AGRICULTURAL
MU Guide
PUBLISHED BY UNIVERSITY EXTENSION, UNIVERSITY OF MISSOURI-COLUMBIA

Virus Diseases of Wheat

Einar W. Palm Department of Plant Pathology

Viral diseases are a very significant problem affecting wheat in Missouri. They generally cause symptoms that are distinctive from other infectious diseases. The most common observable symptoms are dwarfing, excessive tillering and various forms of leaf streaking, spotting, mosaics, chlorosis (yellowing), sterility and other signs which are very hard to identify.

Although the incidence of viruses in wheat (or other cereals–oats, barley, rye, triticale) in a given field may be relatively inconspicuous in some years, virus infections may become very obvious and serious economic losses can occur. Viral diseases, such as barley yellow dwarf, are endemic to Missouri–they occur every year at varying levels in most fields. Other viral diseases such as wheat streak mosaic may be absent entirely or may reach near epidemic proportions if conditions are met (e.g. vectors carrying the virus are abundant in the fall on volunteer wheat).

Viruses are ultra-microscopic entities capable of infecting living cells and causing injury to their hosts. Once they have entered host cells, they move systemically within the plant, taking over management of the entire plant. Viruses are dependent on survival within living hosts. Therefore, they must survive in perennial hosts over winter. They are usually transmitted to annual hosts by insects.

Viruses that cause diseases in cereal crops are often transmitted by various species of aphids, leafhoppers, plant hoppers and mites; by fungi; by infected seed; or mechanically. They are identified by the symptoms produced, their host range, and the vectors involved. For more accurate identification and characterization, sophisticated laboratory procedures are used, including electron microscopy and serological techniques.

Successful control of viral diseases depends upon understanding of host-virus relationships, virus-vector relationships and various characteristics of overwintering and transmission.

Proper field identification of viral diseases is a first step in evaluating and determining their nature and potential control.

Viral diseases common to Missouri wheat are: barley yellow dwarf (aphid vectors), soil-borne mosaic (fungus vector), spindle streak mosaic (fungus vector) and wheat streak mosaic (mite vector).

The mycoplasma disease aster yellows, although considered a minor disease in wheat, barley and some other grass species, will cause infection at times. The symptoms on cereal crops are similar to those caused by barley yellow dwarf virus.

Aphid-borne virus disease

Barley Yellow Dwarf

Barley yellow dwarf (BYD) is caused by the barley yellow dwarf virus (BYDV). This disease is probably the most widely distributed of cereal viruses. It is very common in Missouri, to great extent because there are large acreages of forage grasses (eg tall fescue) which provide a perennial host reservoir for the virus. Several aphid species are able to serve as vectors.

BYD (similar to cereal yellow dwarf, yellow dwarf and red leaf of oats) occurs on most cereals and numerous wild and tame grass species. It does not go to broad-leaved plants.

Symptoms. Stunting and yellowing are the most obvious symptoms. Stunted plants often appear in spots several feet in diameter, with those in the center most severe and damage decreasing outwards. This corresponds to activity of the virus-carrying aphids–working out from an establishment center. Scattered, individually infected plants are also very common.

Barley and oats are more susceptible than wheat, and exhibit more dramatic symptoms. Barley usually is severely stunted and exhibits a bright yellow color. In oats, the virus causes "red leaf" symptoms because infected susceptible varieties have a reddish-brown color of the leaves that provides easy diagnosis.

Symptoms in wheat are usually observed in late spring at about jointing, especially from fall infections. Spring infections will have delayed symptoms that usually are less severe. Leaf yellowing begins at the leaf tips and along the margins and progresses towards the middle and bases of the leaves, with the mid ribs remaining green the longest. Prior to maturation, the flag leaves may have reddish-purple tips.

Sometimes leaves may be darker green than normal, stiff and distorted. Root systems are reduced, heading and filling may be inhibited, and tillering may be reduced. Infected plants are more susceptible to winter injury.

