A Self-Learning Resource From MSU Extension

Cereal Viruses of Importance in Montana

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There are several viruses of wheat and barley in Montana that can be economically important. Here we describe the symptoms and control for these diseases.

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THERE ARE SEVERAL ECONOMICALLY IMPORTANT viruses in Montana cereal grain crops. The principal virus causing disease is **Wheat streak mosaic virus** (WSMV). However, there are additional mite-transmitted viruses, aphid-transmitted viruses, and soilborne viruses that may be important. The purpose of this publication is to describe 1) the principle viruses of importance in cereal crops in Montana, 2) how to recognize virus-infected plants, 3) how viruses move from plant to plant, and 4) how to manage them.

Wheat streak mosaic virus

Wheat streak mosaic (WSM), caused by **Wheat streak mosaic virus** (WSMV) occurs in all wheat-growing regions worldwide. It can infect winter and spring wheat, durum, barley, corn, and many other grass species including grassy weeds. Losses in the central Great Plains region of the United States average 2 percent per year according to estimates from the Kansas Department of Agriculture. WSM was first observed in Montana in 1954 on winter wheat. Since then, there have been major outbreaks of the disease in 1964, 1981, 1993 and 1994 with losses of greater than 10 percent statewide. Losses in individual fields can reach 100 percent.

Symptoms of WSMV infection

Symptoms of WSM include yellowing of the leaf in a streaked or stippled pattern (Figure 1). Severely infected seedling plants may appear lemon yellow and be confused with nutrient deficiency. However, nutrient deficiency is consistent throughout a field or field section, whereas virus diseases are patchy. Symptoms often appear first at the edges of a field or near patches of volunteer wheat. Symptoms in infected winter wheat usually do not appear until after spring warm-up and new growth. Symptom onset is often associated with the accumulation of at least 700 degree days (base 32) or 900 degree days (base 38).

Winter or spring wheat plants infected at early growth stages become stunted, discolored and rosetted (leaves form a prostrate growth habit). Growth virtually stops and few or no heads are formed. Premature death may occur. If infection occurs after tillering but before early jointing, grain can be formed. However, florets are often sterile. When wheat is infected at a later growth stage, grain is produced but test weights may be low. Symptom severity is related to the developmental state of the plant at the time of infection, variety, plant nutrition, air and soil temperature, and the particular virus strain involved. Symptoms can be confused with early stages of barley yellow dwarf, nitrogen or sulfur deficiency, winter or frost injury, and herbicide injury due to imidazolinones or sulfonylureas. Co-infections with more than one wheat virus may cause more severe symptoms and plant death. Later infections, humid weather, moderate temperatures, and adequate nitrogen levels may help minimize losses.

Wheat curl mite as a vector of WSMV

WSMV is transmitted by the wheat curl mite, *Aceria tosichella*. Another common mite on wheat is the brown wheat mite *(Petrobia latens)* which vectors **Barley yellow streak mosaic virus**, but does not vector WSMV. The wheat

FIGURE 1. Leaf symptoms of Wheat streak mosaic virus (WSMV) in barley.

FIGURE 2. Wheat curl mites on a wheat leaf. Note the leaf curling (bottom of photo) which protects the mites and creates a favorable microclimate.

curl mite is not easily seen with the naked eye, but when present in high numbers can make the wheat leaf curl so that the upper surface is rolled inward. Examine a curled leaf with a 10X magnifying lens for presence of the small, white, cigar-shaped mites (Figure 2). Mites are often easy to find on the youngest fully expanded leaflet of WSMV-infected plants. Warm fall temperatures and warm, dry spring weather are ideal for mite increase.

The wheat curl mite is dependent on green host tissue for survival and reproduction. The life cycle of the mite spans approximately 7-10 days under optimal conditions. Reproduction stops at low temperatures but mites can survive freezing temperatures for extended periods, especially when protected within the crown of the plant and insulated by snow cover. The mite survives the winter in the crown of the wheat or grassy weed plants as eggs, nymphs or adults. When infected plants begin growing again in the spring, the eggs hatch and nymphal stages acquire the virus from these plants. The mite vector must acquire the virus from an infected, living plant. The mite feeds with what are known as 'piercing-sucking' mouthparts on plant epidermal cells. This creates silvery flecks on the leaf surface where the tissue has been damaged. Mites are dependent on green leaf tissue for survival. This is why destruction of green tissue (elimination of the 'green bridge') effectively stops the disease.

