2010 Interim Best Management Practices to Control the Swede Midge
(Contarinia nasturtii Kieffer)

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Introduction

The swede midge, *Contarinia nasturtii* (Kieffer) (Diptera: Cecidomyiidae), is a new addition to the pest complex found in crucifer crops produced in Ontario and Quebec in Canada, and in New York State and some surrounding states in the United States. The insect is native to Europe and Asia where it is considered a pest of cruciferous crops. A considerable amount of information on swede midge, including pictures of damaged plants, exists at the following websites and should be used in conjunction with this document.

www.nysaes.cornell.edu/ent/swedemidge
www.nysipm.cornell.edu/factsheets/vegetables/cruc/sm.pdf
www.omafra.gov.on.ca/english/crops/facts/08-007.htm

**Background of swede midge in North America**

In North America, the swede midge was first positively identified in Ontario in 2000, although damage symptoms in cole crops consistent with infestation had been noted since at least 1996. In the US, the first positive identification of swede midge was in Niagara County, New York, during the summer of 2004. Swede midge has become widespread throughout Ontario and Quebec, Canada and in New York State (Figure 1). It has also become established in neighboring regions (Figures 1 and 2).

Figure 1. Swede midge distribution in Ontario and Quebec, Canada and the northeastern United States as of December 2009.

*Not all counties have been surveyed for swede midge. For example, in New York, detection survey work was discontinued after 2007. It is very likely that swede midge occurs in other counties within these states and within other states.*

*Swede midge has also been detected in other Canadian provinces beyond the boundary of this map (see Fig. 2).*

Challenges

Identification

Identification of swede midge is not an easy task. Damage is readily mistaken for common physiological (heat or frost) stress and/or nutritional problems (molybdenum deficiency) found in crucifer fields. Insect feeding by other pests (e.g. flea beetles, tarnished plant bug, worm pests) can leave similar scar tissue and damage to growth points. Mechanical damage to young plants while cultivating can result in multiple heads and the formation of scar tissue on crucifer stalks. A single "symptom" in the field is not cause for definitive diagnosis of swede midge infestation! It is best to find swede midge larvae in association with its damage (Figure 3).
Figure 3. Swede midge larvae (3-4 mm in length) in an infested head of red cabbage. Photo credits: larva (Don Hamilton, University of Guelph) and infested cabbage (Hannah Fraser, OMAFRA).

Symptoms include:

- Swollen, distorted or twisted young shoots and leaf stalks (Figure 4)
- Crinkled, crumpled and asymmetrical heart leaves (drawstring effect) – (Figure 4)
- Brown scarring along petiole or stem (Figure 4)
- Blind head (death of main shoot / growing point) – (Figure 5)
- Multi-stemmed plant (cabbage topping) – (Figure 5)
- Swollen and closed flower buds
- Premature bolting
- Riciness or woodiness of cauliflower
- Presence of secondary bacterial rots

Figure 4. Left: twisted growing tip of broccoli infested with swede midge exhibiting brown scarring and leaf puckering. Right: brown corky scarring caused by swede midge in collards.
The swede midge does not restrict itself to one growth stage in a crop, so any young growing tissue on a plant is at risk. Damage can occur at any time throughout the season (e.g. from the seedling stage through heading). Swede midge populations can build up on the secondary shoots of otherwise healthy looking crops and on plants remaining in the field after harvest.

Swede midge adults are tiny (1.5 - 2 mm), delicate flies that are difficult to see in the field. However, males can be captured using pheromone traps. These traps have proven to be highly sensitive and can detect swede midge before damage or larvae can be found by field scouting.

