E-1330

INTEGRATED PEST MANAGEMENT of the Wheat Midge in North Dakota

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Introduction and Distribution

Wheat is the most widely cultivated plant in the world, providing more than 20 percent of the food calories consumed. The wheat midge (or orange wheat blossom midge), *Sitodiplosis mosellana* (Géhin) (Diptera: Cecidomyiidae), is one of the most destructive pests of wheat. The first reference to a wheat midge larva in wheat was in 1741 in England, although researchers are uncertain if it is the same midge causing trouble today. Wheat midge originated in Europe, and the first record of its occurrence in North America was from Quebec in 1828. Since then, it has been recorded in various locations throughout the Old World and New World, especially in North America, Europe and China. In recent years, wheat midge infestations have been reported in Minnesota, Montana, North Dakota, Alberta, Saskatchewan, Manitoba and British Columbia. In North Dakota, wheat midge occurs throughout the wheat-producing areas and has caused economic damage in the northern tier of the state.

Host Plants

Wheat midge is an oligophagous insect. Common wheat, *Triticum aestivum* L., is the primary host of the wheat midge throughout its modern distribution in Europe, Asia and North America. All 17 species in the genus *Triticum* are hosts for wheat midge. Other grass hosts include durum wheat (*Triticum durum* Desf.), occasionally rye (*Secale cereale* L.) and barley (*Hordeum vulgare* L.). Wheat midge also will deposit eggs on some grassy weeds, such as quackgrass (*Elymus repens* (L.) Gould), slender meadow foxtail, (*Alopecurus myosuroides* Huds.) and other grasses, but larval development on these grassy hosts is questionable.

Identification

Adults (Figure 1)

The adult wheat midge is an orange-colored, fragile, very small insect approximately half the size of a mosquito. It is about 0.08 to 0.12 inch (2 to 3 millimeters) long with three pairs of long legs. It has a pair of wings, which are oval, transparent and fringed with fine hairs. Two eyes are conspicuous and black.

Figure 1. Adult wheat midge.
(Extension Entomology, NDSU)

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Figure 2. Egg of wheat midge. (Saskatoon Research Centre, Canada)

Figure 3. Larva of wheat midge in wheat kernel. (Saskatoon Research Centre, Canada)

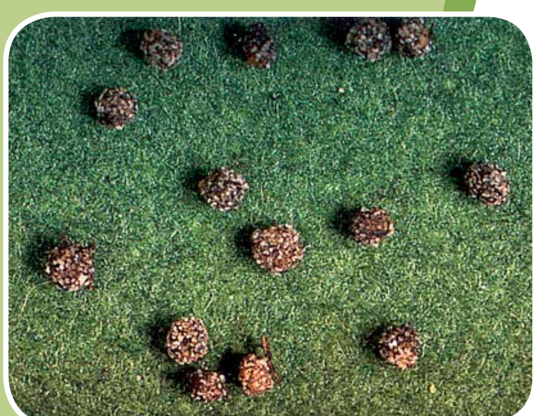

Figure 4. Cocoon of wheat midge. (Saskatoon Research Centre, Canada)

Figure 5. Pupa of wheat midge. (Saskatoon Research Centre, Canada)

Eggs (Figure 2)

Eggs are elongate, whitish and very small. They are about 0.02 inch (0.5 mm) long and laid on the external surfaces of developing wheat spikes.

Larvae (Figure 3)

The wheat midge larvae are orange and about 0.08 to 0.12 inch (2 to 3 mm) long when fully grown. The head capsule is small and mouthparts are reduced. Larvae can be found on the developing seed kernels for two to three weeks. Mature larvae drop to the soil and burrow down into the soil about 2 to 4 inches (5 to 10 centimeters) deep. Within the soil larvae spin small round cocoons (Figure 4).

In very dry conditions, larvae do not complete development and do not shed their last larval skin. They shrink back inside the larval skin and survive until moisture conditions become favorable. Larvae can survive in cocoons for 10 years or more.

Pupae (Figure 5)

Larvae will pupate in the upper soil surface if soil conditions are warm (55.4 F or 13 C) and moist. If conditions are unsuitable, larvae will remain in the pupal stage. Larvae pupate with or without a cocoon, depending on the temperature and soil conditions.

