the combination of non-chemical and chemical approaches can help to reduce the overall level of pesticide use on a given site. The core decision key (Figure 1) is taken from Forestry Commission Practice Guide 15 (Willoughby *et al.*, 2004), and provides a simple means of adopting the integrated approach as recommended by Forest Research, thereby minimising pesticide use as required by the UK Forest Standard (Forestry Commission, 2017), and fulfilling the requirements of voluntary independent certification schemes such as those of the Forest Stewardship Council (FSC, 2005) or PEFC (PEFC, 2012), achieved through the UK Woodland Assurance Standard (UKWAS, 2012). The management options outlined in this Note are therefore grouped under the standard headings referred to in the core decision key.

The *Hylobius* Management Support System (Forest Research, 2017) is a decision support tool developed by Forest Research that utilises 'billet counts' to measure insect presence in combination with a model based on an understanding of *Hylobius* population dynamics to predict if damage is likely on a site, and hence what action or treatment is required (Forest Research, 2017). It can be used to determine the optimum use of many of the approaches outlined in this Note under the headings of 'Avoid the Problem' and 'Remedial Control Measures', in particular the fallow period strategy, choice of most suitable type of transplants, and the effects of entomopathogenic nematodes. Rather

than simply relying on monitoring tree damage and when it occurs attempting to react to it quickly enough to prevent tree death, the system can help predict in advance where and when remedial action, in the form of post-planting spraying with insecticide (referred to as 'top-up spraying'), may be necessary. In effect the *Hylobius* Management Support System provides a sophisticated and effective means of following the core decision key, taking an integrated approach to the management of *Hylobius*, and minimising unnecessary pesticide use.

For lowland pine sites where *Hylobius* only has a one year life cycle, a possible alternative approach to using the *Hylobius* Management Support System is to monitor weevil development in stumps through 'stump hacking' to predict the time of adult emergence and approximate population size. Depending on the risk and likely intensity of attack, sites can be left fallow for a period before planting, immediately restocked with treated trees, or immediately restocked with untreated trees. Monitoring of feeding damage on planted trees can then be used to identify recently planted areas that require top-up spraying. Full details and practical guidance on the use of this approach for lowland pine sites is given in Wainhouse *et al.* (2007). However, the use of stump hacking to monitor weevil population in this way is likely to be considerably more expensive than the use of billet counts if a similar level of accuracy is required.

3.2. Take no action

With no action, losses of replanted trees will range from 0-100%, depending on *Hylobius* population levels, plant characteristics such as root collar diameter, availability of alternative food sources, and environmental conditions. Without monitoring of populations to allow decisions on intervention to be taken using techniques such as the *Hylobius* Management Support System, or very frequent monitoring of damage levels, the 'take no action' option is a very high risk strategy and is therefore not recommended.

3.3. Avoid the problem

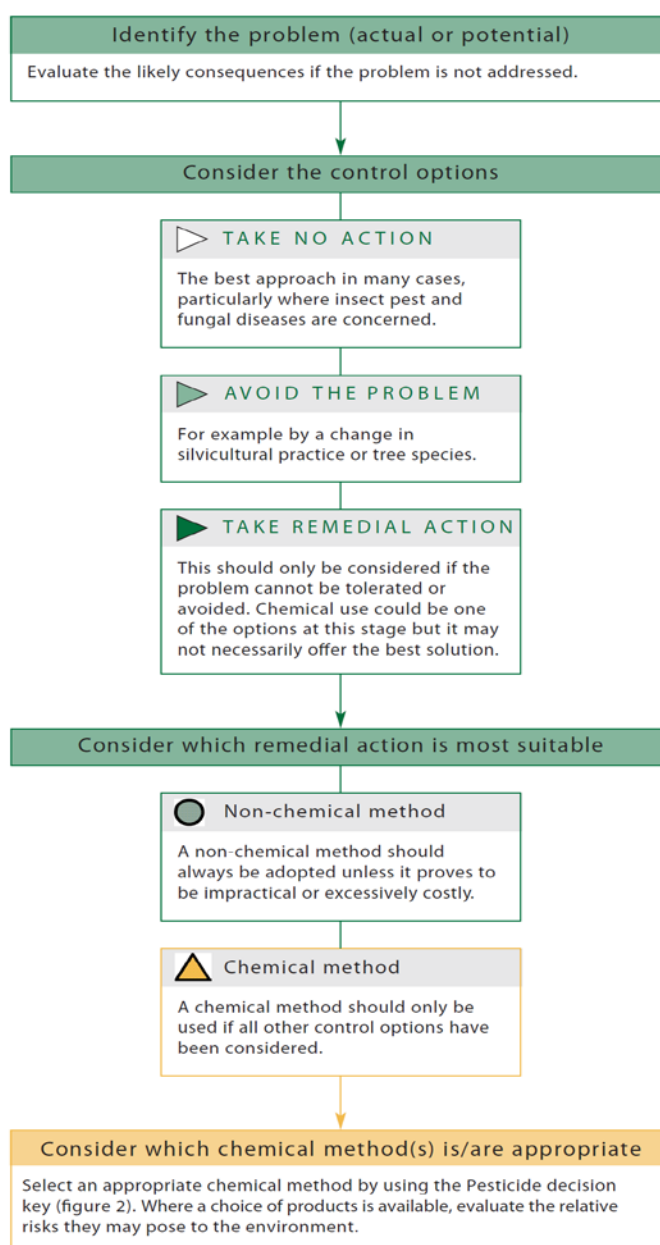
3.3.1. Alternative silvicultural systems or species

For existing conifer forests, using alternative silvicultural systems to clearfelling and replanting with conifers can partly or completely avoid the problem of *Hylobius* damage to young trees. Conifer forests managed on a continuous cover basis are likely to have smaller areas of felling and more alternative food sources for emerging weevils, which means that naturally regenerating or planted trees can sometimes be established without the need for any further protection (Mason *et al.*, 2004). However, successful conversion to continuous cover forestry can take many years, and given the prevailing windy, oceanic climate and inherent lack of tree stability on many British sites, such silvicultural systems are only ever likely to be appropriate for a minority (< 25%) of upland conifer plantations even in the long term (Paterson, 1990).

Although broadleaves planted on ex-conifer sites are liable to be attacked, once they are established, large or isolated broadleaved forests are unlikely to be vulnerable to *Hylobius* damage when felled areas are being restocked.

Figure 1: Core decision key

Use this key to fill in Stage 1 of the recording sheet.



Adapted from Forestry Commission Practice Guide 15; ©Crown copyright; www.forestry.gov.uk/pesticides

3.3.2. Fallow ground strategy

Depending on the tree species, stumps can remain suitable for weevil reproduction for up to 5 years after felling. During this time about two generations of *Hylobius* will emerge on site and, in the absence of suitable further conifer stumps to breed in, will tend to migrate to other sites. Allowing a clearfell site to lie fallow for at least 5 years may therefore allow trees to be planted with little risk of damage. A shorter period of fallow may be possible in some circumstances. See Table 1, (derived from Moore, 2004) for further details.

