SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 60:
Viral Diseases of Soybeans

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Four soybean viruses infect South Dakota soybeans. Bean Pod Mottle Virus (BPMV) is the most prominent and causes significant yield losses. Soybean Mosaic Virus (SMV) is the second most commonly identified soybean virus in South Dakota. It causes significant losses either in single infection or in dual infection with BPMV. Tobacco Ringspot Virus (TRSV) and Alfalfa Mosaic Virus (AMV) are found less commonly than BPMV or SMV.

Managing soybean viruses requires that the living bridge of hosts be broken. Key components for managing viral diseases are provided in Table 60.1. The purpose of this chapter is to discuss the symptoms, vectors, and management of BPMV, SMV, TRSV, and AMV.

Table 60.1. Key components to consider in viral management.

1. Viruses are obligate pathogens that cannot be grown in artificial culture and must always pass from living host to living host in what is referred to as a “living or green” bridge.
2. Breaking this “living bridge” is key in soybean virus management.
   a. Use planting dates to avoid peak populations of insect vectors (bean leaf beetle for BPMV and aphids for SMV).
   b. Use appropriate rotations.
3. Use disease-free seed, and select tolerant varieties when available.
4. Accurate diagnosis is critical. Contact Connie L. Strunk for information. (605-782-3290 or connie.strunk@sdstate.edu)
5. Fungicides and bactericides cannot be used to manage viral problems.

What are viruses?

Viruses that infect soybeans present unique challenges to soybean producers, crop consultants, breeders, and other professionals. Plant viruses are submicroscopic pathogens composed of single or multiple RNA or DNA strands surrounded by a protective protein layer or coat. Their unique size and composition challenge soybean producers and professionals because unlike fungal pathogens, they cannot be seen with the naked eye, magnifying lens, or light microscope. Additionally, they are obligate pathogens that cannot be grown in artificial culture and must always pass from living host to living host in what is referred to as a "living or green" bridge. Breaking this "living bridge" is key to management of soybean viruses.

Insect or other vectors (organisms that transmit the virus) allow soybean viruses to pass from plant to plant along this "living bridge" by overcoming the plant's protective barriers and depositing virus in living cells. Thus, vectors are responsible for introducing the initial viral infection into a field and for disseminating (spreading) virus throughout the field. Vectors have such an important role in the transmission of viruses that they can be considered an additional component to the typical disease pyramid representing the factors necessary for viral disease development (Fig. 60.1).

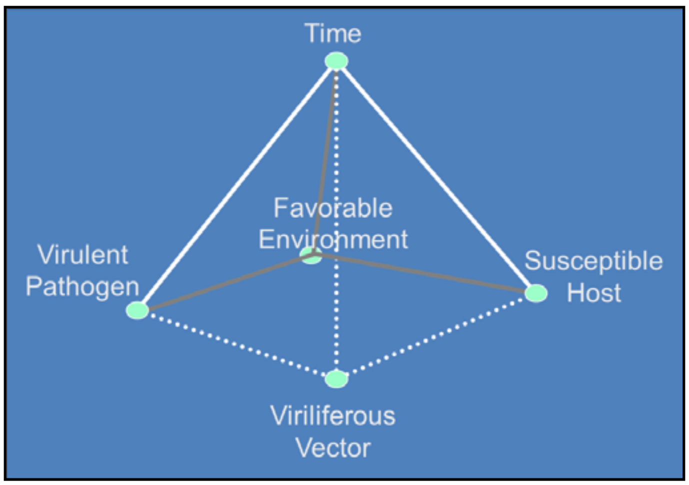

Figure 60.1. Vectors of soybean-infecting viruses serve a vital role in soybean viral epidemiology, and these vectors comprise an additional element in the classic disease pyramid representing the factors needed for viral disease development. (Diagram courtesy of M.A.C. Langham, SDSU)

Viral soybean diseases are a serious economic threat to soybean production impacting growth and yields without being widely recognized. Yield losses caused by soybean viruses can exceed 50% depending on the plant variety, infecting virus, and the growth stage of soybean when infected. However, the variety of symptoms produced by viral diseases, symptom suppression during certain soybean growth stages, and limited familiarity with viral disease symptoms contribute to difficulties in diagnosis.