Symptoms are more pronounced in cool weather when days are long and sunshine is abundant. Fall infections cause more serious stunting and other symptoms than spring infections.

Symptoms of BYD may overlap with other viral diseases–soil borne mosaic, spindle streak mosaic, wheat streak mosaic–complicating identification and evaluation.

The virus. The virus particles (virions) of BYDV are concentrated in phloem cells. They are polyhedral in shape, 21 to 26 nm in diameter. Isolates of BYDV differ serologically and in virulence, host range and vector specificity. Most strains are compatible in wheat and aphids, but some are mutually exclusive, having different compatibilities with certain aphid species. BYDV is not transmitted by seed, soil, sap or other insects.

Transmission. BYDV is transmitted by more than 20 aphid species. Corn leaf aphids, English grain aphids, greenbugs and oat bird cherry aphids are among the most common vectors. Aphids acquire the virus by feeding on diseased plants for periods as short as 30 minutes but usually 12 to 30 hours. After a 4-day latent period, the aphids can transmit the virus to healthy plants when feeding. After acquisition, aphids are able to transmit the virus as long as they live–known as "persistent" or "circulative" virus. Symptom expression after feeding may be in one to three weeks, but the symptoms are very inconspicuous in fall infections.

There are four prominent strains of BYDV that are correlated with the particular vector:

RMV–transmitted regularly by Rhopalosiphum maidis (corn leaf aphid)

RPV–transmitted regularly by R. padi (oat bird cherry aphid).

MAV–transmitted regularly by Macrosiphum avenae (English grain aphid)

PAV–transmitted regularly by R. padi and M. avenae.

Disease cycle. BYDV persists in cereal crops, in annual and perennial grasses, both tame and wild, and in the aphid vectors. Spread is dependent upon vector movement. In the fall, aphids move from grasses or volunteer cereals to newly planted wheat (or other winter cereals). In the spring, aphids that overwinter as adults in grasses or winter cereals become active vectors. Others that develop from eggs acquire BYDV in the spring by feeding on infected grasses and cereals during migration. Most aphids have a "winged model" (alate) form that provides more rapid movement. In feeding, they settle down to a non-wing form, with somewhat slower movement from plant to plant.

Aphid flights can be localized, or they can be disseminated for hundreds of miles when assisted by wind. The movement is associated with the development of the disease from south to north in North America. Missouri is a strategic state in the dissemination of infectious aphid vectors.

The fall infections are the most serious in wheat. Inoculated plants become systemically infected and develop symptoms within 2 weeks at 20º C, within 4 weeks at 25º C, but not at all above 30º C. In other words, cool (not cold) temperatures accentuate symptom expression.

Control. Although there are no high levels of resistance in wheat, there are some tolerant wheat varieties. This is also true of red leaf tolerance in oats.

The use of insecticides in the fall for control of aphids in the field, if properly timed, can reduce the incidence of BYD and increase yields, especially in respect to fall infections. The economics and efficacy of insecticides for vector control must be considered. It must be emphasized that aphids can inoculate the virus within a few hours, so the timing of the insecticide, especially with the short-duration insecticides, would have to be pinpointed better than most farmers could accomplish.

Fall infections can be offset from periods of high aphid activity by planting later in the fall when cooler temperatures slow aphid movements.

Mite-borne virus disease

Wheat Streak Mosaic

Wheat streak mosaic (WSM) is a viral disease that is very serious in Kansas and Nebraska. It is less of a problem in Missouri despite the fact that the wheat curl mite is present in the state in most years. The disease can cause serious yield losses in epidemic years, such as 1981 in Missouri. Severity is variable depending upon the time of virus inoculation, fall or spring, and the extent of the mite activities.

Symptoms. WSM symptoms typically appear in April or May as yellow stunted areas along field margins. These areas are often associated with volunteer wheat from the former crop. WSM symptoms become more serious with time, in contrast to the soil-borne viral diseases, and the disease is much more destructive than barley yellow dwarf. The yellowing and stunting becomes more severe and a gradual spread across the field may be seen. The earliest emerging wheat, often volunteer wheat, usually is most affected.

