University of Nebraska–Lincoln EXTENSION

EC1871

Managing Wheat Streak Mosaic

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Wheat Streak Mosaic Risk Factors in Winter Wheat

- Volunteer wheat arising from pre-harvest hail storm — predominant risk factor
- Volunteer wheat emerging before wheat harvest in summer crops
- Mite host crops or weeds growing past fall wheat emergence
- Early planting of winter wheat
- Spring wheat planted next to mite-infested wheat or volunteer wheat
- Extended warm, dry fall
- Cool, wet summer
- Mild winter

Cover. University research trials compare wheat varieties that are not tolerant to wheat streak mosaic virus (left) with those that are (right).
Figure 1. (top) Close-up of the wheat curl mite on a leaf.
Figure 2. Electron micrograph image of a wheat curl mite.

Wheat streak mosaic was first recognized in Nebraska in 1922 as "yellow mosaic." The disease, caused by wheat streak mosaic virus, has the potential to cause serious crop losses in winter wheat. Spring wheat, oats and barley also can be affected. Wheat streak mosaic virus is most prevalent in the western Great Plains where winter wheat is widely grown. In Nebraska, wheat streak mosaic most commonly occurs in the western half of the state, but it can occur throughout the state.

Plant viruses reproduce only in living hosts; therefore, they require a vector to move them from plant to plant. The only known vector for wheat streak mosaic virus is the wheat curl mite, *Aceria tosichella* (K.) (*Figures 1* and *2*). As with many plant viruses, a major component of effective management of wheat streak mosaic virus is managing the vector.

Symptoms

Serious infection of winter wheat occurs in early fall, but symptoms usually do not develop until spring. As spring temperatures rise, symptoms become more visible and rapidly develop when daily high temperatures first exceed about 80°F for several days. The most serious infections result from mites being spread throughout a field, resulting in a uniform distribution of the virus across the field. In low and moderate infections, there is a gradation of intensity of symptoms across a field, with the most yellowing on the side of the field adjacent to the source of the mites (e.g. volunteer wheat, corn or other summer hosts).

Wheat curl mite-infested leaves tend to remain erect with their edges tightly rolled inward toward the mid-rib *(Figure 3)*. Wheat curl mites feed preferentially within the whorl of the plant and within the rolled leaf edges. On a young plant, the tip of a new leaf often is trapped in the rolled leaf immediately below it so that the developing leaf is curled back on itself, forming a loop *(Figure 3)*. Rolled and trapped leaves are good indicators of heavy mite populations, and their presence is useful in determining if stands of volunteer wheat are potential reservoirs of both the virus and the mite.

Wheat streak mosaic symptoms will be most severe on the oldest leaves with the youngest leaves showing the most characteristic mosaic symptoms. These young leaves will show a yellow mosaic pattern of parallel discontinuous streaks *(Figure 4)*. As symptoms progress, the leaves become mottled yellow, and in the latter stages of symptom expression, the yellowing may be so extensive that it can be confused with that caused by barley yellow dwarf virus *(Figure 5)*. However, the yellowing of leaves infected with wheat streak mosaic virus is often more intense than the pale-yellow color produced by barley yellow dwarf. Also, wheat streak mosaic symptoms occur over the entire leaf, but the yellowing caused by barley yellow dwarf starts at the tip and edge of the leaf and expands toward the middle and base of the leaf.

Winter wheat plants infected during their early growth stages in the fall (i.e. before or in early stages of tillering), become stunted, discolored, and rosetted the following spring. They look similar to plants infected by crown and root rot, but the youngest leaves of virus-infected plants exhibit the characteristic mosaic pattern.

If infection occurs after the plants are well tillered, stunting or rosetting symptoms may be subtle or nonexistent. Another factor that affects the impact of wheat streak on plants is spring temperature. A cool spring will delay the onset of severe symptoms and moderate damage, but an early, warm spring will maximize impact on the plants.