**Life cycle**

Swede midges overwinter as pupae in the top 1-5 cm of soil and then emerge as adults and make their way to the soil surface. Research in Ontario, Canada indicates that the entire overwintering population of swede midge does not emerge synchronously in early spring, but rather in three distinct peaks through the month of June. In Ontario, there appear to be 3 to 5 main population peaks (flights) per year with 2-3 emergence phenotypes. Adults emerge continually from the end of May until the end of September or early October, thus ensuring a long-term battle with the pest. Cooler temperatures (68-77°F) and adequate rainfall provide perfect conditions for development. Mating occurs soon after emergence and females then begin to look for suitable hosts. Eggs are laid in clusters of 2-50 eggs and primarily on the newest growth points of the plants or where the leaf meets the stem (i.e. leaf axil). Each female will lay about 100 eggs during her short (1-5 day) lifetime. Several larvae are typically found in association with the damaged tissue on the plant. The eggs hatch within 1-3 days. The larval stage is the only life stage that can damage cruciferous plants. Larvae produce a secretion that breaks down the plant cell wall allowing larvae to feed on the liquid contents. Larval feeding changes the physiology of the plant and results in the formation of swollen, distorted and twisted tissue, including leaf petioles and leaves. Larvae complete their development in 7-14 days, and then drop to the ground and become pupae in the soil. If conditions are favorable, new adults will emerge 9-14 days later, depending on the temperature, and the cycle will continue. During periods of drought, the pupae in the soil may remain dormant, but may emerge following rainfall or irrigation. The literature suggests that some pupae may remain in the soil for more than one winter, although this has not been confirmed.

**Figure 5.** Left: “blind” broccoli plant with brown scarring at growing point. Right: multiple growing points and shoots in a broccoli plant caused by swede midge feeding.
Figure 6. Life cycle of swede midge.

Best Management Practices

Transplants

Always start off with clean transplant material. This will not only help your operation but will reduce the movement of swede midge to other areas. Be confident about the source of your transplants.

If transplants come from an infested area or are possibly infested by swede midge, insecticide treatments should be applied before transplanting. Check what insecticides are labeled in your area. The effectiveness of different foliar sprays for control of swede midge-infested plants will vary depending on the time when plants became infested with swede midge. For example, in trials conducted at Cornell, the efficacy of acetamiprid (Assail) on swede midge using foliar sprays was 99.5, 100, and 99.8% when cauliflower seedlings were sprayed before inoculation with swede midge, at inoculation and 4 days after inoculation, respectively. The efficacy of acetamiprid was reduced to 69.9% when seedlings were sprayed 8 days after inoculation, and swede midge larvae could successfully pupate and emerge after the spray. Based on these results, foliar sprays on transplants at the early stage of infestation and before shipment of seedlings from swede midge-infested areas are recommended in New York. In the United States, Assail 30SG is not labeled for greenhouse use, thus plants must be removed from the greenhouse prior to treatment.
Prefer to the label for specific product information. Inspect all transplants prior to planting, particularly in known areas of SM infestation. When hardening off young seedlings outside, cover them with fine netting or a floating row cover to prevent any egg-laying activity.

**Crop Rotation**

Crop rotation is perhaps the single most effective way to reduce swede midge populations in the field. With multiple generations and a high reproductive potential, swede midge populations can build up very quickly under continuous production of a host crop. A small number of swede midge adults in the first generation can give rise to tens of thousands by the third generation in July! By late September, high numbers of swede midge drop to the soil to pupate and can create challenging management issues for the following growing season when they emerge in very high numbers in the spring.

To investigate whether swede midge would emerge from soils with or without host plants being present in the soil, Cornell researchers conducted a series of trials in the laboratory. They found that plant type (host or non-host) did not significantly affect the swede midge emergence pattern from soil, i.e. swede midge emergence time and emergence rate from soil that was previously planted to a suitable host plant (cauliflower), alternative host plants (shepherd’s purse and wild mustard) and non-host plants (sweet corn and kidney beans) were very similar to those from fallow soil. This information is important for swede midge management since swede midge has been reported to survive in the soil for 2 or more years and can emerge from soil if climatic parameters (such as temperature and moisture) are suitable, regardless of the presence of host plant. Thus, rotating out of cruciferous crops and weeds can go a long way towards reducing a swede midge population. The longer the rotation period between crucifers the better it will be for managing swede midge.