Individual plants turn yellow and show definite stunting and may have wilting symptoms. Tillers may be partially prostrate. Root development is often reduced.

Mosaic symptoms begin in younger leaves as light green to yellow dashes which enlarge to give a streaked appearance. Finally, the whole leaf blade turns yellow. The younger the plants are when infected with the virus, the more severe the symptoms. Head formation can be nullified. Late infections cause light and dark green streaks on the flag leaves but not much stunting.

WSM goes to spring wheat, barley, corn rye, oats and a number of annual and perennial grasses (wild and tame).

The virus. WSM is caused by the wheat streak mosaic virus (WSMV) that is carried from diseased to healthy plants by the microscopic wheat curl mite, *Aceria tulipae*.

Particles (virions) of WSMV occur in most leaf cells as flexuous rods, 15 x 700 nm. The virus is relatively unstable and difficult to purify. It is easily transmitted through sap as well as the mites.

The vector. The wheat curl mite, *Aceria tulipae Keif*, is the principal means of dissemination of WSMV in nature. There seems to be no evidence of other mites or insects that serve as vectors. Curl mites are extremely small, less than 1/100 inch in length, requiring a dissecting microscope or a 10 to 20 power hand lens for observation. The life cycle, from egg through two larval stages to the adult and egg, can be completed in 7 to 10 days. Therefore, populations can build up dramatically. Under ideal conditions, one adult could theoretically produce several million offspring in 60 days. However, predators or other environmental conditions usually limit population buildups.

Curl mite larvae acquire WSMV within a few minutes of feeding on infected plants. They are able to transmit the virus to healthy plants for at least a week following acquisition. WSMV is carried in the mid and hind gut of all larvae and adult mite stages. The virus does not pass through eggs.

The white and cylindrical mites possess four tiny legs next to the head which provide limited movement. They also have a tail end (anal) sucker for attachment. Their dispersal plant-to-plant and/or field-to-field is via wind. The mites spin webs that act as "sails".

After landing on a suitable host, the mites crawl up to the youngest unrolled leaves in the whorl. They attach themselves to the upper surface by the anal sucker and begin to feed and reproduce. Feeding prevents the leaves from unrolling normally, causing rolled leaf edges. Consequently they are known as "wheat curl mites". Heavy populations may cause enough leaf rolling so that expanding leaves and heads may be trapped. This may help to diagnose wheat curl mite infestations.

As the wheat plants mature, the mites migrate upward, including the ripening heads. If grain is shattered before harvest, especially as a result of hail, the mites attached to such kernels can sometimes survive long enough to move to the sprouting seedling. In such cases, new volunteer seedlings are infected early and can be an early source for field infections.

Without early emerging volunteer wheat , the wheat curl mites and the virus will die quickly following wheat maturity. Hot, dry July weather reduces mites and virus drastically. When deprived of food and water they survive only for hours or at most two days. However, there are always mites that survive on grasses. Wet summer weather conditions permit volunteer wheat to grow, and the earlier it emerges and the curl mites become established, the higher the population. These mites can then be blown into fall seeded wheat.

Warm weather in October and November extends the period of mite activity, with consequent virus inoculations. There is also some evidence that warm weather in February and March may result in further activity of overwintering mites.

Host plants. Wheat is the preferred host for curl mites and the wheat streak mosaic virus. Other cereal grains (barley, oats, triticale, rye) are slightly susceptible. Sorghum species are immune to WSMV and are poor hosts to the mites. A few corn hybrids are susceptible to the virus, and mites migrate to corn fields from mature wheat fields. Infections of corn usually do not cause serious losses, although virus symptoms can be identified. The movement of viruliferous mites from mature corn back to wheat usually is not a serious problem. The corn matures early enough that mites die before fall seeded wheat emerges.