The extent of stunting and rosetting in a field gives some indication as to the severity of the disease and ultimate yield loss. Stunted and rosetted plants compete poorly with weeds compared to healthy or later infected plants, and their yield will be dramatically reduced.

A second virus that is often found in wheat and associated with wheat streak mosaic is the high plains virus (HPV). This virus was discovered in 1993 in

Managing Wheat Streak Mosaic in Winter Wheat

- Control all volunteer wheat emerging before wheat harvest
- Control volunteer wheat in summer crops
- Avoid mite-virus host crops growing after wheat emergence
- Avoid early planting and plant high risk fields last
- Plant tolerant cultivars
- Plant spring wheat early and avoid high risk fields
- Control post-harvest weeds

Figure 3 (top). Leaf rolling and leaf trapping caused by wheat curl mite.
Figure 4 (left). Streaking and mosaic symptoms of wheat streak mosaic on wheat.

Figures 5a and b. Yellowing caused by wheat streak mosaic virus (Figure 5a, left) can be confused with that caused by barley yellow dwarf virus (Figure 5b, right).

several Great Plains states. The high plains virus usually occurs along with wheat streak mosaic virus on both wheat and corn and is known to be transmitted only by the wheat curl mite. Both viruses can be positively identified by a serological test such as ELISA (Enzyme-Linked Immunosorbent Assay).

Disease Cycle of Wheat Streak Mosaic

Wheat streak mosaic virus, a member of the virus family *Potyviridae*, is a flexuous rod-shaped particle that can be seen only under high magnification using an electron microscope *(Figure 6)*. Virus particles consist of a central core of ribonucleic acid (RNA) wrapped in a protein coat. In the field the virus can only be moved from plant to plant by the wheat curl mite. Recent research from Australia indicates that the virus can be seed-transmitted at very low rates (0.5 to 1.5 percent). However, seed transmission of wheat streak mosaic virus has not been demonstrated in the United States. Seed transmission at this low level would have little impact on the disease cycle of wheat streak mosaic virus in North America because the wheat curl mite and the virus are readily found in all agroecosystems where wheat is grown.

The key factor in outbreaks of wheat streak mosaic on winter wheat is the presence of over-summering hosts that enable the mites to carry the virus from the previous wheat crop, build up to large numbers during the summer and transmit the virus to the newly emerging wheat crop in the fall. Wheat curl mites are unable to survive for more than a few days off green plants and must find a living host to survive through the summer. In the central Great Plains the most important summer “green bridge” host is volunteer winter wheat that emerges before harvest, most often as a result of hail storms. If this volunteer wheat survives through the green bridge period *(Figure 7)*, the mites readily move onto emerged winter wheat plants and transmit the wheat streak mosaic virus.

The wheat streak disease cycle *(Figure 7)* begins in the fall with the movement of mites from volunteer wheat and other hosts to newly emerged winter wheat plants. The mite does not have wings and does not produce webbing. It depends entirely on the wind for dispersal. In the fall as mite populations increase, mites leave the protected areas of volunteer wheat plants (rolled leaves and whorls) and crawl to leaf tips or other exposed areas where they become airborne. After landing on a new host, the mites crawl to the youngest leaf and begin to feed and reproduce.

In heavily infested volunteer wheat, most mites will carry the virus, and transmission to the young winter wheat plants requires very few mites. The eggs hatch and the larvae acquire the virus as they feed on infected leaves. It takes only about 15 minutes for the mite to acquire the virus. Mites remain infective for most of their lives (two to four weeks or longer with cool temperatures), but the transmission efficiency of adult mites decreases with age.