However, this approach will only work if neighbouring areas cannot act as sources of beetles. Hence freshly felled sites, or sites felled within the last 4 or 5 years, must be far enough away that the weevils that emerge from them, or are attracted to them, cannot travel to the newly planted ex-fallow site, but these requirements are not always practical. The safe separation distance between freshly felled and newly planted ex-fallow sites is around 1,000 m. For sites felled within the last 4 or 5 years, the safe separation distance is around 25-50 m, and in this scenario planting a 25–50 m barrier strip of insecticide treated trees along the edge of the previously fallow site that is closest to the neighbouring felled area should be sufficient to prevent significant damage to the untreated trees on the remainder of the planting site.

Long fallow periods can increase the risk of nitrate release, with potential impacts on stream acidity, especially in acid sensitive or nitrogen saturated sites, which are common in upland areas. Another possible impact on water is that the benefits that forests can provide in reducing downstream flood risk may be lost during the fallow period. Delaying planting for several years reduces carbon sequestration, and can also result in significant financial loss due to the revenue forgone, which is often not acceptable to the landowners. On more fertile sites, leaving areas fallow allows competing vegetation to flourish, and this can dramatically increase the amount of herbicide which may need to be used to allow trees to establish, as well as necessitating the use of more intensive and disruptive cultivation techniques. Therefore on more fertile sites, adopting a fallow period strategy is likely to result in an increase in overall levels of pesticide use and significantly increased costs. Open areas within a forest block may also increase the risk of windthrow in adjacent stands.

Leaving sites fallow for at least 5 years is therefore worth considering on less fertile, relatively sheltered clearfell sites that are not in sensitive riparian catchments, provided that the sites are far enough away from the nearest 0- to 5-year-old felling. Even then, leaving areas fallow is a high risk strategy unless the site has been assessed using specific monitoring techniques, such as via the *Hylobius* Management Support System, and has been found or is predicted to have a sufficiently low *Hylobius* population.

Table 1. Typical peak *Hylobius* damage periods, and possible safe planting windows, when following a fallow ground strategy

Date of felling ¹	Initial damage period (<i>Hylobius</i> site colonisation and egg laying) ^{2,3}	Peak damage periods (<i>Hylobius</i> stump emergences) ³	First safe planting date for treated trees, no top-up spraying ⁴	First safe planting date for untreated trees, no top-up spraying ⁵
Year 0, January –March	Year 0, April – August	Year 1, August – October Year 2, April – June; August – October Year 3, April – June	Year 4, spring	Year 5, spring. (or back-end Year 4)
Year 0, April – mid August	Year 0, April – August Year 1, April – August	Year 1, August – October Year 2, April – June; August – October Year 3, April – June; August – October Year 4, April – June	Year 5, spring	Year 6, spring (or back-end Year 5)
Year 0, mid-August – December	Year 1, April – August	Year 2, August – October Year 3, April – June; August – October Year 4, April – June	Year 5, spring	Year 6, spring (or back-end Year 5)

Notes

This table, which is derived from Moore (2004), gives an approximate indication of likely damage periods by *Hylobius*, and hence the periods when it may be safe to plant trees without the need to make post-planting (top-up) insecticide sprays if pursuing a fallow ground strategy. For a reliable assessment of the risk of damage, on-site *Hylobius* population levels and attributes of nearby felling sites (such as the area, climate, species, pattern and location) need to be taken into account. This can be done through the use of the *Hylobius* Management Support System (Forest Research, 2017).

- 1 Year 0 is taken to be the calendar year at which felling of the preceding crop takes place.
- 2 Damage to trees can be just as severe during this initial period of colonisation as the 'peak damage period'.
- 3 The period when damage will generally occur if the site is planted as soon as possible after felling.
- 4 The earliest date at which insecticide treated trees can be generally safely planted with no subsequent need for top-up insecticide sprays.
- 5 The earliest date at which untreated trees can generally be safely planted with no subsequent need for top-up insecticide sprays.

3.3.3. Manipulating ground vegetation

In the UK and Ireland, adult *Hylobius* move within clearfell sites mainly by walking, and there is some indication that they avoid areas of open, weed-free ground with exposed mineral soil. In addition, areas with quite high weed cover of other woody plants, such as bramble (*Rubus fruticosus* agg.), can act as alternative food sources, thus diverting attacks away from tree seedlings. Hence the retention of a small amount of cover from non-invasive woody weeds, while maintaining open areas of mineral soil immediately surrounding tree seedlings by appropriate initial site cultivation followed by good weed control, which are in any case both standard elements of good silvicultural practice for tree establishment, may also help to reduce *Hylobius* browsing levels.

However, if large populations of weevils emerge they can overwhelm such defensive strategies and result in high losses of planted or naturally regenerated seedlings. In addition, leaving invasive weeds such as bramble unmanaged on site can itself kill young trees. Therefore whilst this technique may make a useful contribution to reducing overall damage levels as part of an integrated approach to management, it should not be relied on in isolation.

3.3.4. Using good quality planting stock

Seedlings that are vigorous with good root systems and high quantities of resin are able to withstand attack better than small plants with poor defensive systems. All planting stock used should therefore have a good balance between roots and shoots and should conform to British Standard 3936 (Morgan, 1999), as this is also good silvicultural practice and helps to reduce the establishment period and subsequent weeding inputs required. The larger the diameter, the thicker the bark and the more resin that a tree seedling produces, the more likely it is to be able to tolerate low to moderate browsing by *Hylobius*. However, initial attacks can attract other adult weevils to the damaged plants and, if pest populations are high, the plant will quickly succumb to multiple attacks. For this reason, whilst the use of good quality well balanced planting stock with larger root collar diameters may make a useful contribution to reducing overall impact of *Hylobius* as part of an integrated approach to management, it should not be relied on in isolation.

3.4. Take remedial action

A summary of the main remedial control options is given in Table 2.

3.4.1. Biological control with entomopathogenic nematodes

Research has shown that the application of entomopathogenic nematodes (*Steinernema carpocapsae*) to late larval and pupal stages of *Hylobius* in stumps can reduce the numbers of emerging adults, resulting in overall population reductions of up to 20% on spruce sites and between 70-90% on pine sites (Brixey *et al.*, 2006). This leads to fewer adults moving on to nearby restocking sites, and if nematodes are applied to consecutive clearfells within the same forest block, the total population pressure from *Hylobius* can

be reduced to non-damaging levels. When combined with predictions of post-felling population dynamics derived from the *Hylobius* Management Support System, nematodes can therefore help to achieve a significant reduction in the need to use insecticides.

High volumes of water have to be used to apply the nematodes to tree stumps, and specialist forwarder mounted spray rigs are required. This makes nematode use impractical in remote locations where transport of water is difficult and expensive, or in situations where forwarder machinery cannot be used (such as on steep sites, or on soft ground if the brush mats used to protect the soil from wheeled or tracked machinery during harvesting operations have degraded). These sorts of conditions are relatively common in upland conifer plantations. In addition, nematodes are less effective where adult *Hylobius* can migrate from neighbouring forests under different ownership and management, or in forest blocks where clearfelling is small scale, sporadic or isolated, which can often be the case in many smaller, lowland forests.

In summary whilst biological control with entomopathogenic nematodes may have a valuable role to play as part of an integrated approach for managing the problem of *Hylobius* damage in some situations, it is estimated that between a third and two thirds of restocking sites in the UK will never be suitable for the technique due to the limitations of site geography, even if the application technology can be improved and costs can be reduced in the future.

