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Douglas Fir Needle Midge (*Contarinia pseudotsugae*)

A potential threat to Douglas fir in the United Kingdom and Ireland?

Edward Wilson, **Gilles San Martin** and **Gauthier Ligot** highlight a previously unrecognised threat to one of our key forestry species.

Douglas fir (*Pseudotsuga menziesii*) is one of the most important and valuable introduced conifers in Europe. Currently it covers over 0.8 million ha and is the second most cultivated non-native tree species after Sitka spruce (*Picea sitchensis*) (1.2 million ha) (Spiecker et al., 2019). In the United Kingdom and Ireland there are 46,000ha and 10,380ha of Douglas fir, respectively (Forestry Commission, 2019; Forest Service, 2018). As our climate changes Douglas fir is likely to be planted more widely, provided sites are not too exposed and have adequate soil moisture (Ray et al., 2010; Forest Research, 2020). Being moderately shade tolerant, it is also one of the most suitable species for continuous cover forestry (CCF) (Wilson, 2013). At present there are relatively few pests and diseases of Douglas fir that have a significant impact on its growth and performance (Savill, 2019).

Figure 1. Adult female of Contarinia pseudotsugae with extruded ovipositor, in the process of laying eggs within the expanding bud of a Douglas fir shoot.

The recent identification of Douglas fir needle midge (*Contarinia pseudotsugae* Condrashoff) (Diptera: Cecidomyiidae; Genus *Contarinia*) in Western Europe represents a new and previously unrecognised threat to the Douglas fir resource in the United Kingdom and Ireland. This small fly is one of three species of needle midges (the others being *C. constricta* Condrashoff and *C. cuniculator* Condrashoff) known to cause damage to Douglas fir throughout its native range in western North America (Condrashoff, 1961; Roques et al., 2019). Occurrence of the Douglas fir needle midge in other regions was first reported in Michigan in 2003, where it is classed as a 'native invader' transported by human activity to a new habitat (EPPO, 2019). It is now also present in Pennsylvania (Rajotte, 2017). In Western Europe the needle midge was initially reported at several locations in Belgium and the Netherlands in 2015, and then France and Germany in 2016 (Leroy et al., 2015; EPPO, 2019).

Douglas fir needle midge is not currently known to be present in the United Kingdom (Defra, 2020). The UK Plant Health Risk Register states that the overall relative risk from the insect is moderate, but the likelihood of it surviving and perpetuating after it has entered the UK is high (5 on 1-5 scale) (Defra, 2020). A targeted survey is being planned to provide a more accurate assessment of the needle midge's status in the UK; no other mitigation measures are in place

at present (Defra, 2020). Comparable information is not available for Ireland. This article provides an overview of Douglas fir needle midge, its morphology, ecology and impact on the health of Douglas fir. The objectives are to raise awareness of this potential threat to Douglas fir and to outline possible actions that might be introduced to limit its impact.

Identification of the Douglas fir needle midge

The adult Douglas fir needle midge is orange in colour and approximately 3-5mm long (Fischer, 2015; EPPO, 2019) (Figure 1). At the time of emergence in spring the adults can be seen flying around the trees. However, many other Cecidomyiidae have the same morphological characteristics making the Douglas fir needle midge rather difficult to identify. The female is identified by a long ovipositor – typical of the genus *Contarinia* – that is used to probe between bud scales and into partially opened vegetative buds. With this adaptation the female is able to lay her eggs in protected areas. The eggs are long, narrow and orange-coloured. Later in the growing season, the presence of galls on the needles of new shoots is the best way to confirm the presence of the Douglas fir needle midge.

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Life cycle of the Douglas fir needle midge

The life cycle of the Douglas fir needle midge is described in detail by Fischer (2015). The needle midge produces one generation each year. Larvae overwinter in the soil under infested trees. The following spring they pupate and adults emerge from the soil to mate. Adult life span is short: 1-2 days for the male; 2-4 days for the female. The female lays her fertilised eggs in groups on the needles of expanding Douglas fir shoots or directly within opening buds. The eggs hatch a few days later and the larvae burrow into their own individual needle where they induce the formation of a gall (Figure 2). They feed on tissues inside the gall throughout the growing season. From mid-October to December they exit the needle leaving a small triangular hole, drop to the ground and overwinter in the soil (Bulaon, 2005).