Additionally, soybean viral diseases are one component in the complex of viral diseases infecting all legumes (Fig. 60.2). Legume viruses can be roughly categorized into clusters as those that infect soybeans; those that infect dry beans, pulses, peas, and cowpeas; and those that infect alfalfa and other forages. However, there are some viruses that can pass between two of these clusters, and more rarely, a few viruses can pass between all three clusters. Viral vectors may also move between these three legume clusters. Therefore, this interaction between viral diseases, vectors, and legume type plays an important part in the epidemiology of soybean viral diseases and needs to be considered when developing soybean virus management strategies.

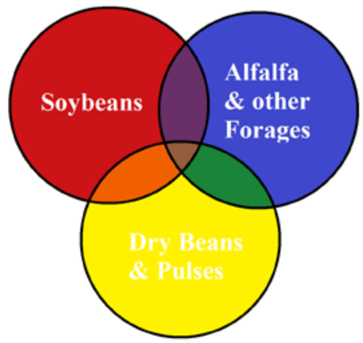

Figure 60.2. Viral diseases of legumes form three clusters: those infecting soybeans (red), those infecting alfalfa, clovers, and other forages (blue), and those infecting dry beans, pulses, peas, and cowpeas (yellow). Orange, violet and green areas represent the viruses that can infect two groups, and the brown area represents viruses that can infect all three groups. (Diagram courtesy of A. Geddes and M.A.C. Langham, SDSU, Plant Virology Project)

Bean Pod Mottle

Bean pod mottle virus (BPMV) was first described in 1948 (Zaumeyer and Thomas, 1948). BPMV was limited in United States soybean production to Southern soybean-producing states until late 1998 and 1999 when BPMV incidence in the Northern Plains states increased dramatically (Giesler et al., 2002). It was first identified from South Dakota in 1998 and has been present as an economic threat ever since (Langham et al., 1999). BPMV has been found in the majority of southeastern South Dakota (Fig. 60.3), and it extends into northern counties. Extremely high incidence levels have been detected in individual fields and counties. Due to high incidence levels and yield losses, BPMV has a significant economic impact on South Dakota soybean production.

Symptoms

BPMV-infected plants are distinguished by leaves with light green or yellow in a mosaic or mottle pattern with a darker green (Figs. 60.4 and 60.5) (Brunt et al., 1996; Semanick, 1972). Mosaic or mottle patterns are typically prominent in the vegetative or early reproductive stages, but tend to fade (symptom suppression) as the plants mature and summer temperatures increase (Gergerich, 1999). A second prominent symptom is distortion of the leaf lamina as seen in Figures 60.4 and 60.5 (Gergerich, 1999). Leaf distortion is only partially suppressed by maturity or temperature and tends to remain present at this decreased level throughout the season. BPMV-infected plants can be severely stunted (Fig. 60.6), but maturity delays in infected soybeans can allow these plants to continue growing after other plants have reached maturity. Thus, infected plants may appear to "catch up" to non-infected plants late in the season.

Maturity delays are also responsible for BPMV-infected soybeans remaining green after other soybeans in the field have matured and abscised (shed) their leaves. Fields with BPMV-infected soybeans may not close the canopy in row spacing as quickly or thoroughly as healthy soybeans due to delays in maturity and reduction in branching (Fig. 60.7). Some soybean cultivars produce seed mottling when infected by BPMV due to color bleeding from the hilum in seeds from infected plants (Fig. 60.8). Seed mottling is typically a quality issue as the virus found in the seed is generally confined to the testa (seed coat).

Yield reduction caused by BPMV in soybean is dependent on cultivar and soybean growth stage when infected (Fig. 60.9) (Langham et al., 2005). Nationally, yield reductions due to BPMV have been reported to vary from 3% to 52%. In South Dakota cultivar evaluations, yield reductions ranging from 1% to 56% have been observed with an average reduction of one pod per node and 0.7 seeds per pod (Fig. 60.7) (Strunk, 2005). Changes in oil and protein percentages of the seed have also been observed in BPMV-infected soybeans.