3.4.2. Mulching and de-stumping

Mulching or de-stumping have the potential to significantly reduce future *Hylobius* populations, particularly if they are carried out within a few months of felling. In order to be reasonably effective either technique must be undertaken prior to the first emergence of damaging adults from the stumps, which is normally a minimum of 14 months after felling on upland restock sites or 12 months in warmer lowland situations, in the current climate. However, it is almost certainly the case that some larvae will remain in roots, stems or branches left on site and, if so, these will still emerge as adult weevils to cause damage. Therefore, whilst mulching or de-stumping may be helpful techniques if they are practised for other reasons (e.g. on sites at high risk of *Heterobasidion annosum* infection, or to prepare a site for planting), they should not be relied on in isolation. These techniques can also pose a number of environmental risks and are not recommended in some situations, for example de-stumping should not be practised on soils classified as having a high risk of causing increased water acidification, or where it will reduce site nutrient status or lead to an additional soil carbon loss (Moffat *et al.*, 2011).

3.4.3. Physical protection

Broadleaves or conifers protected by full tree shelters (1.2–1.8 m tall with no holes or porous mesh) will suffer less damage than unprotected trees. The use of tall tree shelters purely for protection against *Hylobius* damage is likely to be prohibitively

expensive, but if they are needed to prevent browsing mammals damaging trees, then any protection they provide against *Hylobius* is a bonus. Using tree shelters on areas greater than 1 ha is normally not economic, and they can cause instability in young conifers.

Other physical protection methods have been successfully used in Scandinavia, but trials in Britain have found them to be generally ineffective mainly, it is thought, due to the exceptionally high UK populations of *Hylobius* (Moore *et al.*, unpublished). Population levels in the UK and Ireland are often at least 7 times higher than those found on the most populous sites in Sweden (Moore *et al.*, unpublished), which is one reason that some non-chemical approaches that may be effective elsewhere in Europe are not successful here.

Physical protection products found to be effective in other countries, but less effective in the UK, include the following flexible stem coatings applied before planting:- wax (Kjvaee Wax); polysaccharide stem coating (Flexcoat); and a sand and glue based stem coating treatment (Conniflex). In addition, the following physical barriers were also tested and found to be generally ineffective in the UK unless *Hylobius* population levels are low:- custom made plastic weevil guards (MultiPro, and Biosleeve) fitted on site after planting; and lightweight plastic nets (WeeNets) fitted around the root plug and lower stem of the tree at the nursery.

Therefore, physical protection methods are only useful if the *Hylobius* Management Support System or an alternative method of estimating population levels is used and the on-site population is predicted to be low, and if they are combined with site preparation to create a weed and brash free site around the planted tree. In these limited circumstances physical barriers may be a suitable substitute for the use of insecticides.

3.4.4. Insecticides

Unfortunately, even using a combination of non-chemical strategies it is often not possible to avoid the problem of *Hylobius* damage to young trees. In these circumstances, where there are no practical alternatives not involving excessive cost, the only option remaining to allow forest regeneration may be to treat young plants with insecticide. Used correctly, this can be a safe, effective, and economic means of protecting trees. Insecticides can be used before planting ('pre-planting'), during or immediately after planting ('post-planting'), possibly combined with further re-applications at intervals if weevil populations are high and persistent ('post-planting top-up spraying'). Whilst this strategy normally provides very effective protection of seedlings, it has little effect on total populations of weevils on site and when used in isolation, if populations are very high, occasionally the insecticide protection can be overcome.

Currently, the only chemical insecticides approved by the UK Health and Safety Directorate for use in forests to protect against *Hylobius* damage are alpha-cypermethrin, cypermethrin, and acetamiprid. Alpha-cypermethrin and cypermethrin are

non-systemic pyrethroid insecticides with high activity against *Hylobius*, but they are both potentially very toxic to the aquatic environment if misused, even if only very small quantities were to pollute water courses.

Alpha-cypermethrin is only used to treat trees off-site in horticultural tree nurseries, before planting in the forest, and therefore represents a very low risk of damage to the wider environment. Consequently, use in this way is permitted on estates voluntarily certified to Forest Stewardship Council standards via the UK Woodland Assurance Standard without a special derogation (FSC, 2005; UKWAS, 2012).

Cypermethrin has been the preferred insecticide for post-planting top-up sprays to protect young trees from high population levels of *Hylobius* for several years, but environmental concerns have led to a collaborative research effort across the UK forest industry to search for less hazardous alternatives. The concerns around cypermethrin have been over: a) its toxicity to aquatic life if misused, b) its classification as a priority substance under the European Commission Water Framework Directive meaning emissions have to be progressively reduced, and c) the fact that it is classified as 'highly hazardous' by the Forest Stewardship Council so that it cannot be used for post-planting top-up sprays on estates voluntarily certified to FSC standards via UKWAS without a special derogation (FSC, 2005; UKWAS, 2012).

As already noted, the collaborative research programme found that physical protection products were of limited use. Repellents, and natural product insecticides such as garlic, azadirachtin derived from Neem oil, spinosad and pyrethrins were also tested and found to be ineffective. However, acetamiprid was found to be highly effective in preventing *Hylobius* damage to young trees (Moore *et al.*, unpublished; Moore *et al.*, in prep.).

Acetamiprid is a systemic neonicotinoid insecticide that is widely used to control aphids and other damaging insects in agricultural and horticultural crops such as apples, tomatoes, potatoes and oilseed rape, as well as being used extensively in home garden insecticides. Acetamiprid is at least 500 times less toxic to aquatic life than cypermethrin, based on Predicted No Effect Concentrations (PNEC) of 500 ng/l for acetamiprid and 1 ng/l for cypermethrin (European Commission, 2004a; 2005), although when formulated as the pesticide product Gazelle SG it is still classed as potentially very toxic to aquatic life if misused, due to its effect on the early life stages of aquatic insects - see the Appendix for further details. It is therefore increasingly being phased in for post-planting top-up sprays as a replacement for cypermethrin.

3.4.4.1 Pre-plant treatment with alpha-cypermethrin (Alpha C 6ED) applied through an Electro-dyn spray booth

This is a specialised, fully enclosed application system located in industrial buildings in horticultural tree nurseries or depots. It is not used in a forest environment, but as part of the nursery plant production process to pre-treat trees before they reach the forest. The machinery generates electrostatically charged spray droplets that are attracted to the earthed transplants passing on a conveyor belt, enabling use of small volumes of

insecticide (0.1 ml per tree of Alpha C 6ED, equivalent to 0.006 g of alpha-cypermethrin per plant) allowing rapid drying, and providing consistent positioning of the band of insecticide onto the lower part of the stem and root collar of the tree only. The Electrobyn system can only be used with specially formulated pesticides, in this case the forest nursery approved product Alpha C 6ED (60 g/l alpha-cypermethrin; Techneat, 2007).

Treating plants in this way ensures a high level of operator protection, and allows plants to be transported soon after application without the need for a prolonged period of drying. Because pre-treated plants are delivered dry with the insecticide having been absorbed into the tree bark, as long as the trees are not put directly into watercourses, there is very little risk of any environmental contamination. Although the active ingredient alpha-cypermethrin itself is toxic to bees, there is almost no risk of exposure to bees when it is used in this way (see the Appendix for further detail on the risk of exposure to bees from insecticide treated trees).

