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Integrated Pest Management of Wheat Stem Sawfly in North Dakota

Wheat stem sawfly adult
(RKD Peterson, Montana State University)

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Distribution and History

Wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae), is widely distributed across North America, from California to the Mississippi River and from British Columbia to Manitoba. It has been reported from as far south as Kansas and New Mexico. Many authorities consider it a native North American insect that adapted to wheat as European settlers began large-scale cultivation of cereal crops. Alternatively, some researchers have suggested that the wheat stem sawfly may have been introduced into North America inadvertently from northeastern Asia. Whatever its origins, wheat stem sawfly is the most serious insect pest of spring wheat and durum wheat in North Dakota.

Wheat stem sawfly first was reported as a pest of wheat in Saskatchewan and Manitoba in the late 1890s. In 1906, larvae were found attacking wheat in south-central North Dakota. By 1909, losses of up to 25 percent were reported around Minot and in the Red River Valley near Fargo. The North Dakota infestation reached epidemic levels in 1916 but receded rapidly, and by the early 1920s, wheat stem sawfly was a pest of minor importance. During the 1940s, wheat stem sawfly again became a problem, with as much as 50 percent crop loss reported in northwestern North Dakota.

Sawfly populations have fluctuated across years and locations, although infestation levels and damage are greatest in western North Dakota. Wheat stem sawfly has increased steadily in the past 10 years, with the heaviest economic loss occurring in southwestern North Dakota. In 2009, a survey of wheat producers statewide revealed that crop loss due to wheat stem sawfly ranged from 10 to 25 percent. However, some fields in southwestern North Dakota had severe lodging, and 100 percent of the spring wheat fields were lost due to wheat stem sawfly in 2009. Based on current production totals and crop values, North Dakota wheat producers lost between $25 million and $70 million in 2009.

Identification

Egg: Wheat stem sawfly eggs are pale white, somewhat oval-shaped and less than 1/16 inch in length (Figure 1). The eggs are laid singly in the lumen of a wheat stem and can be seen easily when a stem is split. At high infestation levels, multiple eggs may be laid in each stem; more than 10 eggs have been observed in a single stem.

Larva: Newly hatched larvae are colorless (Figure 2) and begin feeding immediately on the stem pith. They turn a greenish yellow as they ingest plant material and become yellow-white when mature (Figure 3). Larvae pass through four or five instars and reach a length of approximately ½ inch. The dark and heavily sclerotized head capsule of the wheat stem sawfly larva and its fairly large body size distinguish it from other larvae that may be found in cereal or grass stems. Larvae that have entered diapause will form a characteristic "S" shape when removed from the stem (Figure 3) in late fall or spring.

Pupa: The prepupa (Figure 4) is a short quiescent instar between the end of the larval period and the pupal period and resembles a fully mature larva. The pupa (Figure 5) is a resting, inactive period and the intermediate stage between the larva and adult. The pupa of wheat stem sawfly is white and resembles the adult, with the limbs lying free but closely attached to the body.

Adult: Adult wheat stem sawflies are dark and slender, with yellow markings on the abdomen (Figure 6). Adults are less than 1 inch long, and females are generally larger than males. Females have short ovipositor sheaths that protrude just past the tip of the abdomen. Males lack this trait. Adults are not strong fliers but will move to nearby fields to mate and lay eggs (Figure 7). Wind also will aid the dispersion of adults longer distances to find wheat fields for oviposition. When adults are present, they are not difficult to see, and the best way to confirm their presence is by using a standard sweep net.

Figure 1. Wheat stem sawfly egg (RKD Peterson, Montana State University)

Figure 2. Young wheat stem sawfly larva (RKD Peterson, Montana State University)

Figure 3. Mature wheat stem sawfly larva (note characteristic "S" shape) (RKD Peterson, Montana State University)

Figure 4. Wheat stem sawfly prepupa (P. Beauzay, NDSU)

Figure 5. Wheat stem sawfly pupae (RKD Peterson, Montana State University)

Figure 6. Wheat stem sawfly adult female (P. Beauzay, NDSU)

Figure 7. Wheat stem sawflies mating (RKD Peterson, Montana State University)

Life Cycle

Wheat stem sawfly has a single generation per year. Although adults are relatively short-lived (seven to 10 days), adult emergence occurs during a long period of time, usually about three weeks but sometimes as long as one month. First emergence is typically during mid- to late June in North Dakota. Female sawflies deposit eggs into the elongating stems of host plants in early summer (Figure 8), and developing larvae feed on stem tissue and move up and down the length of the stem. Although several eggs may be laid within a stem, only a single larva survives to maturity.