Figure 2. Larva of Contarinia pseudotsugae (ventral face with spatula visible) in a Douglas fir needle. The larvae can also be orange or yellow. They can use their spatula to jump by bending their body, jamming the spatula at the posterior end of their body and suddenly releasing the grip. In stands with heavy infestation, the forest floor can literally be covered with these tiny jumping and coloured larvae just before winter.

Damage to Douglas fir trees

There is a distinct pattern to the damage caused to Douglas fir trees by the needle midge, comprising initial infection, seasonal progression and eventual defoliation. Damage occurs on new needles in the current season of shoot extension (Schmitz et al., 2016). The appearance of

Figure 3. Needles of Douglas fir with the galls caused by larvae of Contarinia pseudotsugae. The tissues of the needle are always slightly swollen and the needle can be bent or not. The gall is almost always tainted with brownish, reddish or purple colour, but it can also sometimes become black or remain light green. The presence of larvae inside the gall is discriminant, but the larvae are very small and difficult to see before September.

damage to new foliage is more immediate than with some other pests or pathogens of Douglas fir. The initial sign of infestation is the development of pale patches on needles that form into galls (Figure 3). The needles become swollen and sometimes bent out of shape, which are key diagnostic features. As the season progresses, infested needles gradually darken and turn a reddish-brown colour; there can be significant variation in the colour of infected needles on the current shoot (Figure 4). Once a needle has been attacked it falls prematurely from the shoot during the following winter (Figure 5). In severe and sustained attacks, over several years, the level of defoliation can become significant; especially where other pests or pathogens are also present (Figure 6).

Douglas fir is generally considered to be well-adapted for growth in many areas of Britain and Ireland, and currently has relatively few major pests and diseases (Savill, 2019). Three pests or pathogens that cause damage to needles, and might be confused with Douglas fir needle midge, include the Douglas fir (or woolly) adelgid (*Adelges cooleyi*), Swiss needle cast (*Nothophaeocryptopus gaeumannii*) and *Phytophthora ramorum* (Savill, 2019; Forest Research, 2020).

The Douglas fir adelgid has a complex lifecycle that requires two migration phases between spruce and Douglas fir trees (Wood, 1977). On spruce it forms galls on expanding shoots. On Douglas fir the white woolly aphids can be seen on the underside of needles. Feeding activity causes needle yellowing, bending and twisting that can result in needle drop. Savill (2019) reports that damage can be severe enough to arrest growth in some provenances when trees are young.

Swiss needle cast is an endophytic fungus that causes damage to Douglas fir needles. Symptoms are slow to

Figure 4. Symptoms of Contarinia pseudotsugae infestation on a shoot of Douglas fir showing the variation of colour. Photos taken in Belgium (Paliseul) in October and November 2015.

Figure 5. Shoot of Douglas fir sapling showing moderate needle loss due to infestation by larvae of Contarinia pseudotsugae in combination with terminal necrosis probably caused by Sirococcus conigenus. The needles of the previous year are still present and only the needles of the current year have been attacked and have partially fallen. Photo taken in Belgium (Gedinne) in November 2015.

Figure 6. More severe attack than figure 5. Almost 100% of the needles in the current year are attacked by Contarinia pseudotsugae and will fall during the winter. All the needles of previous years have already fallen due to earlier attacks by Contarinia pseudotsugae or Swiss needle cast. This level of defoliation is now frequent in Belgium. Photo taken in Belgium (Gedinne) in October 2018.

develop and may not be apparent until 2-3 years after infection (Rajotte 2017). In contrast with the needle midge, new shoots in the current growing year remain healthy in appearance. Yellowing (chlorosis) of the needles occurs in the second and third year after infection, leading to necrosis and premature needle loss (needle cast).