Life Cycle (Figure 6)

The wheat midge has only one generation per year and begins to emerge from the soil about the last week of June or first week of July. During the day, adults remain within the crop canopy where conditions are humid. Males emerge earlier than females and seek females on the first evening after hatching. After mating, females lay eggs on the newly emerged wheat heads in the evening. Oviposition begins on the second day after emergence, with the maximum number of eggs laid on the third day after emergence. Mated females deposit their eggs either individually or in groups of three to five underneath the glumes or the palea (small, chafflike bracts enclosing the flower of a grass) in florets of wheat heads primarily just before anthesis. However, eggs can be laid on almost any outer structure of the spikelet, including the rachis (main stem of an inflorescence). Females live usually less than seven days and lay an average of 80 eggs. Eggs hatch in four to seven days, depending on the temperature.

Upon hatching, the larvae find their way to a developing kernel on which they feed. Larvae mature in about two to three weeks and remain quiescent, unsheathed in the second instar larval integument, and remain in this state until they are activated by rain or dew on the heads. Moisture causes them to drop to the soil surface, where they burrow in and form overwintering cocoons.

Wheat midge larvae break diapause and begin to emerge from the cocoons about the third week in May. Larvae move about in the soil and often are found on the soil surface. Pupation begins about mid-June and the first adults are observed during the last week of June or first week of July. Wheat midge larvae have an obligatory diapause, which can delay or even prevent emergence until the following year when soil conditions are dry.

Wheat midge adults emerge in late afternoon and early evening. They exhibit protandry, with males emerging up to three days earlier than females and one to two hours earlier than females on a given day.

Environmental conditions play an important role in wheat midge activity and dispersal. Warm, calm, humid weather is ideal for flight and oviposition. Adults are not strong fliers, and cool temperatures (below 59 F or 15 C) and rainy, windy weather deter activities and between-field movements. Recent field reports suggest that wheat midge can be blown several miles on the wind, aiding dispersion.

Damage

On the northern Great Plains, the wheat midge primarily infests wheat, which is seeded in the spring and harvested in late summer. The wheat midge is a seed feeder and infests a wheat plant during heading through early flowering (Figure 7). Crop injury is caused only by the larval stage. After hatching, wheat midge larvae crawl down to feed on the developing wheat kernel. They feed by exuding enzymes that break down cell walls and convert starch to simple sugars. This causes the wheat kernel to shrivel, crack and become deformed (Figure 8). Wheat kernels may be partially damaged or entirely aborted.

The level of kernel injury is influenced by the growth stage of the plant at the time of infestation. Grains are most susceptible to injury when oviposition occurs during the heading stage. Once the head has passed 50 percent flowering, injury to the kernel is reduced. Larvae hatching after flowering do not develop properly and cause little injury. Injured kernels are small and light, and often pass through the combine with the chaff during harvest. Economic damage caused by the wheat midge reduces yield, grain quality, and germination and growth vigor of seedlings. In addition, the presence of wheat midge larvae in stored wheat grain may cause heating in the grain bins and eventually contaminate flour milled from infested grain. Furthermore, wheat midge adults can act as a vector for microorganisms that infect wheat seeds (wheat scab and glume blotch).

