The Wheat Midge

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The wheat midge (*Sitodiplosis mosellana*) is a common agricultural pest found in most areas around the world where wheat crops are grown. Until the recent development of wheat varieties resistant to wheat midge, all wheat varieties were susceptible to damage by the wheat midge, some species being more seriously affected than others. Although this pest also attacks other members of the grass family, including barley, couch grass, intermediate wheat grass, and rye, infestations on these plants are usually not serious enough to warrant any control methods to be implemented.

In recent years, significant damage to wheat crops have been reported in Alberta, Saskatchewan, Manitoba, southern British Columbia, Minnesota, North Dakota, and Idaho. Due to the economic importance of this insect pest, research and breeding for wheat midge resistant wheat varieties continues at Agriculture and Agri-Food Canada's Cereals Research Centre in Winnipeg, Manitoba, and the Crop Development Centre at the University of Saskatchewan.

Life Cycle and Identification

The life cycle of the wheat midge is comprised of four distinct stages: the egg; larva; pupa; and the adult.

The first phase begins with the egg stage. Egg laying generally takes place in the evenings when wind speeds are less than 10 km/h, and the air temperature is greater than 15^{o}C. The female typically lays her eggs in clusters of three or four directly on the surface of the wheat crop florets. However, it is not uncommon to see single eggs placed on the external surface of the glumes, or in the outer grooves of the florets. The duration of the egg stage is extremely dependant on temperature and other environmental conditions. However, the most frequent time frame would be four to seven days.

Once the eggs hatch, the larval stage begins. Upon emerging from the egg, the small orange larvae migrate from the outer surface of the wheat spikelet into the head to feed on the surface of the developing kernels. Under normal infestations, three to four larvae may feed on one floret at anytime. However, when severe outbreaks occur, there may be as many as 26 larvae per kernel.

The larval stage usually lasts for a period of two to three weeks. During this time, the larva feed and develop, growing to an average length of two to three millimetres. Once complete, the insect will then leave the wheat head and crawl down the stem to the ground surface. It is important to note that under dry conditions, larvae will remain in the wheat head and rather than shedding their last larval skin, will shrink back inside their existing skin and stop developing. The larvae will appear to be enclosed within a transparent envelope and can survive for some time in this protected state. Once moisture conditions improve, the larvae will become active and may move into the soil. However, the larvae may also remain in the wheat heads until threshed out during harvest.

Once the larvae venture to the ground level, they will bury down into the soil and exist within the top 5 cm of the soil. However, they have been found at depths of up to 10 cm. The larvae spin round cocoons that are about half the size of a Polish-type canola seed. Over-wintering larvae may remain dormant until conditions are favourable for development, whether that is the following spring or several years later.

The third developmental stage is the pupal phase. Once temperature and soil conditions end the over-wintering period, the larvae become active and return to the soil surface to pupate. Depending on the conditions, the larvae will pupate with, or without, a cocoon (Figure 2). The emergence of the adult flies begins in late June or early July. However, the frequency is highly dependent on the ambient temperature, soil moisture conditions, and geographic location. Depending on the current environmental conditions, the transition from pupal to adult stage can continue for up to six weeks.

The final stage in the lifecycle of the wheat midge is the adult stage. Looking at the visual characteristics of an adult midge, it is a very small orange fly with an overall length of two to three millimetres. Approximately half the size of a mosquito, the midge has two large black eyes that cover much of its head. The midge has three pairs of legs that are very long in proportion to its body size. Its wings are oval shaped, transparent, and fringed with fine hairs.

Under normal daytime conditions, the adults will remain within the crop canopy where the surrounding environment is humid. In the evening, if conditions are favourable females become active at the top of the wheat canopy, laying eggs on the newly emerged wheat heads. The life span of the female midge is less than seven days. However, during that short time period, the female can lay an average of 80 eggs.

