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SCIENTIFIC NOTE

Pheromone trap monitoring reveals the continued absence of swede midge in the Northern Great Plains

Meghan A. Vankosky[1], Shane Hladun[1], Jonathon Williams[1], Juliana J. Soroka[1], Lars Andreassen[1], Scott Meers[2], Patrick B. Beauzay[3], T.J. Prochaska[4], Lesley Lubenow[5], Anitha Chirumamilla[5], Veronica Calles-Torrez[3], Janet J. Knodel[3], and Boyd A. Mori[6*]

[1]Saskatoon Research and Development Centre, Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan, S7N 0X2, Canada, [2]Crop Diversification Centre South, Alberta Agriculture and Forestry, Brooks, Alberta, T1R 1E6, Canada, [3]Extension Entomology, North Dakota State University, Fargo, North Dakota, 58102, United States of America, [4]North Central Research Extension Center, North Dakota State University, Minot, North Dakota, 58701, United States of America, [5]Langdon Research Extension Center, North Dakota State University, Langdon, North Dakota, 58249, United States of America, and [6]Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, T6G 2P5, Canada
*Corresponding author. Email: bmori@ualberta.ca

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Abstract

The swede midge, *Contarinia nasturtii* (Kieffer) (Diptera: Cecidomyiidae), is invasive to North America, where it was first reported in Ontario, Canada. It is now established in eastern Canada and from eastern Minnesota in the Midwest to the northeastern seaboard of the United States of America. Swede midge is a serious pest of brassicaceous plants, including vegetable and oilseed crops. To ensure its early detection in the Northern Great Plains, a monitoring programme was established using pheromone traps located primarily along the edges of canola fields from North Dakota, United States of America, northwest to the Peace River region, in Alberta and British Columbia, Canada. In North Dakota, 117 trap sites were monitored between 2015 and 2021. In western Canada, monitoring occurred on a small scale from 2006 to 2011, and 521 trap sites were monitored from 2013 to 2021. Swede midge was not detected in canola grown in the Northern Great Plains between 2006 and 2021. Partners in North Dakota and western Canada intend to maintain the monitoring programme to support early detection of swede midge if it does continue to disperse northwestwards. The monitoring programme contributes to outreach activities and fosters farmer and agronomist participation in pest management (*i.e.*, community science) in the Northern Great Plains.

Introduction

The swede midge, *Contarinia nasturtii* (Kieffer) (Diptera: Cecidomyiidae), is an invasive insect pest in North America (Hallett and Heal 2001; Chen *et al.* 2011). Its host plants include a number of brassicaceous weeds, vegetables, and field crops, including canola, *Brassica napus* Linnaeus (Brassicaceae) (Stokes 1953). Adult swede midge begins to emerge in spring, once overwintered larvae have completed larval development and pupation in the soil (Hallett *et al.* 2007). Adults are small (< 2 mm) brown flies that are difficult to identify morphologically. After mating, female swede midge oviposits into the growing points (*i.e.*, meristematic tissues) of host plants (Barnes 1946; Readshaw 1966). Larvae hatch from the eggs and are small (3–4 mm when mature), clear- to yellow-coloured maggots. Larvae feed

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on developing plant tissues for 7–21 days, causing reproductive host plant structures, including canola racemes and the florets of cruciferous vegetables, to become deformed or be aborted (Bardner *et al.* 1971; Hallett and Heal 2001; Williams and Hallett 2018). Mature larvae often jump off the plant to pupate in the soil. In approximately 14 days, adults emerge, and the cycle starts again. Swede midge is multivoltine; larvae of one generation may contribute to a new generation in the same growing season, or they may enter diapause and overwinter, giving rise to a new generation of adults in the subsequent growing season (Readshaw 1966; Hallett and Heal 2001; Hallett *et al.* 2009; Hallett and Sears 2013).