The product Alpha C 6ED is harmful if swallowed or inhaled, so in addition to adopting protective measures when it is being applied using the Electrobyn machinery, anyone handling or planting treated trees must wear the appropriate personal protective equipment, and vent planting bags for 1 hour on site after delivery to the forest to allow any build-up of the volatile naphtha solvent oil to dissipate (see FISA, 2013a+b). Accidental contamination of forest users by alpha-cypermethrin is highly unlikely as only the lower part of the stem of relatively small trees is treated, and as the insecticide is dry it is unlikely to transfer through accidental contact, and even then it is not hazardous in contact with the skin. A full review of the hazard characteristics of alpha-cypermethrin is given in European Commission (2004b). A summary of some of these characteristics, for comparison with other insecticides approved for use against *Hylobius*, is given in Table 3. The Alpha C 6ED product label and approvals document (Health and Safety Executive, 2007; Techneat, 2007) are essential reading and give full details of application methods and other important information for the safe and effective use of the pesticide.

3.4.4.2 Pre-plant treatment with acetamiprid (Gazelle SG) applied via spray booth machinery

This system uses purpose-built spray booth machinery in the nursery to generate a conventional aqueous spray delivering no more than 0.185 g of Gazelle SG product (20% w/w acetamiprid; Certis, 2017) per plant, or 0.037 g acetamiprid active ingredient per plant. The spray booth provides controlled treatment with minimal operator exposure and the plants are left under cover to dry before despatch. Again, in addition to the usual requirement to protect operators when spraying, anyone handling or planting treated trees must wear the appropriate personal protective equipment (see FISA, 2013b.)

As with the Electrodyn system, because plants are treated off-site in an industrial building in a horticultural tree nursery, and are delivered with the insecticide having been absorbed by the tree, as long as the trees are not put directly into watercourses, there is very little risk of any harmful environmental contamination, or risk to forest users or bees.

Details of the hazard characteristics of acetamiprid, based on the advice issued by the Health and Safety Executive, are given in the Appendix. A summary of some of these characteristics, for comparison with other insecticides approved for use against *Hylobius*, is given in Table 3. The Gazelle SG product label and approvals documents (Health and Safety Executive 2011; 2012; 2016; Certis, 2017) are essential reading and give full details of application methods and other important information for the safe and effective use of this pesticide.

3.4.4.3 Immediate post plant spraying with cypermethrin or acetamiprid

If pre-treated trees are not used, it may be possible on a small scale to spray untreated trees immediately after planting with cypermethrin or acetamiprid (see below). This operation must be carried out as soon as stock is planted in order to avoid the high risk that the unprotected plants will be damaged or killed. Both conifers and broadleaves can be treated. However, a cheaper and more effective approach, particularly in larger scale plantings, is to use trees pre-treated in the nursery with acetamiprid or alpha-cypermethrin before planting. In addition, as noted above, nursery treatments can be applied in more controlled conditions, and the resulting risk to the wider environment from the insecticide application is considerably lower.

3.4.4.4 Post plant top up spraying with cypermethrin or acetamiprid

Even if pre-treated trees are used, top-up spraying of cypermethrin or acetamiprid is normally required in the spring of the second year after planting, and sometimes in the autumn of the first year, unless *Hylobius* population levels are low or if a fallow period strategy has been followed.

Typically, if insecticide pre-treated Sitka spruce with larger root collar diameters (e.g. 1½ + 1½ stock) are used, by the autumn of the second year after planting trees are often large enough to resist attack. Smaller plants, or those of other species such as Douglas fir, may need protecting for up to 4 years or more after planting. In all cases the risk is dependent on residual weevil population density on site which in turn depends on factors such as the length of fallow period adopted before planting. Young trees need to be monitored closely during the peak damage times (April – June, and August – October) and treated at the first sign of damage.

For some species and sites, if damage starts to occur, further treatment may be required in the spring and autumn of subsequent years. However, poor weather conditions, particularly rain or wind, may prevent a site being sprayed immediately damage is

recorded, which may mean that trees are damaged so severely that they die before they can be sprayed with insecticide.

Therefore, rather than simply reacting to damage when it occurs, it is recommended that the *Hylobius* Management Support system, or similar, is used to predict likely future risk, and hence avoid unnecessary damage by applying a top-up spray before the onset of damage where required, and also to avoid prophylactic spraying when it is unnecessary and minimise the use of insecticides. It is recommended that a marker dye such as a 2% solution of the food dye Dysol Turquoise (to give an equivalent of 0.8% active ingredient Acid Blue 9 in the final spray volume) is used help target the top-up spray, minimise drift, and prevent unnecessary run-off (Brown *et al.*, 2003). Only trained operators can legally apply pesticides in the forest, and the legal requirements are summarised in the appropriate Pesticides Code of Practice (DEFRA, 2006; Scottish Executive, 2006). Normal good working practices for top-up spraying, including required personal protective equipment, are summarised in FISA (2013a).

Forester (100g/l cypermethrin; Fargro, 2009) is approved for post-planting use in forests. It should be applied as a 10–20 ml spray of a 2% solution of Forester in water (i.e. 20 ml of Forester in 1 litre of water, equivalent to a 0.2% solution of cypermethrin active ingredient), using a handheld knapsack sprayer or spot gun or equivalent. This results in an equivalent of up to 0.4 ml of Forester being applied per tree, or 0.04 g per tree of cypermethrin active ingredient. In conifers, feeding starts in the upper parts of the roots and progresses to the main stem, therefore the spray should be carefully directed to cover the entire circumference of lower half of the stem, allowing the solution to flow down the stem and onto the root collar. Run-off into the soil, or drift to surrounding soil or vegetation should be minimised through the use of low spraying pressures (around 1 bar) and suitable nozzles, such as an adjustable cone nozzle. In broadleaves, *Hylobius* starts to feed at the main bud and progresses down the stem, so the upper part of the tree stem should be treated as well as the lower part. Three applications are permitted each year.

A full review of the hazard characteristics of cypermethrin is given in European Commission (2005). A summary of some of these characteristics, for comparison with other insecticides approved for use against *Hylobius*, is given in Table 3. The Forester product label and approvals document (Health and Safety Executive, 2009; Fargro, 2009) are essential reading and give full details of application methods and other important information for the safe and effective use of this pesticide.