Damage Caused by the Wheat Midge

The wheat midge is a very economically important crop pest, as infestations of the insect can reduce crop yields, and lower the grade of the harvested grain. In addition, should favourable weathers conditions not exist, the midge can remain dormant in the soil for several years before they become a significant problem. However, once optimal conditions are realized, populations can reach epidemic proportions in a very short time period.

All of the damage to a wheat crop is caused by the larval stage. Once the eggs hatch, the midge larvae feed on the developing wheat kernels, causing them to shrivel, crack, and become deformed. As there are no visible external changes in colour, size or shape of the affected wheat head, the damage to the crop is not readily apparent. Damage can only be detected by inspecting the developing seed within the glumes. As such, producers inexperienced with wheat midge infestations can often misdiagnose the symptoms and report that frost or drought was responsible for reduced wheat yields, or grain quality.

Wheat midge damage to the individual kernels is not consistent within a single head. While a few kernels may be aborted entirely, others will not fully develop. As such, the size and weight of the undeveloped kernel may cause it to pass through the combine with the chaff during harvest. Still, others may be only slightly damaged and some kernels may not be affected at all.

The loss of kernels lowers the yield, whereas damaged kernels reduce the grade of the harvested wheat. Standards established by the Canadian Grain Commission limit midge damage in No. 1 CWRS and No. 2 CWRS to 2 per cent and 5 per cent, respectively, before the grade is affected. Damage tolerances for amber durum are 2 per cent, for No. 1 CWAD, and 8 per cent, for No. 2 CWAD. However, if a disease is associated with damage caused by the midge, referred to as severe midge damage, grading tolerances are further reduced to 0.1 per cent and 0.25 per cent for CWAD No. 1 and No. 2, respectively. More detailed information regarding grading is available on the Canadian Grain Commission web site: www.cgc.ca in Chapter 4 - Wheat, of the Official Grain Grading Guide.

Monitoring Midge Infestations

In order to ensure that infestations of wheat midge are identified early, regular monitoring of wheat fields - between heading and flowering - is necessary. Research indicates that wheat heads are the most susceptible to damage when egg laying occurs during heading. Kernel damage, due to wheat midge, can decline by 15 to 25 fold between later stages of heading and early flowering, or anthesis – when the first yellow anthers appear on the wheat head. Therefore, fields should be inspected daily from the time wheat heads emerge from the boot leaf until the anthers are readily visible.

While the susceptibility of most wheat species to a midge infestation decreases after anthesis, there are exceptions. The Glenlea wheat variety remains very susceptible to damage throughout anthesis. As such, producers who plant this type of wheat should assess wheat midge activity throughout the heading and flowering stages.

Field inspections should be carried out in the evening (normally after 8:30 p.m.) when the female midge is most active. Females are more vigorous when the temperature is above 15^{o}C, and wind speed is less than 10 km/h. When wind speeds are greater than 10 km/h, egg-laying may still occur on shorter tillers within the shelter of the crop canopy.

In order to accurately assess wheat midge populations, it is important to inspect the field in at least three or four locations; counting the number of adults present on four or five wheat heads per plant. This is necessary, as midge densities and plant growth stages at the edge and centre of fields may be very different. Midge infestations are often higher at field edges, with populations declining dramatically toward inner parts of the same field. The highest densities are often next to fields where wheat was grown in previous years or in low spots where soil moisture is favourable for midge development. In these situations, control around the field margins may provide adequate control and result in a reduced cost to the producer. However, if midge densities remain relatively constant at all sampling sites, control over the entire field would be warranted.

Since the early 1980's, the recommended method for monitoring wheat midge has been to visually inspect wheat heads for egg laying midge on warm, calm evening just prior or after sunset after the crop has started to head. Monitoring continues every evening for an additional week to ten days until threshold populations have been reached or until anthers are visible on at least one floret in the center of wheat heads throughout the crop. For Glenlea wheat, monitoring continues until about 30 per cent of the florets on each head have exposed anthers.

