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Management practices for wheat midge, *Sitodiplosis mosellana* (Géhin)

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Summary

Wheat midge is an established insect pest in most wheat-producing regions of the world. It was first detected in western Canada in the early 1900's. However, the first major outbreak in Saskatchewan was not recorded until 1983. Since then, wheat midge populations have spread and now infest a large portion of the wheat-producing area of the prairies. Damage caused by larval feeding on kernels can reduce crop yields and lower the grade of harvested grain. Today, wheat producers in western Canada have access to one of the most comprehensive management programs of any insect pest of field crops. Forecasts and risk warnings, monitoring tools, cultural control, agronomic practices, chemical control, biological control and host plant tolerance are all available for producers to manage wheat midge and to conserve its natural enemies.

Background and Current Status

Wheat midge, *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae), is an established insect pest in most wheat-producing regions of the world. It was introduced into western Canada over 100 years ago. The insect was first reported in Manitoba in the early 1900s but did not become a pest until the 1950s [1]. The first major outbreak of wheat midge occurred in northeast Saskatchewan in 1983 when producers in nine municipalities suffered over $30 million in yield losses [2]. Since that time, wheat midge has become a chronic pest of spring wheat (*Triticum* spp.) throughout much of the wheat-growing area of Manitoba, Saskatchewan and Alberta, and neighboring states of North Dakota, Montana and Idaho[3,4,5]. Wheat midge also occurs in Nova Scotia, Quebec, Ontario and British Columbia[6].

In 1984, a research team began comprehensive biological, ecological and agronomic studies on wheat midge. Research initially focused on assessing the impact of wheat midge damage on yield, grade and milling quality[2,7,8,9]; developing methods to monitor midge populations in commercial fields[10,11,9]; evaluating the role of parasitic wasps and ground beetles as biological control agents[12,13]; identifying alternate crops that could be grown with little or no risk of midge damage[14]; and developing methods to improve the timing, placement and efficacy of insecticides applied by aircraft or high clearance ground sprayers[8,9.15,16]. During outbreaks in the 1990s, insecticidal sprays were applied to 300,000-500,000 ha of wheat annually to minimize midge damage[5]. Subsequent research concentrated on identifying the key growth stages that spring wheat is most susceptible to midge damage[17]; evaluating wheat varieties for their susceptibility to midge damage[18,19]; developing new methods of forecasting and monitoring the emergence of adult wheat midge[20,21,22,23]; and developing wheat cultivars with resistance to wheat midge[24,25,26]. This paper describes the pest status of wheat midge and management practices that can be used to reduce its agronomic and economic impact.

Descriptions

Wheat Midge - *Sitodiplosis mosellana*. The adult is a small orange fly approximately 2-3 mm long (Figure 1). The adults have prominent black eyes and relatively long legs and antennae. The male antennae are covered with fine hairs. The wings are clear and fringed with fine hairs. Larvae are found on the surface of developing wheat kernels and reach 2-3 mm at maturity. With moist conditions, the larvae drop to the ground and overwinter in spherical cocoons, usually within 5 cm of the soil surface[22]. The cocoons are 1-2 mm in diameter and are often coated with soil particles.

Figure 1. Adult wheat midge, *Sitodiplosis mosellana* (Photo credit: AAFC – Saskatoon Research Centre).

Parasitic wasp - *Macroglenes penetrans* (Kirby) (Hymenoptera: Pteromalidae) is the predominant parasitoid of wheat midge in western Canada. It is an egg-larval parasitoid. The adult is a very small bluish-black wasp between 1-2 mm long (Figure 2). The wings are translucent. Males have prominent rust-coloured eyes; females have less prominent brownish-black eyes. The female wasp lays an egg inside the egg of its host. The parasite hatches after 5-12 days and starts to develop inside its host[27].

Figure 2. Adult parasitoid, *Macroglenes penetrans* (Photo credit: AAFC – Saskatoon Research Centre).