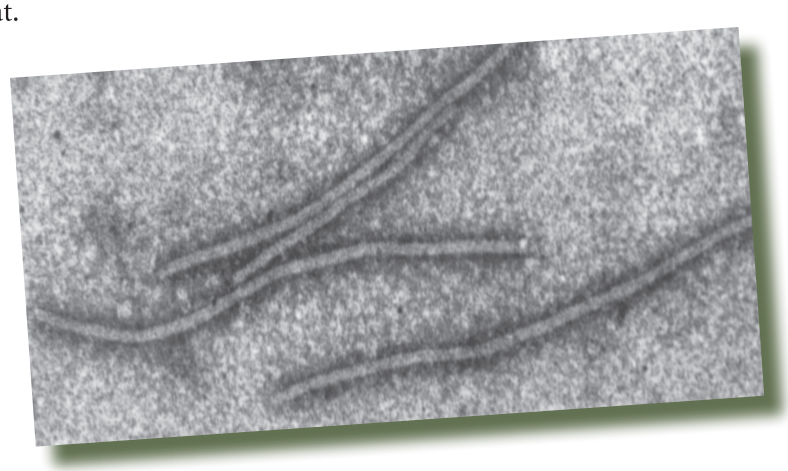

Figure 6. Flexuous rod-shaped particles of wheat streak mosaic virus. Each particle is approximately 15 nanometers (nm) in diameter and 700 nm long.

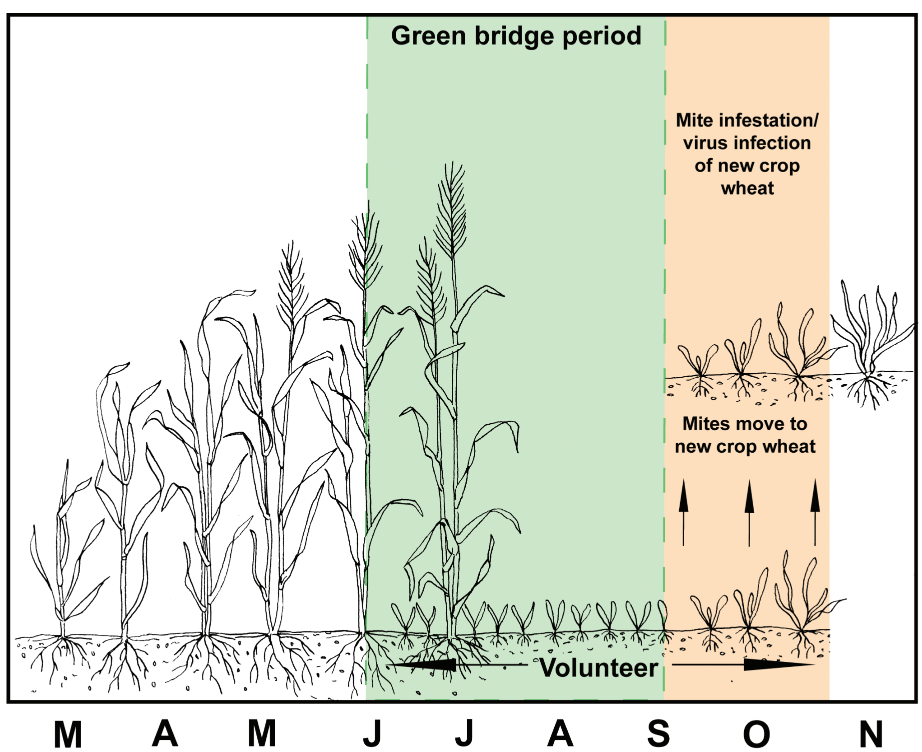

Figure 7. Seasonal cycle of wheat-mite-virus complex. Mites move to volunteer and other hosts before harvest, build up during the green bridge period and infest new crop wheat in the fall.

The earlier winter wheat is planted and the longer mild weather extends through October and November, the greater the risk of spread and development of wheat streak mosaic. Under warm fall conditions, the probability of secondary spread of mites and virus increases, resulting in greater incidence of infection. Reproduction and spread of the mites stop with cool temperatures in the fall, but mites are capable of surviving the cold winter temperatures. The virus survives the winter within the plant, and the mites survive as eggs, nymphs or adults protected in the crown of the wheat plant. As winter wheat greens up in the spring, mites become active and the virus can be spread to healthy winter wheat plants or to emerging spring wheat.