As the plant matures, and usually prior to harvest, the larva moves down to the base of the stem and chews a notch around the inside of the stem. The stem lumen is plugged with frass and sawdust below the notch, forming a chamber. The notch weakens the stem, which usually breaks (Figure 9), producing a stub that remains anchored in the ground (Figure 10). The larva undergoes an obligatory diapause within this chamber and overwinters as a mature larva. The stub often is covered with debris or soil, and therefore is well-protected from excessive cold or dry conditions. Diapause is broken as temperatures, moisture levels and/or photoperiods increase in the spring. Post-diapause development includes prepupal and pupal stages lasting approximately 20 to 30 days, depending on ambient temperatures. Adults emerge from the cocoon and use their mandibles to exit the stub through the plugged end.

Figure 8. Wheat stem sawfly adult female ovipositing into stem (P. Beauzay, NDSU)

Figure 9. Newly cut stem by wheat stem sawfly (RKD Peterson, Montana State University)

Figure 10. Wheat stub indicating overwintering site of wheat stem sawfly (P. Beauzay, NDSU)

Hosts

Spring wheat, winter wheat and durum wheat are the main cereal crops attacked by wheat stem sawfly, although infestation in other small grains such as barley, triticale and spelt has been observed. Barley suffers very little damage, and cultivated oats does not support wheat stem sawfly, although females do lay eggs in oats. Until recently in western North America, wheat stem sawfly primarily attacked spring wheat, while winter wheat suffered less damage because of its more advanced growth stage when sawflies emerge. Wheat stem sawfly has adapted to winter wheat, and winter wheat now sustains extensive damage in the northern Great Plains. Wheat stem sawfly also survives on a number of native and domesticated grasses, including species of *Agropyron, Bromus, Elymus and Elytrigia,* in addition to cereal crops.

Crop Damage

Feeding by wheat stem sawfly larvae reduces the plant's vascular efficiency and results in fewer kernels per head and lower kernel weight. This type of damage can reduce yield on infested stems by up to 20 percent. Sawfly feeding also can reduce the protein content of the grain. Grain loss also is caused by lodging after the inside of the stem is girdled (Figure 11). In Montana and North Dakota, stem infestation levels of greater than 70 percent have been recorded, and losses of up to 80 percent due to lodging have been reported. Lodged plants can be harvested by placing the combine head on or very near ground level and using longer pickup fingers, but this practice can cause additional wear and tear on the machine. Complete harvest of lodged plants is impossible. Yield loss still can range from 10 to 25 percent using this harvest practice.

Figure 11. Lodging caused by wheat stem sawfly near Mott, N.D. (D. Barondeau, NDSU)

Integrated Pest Management (IPM) Strategies

Pest Monitoring

Wheat stem sawfly infestations can be monitored in either the adult stage or as larvae within the stems. The adult stage can be sampled using a standard sweep net. This is relatively easy but may not give an accurate measure of population size unless multiple samples are taken throughout the full adult flight period. This may vary from season to season based on spring temperatures. No correlation has been developed yet between the numbers of adults sampled with a sweep net and the numbers of infested stems.

The sex pheromone of the female wheat stem sawfly has been identified, and pheromone trapping may become a useful monitoring tool for assessing population densities and emergence in the future (Figure 12). A simpler and more accurate assessment of sawfly infestation can be obtained by sampling wheat plants several weeks before harvest. Plants can be uprooted and the stems split open. The infestation level equals the percentage of stems containing sawfly larvae.

The infestation level does **not** equal yield loss because infested stems may produce as much as 90 percent of the yield of an uninfested stem. For this reason, and the fact that cultivars may respond differently to sawfly infestations, developing a useful economic injury level for this pest has not been possible. Also, be sure to sample throughout the field because wheat stem sawfly infestation often is concentrated on field edges.

