13. Annex: Regulated Pests

Wheat streak mosaic virus (WSMV)

July 2023

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1. Technical description of the plague

1.1 Disease name Spanish: Virus del

mosaico estriado del trigo

1.1.1 Etiological agent

Preferred name: *Wheat streak mosaic virus* (WSMV)**,** McKinney

Synonymy: *Wheat streak mosaic rymovirus*
Wheat streak mosaic tritimovirus

Taxonomic categorization:

Class: Stelpaviricetes
Order: Patatavirales
Family: Potyviridae
Genus: Tritimovirus
Species: *Wheat streak mosaic virus*

1.2 Hosts / Species affected

Avena sativa
Aegilops cylindrica
Agropyron repens
Agrostis capillaris
Alopecurus pratensis
Anthoxanthum odoratum
Arrhenatherum elatius
Austrostipa compressa
Avena barbata
Avena fatua
Avena strigesa
Brachypodium distachyon
Briza maxima
Bromus arvenis
Bromus japonicus
Bromus rigidus
Bromus secalinus
Bromus tectorum
Hordeum vulgare

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Cenchrus longispinus
Cenchrus pauciflours
Cynodon dactylon
Digitaria sanguinalis
Echinochloa colonum
Echinochloa crus-galli
Eleusine tristachya
Elymus canadensis
Elymus repens
Eragrostis cilianensis
Eragrostis curvula
Eriochloa acuminata
Eriochloa contracta
Holcus lanatus
Holcus mollis
Hordeum leporinum
Zingiber officinale
Lagurus ovatus
Lolium mitiflorum
Lolium rigidum
Zea mays
Pennisetum glaucum
Panicum capillare
Panicum dichotomiflorum
Panicum millaceum
Phalaris aquatica
Phleum pratense
Poa pratensis
Poa pratensis
Secale cereale
Setaria italica
Setaria viridis
Sorghum bicolor
Tragus australianus
Triticum aestivum

1.3 Cycle of the disease

1.3.1 Transmission and survival

Neegard (1979) reports that transmission of the virus by seeds in maize has been demonstrated. The ISF (International Seed Federation) database (2022) indicates that WSMV affects cereals and grasses, with maize and wheat being its main hosts, and that it can be transmitted by maize seeds, with infection levels ranging from 0.5 to 2% and transmission frequencies of 0.5 to 1.5%. These seeds can

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act as an entry pathway for the pathogen. ISF also indicates that the analysis of a representative sample of *Z. mays* seeds constitutes a management strategy for this pest. According to CABI (2020) this virus can survive in seeds and be transmitted to seedlings, with low transmission rates.

Seed transmission of WSMV was first described in maize in seed production fields in Iowa and a percentage of seed transmission (0.1%) of the virus was found (Hill *et al*., 1974). Jones et *al*. (2005) detected seed transmission of WSMV in eight wheat genotypes from tests conducted at the seedling stage. Seed transmission was 0.2 - 0.5% in all genotypes and up to 1.5% transmission in individual genotypes, indicating that the transmission rate was lower in the entire wheat seed collection tested and higher in individual genotypes. While such a low seed transmission rate is likely to be of little epidemiological significance in an individual field, the epidemiological significance is magnified when the increased likelihood of global spread of the virus through local, regional, and international exchange of germplasm is taken into account.

In Argentina, the working group on maize diseases of the Institute of Plant Pathology (IPAVE) together with the Center for Agricultural Research (CIAP) and the National Institute of Agricultural Technology (INTA), conducted periodic monitoring of lots in different localities of the corn area of the country, detecting the presence of WSMV (De Rossi, 2017). Likewise, Torrico *et al*. (2020) mention WSMV as one of the main viruses affecting maize in Argentina and transmitted by its seed, and indicate that IPAVE in the last 10 years has performed 609 analyses on maize seeds, having detected this virus in two samples studied.

It is believed that the introductions of WSMV into both Argentina and Australia may have been due to infected seed that was imported into the country from the United States and Mexico. The WSMV isolate discovered in Australia was found in greenhouse-grown breeding lines at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. The Australian WSMV isolates were seed-transmitted at a rate of 0.5 - 2%. It is possible that the introduction of WSMV into the United States was also through infected seed (CABI, 2020).

Murray *et al*. (2005) also point out that several grasses can act as potential reservoirs of WSMV, mentioning the following species: *Bromus diandrus, Setaria verticellata, Eragrostis cilianensis, Eleusine indica, Avena fatua, Avena sterilis, Lolium rigidum, Cynodon dactylon* and *Phalaris aquatica.*

WSMV is also transmitted by the wheat curl mite, *Aceria tosichella* (CABI, 2020) while White (2004) points to the wheat curl mite, *Aceria tosichella* *(*CABI, 2020) as a vector.

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nymphs of *Eriophyes tulipae*, which acquire the virus within 15 minutes, but not adults. Adults are vectors only when the virus is acquired as nymphs. The virus is retained in the midgut and hindgut of all larval and adult stages for 6 days.