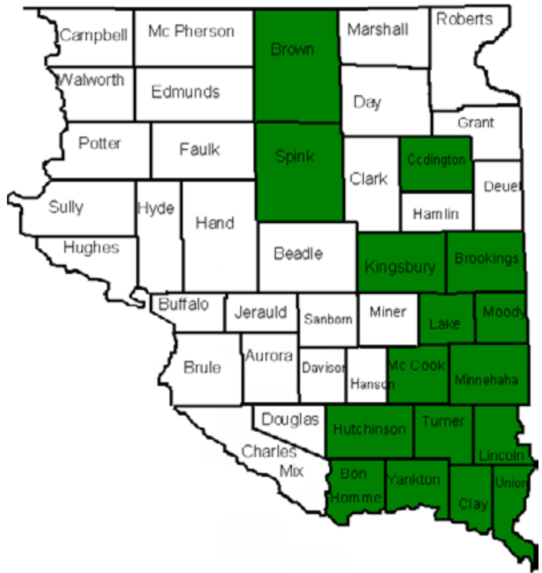

Figure 60.3. South Dakota Counties with confirmed incidences of BPMV during surveys are shaded green. Leaf samples from fifty random plants were tested by ELISA from five producer fields in each county. (Map courtesy of M.A.C. Langham, personal research data)

Figure 60.4. Soybean leaves infected with BPMV display mosaic and distortion on the leaves of the infected soybeans. (Photo courtesy of M.A.C. Langham, SDSU Plant Virology Project)

Figure 60.5. A comparison of BPMV-infected soybean (A) and the same soybean line which is not infected (B) demonstrates the differences in mottling and distortion seen in infected soybean at midseason. (Photo courtesy of M.A.C. Langham, SDSU Plant Virology Project)

Figure 60.6. Stunting is seen when comparing BPMV-inoculated soybeans (I) with a row of the same soybean line (SD99-026R) that was not infected (C). Yellow arrow helps to demonstrate the height differences. (Photo courtesy of C.L. Strunk, SDSU)

Figure 60.7. BPMV-infected soybeans (I) have reduced branching and reduced pod set as compared to non-infected soybeans (C) when mature. (Photo courtesy of C.L. Strunk, SDSU)

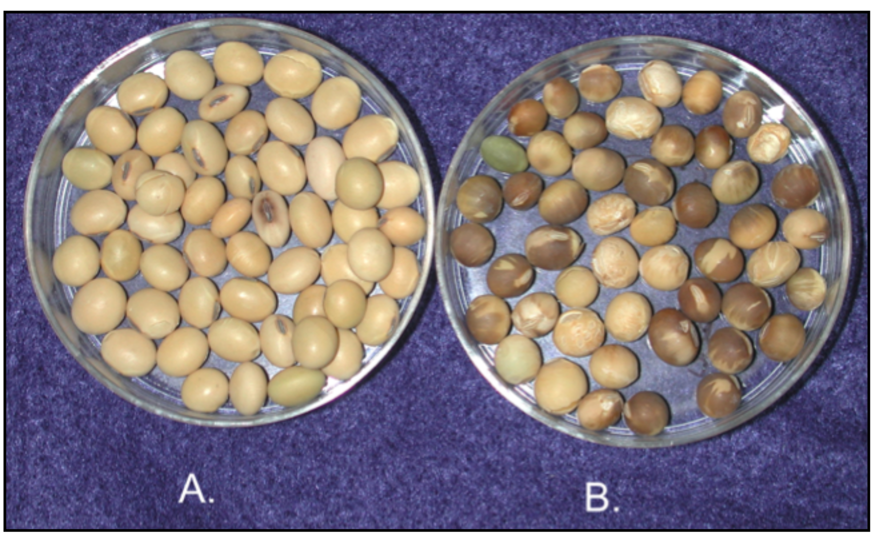

Figure 60.8. Seed mottling in seeds from BPMV-infected soybeans (B) can be compared with seeds from soybean plants that were not infected (A). Seed mottling can result in significant grade reductions. (Photo courtesy of SDSU Plant Virology Project)

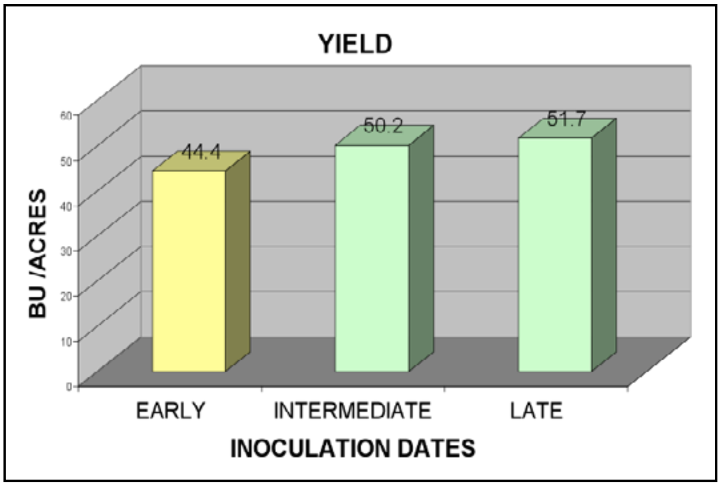

Figure 60.9. Yield reductions due to BPMV inoculated at three dates demonstrate differences in yields. Early BPMV inoculation (yellow) significantly reduced soybean yields more than the two later dates ($P < 0.0001$). (Photo courtesy of M.A.C. Langham, SDSU Plant Virology Project)