Producers use this monitoring technique to estimate wheat midge populations but they do not like it, with good reason. Looking for these small insects at twilight or in the dark with a flashlight while fending-off the mosquitoes has made this one of the least welcomed tasks on the farm. And to make things worse, most producers’ fields are spread over several miles and they may all need to be inspected at the same time.

To avoid having to inspect crops at night, producers have sometimes placed foam pie plates coated with vegetable oil on stakes throughout the crop to monitor their crops for wheat midge, but with varying success. After trying the "sticky-pie-plate" technique, most producers usually go back to visually inspecting their crops at night.

Recently, scientists with Agriculture and Agri-Food Canada evaluated a new version of technique. Instead of pie plates covered with oil, they used 10 sticky cards about the size of playing cards covered with a petroleum-based resin similar to Tanglefoot' placed several meters within the crop after heading. Cards were left in the fields for three days before they were examined. Results show:

- 0-3 midge on the cards means population levels are too low to detect and are probably not economical.
- 4-9 midge on the ten cards means farmers producing high grade wheat will often benefit from an insecticide application.
- More than 10 midge on the ten cards indicates an insecticide is usually warranted.

Those using this technique should be aware that there is a high level of variability with these results, and need to be comfortable identifying wheat midge from other insects caught on the sticky surface (Lamb et al.2002).

Researchers at Simon Fraser University recently identified the female sex pheromone of the wheat midge. Working with Agriculture and Agri-Food Canada and Phero Tech Inc., they developed a target-specific monitoring system. The system uses green delta traps that are not visually attractive to most insects. Thus most of the captured insects will be wheat midge males that are attracted to the species-specific pheromone inside the traps. Captured males are clearly visible as orange spots on the white sticky inserts inside the trap. Because few other midges are found in wheat fields, each orange spot can be reliably assumed to be a wheat midge.

At least three traps should be placed in a 64 hectare (160 acre) field. Traps are monitored at any time for captured male midges. Beginning 5 days before heading examine them every 1-2 days. These pheromone traps are now commercially available, but the research relating trap catches to economic damage is still being reviewed.

When crop scouting, it is important to remember that not every small fly in the crop will be a wheat midge. Due to its small size, the wheat midge may be mistaken for a species of lauxanid fly, *Camptoprosopella borealis* that is common in wheat. In order to prevent this misdiagnosis, the lauxanid fly is typically a little larger than the midge; at 2.5 to 4 mm in length. In addition, the lauxanid has a yellowish-brown exterior as compared to the predominant orange colour of the midge.

Another distinguishing feature between the lauxanid and the wheat midge is the peak period of activity. The lauxanid may be observed during the day and early evening resting on the wheat leaves or the awns. When disturbed during the day, it will fly above the crop canopy. At rest, its body will be oriented in a horizontal position, or with its head pointed towards the ground. In contrast, the midge is usually not active during the day. Normal activity would see the wheat midge fluttering from plant to plant and assuming a vertical position with its head pointed skyward when at rest.

Table 1. Comparing Features of the Wheat Midge and Lauxanid

Characteristics	**Wheat midge**	**Lauxanid**
Size	2 - 3 mm (1/12 - 1/8 in.)	2.5 - 4 mm (1/10-1/6 in.)
Colour	orange, brown head, black eyes	yellowish-brown
Active period	primarily evening	day and evening
Movement habits	tends to flutter from plant to plant in the evening	will fly above the canopy when disturbed during day
Stationary habits	sits with head pointing up	sits on plant in horizontal position or pointing down

Wheat Midge Management

If a wheat midge infestation is discovered in a wheat field, producers have several options, available, including: biological; cultural; and chemical control methods.