Movement of the pathogen and patterns in the field

Yellowing plant symptoms often occur first on field edges, especially those bordering and/or downwind from other infected wheat fields or volunteer wheat. Symptoms also may start in areas bordering rangeland or grassy areas which contain susceptible grass hosts for WSMV. After appearing in field margins, symptoms then may progress toward the middle of the field. Wind dispersal occurs when mites crawl up the tops of host plants and are blown into adjacent areas, often when the plant is drying down due to maturity or herbicide application. Mites are dispersed up to two miles if environmental conditions are cool and humid, but a quarter of a mile is more typical. They can crawl ~3 cm a day. For this reason, do not plant winter wheat next to or downwind from late-maturing corn or spring wheat, as these crops can harbor both the wheat curl mite and WSMV. During hot weather, mites desiccate rapidly and wind dispersal is minimal. Females lay up 3 to 25 eggs, usually about 1 per day, during their life. Mite populations build rapidly at

IMPORTANT: When volunteer wheat is sprayed with herbicide, mites sense their host is dying and will move, so avoid spraying volunteer and grassy weeds upwind of susceptible wheat during cool, moist and windy weather. When the weather is hot and dry, it is less likely the mite will survive to find a new host.

TABLE 1. Capacity of prevalent grassy weeds in Montana to serve as wheat curl mite (WCM) and Wheat streak mosaic virus (WSMV) hosts[1].

Common name	Scientific name	Life cycle	Mite host	WSMV host
Jointed goatgrass	*Aegilops cylindricae*	Annual	Yes	Yes
Crested wheatgrass	*Agropyron cristatum*	Perennial	Unknown	Unknown
Wild oat	*Avena fatua*	Annual	No	Yes
Smooth brome	*Bromus inermis*	Perennial	Yes	No
Japanese brome	*Bromus japonicus*	Perennial	No	Unknown
Downy brome/Cheatgrass	*Bromus tectorum*	Annual	Yes	Yes
Persian darnel	*Lolium persicum*	Annual	Unknown	Unknown
Western wheatgrass	*Pascopyrum smithii*	Perennial	Yes	No
Feral rye	*Secale cereale*	Annual	Unknown	Unknown
Yellow foxtail	*Setaria glauca*	Annual	No	No
Green foxtail	*Setaria viridis*	Annual	Yes	Yes

[1]data taken from Somsen 1970, Townsend 1996, and Brey 1998

temperatures between 75 to 80°F, with a complete life cycle taking approximately 7 to 10 days at these temperatures. Development is very slow at 48°F and essentially stops at 32°F. All stages of the mite can survive several days at 0°F and nearly 3 months at freezing temperatures. Under controlled conditions, mites survive without host plant material for 8 hours at 75°F.

As plants mature, mites migrate to the glume area of the heads. If viable grain shatters before harvest, mites attached to kernels survive long enough to move onto the sprouting seedlings. However, mites die if insufficient moisture or poor seed-to-soil contact does not allow kernels to germinate within a few days after shattering, or if they do not migrate to other growing host plants.

WSMV was found to be transmitted at low levels (0.2 to 1.5 percent) in wheat seed in an Australian study (Jones 2005) and is also thought to have moved to Argentia via seed transmission (Stenger and French, 2009). Currently, seed exported to some countries must be tested for WSMV. Crops with a severe infestation of WSMV may contain grain with the virus (seedborne virus), but this virus may or may not be transmitted to the resulting seedlings (seed transmission).

Management approaches

- The virus and the mite are dependent on green tissue for their survival. They survive on wheat, barley, oats, corn, rye and grassy weeds, but volunteer or cultivated wheat is the ideal host for both the virus and the mite. Eliminating the green bridge by destroying volunteer wheat and grassy weeds using herbicides or tillage during August (2-3 weeks before planting) is the most important control method. Herbicides can act slowly on grassy weeds depending on the conditions at the time of application, so an extended period before planting into the field is critical to eliminate the green bridge. Plants need time to die so they can no longer serve as a pathogen source.
- Fields managed as large blocks rather than strips minimize the field edges that are exposed to mite-infested volunteer wheat or grasses.
- Delayed planting in the fall will minimize exposure of seedlings to mite infestations due to cool temperatures which reduce mite activity.
- There are no pesticides registered for use for WCM control. Imidacloprid has been shown to increase WCM populations and WSMV (Harvey et al. 1998).
- Do not add additional nitrogen to WSMV and mite-infested fields.