Swede midge was first confirmed in North America in Ontario, Canada in the early 2000s, following reports of plant damage consistent with swede midge in the late 1990s (Hallett and Heal 2001). Swede midge is now established in Québec, Prince Edward Island, and Nova Scotia, Canada (Hallett and Sears 2013). In the United States of America, swede midge populations were first confirmed in New York State in 2004 (Kikkert *et al.* 2006) and subsequently detected in New Jersey, Connecticut, Massachusetts, Vermont, Ohio, Michigan, Maine, New Hampshire, Illinois, Pennsylvania, and Minnesota (Chen *et al.* 2009; Philips *et al.* 2017; Estes 2018; Fleischer and Di Gioia 2020; Goossen 2020; Sideman and Bryant 2021). In Ontario, swede midge has caused significant yield losses in field and vegetable crops, including losses to canola crops in excess of 50% of the expected yield (Hallett 2017). As a result of swede midge impacts on yield and the difficulties associated with managing swede midge populations, the area of land sown to canola in Ontario has decreased (Hallett 2017). Economic damage has been reported in many of the regions where swede midge is now established.

The majority of canola production in North America occurs in the Northern Great Plains, a region including Alberta, Saskatchewan, and Manitoba in Canada and Montana, North Dakota, South Dakota, Wyoming, and Nebraska in the United States of America (United States Climate Resilience Toolkit 2021). In the United States of America, canola is planted on approximately 800 000 ha (*ca.* 2 million acres), with North Dakota accounting for the majority of American canola production (approximately 84% of total production in 2019; United States Canola Association 2021). In Canada, the 2020 export value of canola was nearly $CAD 12 billion, grown on 8.26 million ha of land (Canola Council of Canada 2021a). The majority (> 95%) of Canadian canola production since 1986 has occurred in western Canada (Manitoba, Saskatchewan, Alberta, and the Peace River region of British Columbia; Canola Council of Canada 2021b). Following reports of unknown dipteran larvae 'jumping' from canola pods in Saskatchewan in 2003 and because swede midge was spreading in eastern Canada, small-scale monitoring using pheromone traps was initiated by researchers on the Canadian Prairies in 2006. Male swede midge was detected in 2007 (Manitoba) and 2008 (Saskatchewan) on traps deployed by the Canadian Food Inspection Agency (2009). Initial swede midge detections in Ontario, Québec, Manitoba, Saskatchewan, and the northeastern United States contributed to the development of swede midge monitoring programmes using pheromone traps in western Canada, where small numbers of traps were deployed annually beginning in 2006 before being scaled up in 2013. Monitoring began in North Dakota in 2015, following a false-positive detection of swede midge in Winkler, Manitoba in 2014 near the Canadian–American border. No monitoring was conducted in North Dakota in 2016, but monitoring resumed in 2017 because farmers indicated their support for the monitoring programme. Swede midge was also detected for the first time in southeastern Minnesota in Ramsey and Hennepin counties in 2016 (Philips *et al.* 2017). Although no swede midge was detected in pheromone traps monitored in the canola production areas of northwestern Minnesota in 2015 or 2017 (Minnesota Department of Agriculture 2022), the initial detection in Minnesota also contributed to the reinstatement of the monitoring programme in North Dakota in 2017.

Initial small-scale swede midge pheromone trapping in western Canada was undertaken from 2006 to 2011 using white Jackson traps baited with polyethylene cap lures (after Boddum