The virus enters the leaves and spreads to all parts of the plant. The wheat mite can be wind-dispersed from field to field, and can survive as eggs, larvae, nymphs, or adults in the crown and leaf sheaths of volunteer wheat. In the fall the mites move from WSMV-infected volunteer wheat and other grass hosts to newly emerged wheat and transmit the overwintering virus within the volunteer plants. In the spring and summer, the mites move from the maturing wheat crop to volunteer wheat and other grass hosts and transmit WSMV, and to newly emerged wheat to which they transmit the virus, completing the disease cycle. In the spring, the mites multiply rapidly and spread to new wheat lots. These hosts harbor the mite and virus during the summer, completing the disease cycle (FAUBA, S/F).

Since the mite vector of the virus, *A. tosichella,* affects several host species of the *Poaceae family,* including volunteer cereal plants and weed hosts, these can act as "green bridges". The maize crop thus plays an important role in providing an alternative host for the virus and vector from wheat harvest to wheat emergence in the next season (Alemandri *et al.*,2022).

1.3.2 Incidence

Torrico *et al*. (2020) mention WSMV as one of the main viruses affecting maize in Argentina and transmitted by its seed, highlighting the importance of detecting and quantifying the presence of viruses in seeds in order to avoid the spread of these viruses or their variants to new territories. According to Giménez Pecci & De Rossi (2016) the incidence of WSMV for the 2009/2010 season in maize was 28% in the locality of Pinedo (Chaco province) and 9.68% in Vilelas (Santiago del Estero), causing decreases in the yield of this crop.

In 2007, a significant WSMV epiphytotic in wheat was reported in the southeast of the province of Buenos Aires (Argentina), with percentages of up to 100% incidence and total losses in several plots analyzed (Truol, 2009). Likewise, a period with high incidence and severity of WSMV was recorded in that area between 2008 and 2010 (Bariffi *et al*., 2009). In 2012, similar conditions of severity and production losses were observed in the wheat region of Córdoba, with lots entirely affected and not harvested (Alemandri *et al.,* 2014).

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According to a survey conducted by Alemandri *et al.* (2022) of wheat producers who sent a total of 215 samples of this crop with suspected WSMV symptoms for laboratory analysis, most respondents reported an average incidence (percentage of infected plants) of the disease (49%), as well as severity (51%). These samples studied correspond to the fine grain campaign in Argentina, during 2021.

In *Zea mays,* most commercial hybrids are resistant to this pest, while there are varieties such as sweet, blue or dent corn that are very susceptible. There are also hybrids that can be infected with WSMV and be asymptomatic, so that populations of *A. tosichella* can transmit this virus from an apparently healthy corn crop to another wheat crop. It has been shown that the activity of this mite around maize productions starts low in the pre-harvest period of wheat, then increases as its ear develops (Wegulo *et al*., 2008).

1.3.3 Symptoms associated with different organs and phenological stages

The first symptoms on corn appear as small chlorotic spots or broken veins on the tips of young leaves. The streaks become elongated and develop parallel to the veins. Older leaves may become chlorotic near the ends with green margins bordering the veins. Spikelets are poorly developed and have few or no seeds and there is sometimes general yellowing and stunting (UI, 1980). Depending on the germplasm, the spots and stripes later coalesce to form mosaic, mottled patterns that are parallel and bounded by the major veins and often bright yellow (White, 2004; CABI, 2020).

Symptoms may also manifest as chlorotic streaks that may be mild or severe, with varying degrees of necrosis, resulting in a reduced number of seeds and wilting of the kernels. In late infections it only covers a portion of the leaf. Other authors also highlight the presence of chlorotic streaks that can form a mosaic, leaf chlorosis, rickets and sterility (Dumón *et al*., 2013).

1.3.4 Behavior and distribution in the batches

For the wheat crop Coutts *et al*. (2014), cite as an example that, if a seed transmission rate of 0.1% and a density of 100 plants/m^2 are considered, this would mean a potential of 1000 WSMV-infected seedlings per hectare, randomly distributed throughout the crop. In addition, if the

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If the mite vectors are present, the virus would spread within the flock. In this sense, seed transmission of WSMV plays an important role in the epidemiology of this disease.

The activity of *A. tosichella*. in the corn crop starts with low levels in the period prior to wheat harvest and increases as the ear develops, reaching a peak when the ear begins to dry. Survival of the mite varies among hybrids, with some sustaining high populations on the ears until plant drying occurs. Irrigated corn crops can harbor higher populations of the mite than rainfed crops (Wegulo *et al.*, 2008).

1.3.5 Similarities with other pathogens

The symptoms produced by WSMV are very similar to those of *Triticum mosaic virus* (TriMV) under natural conditions, with *A. tosichella* being a vector of both viruses (Tatineni *et al.*, 2010).

Scheets (1997) in maize plants inoculated with WSMV and *Maize Chlorotic Mottle Machlomovirus* (MCMV) reported that the initial symptoms manifested were not different from those inoculated with each of these viruses separately. Later, plants infected with *Maize chlorotic mottle virus* developed more intense chlorosis and a higher density of chlorotic spots than those inoculated with WSMV and MCMV separately.