Information on the level of wheat stem sawfly infestation may be more important for planning next year's crop than for the current crop. The only way this information can be applied in the current growing season is by deciding whether to swath the crop or use a stripper header (see Cultural Control). Next season, however, this information can be used to make informed decisions on tillage practices and the choice of alternative crops or use of solid-stemmed wheat cultivars.

Cultural Control

Several cultural control practices used singly or in combination may help reduce or minimize wheat stem sawfly infestations. Swathing, tillage, delayed planting and crop rotation all have been recommended, although each has an associated cost.

Swathing and using a stripper header are the only pest management practices that can be utilized in the current year of the infestation. Swathing sometimes is conducted on just the outer one or two swaths bordering the field if the infestation is heavy in the field edges only. Swathing prevents sawfly larvae from cutting the stems and reduces yield loss due to lodging.

The disadvantages of this technique are that it requires an additional field operation, and swathing may adversely impact parasitic wasps that attack sawfly larvae in the upper portions of the stems. If a producer decides to swath grain, use a high swathing height to conserve the parasitoids that attack wheat stem sawfly. Research from Montana State University (source: Weaver) has shown that taller residue (at least the lower one-third of the plant) is better for conserving the parasitoids.

To determine if producers need to swath fields, sample wheat crops and determine the percent of plants infested by sawflies before harvest. The presence of wheat stem sawfly can be verified by splitting stems and looking for the S-shaped larvae inside the stems. Another symptom of sawfly feeding is the presence of sawdustlike frass inside the wheat stem. Infested wheat stems often have a darkened area on the stem just below the nodes as a result of the internal feeding from sawfly. This can be used to detect a sawfly infestation without splitting the stems. However, splitting stems to confirm sawfly infested stems is best.

If more than 15 percent of stems are infested by sawflies, producers should swath or use a stripper header on the wheat crop. Producers should swath sawfly-infested wheat as soon as kernel moisture drops below 40 percent to prevent infested stems from lodging. Stripper headers may be used for straight cutting the crop. This header will pick most wheat stems off the ground. Stems that are not firmly attached will be brought into the combine while stems still firmly attached to the ground will have grain stripped from the stem. Usually the volume of straw run through the combine will be less using a stripper header than straw run through the combine when picking up a windrow. Also, stripper headers will leave the majority of the stem intact for improved parasitoid conservation.

Both fall and spring tillage have been used to expose overwintering sawfly larvae to cold and dry conditions to increase larval mortality. Tillage for sawfly control runs counter to the current reduced/no-tillage recommendations. Recent research has demonstrated that 10 percent larval survival in a field will lead to infestation levels as high as the previous season. Tillage practices will not cause great enough larval mortality to be effective. Also, tillage negatively impacts parasitic wasp numbers. In a recent survey of tilled and no-till fields in Montana, 75 percent of the no-till fields had higher parasitoid numbers and less sawfly damage than neighboring tilled fields. Swathing and tillage also add expenses such as fuel, tractor time and labor costs.

Delayed planting (after 20 May) also has been suggested. A late-planted crop will not have reached the stem elongation stage when wheat stem sawfly females are ready to lay eggs, but lower yields usually are obtained because of the late planting date. Also, calendar dates may not accurately reflect sawfly development.

Wheat stem sawfly will not lay eggs into corn, legumes or other broadleaf crops, so rotation with a nonhost crop can reduce populations at least within a specific field. However, sawflies can fly considerable distances, so re-infestation from nearby fields, grass borders or Conservation Reserve Program land is possible in subsequent years. Crop rotation also has disease and pest management and soil fertility benefits.