As wheat plants head, the mites find numerous sites for feeding and protection within the head, and mite populations build to high levels. As wheat matures and dries down, mites begin to move off the plants and disperse throughout the environment. At this time (just before harvest) mite activity in the agroecosystem is extremely high. Mites will infest just about every potential host in the ecosystem, but they will survive and reproduce only on those hosts that are suitable *(Table I)*. After harvest, mite activity will drop to very low levels.

If hail shatters grain before harvest, the mites on kernels

Table 1. Important hosts for wheat streak mosaic, high plains virus and the wheat curl mite.

Common Name	Scientific Name	WCM Susceptibility	WSMV Susceptibility	HPV Susceptibility
Crops				
Wheat	*Triticum aestivum*	+++[1]	+++	++
Corn	*Zea mays*	+[2]	-[3]	-[3]
Rye	*Secale cereale*	++	+	+
Oats	*Avena sativa*	+	+	+
Barley	*Hordeum vulgare*	++	+	+
Sorghum	*Sorghum bicolor*	+	+	-
Foxtail millet	*Setaria italica*	+	+	-
Proso millet	*Panicum miliaceum*	-	+	-
Pearl millet	*Pennisetum glaucum*	+		
Weeds and Other Grass Hosts				
Jointed goatgrass	*Aegilops cylindrica*	+	+	
Downy brome	*Bromus tectorum*	+	+	-
Japanese brome	*Bromus japonicus*	-	+	-
Cheat grass	*Bromus secalinus*	-	+	+
Sandbur	*Cenchrus pauciflorus*	+	+	
Crabgrass	*Digitaria* spp.	+	+	-
Barnyardgrass	*Echinachloa crusgalli*	+	++	-
Canada wildrye	*Elymus canadensis*	+	-	
Stinkgrass	*Eragrosotis cilianensis*	+	++	-
Witchgrass	*Panicum capillare*	+	++	-
Green foxtail	*Setaria viridis*	+	++	-
Yellow foxtail	*Setaria glauca*	+	-	+

[1]+++ = highly susceptible; ++ = moderately susceptible; + = slightly susceptible; - = resistant.

[2]Mites build up on corn only during reproductive stages (ear development).

[3]Most commercial hybrids resistant; some varieties or inbred lines susceptible.

move to the sprouting volunteer seedling. If moisture is insufficient and shattered kernels do not germinate within a few days, the mites die. The mites and virus multiply rapidly through the summer on growing volunteer wheat.

If volunteer wheat does not emerge until after harvest, the potential for serious mite infestations is much reduced; however, some mites will survive on other hosts, e.g. corn or grassy weeds, and may spread to infest either late volunteer wheat or early-planted winter wheat. The risk level of volunteer emerging after harvest is related to the length of time it has been growing and the presence of important mite hosts in surrounding areas. In western Nebraska, volunteer wheat emerging after harvest has a relatively low risk of severe mite populations developing unless a significant mite source (pre-harvest volunteer) is nearby to provide an initial mite infestation. Further east in Nebraska, harvest occurs earlier and winter wheat is planted later than in the west. This increases the risk of this post harvest volunteer because it allows more time for the mites to infest the volunteer and reproduce to significant numbers.

The risk of mite dispersal and virus spread from a source field tends to follow an oval-shaped pattern extending from the northwest to the southeast according to prevailing winds *(Figure 8)*. The size of this oval pattern depends on the size and mite density of the mite source. If mite populations in the source fields are low, spread to neighboring fields will only occur for a short distance and an edge effect of the spread will be evident *(Figure 9)*. If mite populations in the mite source field are high and the mite source field is large, mites and virus will be spread across entire fields neighboring the mite source field and perhaps well beyond *(Figure 9)*. The extent of this distance is not known, but anecdotal evidence indicates that in some instances it may be up to one to two miles. The risk of serious virus spread will decrease with distance from the mite source field. The most important mite movement will occur in the fall soon after winter wheat emerges, completing the disease cycle.