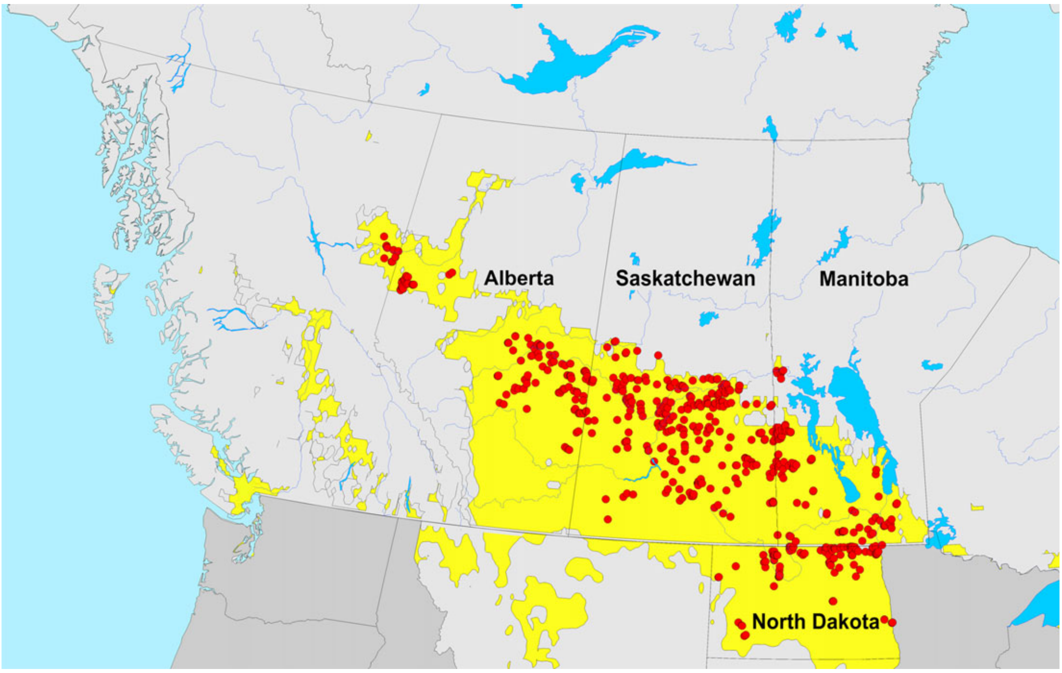

Fig. 1. The distribution of sites where pheromone traps were deployed between 2006 and 2021 to monitor for the presence of *Contarinia nasturtii* (swede midge) across the canola-producing region (yellow-shaded area of the map) of the Northern Great Plains.

et al. 2009) loaded with the synthetic swede midge sex pheromone (Distributions Solida, Saint-Ferréol-les-Neiges, Québec, Canada). Two to four traps were deployed at each trap site, with traps spaced 40–50 m apart along the field edges. Traps were installed from the time of crop bolting to swathing, and the lures were replaced every six weeks during the monitoring season. Crops at the trap sites were diverse, but all included canola (approximately 95% of trap sites) or cruciferous vegetables. Swede midge was not found at any of the locations monitored between 2006 and 2011, and pheromone monitoring was not conducted in 2012. Monitoring for swede midge resumed in 2013, using the same protocol as in previous years, after suspected larval damage was observed in fields in Saskatchewan. The sticky trap liners were replaced approximately weekly and were frozen or refrigerated until they were sent to the Saskatoon Research and Development Centre, Agriculture and Agri-Food Canada (Saskatoon, Saskatchewan) for examination at the end of the growing season to reduce costs associated with weekly shipping of trap inserts. Suspected swede midge specimens on the trap inserts were examined to determine if their external morphology matched that of swede midge, as described by Heal (2002). Trap sites were distributed across Manitoba, Saskatchewan, Alberta, and British Columbia (Fig. 1), with 10 trap sites in 2013, 172 in 2014, 117 in 2015, 61 in 2016, 43 in 2017, 34 in both 2018 and 2019, 8 in 2020, and 42 in 2021, for a total of 521 trap sites from 2013 to 2021. The monitoring programme was supported by volunteers and collaborators, including farmers, professional agronomists, provincial agronomists and entomologists, industry commission staff, and researchers from Agriculture and Agri-Food Canada and prairie universities. The geographic location of the traps was determined by the physical location of the volunteers, and the number of trap sites each year was dependent on the number of volunteers.