Phytophthora ramorum is a fungus-like pathogen best known for its impact on larch. It causes widespread needle loss and tree mortality. Douglas fir is considered susceptible when grown in close proximity to other infected plants, which are a major source of spores (Forest Research, 2020). Abiotic factors that cause needle damage include winter desiccation and late spring frosts.

It has been reported that populations of Douglas fir needle midge can fluctuate widely from one year to the next depending on environmental factors (EPPO, 2019). Heavy infestations can lead to severe defoliation (Figure 6). In Washington State infestation has been reported to be as high as 100 percent of the needles during a severe outbreak of the Douglas fir needle midge (Fischer, 2015). Recovery can take several years, due to the extent of needle loss. Douglas fir needle midge is not considered a lethal pest of its host, but it could reduce tree growth and, where Douglas fir is planted for Christmas trees, it can have a significant negative impact on the aesthetics and market value of the crop (DeAngelis, 1994).

Spread of Douglas fir needle midge in Europe

Adult Douglas fir needle midges are able to fly. However, there is no available information on the species' potential for natural spread. It is also uncertain how the Douglas fir needle midge was introduced to Europe. The most likely cause was trade in Douglas fir plant materials, but this has not been confirmed (EPPO, 2019). The main pathways for human spread of the Douglas fir needle midge include: Douglas fir planting stock; cut branches (including Christmas trees) of Douglas fir; and soil from countries where the Douglas fir needle midge is present (EPPO, 2019; Defra, 2020).

Possible risks to Douglas fir

In North America the Douglas fir needle midge is recognised as a pest in Christmas tree plantations and seed tree orchards (DeAngelis, 1994; pers. comm. M. Vallee, 2020). Pest control measures are sometimes necessary, and focus on surveillance trapping and insecticide application against the adults before they lay their eggs (DeAngelis, 1994; Bulaon, 2005). Traps are placed on the ground to determine the emergence date of the adults, to ensure that the insecticide is applied to maximum effect at the correct moment. In forest conditions chemical control is not considered feasible. Several insect parasitoids are thought to regulate pest populations within the native range (Fischer, 2015).

A recent Continuous Cover Forestry (CCF) workshop (January 2020) in the Ardennes region of Belgium provided an opportunity to observe widespread infestation of Douglas fir seedlings and saplings in regeneration gaps within pure and mixed-species stands managed under CCF principles. Although there was no clear sign of a rapid increase in mortality, there was significant needle loss on many plants (e.g. Figures 5 and 6). The potential impact of this damage on the growth of Douglas fir saplings in stands undergoing transformation to CCF is explored further by Ligot et al. (2020). This study suggests that the growth of Douglas fir saplings is now weaker than it was ten years ago; many Douglas fir saplings are now struggling to out-compete the other admixed species such as Norway spruce (*Picea abies*). Nevertheless, EPPO (2019) states that future impacts of the Douglas fir needle midge are difficult to predict.

Monitoring and research

In Belgium the progress of the needle midge and the levels of attack on host trees are being monitored by field observations at approximately 150 sites. Since the discovery of the species, the infestation level has increased steadily: in 2015 most of the Douglas fir stands had 1-10% of the current year needles attacked; in 2018 the majority of the stands had 30-50% or more of the current year needles attacked, but no massive dieback has been observed. Research has been initiated at a number of laboratories in Belgium and France, including the Walloon Agricultural Research Centre (CRA-W), the Belgian and French Forest Health Observatories (OSF, OWSF) and the French National Research Institute for Agriculture, Food and Environment (INRAE). Since 2015 research on Douglas fir needle midge has included taxonomy, the impact on young trees, and the combined effects with other pathogens. The needle midge is known to combine its effect with the Swiss needle cast and *Sirocccus* blight of conifers (*Sirococcus conigenus*), leading to needle loss and necrosed shoots. Necrosis has been seen mainly in the Ardennes region, which is cooler and rainier than other areas in Belgium. In 2015 the Douglas fir needle midge infestation seemed to be much stronger in that region. Currently, high levels of attack have spread also in other regions.