In terms of biological control options, wheat midge populations on the Prairies are often held in check by a small, (1 to 2 mm in length) parasitic wasp called *Macroglenes penetrans (Kirby)*. In southern B.C., *Euxestonotus error* (Fitch), another small parasitic wasp, attacks the wheat midge similar to *M. penetrans*. These wasps emerge from the pupal stage at approximately the same time as its host and the wasps lay their eggs inside those of the wheat midge. The wasp egg and the midge egg hatch about the same time, and the tiny wasps develop inside the midge larva.

While the midge larvae are parasitized, they are still capable of damaging the crop during the current season, as the wasp remains dormant within the midge larva over winter. However, in the following spring, the parasite grows rapidly and destroys the midge larva. Because the benefits from parasitism will not be realized until the following year, control measures should be considered in the present year if midge populations exceed the economic threshold. If wheat midge are below economic threshold, it is best not to apply insecticides because aside from the application not being economical the insecticides will also kill the parasites.

Saskatchewan estimates collected from samples taken during annual wheat midge surveys indicate that parasitism rates range from 0 to 100 per cent. Generally, the highest level of parasitism occurs in areas where midge populations have been established for a few years. By contrast, the lowest rates of parasitism are usually seen in areas new to the wheat midge.

While natural biological control measures do occur, there are also cultural control methods that can be implemented to reduce the populations of wheat midge. Avoiding continuous wheat cropping is paramount because wheat midge overwinter in cereal fields from the previous season. Rotating from wheat to crops that are not susceptible, at least makes the midge have to fly in search of new host plants, reducing the risk of damage.

Seeding date can also be an effective control method. The wheat midge degree-day model developed by Agriculture and Agri-Food Canada has helped predict emergence and peak activity periods, as well as when field monitoring should take place. Using a base of 5 degrees Celsius, male wheat midge start emerging after 660 growing degree days base 5 degrees C; females start emerging after 700 growing degree days base 5 degrees C.

- 725 GDD - 10% adult female emergence
- 800 GDD - 50% adult female emergence
- 900 GDD - 90% adult female emergence

Spring wheat is expected to head at 550 to 600 GDD on the wheat midge GDD scale.

HRSW planted prior to 110 DD will head before wheat midge emerge; HRSW planted from 110 to 330 DD will be heading at the time wheat midge are emerging; HRSW planted after 330 DD will head after peak emergence and should be at low risk to infestation, higher risk of other factors.

However, research trials with early and later seeding dates have demonstrated variable results in reducing midge damage; the efficiency is variety dependent. Tests with traditional spring wheat varieties showed that early seeding of early maturing varieties greatly reduced midge damage. These early maturing varieties tended to grow through the susceptible stage before the wheat midge emerged from the soil.

In contrast, recent tests with newer spring wheat, CPS, and durum varieties showed late seeding resulted in the least amount of damage from the midge. This result appears to be related to the fact that these newer, higher yielding, varieties have a longer heading interval and remain susceptible for a longer period. For these varieties, there was a direct correlation between the vulnerable stage and midge presence in the field.

Another complicating factor in the more recent trials was that the testing was done during "el Nino" years, with unique environmental conditions. Further testing will be required before any reliable recommendations can be made. However, early seeding of early maturing spring wheat varieties may still be a useful method for non-chemical management of midge populations.

Soil type was another variable identified when considering seeding dates in a cultural control strategy. Days to heading were, on average, five to six days longer on heavy textured soils than on light-textured soils. Therefore, this results in an extended time period when the wheat crop is susceptible to midge damage.

Changes made by the Canadian Grain Commission to its grading tolerances have prompted the re-evaluation of the economic threshold for wheat midge to maintain optimum grades. In areas where growing conditions are favourable for the production of No. 1 grade wheat, chemical control measures may be required when midge populations reach one adult midge for every eight to ten wheat heads during the susceptible stage.

If producing wheat for yield only (not necessarily top grade), an insecticide application is recommended when there is at least one adult midge for every four or five wheat heads. At this level of infestation, wheat yields will be reduced by approximately 15 per cent if the midge is not controlled; the grade of the wheat will also be negatively affected with infestations above this level. With the high price of wheat and durum, producers may want to lower the density of adult wheat midge present in fields as their action threshold. The typical action threshold has been one midge per four to five wheat heads for hard red spring wheat and one midge per seven to eight heads for durum when wheat and durum are below $10 per bushel.