To further evaluate the effectiveness of crop rotation on swede midge control, Cornell University researchers used 11 simulated cauliflower-sweet corn and cauliflower-kidney bean crop rotation systems, with and without the presence of cruciferous weeds as alternative hosts under controlled laboratory conditions. Their results indicated that the cauliflower-sweet corn, and cauliflower-kidney bean rotation systems could provide full control of swede midge. The effectiveness of one cycle of non-host crop rotation was reduced when cruciferous weeds were present; however the swede midge population in a one-cycle non-host rotation system with cruciferous weeds present was significantly lower than that in a non-rotation system. Two consecutive cycles (simulating a cropping season) of non-host plant crop rotations provided full control of swede midge, regardless of the presence of the cruciferous weeds, which suggests that 1) crop rotation can be a very effective tool for swede midge control in the field and 2) cruciferous weeds are not very suitable host plants for swede midge, although weeds can sustain a swede midge population for a limited time.

A field survey of swede midge occurrence on cruciferous weeds in western New York by Cornell scientists indicates that swede midge populations may be maintained to the next season on cruciferous weeds in fields without crucifer crops being available. Trials in Europe indicate that high infestations were reduced to economically acceptable levels for several years following a 2-year crop rotation. Much higher damage has been observed in multi-cropped cole crop fields. Similarly, on a small farm in New York, a once economically damaging swede midge population became practically non-existent just two years after not growing any crucifer crops, despite prevalence of crucifer weeds. Depriving the swede midge of its preferred host plant material (crucifer crops) through crop rotation provides an effective and ecologically acceptable management technique.
Swede midge from the previous year’s cruciferous fields may present a season-long threat to neighboring cruciferous crops. Preliminary work in Ontario (2004) illustrates the importance of a host-free period to swede midge population dynamics. In areas previously under continuous production of susceptible cole crops and then planted to soybeans or corn (non-host crops), swede midge continued to emerge throughout the following year.

We suggest a minimum 3-year crop rotation, recognizing that for many growers this presents a major challenge from the standpoint of available land base and continued access to markets. However, even a single year’s rotation with careful cruciferous weed management practices will reduce the population of swede midge and should be encouraged. More research needs to be devoted to this area.

How far away does the field need to be? Some European data suggests a minimum of 600-1,000 ft between sites; distances of up to 0.6 miles have been proposed. Distances of 50 feet are not at all a deterrent for the previous year’s swede midge to find the current year’s crucifer crops. We lack the data to provide a science-based answer, but caution dictates that new plantings should be as far away as possible from the previous year’s planting to reduce the possibility of swede midge being carried into the field by a light wind. Without a host crop nearby, the swede midge female will not be able to find a place to lay her eggs in her short 1-5 day life span.

**Post-Harvest Crop Destruct**

The second most important thing that you can do to manage swede midge is to destroy your cruciferous crop as soon as possible after harvest. After the marketable portions (i.e. broccoli crown, cabbage head) are harvested, the plants sprout several secondary side shoots, which are ideal sites for swede midge to lay their eggs. Optimum host conditions in combination with the absence of insecticide sprays make post-harvest cruciferous plantings ideal for swede midge to thrive and build up very large populations - the larvae of which will drop to the soil to pupate, and then emerge in droves to find the next susceptible crucifer planting within the same season or the following spring. Leaving harvested cruciferous crops in the field post harvest is especially favorable for swede midge when the weather is still warm in July, August and September. In late October, November and December, swede midge activity drops considerably. Once you are finished harvesting a planting, it should immediately be chopped, disked or plowed, so that it no longer provides living tissue for swede midge to prosper. In western New York, pheromone trap catches tend to drop drastically after crop destruction. On the other hand, trap catches tend to steadily increase when a crucifer planting is left unattended after harvest.