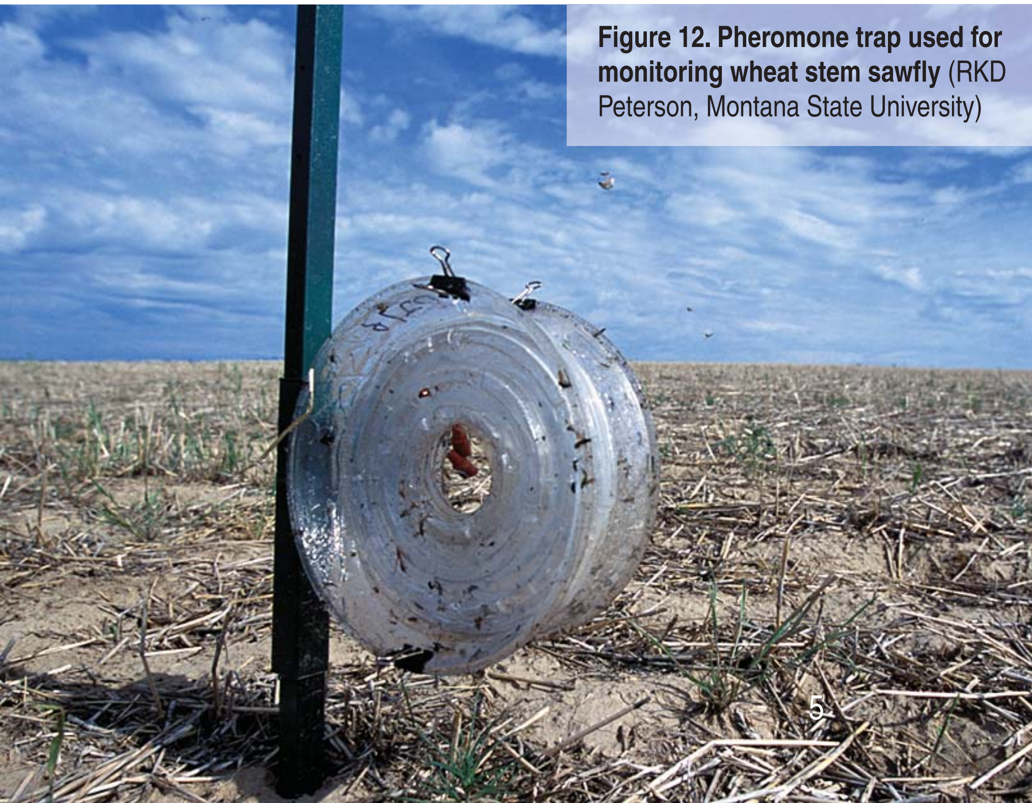

Figure 12. Pheromone trap used for monitoring wheat stem sawfly (RKD Peterson, Montana State University)

Host Plant Resistance

Efforts to develop sawfly-resistant wheat cultivars with solid stems began in the 1930s. The first solid-stemmed cultivar (Rescue) was released in 1946, and this has been followed by the development and release of a number of solid-stemmed cultivars (Table 1). Hard red winter (HRW) and hard white spring (HWS) solid-stemmed wheat cultivars, in addition to solid-stemmed hard red spring (HRS) cultivars, are available for use against wheat stem sawfly. Sawfly larvae suffer higher mortality and cause less damage in solid-stemmed versus hollow-stemmed cultivars (Figure 13).

In addition, the performance of some solid stemmed cultivars has varied across years and locations. One cause of the variable performance is that the degree of stem solidness may be reduced by factors such as light, temperature, moisture, nutrient supply and plant spacing. Also, older solid-stemmed cultivars had lower yield potentials than hollow-stemmed cultivars.

The most recent HRS cultivars, Choteau and Mott, consistently have yielded on a par with the popular hollow-stemmed cultivar Reeder and have had higher yields than any hollow-stemmed cultivars at test locations with heavy sawfly pressure. Protein content, milling traits and baking quality are excellent in both of these solid-stemmed cultivars. The most up-to-date information on wheat variety characteristics and performance can be found in the NDSU wheat guide at www.ag.ndsu.edu/varietytrials/spring-wheat.

Solid-stemmed cultivars do not appear to adversely impact parasitism; parasitism levels often exceeded 50 percent in solid-stemmed cultivars. If 10 to 15 percent of the crop was cut by sawfly in the current growing season, a solid-stemmed variety of wheat is recommended for the following planting season.

Figure 13. Cross section of a hollow-stemmed versus a solid-stemmed wheat variety (B. Berzonsky, SDSU)

Table 1. Released wheat cultivars with resistance to wheat stem sawfly.