Life Histories

Sitodiplosis mosellana has one generation per year and overwinters in the soil as a mature larva[10]. Development during the following spring depends on temperature and soil moisture. If conditions are dry during May or early June, most larvae remain dormant until the following year. In contrast, when precipitation exceeds 20 mm in May or early June, the larvae terminate diapause, leave their cocoons and spend several days on the soil surface before pupating[10,23]. The adults emerge over a six-week period beginning in late June or early July[9,3]. The adults are difficult to detect during the day because they remain within the crop canopy close to ground level where it is more humid. Females become more active in the evening. Most egg-laying on the wheat heads occurs at dusk when conditions are calm and temperatures are above 10–11^{o}C[28]. The larvae hatch after 4-7 days, crawl into the floret and feed on the surface of developing wheat kernels for 2–3 weeks (Figure 3). Mature larvae remain within their cast skin in the wheat head when conditions are dry. If dry conditions persist, larvae remain within the wheat heads until harvest. Once moist conditions are detected, the larvae drop to the ground, burrow into the soil, spin a larval cocoon and overwinter.

Figure 3. Wheat midge larva on wheat kernel (Photo credit: AAFC – Saskatoon Research Centre).

Parasitoids - *Macroglenes penetrans* also has only one generation per year[27] . The adults emerge over a four to five week period beginning in early July in western Canada[22]. The female wasp lays its eggs inside the wheat midge eggs or larvae. The parasitoid hatches after 5-12 days and usually overwinters in its host as a young second-instar larva[29]. As a result, crop damage is not reduced in the current growing season but pest populations are reduced the following year. After diapause is broken the following spring, the parasite consumes its host, pupates and emerges as a wasp in early July, approximately 3-5 days after wheat midge adults[30]. Parasitoid populations tend to follow the wheat midge populations with a one- to two-year lag period[5]. A second parasitoid, *Platygaster tuberosula* Kieffer (Hymenoptera: Platygastéridae), released in 1993 and 1994, has been successfully established as a classical biological control agent in eastern Saskatchewan to supplement the effectiveness of biological control[31]. Follow-up monitoring programs showed that the population density increased five-fold at the release site and showed signs of migrating into the surrounding area by 2001.

Other natural enemies[13] - Floate et al. (1990) identified 14 carabid species (Coleoptera: Carabidae) that fed on wheat midge larvae in the field. Estimates of predation in the field ranged from <1 to 86 midge larvae/m^2. It was found that wheat midge larvae were susceptible to predation during June after breaking larval diapause and during August when they were moving from the wheat heads to the soil to overwinter.

Egg-laying and Potential Crop Losses

Wheat midge females live 3–7 days and lay an average of 80 eggs[28]. Eggs are laid singly or in clusters of up to four eggs. The eggs may be laid underneath the glumes or along grooves of the surface of wheat florets[11]. Usually only some of the florets on a wheat head are infested and the level of infestation can vary from one to eight or more larvae per floret. If two or more larvae develop within a floret, the kernel may abort or not fill properly. Mature kernels from infested florets are cracked, shriveled or deformed (Figure 4). Small, lighter kernels are lost during harvesting operations, resulting in lower grain yield. If one larva develops on a kernel, the surface is scarred and slightly depressed. Damaged kernels that are harvested lower the grade and grain quality[7,9,32].

Figure 4. Kernel damage caused by wheat midge larval feeding (Photo credit: AAFC – Saskatoon Research Centre).

Crop Susceptibility

Wheat midge is a serious pest of spring and winter wheat, *Triticum aestivum* L., in many regions of the world[26,14]. Wright and Doane (1987) reported that varieties of spring wheat, durum wheat (*Triticum durum* Desf.), triticale (*X-Triticosecale*) and to a lesser extent spring rye (*Secale cereale* L.) are susceptible to wheat midge damage. In contrast, six-row barley (*Hordeum vulgare* L.), annual canarygrass (*Phalaris canariensis* L.) and oats (*Avena sativa* L.) suffer little or no wheat midge damage. Canadian varieties of hard red spring wheat, durum wheat and soft spring wheat also differ in their susceptibility to midge damage[18,19]. The severity of damage depends on the synchrony between egg-laying and heading/anthesis. Wheat heads are most susceptible to damage when egg-laying occurs during heading, Zadoks growth stages 51-59[17]. Damage declines dramatically when egg-laying occurs after the anthers are visible. Wheat varieties that head in late June and early July usually have low damage because heading and anthesis occur before high populations of wheat midge are present. Wheat midge populations may exist at low levels for several years causing minor crop losses. However, under favorable conditions, populations can exceed economically-damaging levels within one or two years. Moist conditions in May and June favor larval development; warm, calm conditions increase egg-laying activity. Adults are relatively poor fliers but may be distributed over long distances by thermal updrafts and wind.