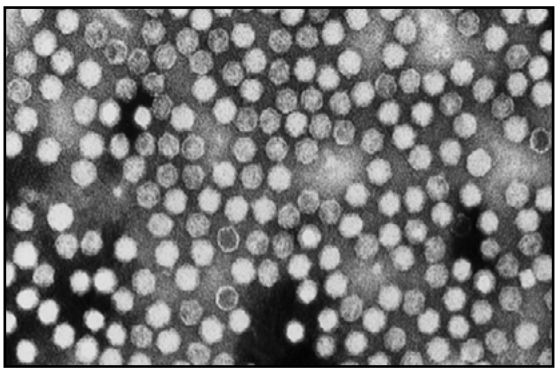

Figure 60.10. BPMV is an icosahedral virus which is approximately 30 nm in diameter. These particles are replicated inside the infected cells of the soybean plant interrupting its normal functions. (Photo courtesy of M.A.C. Langham, SDSU)

Causal agent

BPMV (Genus *Comovirus*; Family *Secoviridae*) is a 30 nm icosahedral virus particle (Fig. 60.10). The virus has two single strands of genomic RNA, which are each packaged in different particles. Thus, both types of particles must be transmitted into the same cell to cause infection (Semancik, 1972).

Vector

BPMV is vectored by leaf-feeding beetles. Transmission by beetles is unique among virus and vector associations because its specificity is not solely dependent on the association of virus and vector, but it is also controlled by the ability of the virus to move rapidly away from the beetle feeding site and to establish primary infection sites in unwounded cells.

The bean leaf beetle, *Cerotoma trifurcata* (Forster), is the principal vector for BPMV and is responsible for the majority of transmission in soybean (Fig. 60.11). It is also important in BPMV epidemiology as overwintering adult beetles transmit the primary inoculum into the fields in the spring as well as transmitting the virus within fields during the season.

Other beetles that have been associated with transmission of BPMV are grape colaspis [*Colaspis brunnea* (F.), *C. flavida*, *C. lata*], banded cucumber beetle (*Diabrotica balteata* Le-Conte), spotted cucumber beetle (*Diabrotica undecimpunctata howardi* Barber), striped blister beetle [*Epicauta vittata* (F.)], Mexican bean beetle (*Epilachna varivestis* Mulsant), soybean leaf miner (*Odontota horni*), and Japanese beetle (*Popillia japonica*) (Gergerich, 1999; Hadi et al., 2012; Werner et al., 2003; Wickizer and Gergerich, 2007).

BPMV management

Management of BPMV focuses on breaking the "living bridge" and reducing the opportunity of BPMV to infect the soybean plant. Key components are provided below.

1. Select a soybean planting date that avoids the peak bean leaf beetle populations (Fig. 60.11). Typically, this has been attempted by delayed planting. Predictive models to use for beetle emergence are developing and can be used to assist in avoiding peak beetle emergence.

2. Use of insecticidal seed treatment or foliar insecticide sprays between soybean emergence and the first trifoliate emergence. This is can be useful in fields where BPMV has been a problem in previous years, but consider the cautions discussed below as mixed results have been reported.

3. Select tolerant soybean cultivars for planting.

4. Utilize disease-free seed.

5. Accurate diagnosis of suspected viral diseases is highly recommended, because different viruses and their differing vectors require unique approaches to management.

6. *Cautions to consider*—Primary BPMV management principles strive to avoid exposure of newly emerging soybeans to overwintered bean leaf beetles vectoring BPMV until the soybeans are mature enough for BPMV effects to be less damaging. Thus, delayed planting dates, insecticide treatment, or foliar insecticide applications after soybean emergence and before emergence of the first trifoliate are often recommended. However, these methods have had mixed results in studies. Their effectiveness depends heavily on whether they are in place prior to beetle emergence and that they limit even small amounts of beetle feeding since primary BPMV infection in a field can be established by even single sites of viruliferous beetle feeding.

