Re-emergence of Tobacco streak virus Infecting Soybean in the United States and Canada

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Re-emergence of Tobacco streak virus Infecting Soybean in the United States and Canada

Abstract
Tobacco streak virus (TSV), an Ilarvirus, was first confirmed as a viral pathogen of tobacco in 1936 (Johnson 1936) and first reported in North American soybean in 1969 (Fagbenle and Ford 1970). TSV has a wide host range with strains able to infect at least 140 different plant genera, including crop, ornamental, and wild species (Fulton 1948). Due to its extensive host range and strain adaptations, TSV is found in commercial crops worldwide. Since 1969, however, TSV has not been a problem on soybean or commonly reported until the 2013 season, when it was found in fields throughout Iowa. A similar situation is found throughout the Midwest, with TSV being reported in recent years in Illinois, Kansas, and Wisconsin, as well as Ontario, Canada.

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Re-emergence of *Tobacco streak virus* Infecting Soybean in the United States and Canada

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*Tobacco streak virus* (TSV), an Ilarvirus, was first confirmed as a viral pathogen of tobacco in 1936 (Johnson 1936) and first reported in North American soybean in 1969 (Fagbenle and Ford 1970). TSV has a wide host range with strains able to infect at least 140 different plant genera, including crop, ornamental, and wild species (Fulton 1948). Due to its extensive host range and strain adaptations, TSV is found in commercial crops worldwide. Since 1969, however, TSV has not been a problem on soybean or commonly reported until the 2013 season, when it was found in fields throughout Iowa. A similar situation is found throughout the Midwest, with TSV being reported in recent years in Illinois, Kansas, and Wisconsin, as well as Ontario, Canada.

TSV associated with bud blight of soybean (*Glycine max*) is often referred to as Brazilian bud blight. As with many viral diseases, timing of infection affects the type or severity of symptoms. Early infection of soybean plants may come from seed and may result in reduced plant height and density (Rabedeaux et al. 2005). Other symptoms associated with early infection include reduced leaf size, excessive axillary branching, and delayed seed development (Fig. 1) that can lead to yield loss by reducing numbers of pods and seeds per plant, as well as smaller seed weights (Rabedeaux et al. 2005). Infection later in the growing season may cause bud blight and necrotic spots on pods, red node, or necrotic streaking at nodes, and delayed maturity (Figs. 2, 3, and 4).

Research on management of TSV in the United States is limited and there is no known plant host resistance available. TSV is seed and pollen transmitted, and transmission can be facilitated by several species of thrips. The specific role that thrips play in the spread of TSV is unclear, especially in relation to soybean. Control of thrips populations, removal of alternative weed hosts from fields and surrounding areas, and delayed plantings have been successful in Brazil to reduce TSV infection in soybean (Rabedeaux et al. 2005).

In August of 2013, the Iowa State University Plant and Insect Diagnostic Clinic received samples of soybean plants from Pottawattamie, Jefferson, and Story counties, IA, with irregular, black streaks and necrotic areas on pods. Samples were also collected from fields in Boone, Marshall, and Hardin counties, IA. All Iowa samples were tested using ELISA to confirm infection by TSV. The presence of the virus was confirmed in leaves, petioles, and pods but varied by sample. Additional plants collected from Champaign, Livingston, McLean, Iroquois, and Ford counties, Illinois, were diagnosed via observation of

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**FIGURE 1**

Soybean plant showing stunting and reduced leaf size caused by TSV infection.
symptoms and ELISA. Presence of TSV was also reported in Illinois for the years of 2006-2008 (Hobbs et al. 2010). In a severely infected field in Story County, IA, with more than 80% of soybean plants infected in some sections, data on yield and seed moisture were collected from plants sampled from 20 plots with varying incidence of TSV. Regression analysis indicated a significant positive relationship between incidence and seed moisture ($R^2 = 0.66, P < 0.0001$) but no significant relationship for yield ($R^2 = 0.12, P = 0.1410$). While this field did not show symptoms until late August, infected soybean plants were still green over a month after non-infected plants were fully mature (Fig. 4), which delayed harvest and caused yield losses on non-infected soybean due to shattering. Seeds from TSV-infected plants grown in Story County, IA, were collected for RNA-seq experiments to determine if viruses were transmitted to the progeny (Groves et al. 2016). Short trimmed RNA-seq reads generated from the seedlings (Groves et al. 2016) were mapped independently to the genomes of seven different TSV isolates using the Bowtie short-read aligner (Langmead et al. 2009). This analysis identified reads that aligned to a TSV isolate originally collected from soybean in Illinois (GenBank Accession Nos. FJ403375.1, FJ403376.1, and FJ403377.1). The presence of TSV in the seedlings demonstrates that TSV was seed transmitted, and it provides additional confirmation that TSV was present in the field-grown parents.

The sudden revival of TSV during 2013 may have been due to the hot, dry weather that is preferred by thrips. An increased number of thrips may have contributed to the increased spread of TSV. In 2013, a similar increase in Soybean vein necrosis virus was observed, which is also transmitted by thrips (unpublished). Interestingly, Soybean vein necrosis virus (Groves et al. 2016) and Bean pod mottle virus (BPMV; data not shown) were also present in the RNA-seq data. This observation suggests that the previous, unexpected finding of Soybean vein necrosis virus seed transmission could be a result of heterologous complementation (Lewandowski and Adkins 2005; Tamai et al. 2003) of cell-to-cell movement, and is consistent with the idea that differences in seed-transmission can be attributable to limitations in viral movement (Johansen et al. 1994).

In 2015, plants exhibiting symptoms of viral infection were located and tested positive for TSV. These plants were collected in several counties in central Iowa from commercial fields and Iowa State University research farms. The Ontario Ministry of Agriculture has also seen an increase in the frequency of TSV being detected. The presence of the pathogen was confirmed

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**FIGURE 2**
Soybean plant exhibiting symptoms of bud blight caused by TSV infection.

**FIGURE 3**
Necrotic blotches on pods (left) and red node (right) caused by TSV infection.
using ELISA in Iowa and Ontario. Additionally, soybean plants with delayed maturity from Riley County, Kansas, were confirmed by Agdia, Inc. (Elkhart, IN) to be infected with TSV.

With increased variability and extreme events predicted for weather patterns by climate change models, pathogens that follow drier conditions such as TSV may become increasingly prevalent. Given that TSV and other viruses such as SVNV can be seed transmitted, these understudied soybean pathogens merit further scientific study.

**LITERATURE CITED**