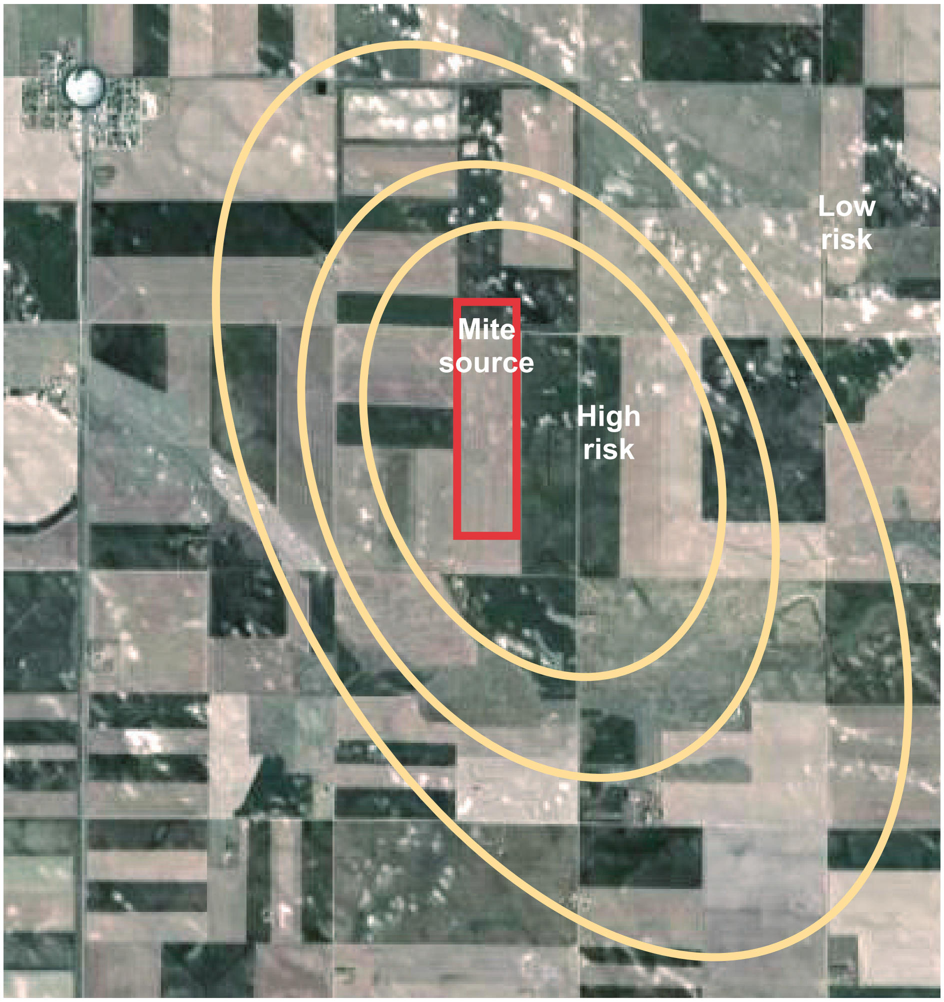

Figure 8. Wheat curl mite movement and virus spread tends to be in an oval direction with the axis along the direction of prevailing winds. Risk of virus is highest close to the source field and decreases with increasing distance from the source field.

Mites also can spread virus into spring wheat fields in the spring shortly after emergence. In some instances, infection has been widespread within a field, causing yield losses approaching 100 percent. Sources of mites and virus that infect spring wheat primarily include volunteer wheat and perhaps winter wheat.

Wheat is the primary host for mites and wheat streak mosaic virus, although the mite also can feed and reproduce on several other grasses *(Table I)*.