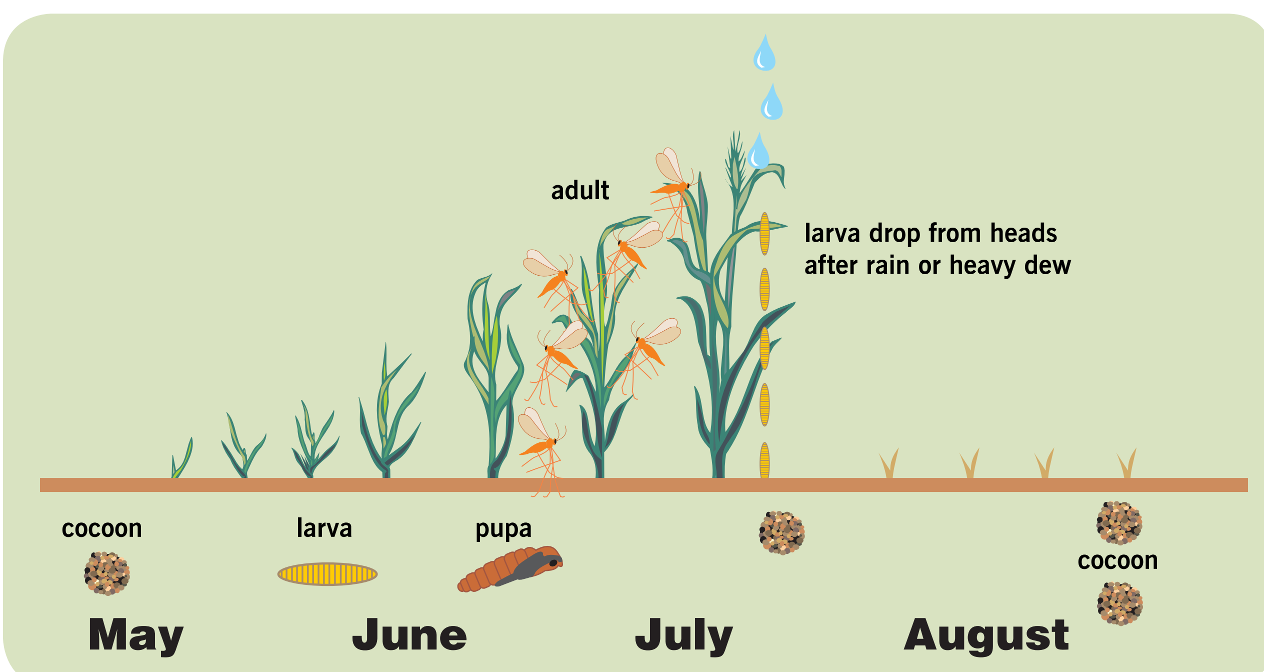

Figure 6. Life cycle of wheat midge. (Extension Entomology, NDSU)

During the wheat midge outbreak of the mid-1990s, crop losses were estimated on more than 725,000 acres of wheat that were valued in excess of $27 million to North Dakota. In response to the outbreak, a fall survey was initiated and conducted by the Department of Entomology and NDSU Extension Service to estimate overwintering populations of wheat midge larvae in soil. Annual surveys have continued and a wheat midge risk map has been created annually from 1994 to 2007 for the benefit of wheat producers and the agricultural industry. Results of the survey indicate areas of high risk (>1,200 midge per square meter) for wheat midge infestation for the following year and are shown by red areas on survey maps. Survey maps and an explanation of the survey's results can be found on the Extension Entomology Web site:
www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/Wheat_Midge/owbm.htm

Identifying Wheat Fields at Risk for Midge Infestation

Based on North Dakota field observations, wheat midge larval infestations were the greatest when heading occurred during peak female emergence (1,475 degree days). Wheat midge degree days (DD) are based on a 40 F (4.5 C) developmental threshold temperature. When using 40 F (4.5 C) as the base threshold for wheat development (normally wheat development is monitored with 32 degrees), heading occurs around 1,000 to 1,100 DD. A wheat growth and wheat midge emergence model is available through the North Dakota Agricultural Weather Network (NDAWN) Web site and can be found at:
http://ndawn.ndsu.nodak.edu/wheat-midgegdd-form.html

Degree Days as a Tool for Wheat Midge Scouting

A model using daily temperatures to calculate degree day (DD) accumulation allows for a more accurate prediction of local adult emergence. Based on data from Canada, the threshold temperature for wheat midge development is 40 F (4.5 C). Observations indicate the following DD accumulations for events in the wheat midge population:

DD	Biological Event
450	Wheat midge breaks larval cocoons and move close to soil surface to form pupal cocoons.
1,300	10 percent of females will have emerged.
1,475	About 50 percent of females will have emerged.
1,600	About 90 percent of females will have emerged.

Observations in North Dakota indicate that by about 1,800 DD, adult numbers decline to the point where field activity is below economic threshold levels. However, in areas where reduced or minimum tillage is common, significant adult activity has been reported and observed up to about 1,900 DD.

Although DD are useful in predicting development of many insect species, these predictions are only estimates. The accuracy of a DD estimate is dependent on the temperatures used in calculating DD. Degree days

Figure 7. Crop stages of hard red spring wheat – heading (left), early flowering (center) and late flowering (right). (Ransom, Department of Plant Sciences, NDSU)

Figure 8. Comparison of healthy (top) and damaged (bottom) wheat kernels from wheat midge feeding injury. (Saskatoon Research Centre, Canada)

should be calculated with temperatures that represent the environment where insects are developing. Temperatures at one site give only a rough estimate of insect development at other sites miles away.