Gazelle SG (20% w/w acetamiprid; Certis, 2017) is also approved for post-planting use in forests. It should be applied as a 10–20 ml spray of a 0.92% solution of Gazelle SG in water (i.e. 9.25 g of Gazelle SG in 1 litre of water, equivalent to a 0.184% solution of acetamiprid active ingredient), using a handheld knapsack sprayer or spot gun or equivalent fitted with a suitable nozzle such as an adjustable cone nozzle. This results in an equivalent of up to 0.185 g of Gazelle SG, or 0.037 g of active ingredient per tree. The spray should be carefully directed to cover the entire circumference of lower half of

the stem, allowing the solution to flow down the stem and onto the root collar. In addition the foliage should be treated, as this allows the systemic insecticide to be absorbed and then translocated around the plant. Run-off into the soil, or drift to surrounding soil or vegetation, should be minimised through the use of low spraying pressures (around 1 bar) and suitable nozzles, such as an adjustable cone nozzle. A maximum of 416.25 g/ha of Gazelle SG or 83.25 g of acetamiprid can be applied per hectare per application, and two applications are permitted each year. For each application this is an equivalent of treating 2250 trees at 0.185 g of Gazelle SG per tree and gives the optimum levels of protection, but for higher initial planting densities the dose rates per tree need to be reduced. Minimum rates of 0.111 g of Gazelle SG per tree are still moderately effective, which would allow up to 3750 trees per hectare to be treated, whilst staying within the maximum permitted dose per hectare. However, there are some indications that on the sites with the highest *Hylobius* population levels, the lower minimum rate of 0.111 g per tree may not be sufficient to prevent all damage (Moore *et al.*, unpublished). Therefore on the sites which are predicted to have the very highest *Hylobius* population levels, if the aim is to reduce the number of trees that need to be replaced (beaten up), it may be better to reduce initial planting densities as far as possible towards 2250 stems per hectare, to allow as close as possible to the maximum rate of 0.185 g of Gazelle SG per tree to be used.

Details of the hazard characteristics of acetamiprid, based on the advice issued by the Health and Safety Executive, are given in the Appendix. A summary of some of these characteristics, for comparison with other insecticides approved for use against *Hylobius*, is given in Table 3. The Gazelle SG product label and approvals documents (Health and Safety Executive 2011; 2012; Certis, 2017) are essential reading and give full details of application methods and other important information for the safe and effective use of this pesticide.

Table 2. A summary of the relative costs, efficacy and potential risks of the main remedial control measures available for protecting trees from damage by *Hylobius abietis*

Method	Approximate cost per treated ha per operation ¹	Approximate total cost per ha for satisfactory restocking ^{1,2}	Efficacy	Summary of potential environmental risks	Comments
Non-chemical methods					
Cultivation to expose mineral soil	£200 - 600 ³	Not possible	Can give some benefit, but unlikely to reduce damage to an acceptable level by itself.	Soil erosion, water sedimentation, nutrient leaching, soil carbon loss, especially on organic soils, destruction of soil fauna, disruption of ground nesting birds and archaeology, and possible atmospheric pollution (especially if machinery is poorly maintained) can all result from inappropriate cultivation if guidelines are not followed.	Mounding or scraping of the soil at the planting position is necessary. This technique will result in the greatest reduction in weevil damage when used on sites with a high density of woody weeds. Planting should be in the centre of the cleared area of mineral soil.
Stump removal	Very variable, but can be in the region of £450–650	Not possible	Can help to reduce damage but may not be wholly effective by itself.	Soil and habitat disturbance, potential soil compaction. On steep sites, potential soil erosion and water sedimentation. Likely increase in decomposition of soil organic matter leading to a reduction of soil carbon stocks. Possible atmospheric pollution from machine use, especially if it is poorly maintained. Removal of stumps from site will result in some loss of nutrients and an increased risk of soil acidification.	De-stumping will be more effective if carried out within a few months of felling. However, some larvae are likely to remain in any roots, stems or branches left on site. Removal of stumps is only worth considering where there is a ready market for the resulting biomass, and where sites are flat and relatively easy to de-stump with a low risk of negative impacts, or there are other particular benefits such as disease control. Stumps should not be windrowed, because <i>Hylobius</i> may still emerge from them. De-stumped ground is ideal for machine-planting the next rotation of trees.
Mulching	£500–2000 ³	Not possible	Can help to reduce damage but may not be wholly effective by itself.	Severe soil and habitat disturbance, although probably somewhat less than for stump removal. Risk of possible atmospheric pollution from machine use, especially if it is poorly maintained, damage to soil and overstorey stems from flailing and any subsequent burning, and atmospheric pollution from burning.	Mulching is likely to be somewhat more effective than de-stumping, if it also destroys roots and branches. Mulching will be more effective if carried out within a few months of felling. However, some larvae are likely to remain in any roots, stems or branches left unmulched on site. It is probably only worth considering if mulching is planned anyway to prepare site prior to planting, and even then careful monitoring of subsequent insect emergence and damage is required. The site may need to be raked and burnt or scarified after mulching to allow planting. Mulching is only worth considering where sites are flat, well drained and relatively easy to work with a low risk of negative impacts.
Tree shelters	£4250 (£1.70 per 1.2 m tall shelter) ³ £5500 (£2.20 per 1.8 m tall shelter) ³	£4250 £5500	Potentially effective, but only if shelters are properly fitted, regularly inspected and maintained.	Unless fully biodegradable or removed, tree shelters will form a source of plastic / petrochemical pollution at the end of their life. Many conifers are not suited to growth in tall tree shelters as they can become unstable when they emerge from the tops of the shelter.	Not economic for protection from <i>Hylobius</i> alone, but if being used anyway to protect trees from browsing mammals, their use may be a viable option. The shelters need to be removed after trees are established.

Proprietary physical barriers, e.g. WeeNet, MultiPro, Biosleeve	Limited trials suggest a cost (materials; fitting and extra planting cost) of around £300 - £1100 ha ⁻¹ , depending on the type of guard fitted, and whether or not plants are supplied with guards pre-fitted. This does not include maintenance costs which could be considerable, depending on design	In the UK, only effective on sites with low <i>Hylobius</i> population levels.	Unless fully biodegradable or removed, they will form a source of plastic / petrochemical pollution at the end of their life.	Can be effective if used in conjunction with the <i>Hylobius</i> Management Support System to identify sites that will only be subject to low population pressure. In the UK, not effective on sites with medium or high <i>Hylobius</i> population levels. The barriers require careful positioning to ensure that they are effective; the ground surrounding the barrier should be level and free from weed and felling debris. The site should be regularly inspected and the barriers maintained to ensure they are pushed into the ground and that no bridging has occurred. Most designs of barrier are designed to split after the main risk from damage is over and in theory may not need to be removed to allow continued tree growth. Non-porous barriers may make subsequent insecticide spraying, if required, difficult unless the guards are removed. Flexible stem coatings have been found to be often ineffective in the UK.
Nematodes: <i>Steinernema carpocapsae</i>	Approximate cost of £350 per ha per year during the 3-4 treatment years.	Can be effective in allowing trees to establish on some sites.	Insect parasitic nematodes are naturally occurring and have no known adverse impacts on non-target organisms. Atmospheric pollution may be possible from application machinery, particularly if it is poorly maintained. Soil compaction is possible from machine trafficking.	If used in conjunction with the <i>Hylobius</i> Management Support System, on consecutive clearfell sites within large forest blocks, may over 3-4 years reduce population levels sufficiently such that no further remedial control measures are required (i.e. insecticide use is not required). Not suitable for small scale, sporadic or isolated clearfells, or on steep sites or where the high volumes of water required cannot be sourced or transported.