**Soil Manipulation**

Since swede midge pupate in the soil, soil manipulation can be an important aspect of control. Experiments conducted at Cornell indicate that swede midge can infest crops in many different soil types, but that varying the moisture level or depth at which pupae reside can make a difference in their ability to emerge. Laboratory results indicated that extremely dry and extremely wet soil hinders swede midge emergence. Optimal moisture content for swede midge emergence was from 25 – 75 %, and varied in different soils. The distribution of swede midge pupae was also studied in different soils. Under laboratory conditions, most swede midge pupated within the top 1 cm of soil, regardless of soil types. In a follow-up set of experiments, we covered swede midge pupae with 2, 5, 10 and 15 cm depths of soil, and then checked the emergence number and timing. We found that 2 cm depth of soil cover had no negative impact on adult emergence. However, more than 5 cm depth of soil cover greatly reduced the emergence number and delayed the time of emergence.
These results suggest that cultural practices, such as flooding fields during non-cropping periods to achieve 100% soil moisture level or even drying the soil, may be viable methods to reduce swede midge emergence. Similarly, swede midge populations and damage are expected to be reduced when saturated soil or drought conditions occur. However, tillage trials in Canada indicate that swede midge emergence can be enhanced by deep plowing of soil, since that brings some of pupae to the soil surface. Therefore, until further work is conducted, it is not recommended that growers in affected areas use deep plowing in the spring.

Field Selection

Swede midge is considered a poor flier. Growers with swede midge populations have found less damage when they plant crucifers in open fields. Damage symptoms are typically first observed in the field along tree-lines, buildings and hedge rows, because the insect is easily blown into these areas. Planting in isolated areas, up from prevailing winds, may help decrease the risk of spread. Rotating crucifer crops upwind from previous swede midge infested sites may also interfere with them finding their host.

Crop Selection

The swede midge will attack most members of the Brassicaceae family. Some studies in Canada suggest that the highest levels of damage occur on collards, broccoli, Chinese broccoli (gai lan), Brussels sprouts, cauliflower, and Chinese cabbage (choy sum). The broccoli variety "Paragon" appears to be highly susceptible to swede midge damage, while "Everest" and "Triathlon" are less susceptible than some other broccoli varieties. Canola is readily attacked. Cruciferous weeds including wormseed, dog and wild mustards, yellow rocket, shepherd's purse, field pennycress, field pepper grass and others are also hosts and may act as reservoirs for swede midge populations in the absence of crucifer crops or canola. However, under laboratory conditions, when cauliflower and weed plants (wild radish, field pennycress, shepherd’s purse, field pepper grass, wild mustard and yellow rocket) were simultaneously exposed to swede midge adults, significantly greater number of swede midge larvae were found on the cauliflower plants 8 days after oviposition, suggesting that cruciferous weeds are less preferred by swede midge.

Field Sanitation

In studies conducted at Cornell from 2005 to 2007 in western New York, more than 3,000 cruciferous weeds were sampled in different fields in which pheromone traps had caught swede midge adults. Weeds were separated according to species and then placed in emergence cages and the number of adults that emerged was calculated per 100 grams of dry weight. Swede midge adults were found in yellow rocket, wild mustard, field pepper grass, field pennycress, hedge mustard and shepherd’s purse. In 2006, the weed species that yielded the highest number per 100 grams of dry weight was shepherd’s purse. These studies suggest that cruciferous weed hosts of swede midge may serve to sustain a swede midge population to some extent and should be managed whenever possible.

Planting and Harvesting Dates

Planting only early season crucifer crops is another control strategy to reduce damage levels and population growth. The amount of damage is directly related to the plant growth stage at the time of attack. The younger the plant when attacked, the more severe the damage. As plants grow, damage becomes increasingly evident. The first emergence of swede midge occurs from mid to late May. Damage to early plantings will be less severe than to late plantings because the plant development will be advanced by mid-July when high populations occur. Harvesting of early season crucifers begins in July, which minimizes the amount of damage to the crop. Avoidance of late season crops will also help to
reduce the size of the overwintering population in your fields. This strategy will not work for long season crucifer crops like Brussels sprouts. Also, an early planting may have high levels of swede midge damage if it is located at the same site as last year’s crucifer crop, because it can be subjected to the emergence of a large overwintering population.