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3. Annex: Figures

Figure 1: *Wheat streak mosaic virus* (WSMV) symptoms on maize (Zea mays) leaves in plants inoculated with this virus (Tatineni *et al*., 2017).

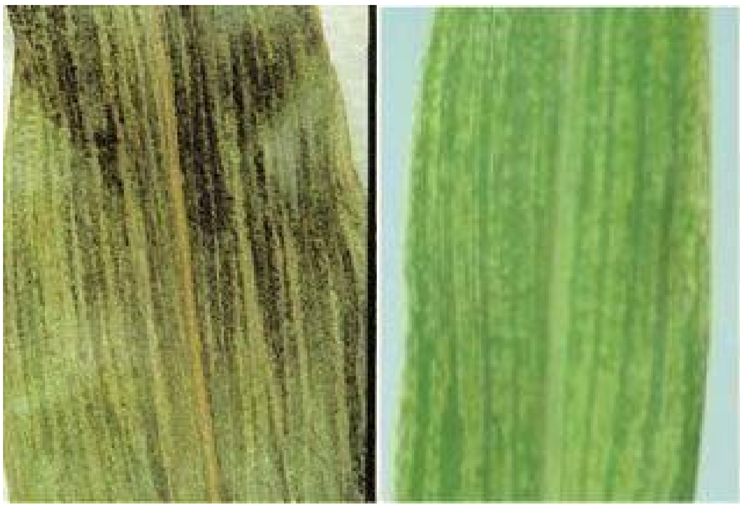

Figure 2: Chlorotic streaks produced by *Wheat streak mosaic virus* (WSMV) on maize leaves. In the left image, necrosis of leaf tissue is also observed (Left image: Tatineni *et al*., 2017. Right image: Tatineni *et al*., 2010).

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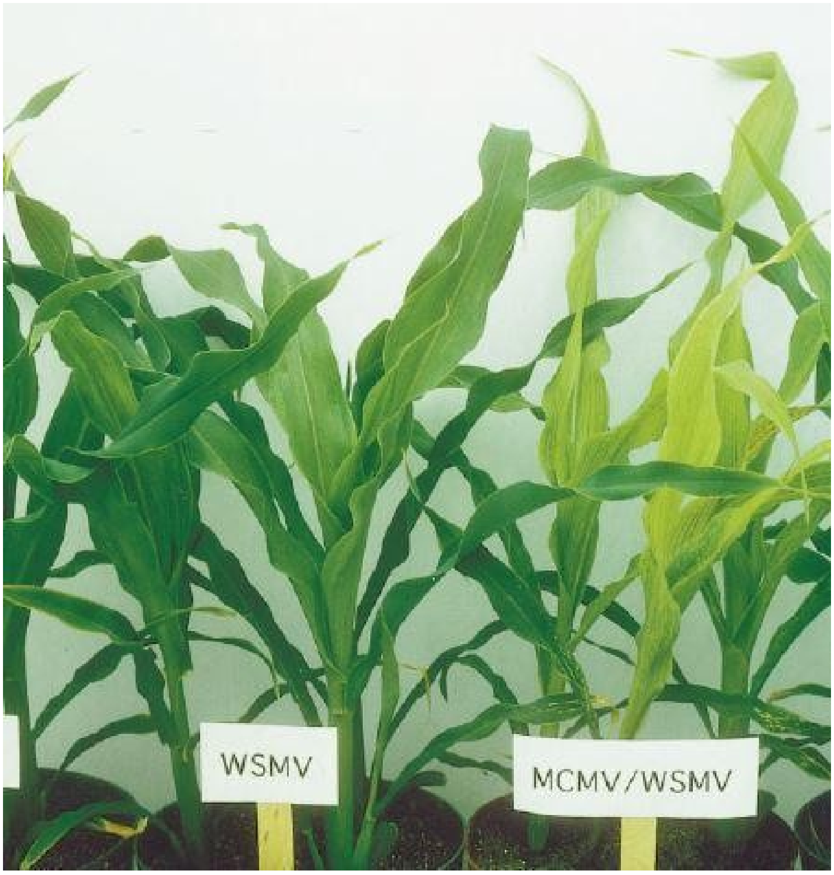

Figure 3: *Zea mays* plant inoculated with *Wheat streak mosaic virus* (WSMV) (left) and with WSMV and *Maize Chlorotic Mottle Machlomovirus* (MCMM) (right). Chlorotic streaks can be seen in all plants, which is accentuated in those inoculated with both viruses (Scheets, 1998).

Figure 4: *Wheat streak mosaic virus* (WSMV) symptoms, chlorotic streak mosaic on leaves and different degrees of necrosis in wheat (Alemandri *et al*., 2022).

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.

Figure 5: Hosts of *Wheat streak mosaic virus* (WSMV), *High Plains wheat mosaic virus* (HPWMoV) and *A. tosichella* (WCM) (Wegulo *et al*., 2008).

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