Role of grassy weeds and grasses in virus epidemics

Wheat curl mites and WSMV can both survive in grassy weeds, but neither can survive on or in broadleaf weeds. In Kansas, WSMV was found infecting many wild grasses including green foxtail and common witchgrass. In 1995, native and non-native grasses in Chouteau County, Montana were surveyed throughout the growing season and tested for presence of mites and WSMV. Results indicated that downy brome, green foxtail and jointed goatgrass are capable of hosting both the wheat curl mite and WSMV. Western wheatgrass and smooth brome, both perennial grasses, are hosts to the wheat curl mite but not the virus. WSMV was not found in smooth brome, crested wheatgrass, or yellow foxtail. More recently, laboratory inoculation of various weeds common in Montana identified wild oat as very susceptible to the virus. The status of prevalent weeds in Montana as WSMV and mite hosts is summarized in Table 1.

Variety tolerance to WSMV infection

No varieties have shown consistent resistance to WSMV, however, some are more tolerant than others. Symptoms in the crop do not necessarily mean there will be a significant yield loss. In field experiments conducted in Bozeman from 2008 to 2011, winter wheat averaged ~15 percent yield loss and spring wheat ~40 percent yield loss due to WSMV (Tables 2 and 3).

TABLE 2. Yield loss (%) of winter wheat due to mechanical inoculation with Wheat streak mosaic virus at tillering.

Variety	2008*	2009	2010*	2011
CDC Falcon	+25.1	23.8	+0.7	14.8
Decade			16.5	24.6
Genou	24.9	14.3	+5.0	16.2
Jagalene	10.3	14.5	18.1	18.6
Jerry		13.0	+0.3	9.3
Ledger	+31.2		17.7	+4.5
Mace			3.3	+2.0
Morgan	24.2	20.4	9.6	10.3
Neeley	42.5	32.9		
Pryor	+14.4	14.0	21.1	21.2
Rampart	15.6	+1.7	+18.0	22.5
Rocky	19.0	10.7		
Tiber	40.9	17.7	+1.0	23.0
Yellowstone	13.7	17.3	11.3	12.5
Average	13.1	16.3	6.0	17.3

* hail damage; + yield gain from WSMV

CONTROL SUMMARY

The three most economically feasible methods of controlling WSMV outbreaks are:

- Elimination of the 'green bridge' by managing volunteer wheat and grassy weeds in August, 2-3 weeks before planting
- Using tolerant or resistant varieties
- Planting date

Insecticides are not effective for control of the wheat curl mite and prevention of WMSV spread.

Recommended planting dates to avoid WSM

WSM management is based on avoidance of the vector, destruction of the green bridge, and temperature at time of planting. Volunteer wheat and grassy weeds that are left uncontrolled are a source of mite and virus – they form a green bridge to the crop planted in that field. Destruction of the green leaf material prior to winter wheat seeding will effectively break the disease cycle. Winter wheat is more likely to become infected with WSMV if the mite and virus are present in live (green) tissue, both in field and adjacent to stubble fields. However, cool temperatures reduce the activity of the mite and spread will be reduced. In the same fashion for spring wheat, early seeding reduces the risk of WSMV infections as temperatures are too cool for mite activity and buildup. Allowing the mite populations to increase in the fall can result in massive migration of WSM to winter wheat. Also, delaying spraying of the stubble fields until spring with glyphosate will result in migrations of the mite to newly planted spring wheat. Volunteer and grassy weed management in August will solve the fall and spring infection cycles.

Winter and spring wheat seeding date as a management tool for WSM is a balancing act of planting early to establish a vigorous plant for yield potential and avoiding the transmission of WSMV by the wheat curl mite. Although planting date is no guarantee to avoid disease, cooler fall temperatures will minimize mite migration and virus transmission. General guidelines for winter wheat planting date is after September 5 in northern Montana, September 15 in central Montana, and September 20 in southeastern Montana. Fall planting depends on local weather conditions. If it is unseasonably warm when fall planting should begin, it may be necessary to postpone seeding as warm weather keeps mites active for a longer time and wheat may become infected.

Spring wheat crops should be planted as early as possible, no later than the end of April. Late-seeded spring wheat does expose susceptible seedlings to an active population of the mite with the higher temperatures. Spring wheat should not be planted near winter wheat with symptoms of WSM, or in fields that were heavily infested with the wheat curl mite in the previous fall.

Chemical Control

Seed and foliar insecticide (acaracide) applications are not effective for control of WSMV.

Adding nitrogen to the plant increases plant susceptibility to WSMV and the reproduction of the WCM. If a field is infested, do not add additional nitrogen. Yield losses due to WSMV eliminate any yield benefit provided by the nitrogen application, and cause the disease to spread more than if nitrogen had not been applied.