Some of these grasses are hosts to the mite, wheat streak mosaic virus and/or high plains virus. It is unlikely that these hosts will permit increase of both virus and mites sufficient for severe epidemics, but some grasses may play a more important role in local outbreaks within a small geographic area where cropping or other conditions have created very weedy fields. Mostly, the host native grasses and grassy weeds are reservoirs for long-term survival of mites and virus, and in some years, certain wild grasses probably are a source of sufficient virus-carrying mites to provide a background infection of virus in a small percentage of wheat plants.

Most corn hybrids are resistant to both viruses, but some inbred lines, sweet corn, dent corn, and blue corn are very susceptible. Most field corn hybrids are considered to be symptomless carriers as mite populations can move out of apparently healthy looking corn and transmit both viruses to wheat. Mite activity around corn fields has been shown to begin at low levels during the period before wheat harvest. This mite activity increases as corn ears develop and peaks when corn ears begin to dry down. Mite survival varies between corn hybrids. Many hybrids support high populations of mites in the ear until the plants dry down in the fall. Irrigated corn is likely to carry more mites than dryland corn because the mites leave the dryland corn earlier as it dries in late summer or early fall.

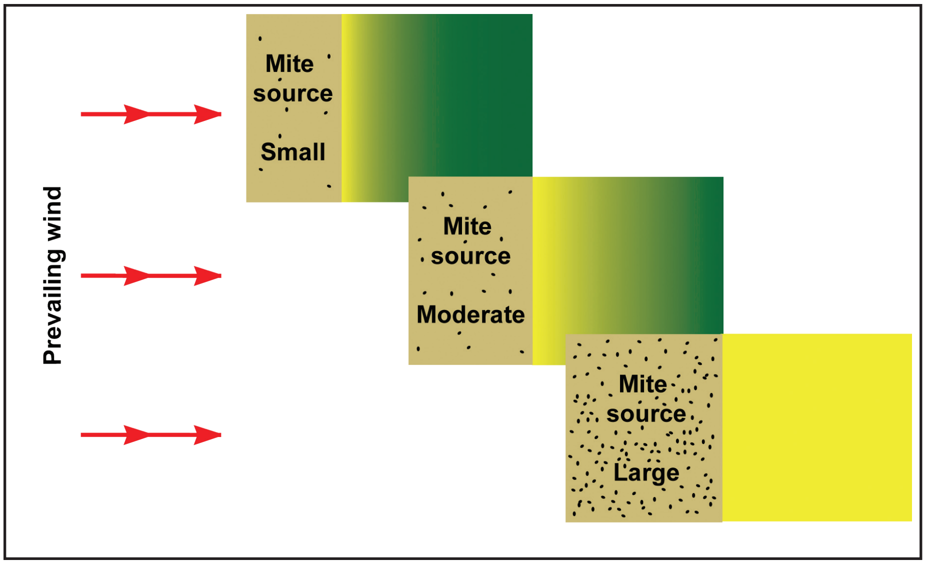

Figure 9. Wheat curl mite movement and virus spread is governed by the size of the mite source. The size of the mite source is determined by the mite density and the area of the source field.

Wheat Streak Mosaic Risk Factors

Manageable Risk Factors (Highest Risks First)

• Hail storm when wheat is in the milk through hard dough stages, resulting in preharvest volunteer wheat. Volunteer wheat that emerged before wheat harvest, if left uncontrolled until wheat emergence in the fall, virtually assures serious wheat streak mosaic virus infections in surrounding fields.

• Poor volunteer wheat control in summer crops, such as sunflowers, millet, corn, etc. If this volunteer is growing during the wheat pre-harvest period when mites are very active, it will have a high likelihood of serious mite infestations.

• Use of mite host crops (e.g., foxtail millet, oats and wheat) as plantings, companion crops or cover crops that grow through the over-summering period and remain green until after wheat emergence in the fall.

• Planting winter wheat adjacent to late maturing irrigated corn.

• Planting winter wheat earlier than recommended for your geographical area. The earlier wheat is planted, the greater the risk of wheat streak mosaic virus.