Certain summer annual grasses such as barnyardgrass, crabgrass, foxtails, sandbur and witchgrass are susceptible to the virus and can serve as potential oversummering hosts. Buffalograss, smoothbrome and western wheatgrass are perennial grasses that are immune to the virus but can support mite populations.

All soft red winter wheat and hard red winter wheat varieties are more or less susceptible to WSMV. Therefore, various cultural practices must be used to minimize infection.

Disease cycle. The virus (WSMV) and the wheat curl mites persist on wheat, corn, millet and certain susceptible grasses, such as buffalograss, crabgrass and foxtail.

From spring through fall, winds distribute the mites to new cereal and grass hosts. Since the virus and the mites must persist on living susceptible hosts, they are subject to extinction when wheat is ripe and gone to harvest.

In mature or recently harvested fields, the mites will survive on green shoots or on volunteer plants developed from shattered grain.

Volunteer wheat, therefore, becomes very important to sustaining mite populations. From these plants, which can become infected by mites feeding and reproducing, the viruliferous mites can be windborne into the wheat field.

If weather conditions are warm, the increase of mites in the field can be great and the virus can be extensively inoculated. Fall infected wheat is the most seriously affected by the virus.

Control. WSM is controlled mainly by certain cultural practices that minimize sources of WSMV and the mite vectors prior to the emergence of the fall planted wheat.

- Destruction of volunteer wheat will reduce a main source of virus and some of the mites.
- Late fall planting (about the time of the "fly free day" for Hessian fly avoidance) will also help, since mite activity becomes slow as temperatures cool.
- Since certain grasses, including weed grasses, and other non-wheat cereals can be harboring places for the virus and mites, destroying these plants may be beneficial.
- Most commercial wheat varieties are variable in susceptibility. There is resistance to WSMV or to mite feeding in certain grass species, but these genes have not been transferred to wheat to any practical extent.

Soil-borne viruses

Wheat Soil-Borne Mosaic

Wheat soil-borne Mosaic (WSBM) is caused by the wheat soil-borne mosaic virus (WSBMV). It is relatively common in Missouri, and is more prevalent and observable in hard red winter wheat varieties than in the soft red winter wheats, which are dominant in acreage.

WSBM is one of the earliest known wheat viral diseases and was first characterized as soil-borne. It was sometimes known as "green mosaic", "yellow mosaic", "mosaic rosette" and "eastern wheat mosaic" in describing what was believed to be various strains. The unique characteristic of having a fungus as a vector makes the disease of great interest.

Symptoms. Symptoms of WSBM range from mild green to prominent yellow leaf mosaics. Stunting and rosetting are often observable. Fields may be uniformly diseased or more often may have spots in the field with virus symptoms. Symptoms are most prominent in early spring. Warming spring temperatures tend to slow disease development and eventually the symptoms are almost completely masked.

The virus. Particles (virions) of the wheat soil-borne mosaic virus (WSBMV) are hollow rigid rods 20 nm wide and of two lengths, 110-160 and 280-300 nm. The longer rods resemble the particles of tobacco mosaic virus. Particle lengths differ somewhat with strains of the virus, but both short and long rods appear to be necessary for infection.

The vector. In nature, the way of transmission is via a soil-borne fungus, *Polymyxa graminis Led.* This fungus is a parasite in the roots of many higher plants, including wheat. The fungus enters roots through root hairs and epidermal cells of the roots under wet soil conditions by way of motile zoospores. The fungus carries the virus into the roots in which it colonizes. The virus is released into the plant tissues, proceeding in cell-to-cell "takeover".

Disease cycle. The virus survives in the soil in close association with the fungus, *P. graminis.* Soils may remain infested with the fungus/virus for many years.

The fungus infects wheat roots during cool, wet periods in the fall and possibly in the early spring. Fall infections permit the virus to elaborate to damaging proportions and predispose plants to other diseases and winter injury. Normally, spring infections occur too late to cause very much injury before warmer temperatures and crop maturation inhibit virus development.