Monitoring for Wheat Midge in the Field

Mated wheat midge females lay their eggs underneath the glumes or the palea in florets of wheat heads between the period of heading and early flowering. Therefore, fields should be monitored frequently from the time when wheat heads start to emerge from the boot leaf until a few days after anthers are visible. Field monitoring should be done after 8.30 p.m. because wheat midge females are most active during this period. Careful visual observations of wheat heads are necessary to confirm the presence of wheat midge females in the field. Typically, the most significant flight period for the entire wheat midge population extends during a 14- to 18-day time window within a geographic region. Individual adult wheat midge may survive from three to seven days, depending on environmental conditions.

Wheat midge populations are estimated by counting the number of adults on developing wheat heads during night scouting at several locations in a field. Examine wheat heads at dusk (after 8.30 p.m.) when temperatures are above 59 F (15 C) and wind speed is less than 6 mph (10 kilometers per hour). The orange-colored female wheat midge can be seen fluttering from plant to plant and laying eggs on the wheat heads. Wheat plants are susceptible from heading to early flowering. Visit three or four different sites in the field. At each location, count the number of adult wheat midge on several sets of wheat heads (four to five heads per set). Record the number of adult wheat midge and calculate your average for the field. Wheat midge scouting can be difficult and inaccurate for the novice scout because adults fly at dusk and after dark only when environmental conditions are optimal.

Environmental conditions play an important role in wheat midge development and activity. Soil moisture must be adequate to allow adult emergence from the soil, and wheat midge also requires warm temperatures, calm conditions and adequate moisture during heading to cause economic injury. Soil conditions in reduced-tillage situations will vary from normal tillage conditions and may delay some wheat midge emergence in a region. Conditions that favor survival of adult wheat midge even may place later planted wheat at some risk. Scouting until adult wheat midge activity has decreased below economic levels or the crop no longer is susceptible to wheat midge infestations is the best way to avoid unnecessary losses. The highest wheat midge populations can be found in fields where wheat was grown in previous years and in fields that are next to the fields of wheat grown in previous years.

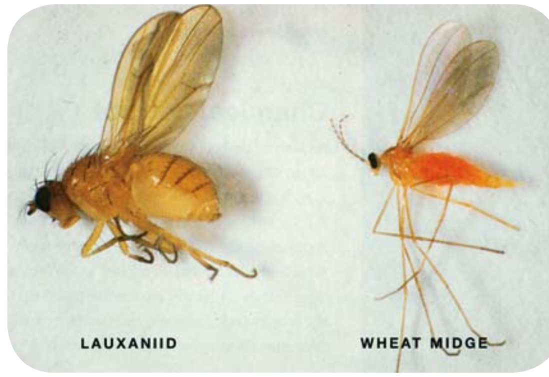

Figure 9. Lauxaniid fly (left) and wheat midge (right).
(Saskatoon Research Centre, Canada)

Be careful not to confuse the lauxaniid fly, *Camptoprosopella borealis* (Diptera: Lauxaniidae), with wheat midge (Figure 9). The lauxaniid fly is yellowish brown and larger – about 1/10 to 1/6 inch (2 to 4 mm) in length – than the wheat midge. It also actively flies above the wheat canopy during the day and early evening. In contrast, the wheat midge flutters from plant to plant only in the evening. At night, the lauxaniid can be observed resting in the wheat canopy in a horizontal position with its head pointing down in contrast to the wheat midge, which rests with its head pointing upward.

Economic Threshold Levels

Economic thresholds vary with the value of wheat. Typical economic thresholds are given below.

Economic Threshold Levels:

Hard Red Spring Wheat = one or more wheat midge for every four or five heads

Durum Wheat = one or more wheat midge for every seven or eight wheat heads

Treatment after 50 percent of the heads have flowered is not recommended due to reduced levels of efficacy and to protect parasitoid wasps that attack the wheat midge.