Chemical methods

Insecticides, general			Can be very effective, even on sites with high <i>Hylobius</i> population pressure.	If misused, all insecticides present a risk to operator health, risk of soil and water pollution, potential risk of poisoning of wildlife and damage to non-target vegetation and insects. Risks are reduced by spot treatment in the forest or use under highly controlled conditions in off site horticultural tree nurseries. No long-term harmful effects have been detected at planting sites.	
Pre-plant treatment of trees with alpha-cypermethrin applied via ElectroDYN spray booth	£80	£80-£440	Provides very good protection for first season, but dependent on weather and pest population	Used only in highly controlled conditions in off-site horticultural tree nurseries, where if not adequately controlled the insecticide could be harmful if swallowed or by inhalation. Once the insecticide has dried on stems, there is believed to be a low risk to the wider environment when treated trees are planted in the forest, but planters still need to wear PPE.	Only suitable for bare-rooted stock treated before planting. The plants usually require additional top-up treatment(s) in the second and sometimes the third year after planting, particularly when insect populations are high and if small sized plants are used ⁴ .
Pre-plant treatment of trees with acetamiprid	£30	£30-210	Provides very good protection for first season, but dependent on weather and pest population.	Used in highly controlled conditions in off-site horticultural tree nurseries, where if not adequately controlled the insecticide could be harmful if swallowed. Once the insecticide has dried on stems, there is believed to be a low risk to the wider environment when treated trees are planted in the forest, but planters still need to wear PPE.	The plants usually require additional top-up treatment(s) in the second and sometimes the third year after planting, particularly when insect populations are high, and if small sized plants are used ⁴ .

Post-plant top-up spraying with cypermethrin	£60	£240 - £480	Provides protection for around 8-10 weeks after application, depending on population levels.	With proper controls in place cypermethrin can be used safely in the forest, but cypermethrin is a broad spectrum insecticide and if misused many non-target insects could be killed. It is harmful if swallowed, irritating in contact with skin and a skin sensitizer, very toxic to aquatic organisms and dangerous for the environment, and may cause long term adverse effects in the aquatic environment. Once the insecticide has dried on stems, there is believed to be a low risk to the wider environment.	Treatment must take place during dry weather and all normal controls and good working practices when using pesticides must be in place. The deposit becomes rain fast once dry. Applications should be timed such that a minimum rain free period of at least 1 hour, and preferably 6 hours, occurs after spraying. Dyes may be added to the solution to check coverage. Plants typically need treatment for at least 2 years after planting with 1-2 treatments a year, depending on population levels. Population and likely damage due to <i>Hylobius</i> can be predicted by using the <i>Hylobius</i> Management Support System, which avoids the need for unnecessary prophylactic sprays or waiting for damage to occur before treating. If combined with the use of pre-treated trees, top-up spraying may only be required for the second year after planting (i.e. total cost of protecting trees to establishment of around £120 /ha). For some species and sites top-up spraying may be required for 4 years or more after planting ⁴ . Individual treatment costs, efficacy and environmental risks are identical for immediate post-planting spraying of cypermethrin.
Post-plant top-up spraying with acetamiprid	£30	£120-240	Provides as good as or better protection than cypermethrin due to its systemic activity, i.e. effective for at least around 8-10 weeks after application, depending on population levels.	With proper controls in place acetamiprid can be used safely in the forest, and compared to cypermethrin it is more selective, less hazardous to the aquatic environment and less hazardous to bees. However, if misused acetamiprid is harmful if swallowed, very toxic to aquatic organisms and dangerous for the environment, and may cause long term adverse effects in the aquatic environment. Once the insecticide has dried on stems, there is believed to be a low risk to the wider environment.	Treatment must take place during dry weather and all normal controls and good working practices when using pesticides must be in place. The deposit becomes rain fast once dry. Applications should be timed such that a minimum rain free period of at least 1 hour, and preferably 6 hours, occurs after spraying. Dyes may be added to the solution to check coverage. Plants typically need treatment for at least 2 years after planting with 1-2 treatments a year, depending on population levels. Population and likely damage due to <i>Hylobius</i> can be predicted by using the <i>Hylobius</i> Management Support System, which avoids the need for unnecessary prophylactic sprays or waiting for damage to occur before treating. If combined with the use of pre-treated trees, top-up spraying may only be required for the second year after planting (i.e. total cost of protecting trees to establishment of around £90 /ha). For some species and sites top-up spraying may be required for 4 years or more after planting ⁴ . Individual treatment costs, efficacy and environmental risks are identical for immediate post-planting spraying of acetamiprid.

Notes

- 1 Costs are approximate and are included for comparison purposes only, and may not reflect the actual cost achievable in particular circumstances and locations. The cost for individual insecticides includes chemical plus application costs, assuming 2500 trees being treated per hectare.
- 2 The total cost figure includes any repeat treatment that may be required to achieve satisfactory restocking using only this single method. In reality, a combination of different techniques is often required.
- 3 This operation may be being undertaken in any case for its silvicultural benefits, in which case there is effectively no marginal cost for any additional *Hylobius* protection obtained.
- 4 The number of years for which the plants will require protection will also depend on factors such as the length of any pre-planting fallow period imposed and the size of the *Hylobius* population.

Table 3. A comparison of some of the hazard characteristics of insecticides used for protecting trees from damage by *Hylobius abietis*

Pesticide	Mode of action	Rate applied active ingredient (kg ha ⁻¹)	Rate applied active ingredient (mg m ⁻²)	Active ingredient toxicity to mammals (rats): oral (LD ₅₀ , mg kg ⁻¹) ¹	Active ingredient toxicity to mammals (rats): contact (LD ₅₀ , mg kg ⁻¹) ¹	Active ingredient toxicity to mammals (rats): oral NOEL (mg kg ⁻¹ daily by body weight) (duration) ²	Formulation toxicity to mammals (rats): oral (LD ₅₀ , mg kg ⁻¹) ¹	Formulation toxicity to mammals (rats): contact (LD ₅₀ , mg kg ⁻¹) ¹	Hazard classification of product formulations	Toxicity to invertebrates (bees): contact (LD ₅₀ µg per bee) ¹	Hazard classification of product formulation: potential risk to aquatic life	FSC 'highly hazardous' list	Persistence in soil DT ₅₀ (days) ³
Alpha-cypermethrin	Insecticide	0.02	2	57	>2 000	> 1.5	629	2 000	Harmful by inhalation or if swallowed, may cause lung damage if swallowed Skin sensitizer.	Not toxic ⁴ 0.059	Very toxic May cause long term adverse effects Dangerous for the environment	Yes ⁵	91
Cypermethrin	Insecticide	0.05-0.1	5-10	250-4150	>4 920	5 (2 years)	300-2 000	>2 000	Harmful if swallowed Irritating to skin Skin sensitizer	Not toxic ⁴ 0.02	Very toxic May cause long term adverse effects Dangerous for the environment	Yes ⁶	35
Acetamiprid	Insecticide	0.08	8	314	>2 000	7.1 (2 years)	1 065	>2 000	Harmful if swallowed	Not toxic ⁷ 8.1	Very toxic ⁸ May cause long term adverse effects Dangerous for the environment	Yes ⁹	1-5

Notes

This table is a collation based on published information from MacBean (2012), European Commission review reports, individual product material safety data sheets and product labels. No testing has taken place by Forest Research. **The table is intended as a guide to the relative characteristics of different pesticides for general comparison purposes only, to aid in the selection of the least hazardous pesticide option, if there are no viable non-chemical alternatives. Different approved products with the same active ingredients may have different characteristics. Refer to the product label and material safety data sheet for specific products for definitive information on hazards and safety before making and final decision on pesticide selection, and before making any application.**