The virus and its fungus vector appear to be spread by cultivation, wind, water and other factors that cause movement of infested soil within a field.

Control. Resistant varieties offer the most practical control of WSBM. Soft red winter wheat varieties suffer little injury. There are certain hard red winter wheat varieties that are more tolerant than others.

Crop rotation and planting times may have minimal benefits.

Wheat Yellow Mosaic (Wheat Spindle Streak Mosaic)

Wheat yellow moaic (WYM), also known as wheat spindle streak mosaic (WSSM), is another soil-borne disease common to Missouri wheat fields. There are some similarities to wheat soil-borne mosaic in respect to symptoms and dissemination. However, the wheat spindle streak mosaic virus (WSSMV) tends to be uniformly distributed in fields rather than in pockets. Symptoms of WYM are most evident on lower leaves in early spring, and like WSMB when temperatures rise, the symptoms become masked.

Symptoms. Symptoms appear in early spring as yellow-green mottling, dashes and streaks on leaves. Discontinuous streaks run parallel with veins and taper to form chlorotic spindles. When temperatures are cool, the streaks progress to the flag leaves. Discolored areas

tend to coalesce, followed by necrosis. Reddish streaking at the leaf tips often precedes necrosis.

Some stunting and poor tillering occur in infected plants. Head numbers and seed production are reduced, but kernel weight appears to be maintained. The virus can cause production losses if it becomes extensive.

The virus. Particles (virions) of WSSMV are rods that are normally 15 to 18 nm wide and 200 to 2,000 nm in length. The threadlike virions are rather unique, and they are often clustered together, characteristics that are helpful diagnostic features for electron microscopy.

The WSSMV particles usually are found in epidermal and parenchyma tissues of infected leaves. They are sparse and are difficult to isolate in leaf-dip preparations.

The vector. Interestingly, the wheat spindle streak mosaic virus has the same fungus vector as the wheat soil-borne mosaic virus. *Polymyxa graminis* harbors the virus, and the virus enters the wheat plants through root entry by the fungus.

Disease cycle. The virus survives for many years in agricultural soils even in the absence of wheat. Apparently, WSSMV can exist for a long time in association with the *Polymyxa graminis* fungus.

The virus enters wheat plant roots via the fungus in the fall. Fall infections are most serious and account for the symptoms seen in early spring. Spring inoculations occur but are not as important.

The disease is most significant under cool spring temperatures, and is of little consequence under warm conditions. This relationship to cool temperatures probably has much to do with prevalence in any given season, and also explains the association between occurrences and geographic locations. For example, there are more incidents of the spindle streaks mosaic disease in southeast Missouri than in northern Missouri, where soil-borne mosaic seems to be more prevalent.

Control. Late fall planting reduces and retards spindle streak infections. Crop rotations also appear to limit incidence, in spite of the fact that the virus can survive for many years. Liberal use of nitrogenous fertilizers such as urea and poultry manure decrease soil infectivity.

There are variations in susceptibility among winter wheat cultivars.

Other virus or virus-like diseases

Since there are other viruses of cereals in other parts of the world where wheat production is practiced, it is very possible that some of these viruses could be involved in our own state. Symptoms may be similar to other known viral diseases or they may be inconspicuous. Certain virus-like diseases caused by mycoplasma-like organisms (MLO's) also may be involved in Missouri wheat.

Brome mosaic virus (BMV), which was described on bromegrass, is capable of affecting wheat, oats, corn, barley and rye. However, natural infections of wheat are of little economic importance. Some wheat cultivars are symptomless carriers of BMV while others may develop streak-like mottle symptoms.

Maize dwarf mosaic (MDM) is a serious disease of corn. The maize dwarf mosaic virus (MDMV) is a strain of the sugarcane mosaic virus and is, of course, most important on corn and sorghum. However, it can be transmitted to wheat by aphids. MDMV in wheat induces mild leaf mottling. It will be difficult to identify.

