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RESEARCH ARTICLE

Wheat streak mosaic virus: incidence in field crops, potential reservoir within grass species and uptake in winter wheat cultivars

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Abstract

Wheat streak mosaic virus (WSMV) has become a re-emerging pathogen in cereal crops in the Czech Republic. WSMV was first reported in the former Czechoslovakia in the early 1980s, and then no record of the virus was documented until 2009. The incidence of the virus was recorded in recent years in several winter wheat fields and many grass species. Here, we surveyed the incidence of WSMV in cereal crops. The results demonstrated the existence of the virus in winter wheat and volunteer wheat during each year of the monitoring period, which spanned from 2013–2016. Although the range of infected samples was low (6.4% of the total tested samples), a high incidence of well-distributed virus was recorded. In at least six fields, the virus reached severe and potentially epidemic levels. In accordance with our previous report detailing WSMV infection of native grasses, we tested several grass species commonly grown in the Czech Republic. We found that some grass species acted as experimental hosts and possible reservoirs of the virus; these included *Anthoxanthum odoratum* (sweet vernal grass), *Arrhenatherum elatius* (false oat-grass), *Lolium multiflorum* (Italian rye-grass), *Bromus japonicus* (Japanese chess), *Echinochloa crus-galli* (barnyard grass), *Holcus lanatus* (meadow soft grass) and *Holcus mollis* (creeping soft grass). Some of these grass species are also important weeds of cereals, which may be the potential source of WSMV infection in cereal crops. Several widely used winter wheat cultivars were tested in the field after artificial inoculation with WSMV to evaluate virus titre by RT-qPCR. Overall, the tested cultivars had a low virus titre, which is associated with mild disease symptoms and may provide a good level of crop resistance to WSMV.

Keywords: WSMV, survey, grass species, cereal crops

1. Introduction

Wheat streak mosaic virus (WSMV) is the type member of the genus *Tritimovirus* of the family *Potyviridae* (Rabenstein *et al.* 2004). WSMV is widespread throughout the world and represents a severe threat in most wheat-growing regions (Rabenstein *et al.* 2002; Hadi *et al.* 2011; Coutts *et al.* 2014). WSMV infects many plant species of the family *Poaceae* (Brakke 1971; French and Stenger 2002), including wheat (*Triticum aestivum* L.), oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), maize (*Zea mays* L.), millet (*Panicum*,

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Setaria, and *Echinochloa* spp.) and several grasses (see Table 1). Symptoms caused by WSMV include leaf mottling (mosaic pattern of green and chlorotic zones) and leaf streaking and are mainly observed in wheat (Vacke *et al.* 1986; Murray *et al.* 1998). The symptoms may progress to chlorosis and severe stunting of the plant, and in many cases, plants become sterile or produce shrivelled seeds (Ellis *et al.* 2004). WSMV is transmitted by wheat curl mites (WCMs, *Aceria tosichella*) (Slykhuis 1955; Orlob 1966), which are dispersed passively by air currents (Slykhuis 1955). The virus is also transmitted at low levels by seeds in wheat (Jones *et al.* 2005). Estimated levels of WSMV in seed lots originating from infected commercial wheat crops range from 0 to 0.22%, with an overall transmission rate of 0.06% (Lanoiselet *et al.* 2008).

WSMV was first reported in the Great Plains Region (GPR) of North America in 1922. Since then, WSMV has been recorded in many wheat-growing regions of the world, including North and South America, Europe, the Middle East, Asia, Australia and New Zealand (Navia *et al.* 2013; Skoasracka *et al.* 2014). Crop losses caused by WSMV vary widely, ranging from 7 to 13% in Kansas (Atkinson and Grant 1967), reaching 18% in Canada (Christian and Willis 1993) and reaching up to 83% in wheat in Australia (Lanoiselet *et al.* 2008). WSMV spreads to cereal crops from virus reservoirs, which can include volunteer wheat plants and some grasses. At least 45 grass species are reported to be natural hosts for WSMV, and the majority of them are annuals (Sill and Agusiobo 1955; Christian and Willis 1993; French and Stenger 2002; Ito *et al.* 2012). Many of these WSMV grass hosts are also hosts for WCM (for review, see Navia *et al.* 2013).