- 1 LD₅₀ is the lethal dose of the substance in milligrams of active ingredient for each kilogram of bodyweight of the target that, if ingested, is likely to kill 50% of the population.
- 2 NOEL is the No Observable Effect Level, the amount that can be consumed daily for each kilogram of body weight of the consumer with no observable effect.
- 3 DT₅₀ is the half-life for the substance in soil, the time taken in days for 50% of the substance to break down. It gives an approximate estimate only of likely persistence in soil. Actual breakdown rates will depend on soil type and weather conditions. Breakdown in water and plants is often quicker. Often a substance may be bound up and effectively safely immobilised in soil very rapidly, even though actual decomposition may take many days.
- 4 Although the active ingredient itself can clearly be highly toxic to invertebrates, the UK Health and Safety Directorate have judged that the product formulation will not be harmful to bees when used as directed.
- 5 No FSC derogation required for plant pre-treatment in off site horticultural tree nurseries.
- 6 Temporary FSC derogation for use in certified forests until 31st October 2017.
- 7 Although the active ingredient itself can clearly be toxic to invertebrates, the UK Health and Safety Directorate have judged that the product formulation will not be harmful to bees when used as directed.
- 8 Acetamiprid is around 500 times less toxic to aquatic life than cypermethrin although the products themselves have similar broad hazard classifications – see the Appendix for details.
- 9 Although in theory on the FSC 'highly hazardous' list, the need for a derogation in certified forests is suspended pending a review of FSC pesticides policy.

4. Conclusions

Hylobius abietis can cause catastrophic damage to newly planted trees, effectively preventing regeneration within recently felled areas of conifer forest. It is recommended that an integrated approach to the management of this pest is adopted, firstly by understanding its life cycle and likely impacts, and then by considering the full range of potential approaches available to prevent it damaging young trees, if necessary by using different techniques in combination with each other. Although research into non-chemical approaches is ongoing, currently on many sites in the UK and Ireland it is likely that insecticides will still need to be used as part of the integrated management of *Hylobius*. Where insecticide use is unavoidable, pre-treatment of young trees in an off-site horticultural tree nursery with alpha-cypermethrin or acetamiprid, possibly combined with later post-planting top-up sprays in the forest of those trees with acetamiprid, when used as described on the Health and Safety Executive approved pesticide product labels, and when combined with the additional precautionary measures in place as described in this Note, should not pose any unacceptable risk to consumers, operators, bystanders, neighbours or the wider environment.

5. References

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Appendix 1.

6. Acetamiprid safety

6.1. Introduction

Acetamiprid is a systemic, neonicotinoid insecticide that is widely used to control aphids and other damaging insects in agricultural and horticultural crops such as apples, tomatoes, potatoes and oilseed rape, as well as being used extensively in home garden insecticides.

Acetamiprid is used in forestry in a very different way to conventional agricultural insecticide spraying. Instead of mechanised boom sprayers on tractors applying a chemical to entire fields, forest use of acetamiprid involves carefully directing a maximum of 20 millilitres of the dilute insecticide formulation (an equivalent of 0.185 g per tree of Gazelle SG, or 0.037 g per tree of acetamiprid) via handheld applicators as a targeted spray, minimising run-off, onto the vulnerable part of the stem and foliage of each young tree (which are usually between 15 centimetres to 1 metre in height) without overspraying the surrounding soil or vegetation. Unlike arable or horticultural crops, insecticide applications in forestry are normally only made once or twice a year for the first 2-3 years of a typical forest rotation of 50-80 years.

Pesticide surveys have estimated that a total of 425,733 kg of insecticide active ingredient (a.i.) was used in agricultural and horticultural situations in 2015, and this included 308 kg of acetamiprid (FERA, 2017). There are no equivalent surveys of insecticide use in forestry by which to make direct comparisons, but likely future annual usage can be very roughly estimated based on the total area of forests that are restocked with coniferous species, which in 2015 was reported to be 9,900 ha (Forestry Commission, 2016). If top-up sprays of acetamiprid were to be made on all restocking sites then a theoretical absolute maximum of 824 kg a.i. of acetamiprid might be used. However, on average at least 15% of the area of any restocking site is occupied by roads, rides, and watercourses (Hamilton and Christie, 1971), and so would never be treated. Of the remaining 8,400 ha, the majority of sites would not be treated either because *Hylobius* populations did not warrant it, or because other methods of avoiding the problem or other non-chemical remedial control methods could be adopted. Based on typical past insecticide usage in the state forest sector, including sites treated in multiple years, it is likely that only around 40% of the total restocking area would ever be treated, giving a maximum GB area treated of very roughly around 4,000 ha per year, equating to an estimated realistic maximum annual use in GB forestry at current restocking levels of around 300 kg a.i. acetamiprid (this excludes the amount of acetamiprid used to treat trees in horticultural nurseries that are then subsequently planted out in the forest). As very few if any other insecticides are likely to be used, the

total amount of active ingredient of insecticides applied in GB forests each year is also unlikely to exceed 300 kg.

In judging whether or not it is safe to use an insecticide such as acetamiprid, Forest Research, and the wider forest industry, relies on the expert advice and guidance provided by the Chemicals Regulation Division of the UK Health and Safety Executive, whose primary focus is the protection of human health and the environment (Health and Safety Executive, 2017a).

6.2. The approvals process for acetamiprid

Acetamiprid has been subject to international peer review of toxicology and environmental impact by the 28 member states of the European Union (European Commission, 2017). The chemical has been accepted as safe to use in Europe (European Commission, 2004a). In 2015, acetamiprid was placed on a 'Watch List' under the Environmental Quality Standards Directive for the purpose of collecting more high quality water monitoring data to help determine whether any further risk reduction measures are required (European Commission, 2015).

In the UK, pesticide use is subject to stringent government controls through legislation such as the Control of Pesticides Regulations, the UK implementation of the Sustainable Use Directive and the Plant Protection Products Directive, and the Control of Substances Hazardous to Health Regulations. Regulatory control is enforced by the Health and Safety Executive (Health and Safety Executive, 2017a). After expert scientific scrutiny of all available safety data, the Health and Safety Executive have judged that acetamiprid, and the product Gazelle SG (20% w/w acetamiprid; Certis, 2017), do not pose an unacceptable risk to consumers, operators, bystanders or the wider environment if used according to the conditions of use they have specified on the approved product label, and hence have granted approval for its use in agricultural, horticultural and home garden situations (Health and Safety Executive, 2017b; Certis, 2017).

Because research showed acetamiprid to be as effective as cypermethrin in protecting young transplants from damage by *Hylobius* (Moore *et al.*, in prep.), whilst being at least 500 times less toxic to aquatic life than cypermethrin (based on Predicted No Effect Concentrations (PNEC) of 500 ng/l for acetamiprid and 1 ng/l for cypermethrin) (European Commission, 2004a; 2005), the forest industry applied to the Chemicals Regulation Division of the Health and Safety Executive for an Extension of Authorisation for Minor Use (often abbreviated to 'EAMU') to use Gazelle SG (containing acetamiprid) in forests. After reviewing all of the safety data, the Health and Safety Executive judged that this new use did not pose any additional risk to operators, bystanders and the wider environment, and hence they granted an approval (Health and Safety Executive, 2012).