Wheat cultivar	Type[1]	Year released	Releasing agency[2]
Rescue	HRS	1946	AC
Chinook	HRS	1952	AC
Rego	HRW	1957	MAES & USDA-ARS
Cypress	HRS	1962	AC
Sawtana	HRS	1962	MAES & USDA-ARS
Sawmont	HRW	1965	MAES & USDA-ARS
Fortuna	HRS	1966	MAES & USDA-ARS
Tioga	HRS	1974	NDAES & USDA-ARS
Canuck	HRS	1974	AC
Chester	HRS	1976	AC
Lew	HRS	1976	MAES & USDA-ARS
Leader	HRS	1981	AC
Glenman	HRS	1985	MAES
Lancer	HRS	1985	AC
Cutless	HRS	1986	NDAES
Rambo	HRS	1986	WPB
AC Eatonia	HRS	1993	AC
Ernest	HRS	1995	NDAES
Vanguard	HRW	1995	MAES
Rampart	HRW	1996	MAES
AC Abbey	HRS	1998	AC
Scholar	HRS	1998	MAES
Conan	HRS	1999	WB
Agawam	HWS	2005	WB
Explorer	HWS	2002	MAES
Choteau	HRS	2003	MAES
Genou	HRW	2004	MAES
AC Lillian	HRS	2005	AC
Mott	HRS	2009	NDAES

[1] HRS = hard red spring wheat, HRW = hard red winter wheat, HWS = hard white spring wheat.

[2] AC = Agriculture Canada; USDA-ARS = U.S. Department of Agriculture, Agricultural Research Service; MAES = Montana Agricultural Experiment Station; NDAES = North Dakota Agricultural Experiment Station; WB = WestBred LLC.

Biological Control

Several natural enemies attack wheat stem sawfly, although they are not always effective in keeping sawfly populations low. In North Dakota, the most important species in wheat is *Bracon cephi,* a parasitic wasp (Figure 14). Another species, *Bracon lissogaster*, attacks sawfly in more native grass habitats (Figure 15). *Bracon cephi* females are able to sense sawfly larvae feeding in the stem, and the females lay their eggs in the wheat stem near the sawfly larvae. Once the parasitic wasp larvae emerge, they begin feeding on sawfly larvae and will kill them (Figure 16).

Parasitic wasps develop two generations per year. The first generation will cut a small circular hole in the stem when it emerges during midseason (Figure 17). Parasitoids overwinter in the upper half of the wheat stem in cocoons (Figure 18). In some years and locations, these natural enemies can kill a high proportion of sawfly larvae (sometimes more than 80 percent). A survey conducted in western North Dakota during 2000-03 found that parasitism ranged from 7 to 88 percent and averaged 35 percent. In general, parasitism was low where sawfly populations were low. Recent research indicates that parasitoids are able to survive in solid-stemmed wheat varieties, increasing the value of biological control as an IPM strategy that is compatible with host plant resistance.

Figure 14.

A. Parasitoid of wheat stem sawfly, *Bracon cephi* (P. Beauzay, NDSU)

B. Parasitoid of wheat stem sawfly, *Bracon cephi* (RKD Peterson, Montana State University)

Figure 15. Parasitoid of wheat stem sawfly, *Bracon lissogaster* (RKD Peterson, Montana State University)

Figure 16. Parasitoid attached to sawfly larva (RKD Peterson, Montana State University)

Figure 17. Parasitoid emergence hole from first generation (RKD Peterson, Montana State University)

Figure 18. Parasitoid cocoon inside wheat stem (RKD Peterson, Montana State University)

Chemical Control

Insecticides generally have not been effective against the wheat stem sawfly. The egg, larval and pupal stages are well-protected inside the plant stem. Spraying for adults has not been successful because newly emerged adults can migrate into a field that was sprayed, the sawfly emergence window is so long and adults that emerge after spraying have reduced exposure to insecticide. The adult does not feed or drink water, which minimizes exposure to insecticides. Recent research found that three applications of a pyrethroid insecticide timed for the beginning, peak and end of sawfly flight reduced damaged stems by half compared with the untreated check; however, the yield gain was only 3.3 bushels per acre in the insecticide-treated plot versus the untreated check.

The estimated cost of the insecticides was $30 per acre (or $10 per acre per insecticide application). If wheat is valued at $5 per bushel, the gross revenue increase due to yield is $16.50 per acre. This results in a net loss of $13.50 per acre ($16.50 minus $30) in spite of the three applications of insecticides. Overall, insecticides are relatively costly for a low-value, large-acreage crop such as wheat; ineffective in controlling wheat stem sawfly; and damaging to beneficial parasitoid populations.

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

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