Discussion and recommendations

In June 2019 the UK legislated to set a target of net zero greenhouse gas (GHG) emissions by 2050 (Natural Capital Committee (NCC), 2020). To deliver this target the UK's Committee on Climate Change has called for both a rapid reduction in greenhouse (GHG) emissions and land use change, including an increase in the annual tree planting rate to 30,000ha (i.e. 90-120 million trees/year). Unfortunately, it is unlikely the domestic nursery sector has capacity to supply all the necessary seedlings (NCC, 2020). Importation of planting stock from European growers is likely to continue, despite the known link with previous introductions of tree pests and diseases (NCC, 2020). Managing an invasive pest or pathogen after it is established in a new area brings significant challenges to forest management (Roberts et al., 2020); clearly the most important strategy is to strengthen prevention, quarantine and biosecurity measures.

The presence of Douglas fir needle midge in Western Europe represents an emerging risk to the health of Douglas fir in the United Kingdom and Ireland. The most likely route of introduction will be via trade in tree seedlings, other plant materials and soil from infected areas. The likelihood of the insect surviving and perpetuating once it has entered the UK is high (Defra, 2020). According to the UK Plant Health Risk Register, the planned action for Douglas fir needle midge is to complete a targeted survey, but no further details have yet been published (Defra, 2020). Given the current spread in several European countries, it would appear prudent to initiate the targeted surveys as soon as possible, provide training for surveyors and other staff, and consider collaboration with active research groups in Belgium, France and elsewhere. Six actions can be recommended in the short term for foresters and woodland owners working with Douglas fir:

Identify – As with all pests and pathogens, it is important to understand the lifecycle, identification features, and the signs and symptoms of damage due to Douglas fir needle midge. It is also necessary to differentiate other causes of damage as part of early detection surveys.

Report – Report any suspicious lesions in Douglas fir

seedlings and saplings as soon as possible to Forest Research, using the Tree Alert tool and protocol (see details below).

Trusted suppliers – Specify planting stock from approved growers and trusted suppliers, and ideally avoid importing seedlings from areas where Douglas fir needle midge is known to be present. Phytosanitary procedures and regulations should be considered to minimise the potential risk of transporting contaminated soil or plant material from one region or site to another.

Traceability – As with all establishment projects, consider traceability of planting stock. Detailed documentation should be retained for seedlings from the nursery to their eventual destination. It will be essential to have these records if there is a pest outbreak and any chance of mounting effective control measures.

Awareness – Raise awareness among colleagues and throughout the wider community of the potential threat to Douglas fir in the UK and Ireland. An extension of this would be to consider the role of citizen scientists, although more research is required to assess the risk severity, potential impact and ease of identification of the Douglas fir needle midge. The anticipated targeted survey in the UK will be an important opportunity to learn and promote awareness of this potential threat to Douglas fir.

Research – Monitor research and developments in nearby European countries. Consider a systematic review of pests and diseases of Douglas fir. This could follow a similar structure to recent work on threats to Sitka spruce by Tuffen and Grogan (2019). This would underpin a wider strategy aimed at reducing the risk of other pests and pathogens being introduced that could threaten the resilience of Douglas fir in the United Kingdom and Ireland.

Conclusions

Douglas fir is one of the most important conifer species cultivated in the United Kingdom and Ireland. Until now Douglas fir has been relatively free from pests and diseases in these countries. The Douglas fir needle midge was first reported in Western Europe in 2015-2016, where an active programme of monitoring and research has been established. Measures to minimise the risk of Douglas fir needle midge being introduced to the United Kingdom and Ireland should be combined with advanced monitoring; early detection of any introduced pest gives the greatest opportunity for effective management and control. The ability to recognise signs and symptoms of the Douglas fir needle midge, and to distinguish these from other pests and pathogens, is crucial. Finally, it is recommended that research and increased awareness activities are commenced at the earliest opportunity to protect the Douglas fir resource in the United Kingdom and Ireland from this new biotic threat.

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