Safety assessments such as those carried out on acetamiprid are subject to periodic reviews to ensure that conditions of use and any restrictions in approval are in line with the latest internationally peer reviewed evidence and experience. Any changes in the

conditions of use specified by the Health and Safety Executive as a result of this process would have to be fully complied with by the forest industry.

Forest Research, and the wider forest industry, relies on this independent, expert assessment of safety, and the summary of the risks involved in using acetamiprid presented in this Note is based largely upon the assessments published by the European Commission (European Commission, 2004a), and on the conditions of use specified in the approved product label for Gazelle SG by the Health and Safety Executive (Certis, 2017; Health and Safety Executive, 2017b). These bodies should be contacted directly if further detail of the data, studies and methodology they have used to come to their conclusions is required.

6.3. Some hazard and risk characteristics of acetamiprid

Multiple studies have shown that acetamiprid has a lower impact on bee species than other neonicotinoids, and to date it has not been linked to bee decline (e.g. Lundin *et al.*, 2015). It is 400 times less toxic to bees than cypermethrin, the insecticide it is increasingly replacing for protecting trees (based on a contact LD₅₀ to bees of 0.02 µg per bee for cypermethrin and 8.1 µg per bee for acetamiprid) (European Commission, 2004a; 2005). When acetamiprid is formulated as the product Gazelle SG and used according to the conditions of use on the product label, it is not classified by the Health and Safety Executive as toxic to bees (Certis, 2017).

In common with most insecticides the active ingredient acetamiprid could, in theory, be toxic to bees if it were to be ingested by them. However, once the sprayed product has dried on the planted trees, it is likely that bees would have to ingest parts of the plant to have significant exposure to the insecticide. Since they do not feed on trees and are unlikely to land on the tree stems or foliage when foraging, cross contamination is therefore highly unlikely. No deliberate spraying of surrounding soil or vegetation should take place, so that even if other flowering plants that bees might forage from for nectar and pollen establish on a clearfell site, these plants would not be sprayed, although there is a theoretical risk of misapplication causing spray drift onto these flowering plants. Honey bees are also unlikely to come into contact with treated trees while sourcing resin to make propolis since they are more likely to obtain resin from the much larger source associated with any nearby mature trees.

The product Gazelle SG, is classified by the Health and Safety Executive as harmful to humans if swallowed (Certis, 2017). Acetamiprid itself has an oral toxicity to rats (one measure of which is the LD₅₀ – the lethal dose of the substance for each kg of body weight of the target that, if ingested, is likely to kill 50% of the population) of 314 mg/kg bodyweight (1 milligram (mg) = 0.001 g) (European Commission, 2004a). This is a similar level of toxicity to caffeine (LD₅₀ 367 mg/kg bodyweight; Adamson, 2016), and represents a level of toxicity that is classified as 'Moderately Hazardous' by the World

Health Organisation. Based on studies reported by the European Commission, an average person weighing 70 kg could in theory consume 7 mg (0.007 g) of acetamiprid with the likelihood that there would be no short or long term effects on their health. This is based on an acute reference dose (ARfD) for acetamiprid of 0.1 mg/kg bodyweight per day (European Commission, 2004a), where the acute reference dose is defined as the amount that can be ingested over a short period of time, usually during one meal or one day, without appreciable health risk to the consumer on the basis of all known facts at the time of evaluation (European Commission, 2001). Nevertheless, the aim should be to prevent any exposure to users of the forest, or those living in or close to it. This can be achieved by following normal good working practices such as carefully targeting the spray onto the foliage and stems of small trees, erecting warning signs to warn users to avoid the plants until they are dry, and adopting adequate no-spray buffer zones.

Acetamiprid is not persistent in soil and rapidly degrades by aerobic metabolism to non-toxic metabolites. The chemical half-life in soil is quoted as ranging from < 1 to 8.2 days in the field (US EPA, 2002). Acetamiprid is highly soluble in water and weakly absorbed by the soil, making it moderately to highly mobile in most soils. It is metabolised moderately rapidly in aerobic aquatic conditions (European Commission, 2004a; MacBean, 2012).

The Health and Safety Directorate classify the product Gazelle SG as potentially very toxic to aquatic life with long lasting effects if it is misused, because although it is relatively safe to fish, it can readily kill the early life stages of aquatic insects. However, provided it is used as directed on the approved product label to prevent water contamination, the Health and Safety Executive have concluded that Gazelle SG does not pose an unacceptable risk of harm to the wider environment (Certis, 2017). To help prevent water contamination, one important restriction and condition of their approval for Gazelle SG is the use of 1 metre wide no-spray buffer areas separating treated trees and all watercourses. However, to further minimise the risk of the chemical reaching streams, the UK Forestry Standard extends this level of protection by stipulating the precautionary use of much wider buffers than the 1 metre minimum legal requirement (Forestry Commission, 2017). Recommended buffer widths for all pesticide applications in forestry, which have been adopted in forests being managed to the UK Forestry Standard (Forestry Commission 2017), which is independently verified in those estates certified via the UK Woodland Assurance Standard (UKWAS, 2012), are as follows:-

- For permanent watercourses with a channel < 2 metres wide – a minimum 10 metre wide unsprayed buffer zone.
- For watercourses > 2 metres wide, and for lakes, reservoirs, large ponds and wetlands – a minimum 20 metre wide unsprayed buffer zone.
- Around abstraction points for public and private water supplies, such as springs, boreholes, wells and surface water intakes – a minimum 50 metre wide unsprayed buffer zone.

A permanent watercourse is defined as a stream or river that is delineated on a 1:10,000 Ordnance Survey map, or an open drain that flows directly into a stream. Drains that are separated from watercourses by an adequate buffer area are excluded from this definition. Boggy source areas for streams, even if they are dry at the time of pesticide application, are counted as part of the watercourse. Before spraying pesticides, checks should be made to ensure that any drainage channels in the area to be treated do not discharge directly into watercourses, and where they do, buffer areas should be extended along these. No-spray buffer zones should also not be used for mixing and filling.

The UK Forestry Standard (Forestry Commission, 2017) includes a number of other water guidelines aimed at protecting the water environment from pesticide use, covering the storage, transport, disposal, handling and application of pesticides. Some of the guidelines have legal status in Scotland as General Binding Rules (SEPA, 2017), while related aspects of good practice such as avoiding spraying in windy conditions to minimise drift, having an emergency plan for dealing with spillages, and safe pesticide disposal, are detailed in the relevant Pesticides Codes of Practice (DEFRA, 2006; Scottish Executive, 2006), which all spray operators are legally obliged to comply with.

If these measures are followed, including the enhanced precautionary buffer zones outlined in the UK Forestry Standard, it is highly unlikely that acetamiprid use in forests will result in any contamination of watercourses, and the risk of exposure of the public to acetamiprid is likely to no greater than that posed by agricultural, horticultural and home garden use, or the risk posed of exposure from residues on food. Forest Research are currently undertaking an exercise to specifically check the risk assessment for water by monitoring the downstream effects of planting out acetamiprid pre-treated trees or through using acetamiprid in top-up sprays as described in this Note.

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