In terms of chemical control options, Cygon, Lagon, Lorsban 4E, Nufos, Citadel and Pyrinex, are registered to control midge in Canadian wheat. An insecticide application is recommended if the action threshold has been reached before the crop has flowered. Because the timing of the application will vary with the insecticide being used, it is important to consult the specific recommendations for the product. All insecticides should be applied in the evening when the female midge is most active at the top of the crop canopy. However, early morning applications may also produce acceptable results.

As an important note, chemical applications made during the advanced stages of flowering are discouraged because plants in this growth stage are no longer susceptible to an attack. As such, any larvae already inside the florets are unlikely to be affected by the insecticide. Instead, the insecticide will actually have a negative impact on midge parasites.

Cygon and Lagon applied with ground or aerial equipment provide contact control of adults, and some residual management. However, they do not control the eggs. Chemical applications should be made within 24 hours of reaching the action threshold - while the adults are still active. If the adult midge persists, a second application may be required, provided that the crop has not started to flower.

Lorsban 4E, Nufos, Citadel and Pyrinex will control the adult and egg phases of the wheat midge. Because these insecticides control eggs, they do not have to be applied within 24 hours of having reached the action threshold, as is the case with Cygon and Lagon. In fact, applications should be delayed up to four days after the recommended action threshold has been reached. This strategy allows a maximum number of wheat heads to emerge, resulting in increased protection. However, Lorsban 4E, Nufos and Pyrinex should not be used within 60 days of harvest and access to the field should be restricted for at least 48 hours after application.

Application rates for Lorsban 4E, Nufos and Pyrinex are lower for ground sprayers than for aircraft. For ground application units, field sprayers equipped with flat fan (F) nozzles, oriented at a 45^{o} angle forward, provide the best coverage. Boom height should be adjusted to comply with recommendations of the nozzle manufacturer. The insecticide should be applied at 240 to 275 kPa in the highest recommended water volumes, as high volumes (75-100L/ha) provide better protection than low water volumes (25-50 L/ha).

New sprayer technology (e.g. air-assisted, Venturirr nozzles) in application of insecticides for control of wheat midge has not been adequately researched to determine efficacy with lower water volumes. As such, if the chemical application is conducted via aerial application, the insecticide should be applied in the evening using water volumes of 18.7 to 37.4 L/ha. Because the uniform insecticide coverage of wheat heads is essential for the control of eggs higher water volumes are recommended.

Progress has been made towards developing wheat cultivars that are resistant to wheat midge damage. Researchers have discovered a powerful resistance gene, called Sm1, in winter wheat from eastern North America, and have incorporated this gene in the main classes of spring wheat grown in western Canada (McKenzie et al. 2002). The gene was transferred to spring wheat using conventional plant breeding methods. The resistance prevents larvae from feeding on young developing seeds so that they eventually die, probably from starvation. The chemical basis for the defense is understood, and the gene does not affect the quality of the ripe wheat seeds (Ding et al. 2001). The resistance all but eliminates wheat midge damage and wheat midge from wheat tested across Manitoba and Saskatchewan (Lamb et al. 2000). Three new midge-resistant varieties are in the registration pipeline (Unity, Goodeve and BW365), but they likely won't be available commercially until 2009.

Conclusion

Some provinces and states conduct annual surveys for wheat midge both to determine the distribution patterns and to warn producers of possible outbreaks. Consult your local extension office for details in your area.

Lamb, R. J., R. I. H. McKenzie, I. L. Wise, P. S. Barker, M. A. H Smith, and O. O. Olfert. 2002. Making control decisions for *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) in wheat (Gramineae) using sticky traps. Can. Entomol. 134:851-854.