TABLE 2. Yield loss (%) of spring wheat and barley due to mechanical inoculation with Wheat streak mosaic virus at tillering.

Variety	2008*	2009	2010*	2011
Amidon	8.8	38.7	47.2	51.4
Choteau	33.6	51.9	71.0	68.7
Conan	24.2	32.5	41.6	33.7
Corbin	18.0	31.9	48.1	53.3
Duclair				51.1
Ernest	34.7	57.3	72.1	69.7
Fortuna	32.7	42.2	58.5	50.3
Hank	21.8	28.4	36.5	34.6
McNeal	39.9	50.4	63.2	63.9
Reeder	22.8	34.2	52.0	52.2
Scholar	45.9	44.3	47.5	43.5
Vida				52.6
Haxby	N/A	13.3	39.2	18.5
Metcalfe	N/A	16.7	44.9	24.1
Mean	28.2	36.8	51.8	47.7

*Hail damage; + yield gain from WSMV

Other viruses to be aware of

Wheat mosaic virus and Triticum mosaic virus

There are two additional wheat curl mite-transmitted viruses present in the U.S. which rarely occur in Montana. Changes in management practices in Montana including earlier planted winter wheat next to late-maturing spring cereals, increased corn production, reduced tillage that favors the green bridge and grassy weed production, and a warming climate favoring mite survival and reproduction, may increase virus epidemic frequency. The first of these viruses of concern is Wheat mosaic virus (WMoV), formerly known as High Plains virus (HPV). WMoV was

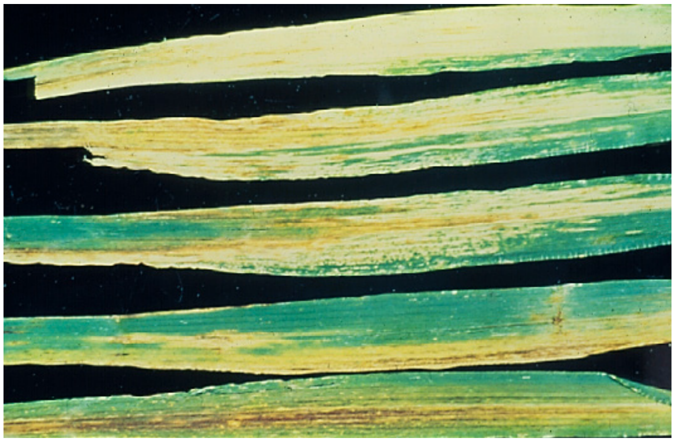

FIGURE 3. Symptoms of Barley yellow streak virus on barley.

first identified in corn and WSMV-resistant winter wheat in Kansas in 1993. It is seed transmitted in corn at very low levels. Sweet corn varieties are more susceptible than field corn to WMoV. Since until recently there has been very little corn in the Montana cropping system, this may explain why this virus has not been important here. WMoV was identified for the first time in wheat and barley in central Montana in 2008, suggesting it has been in the state for an extended period of time but was not recognized (Burrows 2009).

The second virus is Triticum mosaic virus (TriMV), identified in WSMV-resistant winter wheat in Kansas in 2006. It has been identified in Montana but very infrequently and always associated with WSMV infections. Co-infections of two or more of these viruses can cause much more severe symptoms and yield loss than infection by a single virus (Stenger 2007). Control of these viruses is the same as for WSMV.

Brown wheat mite transmitted virus: Barley yellow streak mosaic virus

Barley yellow streak mosaic virus (BaYSMV) was discovered by scientists from Montana State University working on barley in 1982, and later reported in several western states, as well as in Alaska and Alberta, Canada (Lapierre 2005). Barley plants infested with BaYSMV show chlorotic streaks, stripes, and dashes parallel to the leaf veins and often only on half the leaf (Figure 3). Plants can also have varying degrees of stunting.

Yield losses reaching 100 percent in individual fields have been reported when barley seedlings are infected with BaYSMV and infested with the brown wheat mite vector, *Petrobia latens*. The mite's eggs are the overwintering reservoir of BaYSMV, bridging the virus from summer/fall to spring plant infections. Destroying the green bridge will reduce mite populations by eliminating a feeding source but mite eggs (red eggs for active populations; white eggs for inactive populations) might survive on standing stubble and under field rocks. Disease incidence and severity are greatest

WSMV Risk Analysis 'Top 10'

The risk analysis presented here can help you determine potential problems arising from WSMV in both winter and spring wheat. To ascertain your own potential risk, you must scout your fields for mites especially on field edges and note any symptom development in the wheat crop. Be aware of crop conditions within the immediate area (within 2-3 miles) throughout the production season. The largest possible score in this test is 90. A high score indicates significant risk, a low score reduced risk.