**Monitoring and Scouting**

Do not assume that you have an established population of swede midge on your farm, but be on the lookout for signs and symptoms, particularly if you are located within an infested county. Early detection of swede midge is key to maintaining pest populations at manageable levels. Familiarize yourself with the information provided in various OMAFRA and Cornell resources.

Attention should be paid to sheltered areas, along field edges and buildings. Swede midge adults are not strong fliers and tend to prefer areas of low wind movement. Examine young crop plants for unusual growth habits, with emphasis on the growth point and any side shoots. Check young plants for galls at the growth point and for swollen leaf bases. Brown, corky scarring is a key diagnostic feature, indicating larval feeding. Infested plant material often has a "moist" or "wet" appearance where larvae are actively feeding.

Once a suspect plant is found, new growth should be carefully examined for the presence of larvae. Larvae can be seen with the naked eye or a hand lens. If larvae are not found, place the suspected plant material in a vial of rubbing alcohol and shake; typically, the larvae will come right out of the plant material. If no larvae are found, they may have already dropped to the soil to pupate. So keep looking!

A pheromone trap is available commercially. It is possible for consultants/growers to order swede midge pheromones, traps and liners from Sweden through Phero Net (http://www.phero.net). Other companies distribute these products from Phero Net, including the North America distributor Solida in Quebec. These traps are highly species-specific and will trap swede midge males at low population densities, making monitoring, identification and timing of spray applications a much simpler task. With proper training, swede midge males can be distinguished from other insects caught in pheromone traps.

**Insecticides and Spray Timing**

Well-established thresholds have not been determined for swede midge. Preliminary research results from Ontario, Canada indicate that growers may have opportunities to optimize their spray applications for swede midge by monitoring pest pressure with pheromone traps.

Growers with swede midge populations capable of causing economic damage are advised to initiate a pest control program incorporating both cultural and chemical management. Transplants should be protected as soon as they are removed from the greenhouse, or immediately after planting. Management of early swede midge populations will reduce the potential for a population explosion by the end of the season.

Once plants are in the field, monitoring swede midge population with pheromone traps and timing insecticide sprays are the keys to achieve satisfactory control of swede midge. In a greenhouse study conducted at Cornell, Assail 30SG provided very effective control of swede midge on cauliflower plants as foliar spray regardless of plant sizes (if coverage was good) and swede midge densities (related to population pressure). However, Assail 30SG provided only up to 9 days of control, after which time, control decreased significantly. When swede midge pressure is high, susceptible crucifer crops need to be protected at all times.
In greenhouse trials conducted at Cornell in 2005, most pyrethroid, carbamate and organophosphate insecticides that are commonly used to control caterpillar pests in crucifers were toxic to swede midge. However, in field situations where swede midge are protected from direct contact with insecticides, many of these materials provided minimal control. No materials that meet organic standards provided effective control of swede midge in laboratory trials.

Based on laboratory and field studies, Cornell was able to provide data to New York regulators to have the following products labeled in New York State. However, check the label before any applications. In areas where swede midge is known to be present and abundant, the safest strategy would be the use of imidacloprid soon after transplanting to provide an estimated 3-5 weeks of control, followed up by foliar sprays of another insecticide.

**Federal Labels in the United States**

**Assail 30SG** (EPA No. 8033-36-82695, a.i. acetamiprid) – rate: 4 oz per acre for control of swede midge in broccoli, gai lon, rapini, Brussels sprouts, cabbage, bok choy, gai choy, caralo broccoli, cauliflower, collards, kale, kohlrabi, mizuna, mustard greens and rape greens. REI: 12 hours, PHI: 7 days. Do not make more than 4 applications per season. Do not apply more than once every 7 days.

**Assail 70WP** (EPA No. 8033-23-82695, a.i. acetamiprid) – rate 1.7 oz for control of swede midge in the same crucifers as listed on the Assail 30SG formulation above. Do not exceed 8.5 oz per season.