There is limited protection of cereal crops against WSMV and its WCM vector. Host resistance against the virus and/or vector is the most effective way to reduce the yield loss caused by WSMV (Thomas *et al.* 2004; Richardson *et al.* 2014). Three resistance genes, known as *Wsm1*, *Wsm2*, and *Wsm3*, have been identified and introduced in wheat breeding lines. *Wsm1* and *Wsm2* resistance sources were found to be more temperature-sensitive (Seifers *et al.* 2013) than *Wsm3* (Fahim *et al.* 2012); however, they have not yet been introduced into a commercial cultivar. The *Wsm2* gene is the most widely used and has been successfully introduced into several wheat cultivars, including RonL (Seifers *et al.* 2006), Snowmass (Haley *et al.* 2011), Clara CL (Martin *et al.* 2014) and Oakley CL (Zhang *et al.* 2015a). However, with the deployment of WSMV-resistant cultivars, the limited resistance sources in these cultivars may be broken down by selective pressure on the virus (Zhang *et al.* 2015b).

WSMV was first reported in the former Czechoslovakia in the early 1980s (Vacke *et al.* 1986). The incidence of the virus in recent years has become more frequent in winter wheat crops (Gadiou *et al.* 2009; Dráb *et al.* 2015). Vacke *et al.* (1986) reported the existence of WSMV in wheat, barley, oat and some cultivars of corn as well as in some grass species, including *Avena fatua*, *Avena strigesa*, *Panicum miliaceum*, *Lolium multiflorum*, *Lagurus ovatus* and *Digitaria sanguinalis*. In the present work, we report the results of a four-year survey of the incidence of WSMV in cereal crops, which was recorded for several winter wheat fields each year. We previously found that several grass species can become naturally infected with WSMV (Dráb *et al.* 2014), which may be a source of virus inoculum for cereal crops. We tested several grass species commonly grown in the Czech Republic and found that some of them were experimental hosts and possible reservoirs of the virus, such as *Anthoxanthum odoratum* (sweet vernal grass), *Arrhenatherum elatius* (false oat-grass), *L. multiflorum* (Italian rye-grass), *Bromus japonicus* (Japanese chess), *Echinochloa crus-galli* (barnyard grass), *Holcus lanatus* (meadow soft grass) and *Holcus mollis* (creeping soft grass). Several widely used winter wheat cultivars were tested in field experiments after artificial inoculation with WSMV to evaluate virus titre using real-time RT-qPCR. Several of the wheat cultivars, including Caldwell, Cubus, Florida, Matchball and Cim rana, had low levels of virus uptake. Furthermore, in one triticale cultivar, Koler, WSMV was undetected even when highly sensitive RT-qPCR was used. This low virus uptake in cultivars may be associated with a significant level of crop resistance to WSMV.

2. Materials and methods

2.1. Survey of WSMV in crop and grass hosts

Samples from cereal fields, the fields' margins and perennial meadows were collected from 2013–2016 in different regions of the Czech Republic. The samples were collected during the early spring to autumn period randomly based on disease suspicion in the fields (Table 2).

2.2. Experimental hosts within grass species

Twenty-four species of grass (see Table 2) from *Poaceae* that naturally occur in the agro-ecosystem of the Czech Republic were tested. The plants were grown in greenhouses, and they were mechanically inoculated with a WSMV isolate (CZlab, accession number FJ216408) at the two-leaf stage. To accomplish this, individual plant leaves were smeared with sap containing the WSMV isolate with 0.1 mol L^{-1} phosphate buffer (pH 7.2) and carborundum powder. One month post-inoculation, the plants were tested by TAS-ELISA and then by RT-PCR as described in Gadiou *et al.* (2009).