In North Dakota, swede midge traps were monitored in canola (90% of trap sites) and cruciferous garden crops (10% of trap sites) in the primary canola-producing areas, including

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the northeast and north–central areas near the Canadian–American border. Thirteen sites were monitored in 2015, 22 in 2017, 20 in 2018, 19 in 2019, 22 in 2020, and 21 in 2021, for a total of 117 trap sites between 2015 and 2021 (Fig. 1). One delta trap (white Jackson traps or Scentry Red LPD traps; Great Lakes IPM, Vestaburg, Michigan, United States of America) was deployed at each field. The white Jackson trap was used in 2015, 2017, and 2018, and the Scentry Red LPD traps were used from 2019 to 2021 because of the limited availability of Jackson traps. All traps were baited with a synthetic swede midge sex pheromone lure (Great Lakes IPM), following the same protocol as described for the monitoring programme in western Canada. The majority of swede midge traps were placed in projected high-risk areas close to the Canadian–American border and in the major canola-producing areas of northern North Dakota. As such, 45% of all the traps were in the northeast, 30% were in the northwest, and 13% were in the north–central region of the state. The remaining swede midge traps were placed at low-risk trapping sites, such as at research extension centres in the southern areas (5% in the east–central, 4% in the southwest, and 3% in central North Dakota). For logistical reasons (including to reduce shipping costs), all trap liners were shipped to North Dakota State University, Fargo, North Dakota for examination at the end of the monitoring season. Specimens were examined to determine if their external morphology was consistent with that of swede midge, based on Heal (2002).

Between 2006 and 2021, adult swede midge was not detected in pheromone traps distributed across western Canada and North Dakota. Moreover, no observations of crop damage have been attributed to swede midge during this time. Although the number of trap sites monitored each year was relatively low considering the geographic area being monitored and although swede midge specimens were collected in Manitoba and Saskatchewan in the late 2000s, evidence from the monitoring programme indicates that swede midge has not established reproductive populations in the Northern Great Plains despite the abundance of acceptable host plants. We expect that swede midge has not established populations in these canola-rich agroecosystems because (1) it has not been introduced in sufficient numbers to establish viable populations and (2) the abiotic conditions there are not favourable for swede midge development or reproduction. Olfert *et al.* (2006), for example, developed a species distribution model for swede midge and conducted sensitivity analyses that indicated that swede midge is particularly sensitive to soil moisture as determined by precipitation. The canola-growing area of western Canada is characterised by relatively low total annual rainfall (Willms *et al.* 2011). In hot, dry conditions, the area of western Canada with conditions suitable for swede midge survival shrunk as compared to scenarios where annual precipitation remained constant or increased (Olfert *et al.* 2006). Olfert *et al.* (2006) also found that swede midge distribution was negatively correlated with increasing cold stress that is associated with overwintering conditions typical of the Northern Great Plains.

Although swede midge has not been detected in western Canada for nearly 15 years and has never been detected in North Dakota, the pest remains a potential threat to canola production in these areas. Measures are needed to ensure that swede midge is not accidentally introduced. Monitoring programmes, similar to those described here, are necessary to ensure early detection of encroaching swede midge populations. The swede midge monitoring programme in western Canada is currently overseen by the Prairie Pest Monitoring Network (Saskatoon, Saskatchewan) and its many provincial, industrial, and academic collaborators. The Prairie Pest Monitoring Network plans to maintain the annual pheromone-based monitoring programme for swede midge as part of its annual survey and monitoring activities in field crops. Plans are also in place to continue using pheromone traps to monitor for swede midge in canola crops in North Dakota because adult midges are difficult to detect and identify in the field and crop damage can easily be attributed to other causes, such as herbicide injury. These traps provide important baseline data about swede midge presence and, if present, where swede midge may be becoming established in North Dakota. Trapping also assists extension educators, crop scouts, and producers by providing pest alerts and pest management education on swede midge.

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Competing interests. The authors declare no competing interests.

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