**Admire Pro Systemic Protectant** (EPA No. 264-827, a.i. imidacloprid) - rate: 4.4 to 10.5 fl oz per acre for control of swede midge in cabbage, cauliflower, broccoli, Brussels sprouts and radish. PHI: 21 days, REI: 12 hours. **Note: as of January 31, 2010, generic versions of imidacloprid (soil applications) are not labeled for swede midge.**

**Lorsban 75WG** (EPA. No. 62719-301-10163, a.i. chlorpyrifos) – rate: 0.67 to 1.33 lb per acre for control of swede midge in broccoli, Brussels sprouts, cabbage, cauliflower, collard, kale and kohlrabi. PHI: 21 days, REI: 24 hours, 3 days for cauliflower. Do not make a second application of chlorpyrifos within 10 days of the first application. **Note: as of January 31, 2010, generic versions of chlorpyrifos are not labeled for swede midge.**

**Provado 1.6 Flowable Insecticide** (EPA No. 264-763, a.i. imidacloprid) – rate: 3.8 fl oz per acre for control of swede midge and onion thrips in cabbage, cauliflower, broccoli and Brussels sprouts. PHI: 7 days, REI: 12 hours. Minimal interval between applications: 5 days. Maximum allowed per season: 19.2 fl oz per acre. **Note: as of January 31, 2010, generic versions of imidacloprid (foliar sprays) are not labeled for swede midge.**

**Warrior Insecticide with Zeon Technology** (EPA No. 100-1112, a.i. lambda-cyhalothrin) - rate: 2.56 – 3.84 oz per acre for control of swede midge in cabbage, cauliflower, broccoli and Brussels sprouts. PHI: 1 day, REI: 24 hours. **Note: as of January 31, 2010, generic versions of lambda-cyhalothrin are not labeled for swede midge.**

Insecticides should be wisely used in conjunction with accurate swede midge population monitoring tools to ensure optimal control. However, with very high populations, insecticides will not be able to prevent injury. With a limited tool-kit, the development of resistance to the available insecticides is a serious concern. Choose and use products wisely. Research teams in New York and Ontario, Canada are working collaboratively towards the evaluation and registration of additional insecticides for use in both the field
and greenhouse. Check with your Cooperative Extension Service for registration updates. Read labels carefully!

**Final Thoughts and Take Home Messages**

The swede midge is an unwelcome guest, which once established on your farm, will be virtually impossible to eradicate.

Typically, vegetable growers in western New York rotate their fields to crucifers every 3-5 years. This practice likely prevents the long-term buildup of swede midge and should be the foundation for control. It is important to remember that no single strategy will provide 100% control of swede midge. With proper management that incorporates all cultural techniques and sound chemical practices, populations can be kept at levels low enough to avoid economic injury. In Canada, the areas where swede midge have been typically problematic are those areas in which the pest was not detected early and built up to high populations. Factors that also contributed to the build-up were the lack of rotation to non-crucifer crops and growers not having knowledge of which insecticides could be effective. Small scale organic growers are particularly in a difficult situation since studies at Cornell indicated that there were no effective insecticides that meet organic standards. There remains a case study in western New York of an organic farm where swede midge was first detected in 2005, but that has yet to develop a swede midge problem most likely because they have long crop rotations over a large land base. More research is needed to document the effects of such practices. Pheromone traps are critical to the development of IPM programs for timing applications of pest control products.

Your swede midge management plan should include:

1. Using clean transplants
2. A 2 to 3 year crop rotation to non-crucifer crops
3. Monitoring/scouting for swede midge detection
4. Field sanitation and post-harvest residue management
5. Selection of less susceptible cultivars
6. Early planting to avoid / prevent high populations, when possible
7. Field selection - use open fields where possible
8. Preventative insecticide applications as required

While we have learned much about swede midge in the last several years, much remains to be learned about its biology and management. Considerable research efforts are needed to identify less susceptible crop varieties and to document the ways in which swede midge spreads over short and long distances. Swede midge is becoming an increasingly important pest of crucifers in North America, and it is imperative that management strategies be implemented while it is still a relatively new pest. Assume that you have swede midge, or that you will be getting it. Practice excellent crop rotation and immediate post harvest crop destruct, and be sure that you know how to identify swede midge damage.