• The risk from volunteer wheat emerging after harvest will be much lower than from pre-harvest volunteer. The risk from post-harvest volunteer increases with the time it grows through the green bridge period.

• Growing spring wheat adjacent to mite-infested volunteer wheat or winter wheat fields.

Environmental Risk Factors that Increase Virus Risk

• Cool, wet summers which encourage volunteer wheat and enhance mite survival.

• Warm, dry weather through the fall, resulting in increased reproduction and spread of the wheat curl mite and buildup of the virus in the plant.

• Mild temperatures in February and March increase the spread of the curl mite and virus to spring cereals.

• Warm temperatures in the early spring will increase the impact of wheat streak mosaic on wheat plants.

Management of Wheat Streak Mosaic

Wheat streak mosaic is managed by cultural practices that minimize the ability of mites to over-summer and carry the virus into the emerging wheat crop in the fall. Prevention is the key to successful management — once the crop is infected, nothing can be done to correct the problem. Although there are no absolute guarantees when it comes to management of wheat streak mosaic, the following are the best preventive measures available.

• Control pre-harvest volunteer wheat. The volunteer must be killed either with tillage or herbicides at least two weeks before fall planting. A community effort of controlling volunteer wheat in stubble fields will be beneficial in mosaic-prone areas with extensive pre-harvest volunteer.

• Ensure good control of volunteer wheat in summer crops such as corn, sunflowers and millet.

• Avoid growing mite and virus host crops (e.g. foxtail millet, oat or wheat cover or companion crops) into the fall after wheat emergence.

• Do not plant winter wheat too early for your growing area. Plant at the proper date. Your local Extension educator can provide information on winter wheat planting dates for your area.

• Winter wheat planted in areas of higher disease risk (e.g. adjacent to uncontrolled volunteer, irrigated corn or late maturing foxtail millet) can be planted late to reduce (but not eliminate) the disease risk. Also, use virus-tolerant varieties in these situations.

• Plant varieties with greater tolerance to wheat streak mosaic. A variety with a high level of tolerance is Mace (N02Y5117); varieties with mild levels of tolerance include 2137, Millennium and Pronghorn. Varieties under development are showing promise for improved resistance. Consult your seed dealer or Extension educator about cultivar response to wheat streak mosaic virus. Take time in June to observe a wheat cultivar trial in your area.

• For spring wheat, avoid planting in high risk areas and plant as early as possible.

• Practice good weed control in stubble fields following harvest. Preventing establishment of volunteer and other grassy weeds reduces potential reservoirs of the curl mite and virus.

Volunteer Wheat Control

Effective control of wheat streak mosaic largely hinges on successful control of volunteer winter wheat. In addition to the reduced risk from disease, eliminating volunteer wheat will benefit the grower by conserving soil moisture and minimizing other potential pest problems.

Volunteer wheat can be effectively controlled with tillage or herbicides. The key to effective mite control is to provide complete control of volunteer wheat. Plants must be completely dead for mite populations to be eliminated. Volunteer control should be initiated a minimum of two weeks before planting. If control is initiated within two weeks of planting, tillage may be the best option as it will result in a faster kill of mites when the plants dry down rapidly. The effectiveness of tillage will be enhanced under dry conditions. Herbicide control will be slower than tillage with dry conditions, but herbicides may be more effective under wet conditions.

An important consideration in volunteer control is to have good broadleaf weed control in the previously growing winter wheat crop. After harvest, the primary weed control target will be volunteer wheat. An application of glyphosate with spray-grade ammonium sulfate at 2 percent weight/weight (17 lbs/100 gal) plus surfactant, if the glyphosate doesn't already contain surfactant, should be made soon after harvest to control pre-harvest volunteer. Allow at least six hours for the glyphosate product to become rainfast; some weeds will require a longer rainfast period. For example, barnyardgrass may require as much as 24 hours without rain for maximum control. With glyphosate, use a spray volume of 5 to 10 gallons per acre, and do not apply when temperatures reach or exceed 95°F.