Additional information on BPMV management is available at Hadi et al., 2012 and NCSRP, 2012.

Figure 60.11. Bean leaf beetles are the primary BPMV vector. Beetles cause feeding wounds by cutting through the leaf lamina and consuming sections of the tissue. (Photo courtesy of Adam Sisson, Iowa State University, Bugwood.org)

Soybean Mosaic

Soybean mosaic virus (SMV) is an economic threat across U.S. soybean production. In South Dakota, it has been identified in at least 15 eastern South Dakota counties (Fig. 60.12). Soybean mosaic is reported to produce yield losses of 8-35% in susceptible cultivars (Hill et. al., 1999). However, SMV can form a synergistic relationship when it occurs in co-infection with BPMV. Yield losses up to 75-94% have been reported from the double infection (Giesler, 2009, Hill et. al., 1999). With both viruses occurring in South Dakota, this synergistic reaction presents a true concern for South Dakota soybean production.

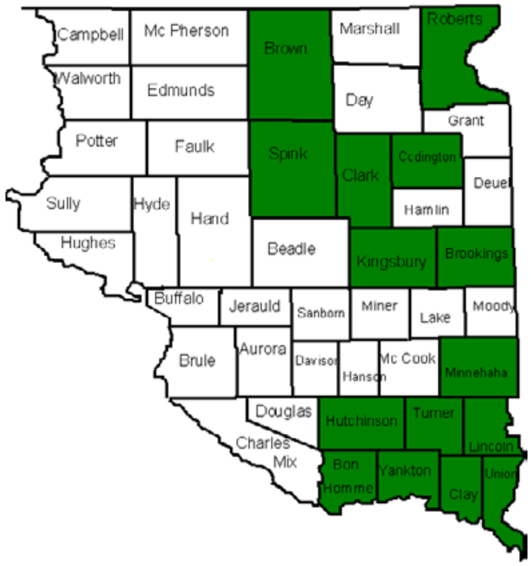

Figure 60.12. South Dakota counties (green) with confirmed incidences of SMV during surveys are shaded green. Leaf samples from fifty random plants were tested by ELISA from five producer fields in each county. (Photo courtesy of M.A.C. Langham, personal research data)

A

B

Figure 60.13. SMV infecting soybean causes mosaic and distortion of the leaf lamina seen in part A. The distinctive downward curling of the leaves is featured in part B. (Photographs courtesy of S. Tolin, Virginia Polytechnic Institute & State University)

Symptoms
SMV-infected soybeans have mosaic color patterning on the leaves (Fig. 60.13). In some cultivars, this mosaic is more subtle than those found with many other soybean viruses. An additional color patterning that can be present in SMV-infected plants is a narrow, darker green band along the veins with lighter green in the lamina between veins. This vein banding does not occur in all soybean cultivars, but can be distinctive in some cultivars. Distortion of the leaf lamina or deformation of leaf shape is also prominent, particularly downward curling of leaves. Stunting also occurs in infected plants. SMV also causes prominent seed mottling in soybean seed from infected plants (Fig. 60.14). Color bleeding from the seed hilum such as that seen with BPMV is also present, but it is often darker than that caused by BPMV.

Causal agent
SMV (Genus: *Potyvirus*; Family: *Potyviridiae*) is a long, flexuous rod virus approximately 15 nm by 750 nm (Fig. 60.15) (Bos, 1972). This virus has a single-stranded RNA genome that is coiled inside the particle and performs a vital role in holding the particle together. Thus, these particles do not form unless the RNA is present whereas some icosahedral viruses, such as BPMV, can form the protein coat into a particle before RNA is added.

Vectors
SMV is vectored by more than 16 species of aphids with the soybean aphid (Aphis glycines) being the primary vector (Bos, 1972) (Fig. 60.16). Emergence of the soybean aphid has provided SMV with a prolific vector for transmission. SMV is transmitted by aphids in a nonpersistent manner. This means that the aphids can acquire or transmit the virus in only a few seconds. Thus, the aphid can transmit SMV almost as rapidly as it can land on the soybean plant.

Seed transmission
SMV is transmitted by true seed transmission with the soybean embryos being infected during seed formation. True seed transmission is extremely important in SMV epidemiology, because it provides a site for the virus to overwinter as well as introducing the primary inoculum into the soybean field. Viruses with efficient aphid vectors can rapidly spread to high incidence levels when introduced even by very low levels of seed transmission. SMV seed transmission rate ranges from 5-75% with many current varieties having transmission rates at the lower end of this range (Bos, 1972; Hadi, 2012b). However, this is a trait that must continue to be evaluated as new soybean cultivars are developed to maintain these low SMV transmission levels.