Figure 10. White plastic foam plate (trap) used to monitor for adult wheat midge. (Knodel, Department of Entomology, NDSU)

Figure 11. Emergence trap used to monitor for adult wheat midge. (Knodel, Department of Entomology, NDSU)

Figure 12. Yellow sticky trap used to monitor for adult wheat midge. (Knodel, Department of Entomology, NDSU)

Figure 13. Sex pheromone trap used to monitor for adult wheat midge. (Knodel, Department of Entomology, NDSU)

Figure 14. Parasitoid, *Macroglenes penetrans*, of wheat midge. (Saskatoon Research Centre, Canada)

Figure 15. Dissected parasitoid larva (circled) that was developing inside the wheat midge larva. (Anderson, Department of Entomology, NDSU)

Other Methods for Detecting Adult Midge in Wheat Fields

Plate traps (Figure 10) can be used to capture wheat midge adults in wheat fields. A simple trap design uses a white plastic foam plate attached to the top and bottom of a surveyor's flag. The plate's surface is coated with Tanglefoot or vegetable oil to capture adults that are flying about. Sticky traps are of limited use. They can alert an individual to the presence of wheat midge and help in identifying midges, but do not provide information about the need to treat.

Emergence traps (Figure 11) are containers placed on the soil surface to collect wheat midge adults as they emerge from the soil. These traps have been used to alert researchers and Extension personnel to the start of wheat midge emergence and aid in calculating DD models.

Yellow sticky traps (Figure 12) can be used to monitor wheat midge populations and help make control decisions. Both sexes of wheat midge, as well as many other insects, are captured, so correct identification is essential. The number of adults trapped on yellow sticky traps has been correlated to the subsequent number of larvae that infest and injure seeds. When wheat is beginning to head, 10 yellow sticky traps are spaced 33 feet (10 meters) apart in a row 50 ft (15 m) from the edge of the field and placed at the height of wheat heads for three successive nights. An insecticide application is recommended when five to 20 wheat midge adults are captured per trap. This infestation level is estimated to cause about 2 percent seed damage. When traps capture more than 20 adults per trap, fields may have more than 5 percent seed damage and economic yield loss. Yellow sticky traps are commercially available from pheromone trap suppliers and are a relatively inexpensive method (about $0.60 per trap) for monitoring wheat midge population densities.

Sex pheromone traps (Figure 13) are commercially available and attract only the adult male wheat midge. Researchers have found a significant correlation between the number of captured males and the percent of seed damaged at harvest. The delta-styled traps are placed in the field five days before heading at wheat head height and about 75 feet (25 m) from the field edge, and are spaced at least 300 feet (100 m) apart. Three traps per 160 acres (64 hectares) are recommended. Examine traps at one- to two-day intervals and count the number of captured male wheat midge (look like orange spots). If cumulative trap catches exceed nine to 10 wheat midge males per trap at three days after heading, then this indicates an economic risk to the wheat crop and an insecticide application may be necessary. Wheat midge pheromone traps cost approximately $7.20 per trap unit (trap + pheromone) and are available only from Phero Tech Inc. in Delta, British Columbia, Canada (www.pherotech.com/). [Note: Mention of a product does not constitute an endorsement or recommendation by the NDSU Extension Service.]

Additional research is necessary to refine and validate these trapping methods for use in making control decisions for populations of adult wheat midge in wheat fields in North Dakota.

Integrated Pest Management

Although infestation pressure from wheat midge has declined, it remains an economic concern for wheat producers in North Dakota. Since 1995, wheat midge has been detected in all counties east and north of the Missouri River. One contributing factor to past outbreaks was the delayed planting of wheat due to excessively soil moisture in the spring. Any factor that results in having heading wheat present in the fields during wheat midge emergence will put a wheat crop at risk for infestation.

Cultural, biological and chemical control methods are used for controlling wheat midge on wheat.

Cultural methods

1. Selecting early maturing varieties and planting early before 200 wheat midge growing DD have accumulated.

Early planting is the most useful cultural control method. This method is suitable only for hard red spring wheat. Early planting is not as effective with durum because most durum wheat varieties are later maturing than spring wheat. By planting early maturing wheat varieties, wheat midge infestation is minimized because the crop heads and flowers before peak emergence.

Planting early maturing varieties will not help if planting is delayed and occurs during the time frame that causes the wheat to head as wheat midge is emerging. Degree days are used to help identify the high risk planting window for hard red spring wheat. Wheat reaches heading stage at 1,000 DD (when using the same wheat midge DD accumulations). The following guidelines are provided to identify at-risk planting dates for wheat midge infestation in hard red spring wheat (HRSW).