Management

Forecasts of potential wheat midge infestations are developed from soil surveys of wheat fields after harvest[5]. Soil samples are evaluated to determine cocoon numbers, larval viability and percentage parasitism. The survey data are mapped to identify areas at risk to damage the following year. Significant damage and economic losses can occur when wheat midge populations in the soil reach 600 cocoons per square metre.

Degree-day accumulations above 5°C provide the most accurate estimates of adult wheat midge emergence[23]. To assist in monitoring, a website was created in 2008 (http://www.cwb.ca/weather/midge) to provide wheat producers in western Canada with daily updates of degree-day accumulations and an estimate of percent adult emergence. Pheromone traps and sticky traps are also used to monitor adult wheat midge in commercial fields[20,21].

Macroglenes penetrans plays a significant role in reducing wheat midge infestations on the Northern Great Plains[31,5,4]. In many areas, the wasp controls more than 40% of the wheat midge population. The estimated value of the parasitoid, due to savings in insecticide costs in Saskatchewan alone, was estimated to be in excess of $248.3 million from 1991-2000[5]. The environmental benefits of reduced pesticide application are an additional bonus.

Cultural practices are important in the management of wheat midge. Continuous wheat cropping should be avoided to discourage the buildup of wheat midge populations. In areas where populations exceed 1200 larvae per square metre, producers are encouraged to grow resistant crops such as canola, flax and legumes. Other cereal crops such as hulled barley, oats and annual canarygrass can be grown with little or no risk of wheat midge damage[14]. Canadian varieties of hard red spring wheat, durum wheat and soft spring wheat differ in their susceptibility to damage. With the exception of soft spring wheat, early-maturing varieties suffer less damage than late-maturing varieties. For low to moderate infestations, damage can be reduced by selecting less susceptible varieties, planting before May 10 and planting seed at higher rates to discourage tillering. Higher seeding rates and early planting promote uniform and advanced heading to avoid high populations of adult wheat midge that occur in mid to late July. In comparison to heterogeneous stands from crops seeded at lower rates, uniform crops are easier to monitor and determine the optimum time to apply a more effective insecticide treatment.

An insecticide application is recommended when wheat midge densities during heading reach one adult for every 4-5 wheat heads at several locations in the field. The edges and centre of the field should be inspected from the time that the wheat heads are exposed in the boot until anthers are visible on most heads. Inspections should be done in the evening from 1800 hours until dusk when egg-laying occurs. The timing of the insecticide application varies depending on the insecticide and its spectrum of activity against egg and adult stages of wheat midge[8]. Insecticides such as chlorpyrifos control the eggs and neonate larvae of wheat midge and are applied 4-6 days after egg-laying begins[8,16]. The uniformity of deposits on wheat heads can be improved by applying the spray at higher water volumes and orienting the nozzles on ground sprayers 40 degrees forward rather than downward[9,15,16]. Guidelines from the chemical manufacturer should be consulted to ensure that the product is applied in the recommended manner.

Wheat midge-tolerant varieties are a recent management strategy designed to address the major issues of lower yields and market grades. In turn, they offer producers more flexibility in crop rotations. A novel gene (*Sm1*) that confers feeding resistance to the wheat midge was discovered at the Cereal Research Centre in Winnipeg[25]. The gene prevents larvae from establishing on developing seeds. Gene expression activates a natural response within seeds when larvae begin to feed by releasing ferulic and p-coumaric acids at the feeding site[24]. These acids return to normal levels at maturity and do not affect seed quality. Tolerance based on a single gene is often short-lived due to genetic mutations that occur in insect pest populations. To conserve the effectiveness of the *Sm1* gene, new tolerant cultivars have been released as a blend, containing a ratio of 90% resistant seed and 10% seed of a registered susceptible cultivar. The blend helps to prevent the development of resistant mutations in midge populations by allowing sufficient numbers of susceptible midge to survive and mate with midge that become resistant to the *Sm1* gene. The susceptible cultivar also serves as a refuge and helps to conserve the parasitic wasp, *M. penetrans* [26]. Four wheat varieties (three Canada Western Red Spring and one Canada Western Extra Strong) with improved tolerance to wheat midge damage were registered in 2007. Unity VB and Goodeve VB, both CWRS varieties, were available for commercial production in 2010. The other two varieties, Fieldstar VB (CWRS) and Glencross VB (CWES) will be available for commercial production in 2011. All four varieties will be released as varietal blends.

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