Management
(Hadi, 2012b; NCSRP-PHI, 2012b)

1. Use SMV-free seeds in planting. Infected seed provide a primary source of initial inoculum that can quickly be spread within the field by its aphid vectors.

2. Infection in early growth stages causes the greatest damage. Managing planting dates to avoid peak aphid populations can limit the spread within the fields.

3. Use resistant or tolerant soybean varieties when available for your growth area. The number of resistant cultivars is currently limited, but more promising varieties are in development and will be available in the future.

4. Foliar applications of insecticides have not been effective in limiting the transmission of SMV. The presence of migratory aphids entering the field may be responsible for this, but insecticides have also been shown to be ineffective in limiting the spread of nonpersistently transmitted viruses in other crops due to the rapidity of transmission and the sampling feeding behavior with which SMV transmission is associated.

Figure 60.14. Color bleeding hilum in soybean infected with SMV can be found in some soybean cultivars.
(Photo courtesy of C. Grau, University of Wisconsin)

Figure 60.15. Electron micrograph of flexuous rod virus demonstrating the particle morphology found in SMV. (Micrograph courtesy of W. Gardner, formerly at South Dakota State University)

Figure 60.16. Soybean aphids reproduce abundantly on soybean leaves. Both adults and numphs can be found in these populations. (Courtesy of E. Beckendorf (photographer) and L. Hesler (project leader), USDA-ARS North Central Agricultural Research Laboratory, Brookings, SD)

Tobacco Ringspot

Tobacco ringspot virus (TRSV) is the third viral disease affecting soybeans in South Dakota. TRSV is not as widely recognized as some of the other soybean viruses. However, it can have significant impacts on soybean with yield losses reported to range from 25-100% (Malvick, 1992). Additionally, TRSV is unique among the soybean viruses in South Dakota because it has a wide host range that includes many hosts that are not legumes where many other soybean viruses are limited to legume hosts.

Symptoms

TRSV causes mosaic, necrotic spots, chlorotic ringspots and veinbanding in infected soybean plants. However, these symptoms typically disappear soon after infection (Brunt et al., 1996; Stace-Smith 1985). TRSV is more often recognized for the bud necrosis that it causes. When plants are infected at an early stage, bud blight causes necrosis and death of the terminal bud, resulting in a crook shape as it bends down. Other buds may also become brittle and shatter. TRSV-infected plants have maturity delays, and they often remain green long after other plants have matured (Fig. 60.17). These plants may have pods that are flattened and contain only one seed (Fig. 60.18). TRSV may also reduce root growth and nodulation (Malvick 1992).

Causal agent

TRSV (Genus: *Nepovirus*; Family: *Secoviridae*) has 25-28 nm icosahedral virus particles that closely resemble the ones found in BPMV. It also has two single-stranded RNA genome pieces that are packaged in separate particles (Brunt et al., 1996; ITCVdB, 2006).

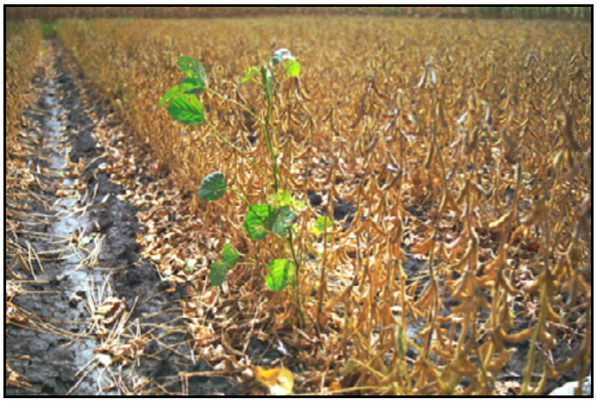

Figure 60.17. Plants infected with TRSV remain green long after the surrounding plants have matured. (Photo courtesy of M.A.C. Langham, SDSU Plant Virology Project)

Figure 60.18. TRSV-infected plants often produce few pods that tend to be flattened and have only one seed. (Photo courtesy of M.A.C. Langham, SDSU Plant Virology Project)

Vector

Nematode and Insect Vectors—The most well established vector for TRSV is the dagger nematode (*Xiphinema americanum*). Abundant evidence has been established for its specific relationship with TRSV. However, TRSV's ability to spread rapidly in some soybean fields has led to a search for insect or mite vectors that could also be transmitting TRSV. Two aphids (*Myzus persicae* and *Aphis gossypii*), grasshoppers, the tobacco flea beetle, and thrips have been tested and may have a nonspecific relationship with TRSV, but these relationships are neither strong nor capable of explaining the rapid transmission that has been documented in some soybean fields. Thus, the search for a more efficient TRSV vector continues (Brunt et al., 1996; ITCVdB, 2006; NCRSP, 2012c).