Risk Factor	**Score**
1. Presence of green bridge	
- Volunteer wheat	20
- Grassy weeds (see Table 1)	10
2. Presence of wheat curl mites in the field (fall or spring)	15
3. Symptomatic, yellow plants (and/or tested virus positive)	
- Also identified wheat curl mites	15
- No wheat curl mites found	5
4. Planting date (see text for your location)	
- Before recommended date	10
- After recommended date	5
5. Variety tolerance to **Wheat streak mosaic virus**	
- Tolerant (less than 10%)	1
- Moderate (10-30%)	5
- Susceptible (more than 30%)	10
Spring and winter wheat: use percent yield loss from Table 2 or 3 or from Variety Description.	
6. Presence in immediate area of late-maturing wheat or corn upwind during planting (within 3 miles)	5
7. Tillage management	
- Chemical fallow	5
- Mechanical tillage	1
8. Strip tillage with more edge areas	3
Field arranged in one large block, few edges	1
9. Presence of fields in Crop Reserve Program upwind	2
10. Presence of WSMV the previous season	
Yes	5
No	0

Total score possible = ______

Other risk factors could include WSM incidence in the previous season, weather conditions during chemical control of green bridge or while wheat is in the seedling stage (warm, dry conditions favor mite reproduction), and hailstorms which increased the amount of volunteer wheat in a field.

FIGURE 4. Symptoms of barley yellow dwarf on wheat. Note purpling and yellow streaks on leaves.

FIGURE 5. Wheat soilborne mosaic virus symptoms often occur in low-lying areas.

in recrop barley and non-irrigated crops under drought conditions. This virus can also infect wheat to a low extent (less than 10 percent) when mite populations are high and the wheat is planted next to infected barley. The natural plant host range also includes three grasses, barnyardgrass *(Echinochloa crusgalli)*, Persian darnell *(Lolium persicum)*, and green foxtail *(Setaria viridis)* (Lapierre 2005). No resistant barley cultivars are known, and chemical control for the mite vector is generally not cost effective.

Aphid transmitted viruses: Barley yellow dwarf

Aphid transmitted viruses can occur sporadically in Montana. They are usually associated with aphids flying from other states rather than aphids overwintering in Montana. These flights change yearly and are hard to predict. The most common aphid transmitted viruses we see are **Barley yellow dwarf virus** (BYDV) and **Cereal yellow dwarf virus** (CYDV). Symptoms include yellowing and/or streaking of leaves and often purpling of the flag leaf and/or stem (Figure 4).

BYDV and CYDV cause Barley yellow dwarf (BYD) disease. They are only acquired by the vector and transmitted to a healthy plant if the aphid has an extended time to feed (more than two hours). Because of that fact, aphids that colonize the plants generally vector this disease rather than aphids that do not colonize cereal grains. However, the Russian wheat aphid *(Diuraphis noxia)* is not a vector. The most common vectors in Montana are the greenbug *(Schizaphis graminum)*, the bird cherry oat aphid *(Rhopalosiphum padi)*, the English grain aphid (*Sitobion avenae*), and the corn aphid *(Rhopalosiphum maidis)*.

For more information on identifying aphids in the field, see the Montguide *Aphids of Economic Importance in Montana* (MT200503AG), available from MSU Extension Publications or by contacting your county Extension agent. The aphid vector(s) can be effectively controlled using an insecticide. If there are already high numbers of plants in the field showing symptoms, it is likely the infection is nearly 100 percent and control of aphids at that point is not recommended. In the case of severe virus infection, winter wheat could be destroyed in the fall and replanted to spring crops.

Soilborne viruses

Wheat soilborne mosaic virus (WSbMV) is known to occur sporadically in Montana. This virus is transmitted by a flagellated protista named *Polymyxa graminis*. This organism prefers low-lying wet areas in fields (Figure 5). The virus contaminates fungal structures called zoospores, or swimming spores, and infects a plant during feeding and infection of the vector, *Polymyxa*. The virus can survive in the soil as an infection of the oospore (fungal reproductive structure) for years. The virus will spread associated with soil on field equipment and via blowing of contaminated soil in the wind.

Control of this virus is very difficult. Resistant or tolerant wheat varieties have been developed by Kansas State University, but it is not known how effective they are in Montana. Because of the longevity of the vector in soil, it is not known how effective crop rotation to a non-cereal will be to minimize the disease. Soil fumigation to kill *Polymyxa* host is an option but is economically prohibitive.

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