Tobacco mosaic (TM), caused by the tobacco mosaic virus (TMV), is a prevalent and stable virus in nature with a wide host range, especially among dicotyledonous species. It can, however, infect certain grasses, among them wheat. In the case of a double infection when another wheat virus is involved, some additional symptom expression could be observed. However, neither the origin nor the practical importance of natural double infections are known.

Wheat spot mosaic (WSpM) has been identified in Ohio on wheat and corn. Barley, rye and some grasses are also hosts to the virus (WSpMV), but wheat is most susceptible. This virus is mite borne *(Aceria tulipae Keifer)*. The disease would likely be in company with wheat streak mosaic, and would be identifiable only under careful assessment of the wheat streak disease.

Aster yellows is caused by mycoplasma-like organism (MLO). MLO's cause symptoms that are similar to viruses. However, the ultra-microscopic organisms are more like bacteria than viruses. They do not have rigid cell walls, but have a fine outer membrane which allows greater flexibility than bacteria. Since Aster yellows has a wide host range and is very prevalent in nature, wheat can ostensibly have aster yellows infections. It is leaf hopper transmitted. Essentially, it is of minimal consequence to wheat production.

Additional References

Compendium of Wheat Diseases (1987). American Phytpathological Society, 3340 Pilot Knob Road, St. Paul, Minn. 55121.
Wheat Health Management (1991). American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minn. 55121.
Wheat Diseases (1984). Kansas State University Cooperative Extension Service, Manhattan, Kan. 66506.

How to Identify Wheat Viruses

	Barley Yellow Dwarf	Wheat Streak Mosaic	Soil-Borne Mosaic	Spindle Streak Mosaic	Maize Dwarf Mosaic
When symptoms are observed	6-8 weeks after spring growth begins–yellowing at maturation, yellow to reddish flag leaves	4-6 weeks after spring growth begins. In fall on volunteer wheat	Early spring. 1-2 weeks after spring growth begins. Rarely in fall	Early spring. 1-2 weeks after spring growth begins	Rare in wheat
Pattern in field	Random circular areas	Often along edges of fields or near volunteer wheat. Diminishing with distance	Somewhat circular areas, especially in wet areas	More widespread in field than soil-borne mosaic	Random plants
Leaf symptoms	Leaf tips bright yellow on upper leaves, or reddish flag leaves–most distinct	Bright yellow leaves with streaking patterns toward tips. Most prominent on upper leaves. Curling of upper leaves	Pale yellow leaves with mosaic patterns	Yellow-green mottling dashes and streaks parallel with veins	Mosaic, mottling
Stunting	Some–but hard to identify; fewer tillers	Severe stunting from fall infections	Some stunting but also some recovery after warm weather	Mild stunting and fewer tillers	Mild stunting
Other symptoms	Poor roots; susceptible to winter injury	Poor roots; wilting; prostrate tillers	Poor roots; winter injury	Poor roots; winter injury	Inconspicuous
Vectors	Several aphid species	Wheat curl mite *Aceria tulipae*	Fungus–*Polymyxa graminis*	Fungus–*Polymyxa graminis*	Several aphid species
Conditions favoring infection	Long warm fall	Long warm fall. Early volunteer wheat from hail or other factors at harvest	Wet soil in fall. Cool temperatures in spring	Wet soil in fall. Cool temperatures in spring	Proximity to infected Johnson-grass
Where serious	General and serious in most wheat in Missouri	Sporadic. More serious in southwest Missouri when it occurs	Mainly in northern and central Missouri. Most obvious on hard red winter wheat	Mainly in southeast but may occur in central Missouri	Generally not serious
Control	Resistant or tolerant varieties	Destroy volunteer wheat. Delay planting to "fly free date"	Soft red winter wheat varieties usually more tolerant than hard red winter wheat varieties	Resistant cultivars. Late planting	Not needed

University Extension
UNIVERSITY OF MISSOURI
COLUMBIA

■ Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914 in cooperation with the United States Department of Agriculture. Gail L. Imig, Director, Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, Missouri 65211. ■ An equal opportunity institution.