Seed and Pollen Transmission—TRSV can be transmitted by seed and by pollen. Anthers in TRSV-infected plants produce less pollen, and the pollen that they produce germinates more poorly than the pollen from healthy plants (Yang and Hamiliton, 1974). Plants that are infected early and have severe bud necrosis produce few seeds, but these seeds have a high risk of seed transmission (90%). Soybeans that are infected later and have less severe symptomatology have a low risk of seed transmission (Brunt et al., 1996; ITCVdB, 2006; NCRSP, 2012c).

Management

(Malvick, 1992; NCRSP, 2012d)

Management practices for TRSV are not as well established as for BPMV and SMV. However, there are some practices that can improve TRSV management. These key factors are provided below.

1. Accurate diagnosis will allow you to determine that TRSV rather than other legume viruses is your problem.
2. Plant clean seed. Although many seeds from TRSV-infected plants are small and are lost during harvest and processing, insuring that you have clean seed will prevent TRSV introduction into your field.
3. If your field has a TRSV history, control of dicotyledonous (plants with two seed leaves) weeds that may act as secondary hosts for TRSV can help limit transmission from these hosts.

Alfalfa Mosaic

Alfalfa mosaic virus (AMV) is a fourth virus that is found in South Dakota soybeans. It is unique in that it is one of the viruses that infect hosts from all three clusters of legumes. Of the four viruses identified in South Dakota soybeans, AMV is the one that is the least commonly identified, but it has a large potential for expansion due to the number of alternate legume hosts in South Dakota.

Symptoms

AMV is known for the bright mosaic that it produces in soybean. This mosaic tends to have bright yellow areas or patches (Fig. 60.19) (Brunt et al., 1996; Jaspers and Bos, 1980). It is often referred to as a calico or flashy mosaic. Calico mosaic refers to leaves having a primarily yellow background with small areas of green and is thought to resemble a calico print. Flashy mosaic refers to the fact that many AMV cases are spotted in the field when a leaf with this bright mosaic moves in the wind and a flash of bright color is spotted. AMV also produces a bright vein banding. Stunted plants and distorted leaves are also found in AMV-infected soybean.

Causal agent

AMV (Genus: *Alfamovirus*; Family: *Bromoviridae*) has four bacilliform particles (elongated with rounded ends). The particles are 18 nm wide and are 30, 35, 43, and 56 nm in length. With three strands of genomic single-stranded RNA and a requirement for coat protein in order to replicate, AMV is the most complex of the soybean viruses found in South Dakota (Brunt et al., 1996).

Vector

AMV is transmitted in a nonpersistent manner by at least 15 aphid species including the soybean aphid (Brunt et al. 1996; Grau ----). It can also be transmitted by five species of the parasitic seed plant, dodder (*Cuscuta* spp.). However, the role of dodder as a vector in soybean is limited to fields with prominent dodder infestation (Jaspars and Bos, 1980). AMV is seed-transmitted in soybean; although, the level of seed transmission is dependent on the AMV strain infecting the soybean (C. Grau, personal communication).

Management

1. AMV management is dependent on avoiding aphid transmission at early stages of development similar to SMV.

2. Accurate diagnosis insures that you are dealing with AMV and not other soybean viruses or a combination.

3. Use clean seed.

4. In severe cases, nearby forage legume fields should be checked to see if they are serving as an alternate AMV source.

5. AMV-resistant soybeans are not widely available. As they are developed, AMV-resistant varieties should be added to management practices.