Wheat Midge Degree Days Used as a Guideline for HRSW Risk Assessment
HRSW planted **PRIOR** to accumulation of **200 DD** will head before wheat midge emerge.
HRSW planted **FROM 200 to 600 DD** will head at the time wheat midge is emerging.
HRSW planted **AFTER 600 DD** will head after peak emergence and should be at low risk to wheat midge infestation (higher risk of frost).

2. Planting late after 600 wheat midge growing DD have accumulated.

Late-planted hard red spring wheat will head after peak wheat midge emergence and be at a lower risk for wheat midge infestation and crop damage. However, late-planted wheat can be susceptible to frost injury.

3. Crop rotation

Continuous wheat cropping should be avoided because this practice encourages the buildup of wheat midge populations. The wheat midge life cycle largely depends upon the presence of wheat to infest, and the successful overwintering of wheat midge larvae in the soil. Planting crops that are not susceptible to wheat midge, such as soybean, sunflower, flax, pea, lentil, chickpea, oat or corn, will reduce the reproductive opportunities for wheat midge.

Biological Control

One of the most important biological control agents of wheat midge in North Dakota is *Macroglenes penetrans* (Kirby) (Hymenoptera: Pteromalidae) (Figure 14). It is a small parasitoid wasp about 1/10 inch (1 to 2 mm) long and metallic black. It is an egg-larval parasitoid that emerges at a similar time as wheat midge. This parasitoid wasp lays its eggs inside the wheat midge eggs or larvae. The wasp egg develops while the wheat midge develops and the parasitoid grows inside the developing larva (Figure 15). Wasp larvae overwinter inside the wheat midge larvae and grow rapidly during the following spring and ultimately kill the wheat midge larva. Based on the wheat midge soil surveys, the parasitism rate for wheat midge averaged 22 percent and ranged from 0 percent to 100 percent, depending on the year (1995-2006) and location in North Dakota. Populations of parasitoids tend to follow the populations of wheat midge by at least a one-year lag period.

Chemical control

The adult wheat midge is active from late June to early August. Peak activity is from late June to mid-July. Wheat is attractive for oviposition by midge from the time the head emerges from the boot through flowering. Insecticides for the control of wheat midge are targeted at adults and larvae as they eclose from the eggs. However, insecticides are not effective in controlling older wheat midge larvae, which are protected within the glumes as they feed on the developing kernels. Eggs laid on the exposed parts of the florets also may be killed with certain insecticides. For example, organophosphate insecticides with the active ingredient chlorpyrifos can kill eggs.

If the economic threshold has been reached, an insecticide application is recommended using the following guidelines:

- **If 30 percent of wheat is at heading,** wait up to four days, then treat.
- **If 70 percent of wheat is at heading to flowering,** treat immediately.
- **If 30 percent to 60 percent of wheat heads are at flowering** (at least one anther visible), spray immediately, but control likely will be reduced.
- **If 80 percent of the heads are flowering,** treatments are ***not recommended***. Applications at this time are no longer effective because most larvae will be feeding on kernels and well-protected inside the glumes. Or, plants are no longer attractive to adult wheat midge and further infestation of primary heads and first tillers is unlikely. In addition, late application will kill the parasitoid wasps, reducing natural biological control.

Insecticide application is recommended at dusk because female adults are most active in the top of the crop canopy. Apply in a minimum of 3 to 5 gallons of water per acre for aerial applications and 10 gallons of water per acre for ground applications. For ground applications, nozzles should be angled forward at a 45-degree angle for optimal coverage of the wheat head. Insecticide labeled for wheat midge can be tanked-mixed with fungicides for *Fusarium* head blight (or scab) control during early flowering.

Use of insecticides is the most common and effective method for management of economic population densities of wheat midge. Please consult the most current "North Dakota Field Crop Insect Management Guide" for a listing of available insecticides at:

www.ag.ndsu.edu/pubs/plantsci/pests/e1143w1.htm

Use of Resistant Varieties

A highly effective resistance trait called *Sm1* was discovered in wheat genotypes in 1996. *Sm1* reduces survival of early instar wheat midge. If wheat genotypes carrying *Sm1* perform well in Canadian registration trials, deployment will begin within one to five years in the hard red spring wheat (*Triticum aestivum* L.) in the northern Great Plains. Deployment of the same gene in durum wheat (*Triticum turgidum* L.) is expected to follow.

For more information on this and other topics, see: www.ag.ndsu.edu

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