Figure 60.19. AMV is known for its bright colored mosaic pattern that is often referred to as calico or flashy mosaic. (Photo courtesy of C. Grau, University of Wisconsin)

Summary

Four soybean viruses infect South Dakota soybeans. BPMV is the most prominent and causes significant disease losses. SMV is the second most commonly identified soybean virus in South Dakota. It causes significant losses either in single infection or in dual infection with BPMV. TRSV and AMV are found less commonly than BPMV or SMV. However, they can cause significant damage where they are found. All four of these viruses can occur in mixed infection, but the effects of these combinations are less well known than the effects of BPMV and SMV co-infections. These four viruses are only a portion of the viruses that infect soybean.

Watchfulness should be maintained to detect movement of additional soybean viruses found in neighboring states, such as tobacco streak virus and soybean vein necrosis virus, into South Dakota. Vigilance and accurate detection are the best long-term management practices that can be applied in South Dakota soybean production.

References and additional information

Bos, L. 1972. Soybean mosaic virus. Descriptions of Plant Viruses. No. 93. Association of Applied Biologists. Available at http://www.dpvweb.net/dpv/showdpv.php?dpvno=093

Brunt, A.A., K. Crabtree, M.J. Dallwitz, A.J. Gibbs, L. Watson, and E.J. Zurcher (eds). (1996 onwards). Plant Viruses Online: Descriptions and Lists from the VIDE Database. Version: 20 August 1996. Available at http://pvo.bio-mirror.cn/refs.htm

Gergerich, R.C. 1999. Comovirus: Bean pod mottle virus. In Compendium of Soybean Diseases. 4th edition. G.L. Hartman, G.J.B. Sinclair, and J.C. Rupe, eds. American Phytopathological Society Press, St. Paul, MN.

Gielser, L.J. 2009. Soybean mosaic virus. University of Nebraska Lincoln-Extension. Available at http://pdc.unl.edu/agriculturecrops/soybean/soybeanmosaic

Giesler, L.J., S.A. Ghabrial, T.E. Hunt, and J.H. Hill. 2002. Bean pod mottle virus: a threat to U.S. soybean production. Plant Dis. 86: 1280-1289.

Grau, C. (Date not available). Epidemiology and control of the major soybean viruses in Wisconsin. University of Wisconsin-Madison, Departments of Agronomy, Entomology, and Plant Pathology. Available at www.plantpath.wisc.edu/soyhealth

Hadi, B.A.R., J.D. Bradshaw, M.E. Rice, and J.H. Hill. 2012. Bean leaf beetle (Coleoptera: Chrysomelidae) and bean pod mottle virus in soybean: Biology, ecology, and management. J. Integ. Pest Mngmt. 3:1-7. DOI. Available at http://dx.doi.org/10.1603/IPM11007

Hadi, B., L. Giesler, D. Malvick, and L. Osborne. 2012b. NPIPM:Soybean mosaic virus on soybean. Northern Plains IPM Guide. Available at http://wiki.bugwood.org/NPIPM:Soybean_mosaic_virus_on_soybean

Hill, J.H. 1999. Soybean mosaic virus. In Compendium of Soybean Diseases. 4th edition. G.L. Hartman, J.B. Sinclair, and J.C. Rupe, eds. American Phytopathological Society Press, St. Paul, MN.

ICTVdB Management. 2006. 00.018.0.03.027. Tobacco ringspot virus. In: ICTVdB - The Universal Virus Database, version 4. Büchen-Osmond, C. (Ed), Columbia University, New York, USA.

Jaspers, E.M.J., and L. Bos. 1980. Alfalfa mosaic virus. Descriptions of Plant Viruses. No. 229. Association of Applied Biologists. Available at http://www.dpvweb.net/dpv/showdpv.php?dpvno=229

Langham, M.A.C., C.L. Cihlar-Strunk, and A.E. Hoberg. 2005. Evaluation of high pressure spray inoculation of bean pod mottle virus on yield and test weight of soybean. (Abstr.) Phytopathology 95:S164.

Langham, M.A.C., D.C. Doxtader, J.D. Smolik, and R.A. Scott. 1999. Outbreak of a viral disease affecting soybeans [Glycine max (L.) Merrill] in South Dakota. (Abstr.) Phytopathology 89:S43.

Malvick, D.M. 1992. Virus diseases of soybeans. No. 505. Report on Plant Disease. University of Illinois Extension. Available at http://ipm.illinois.edu/diseases/rpds/505.pdf

North Central Soybean Research Program-Plant Health Initiative. 2012. Bean pod mottle virus - management. Available at http://www.planthealth.info/bpmv_mgmnt.htm

North Central Soybean Research Program-Plant Health Initiative. 2012b. Soybean mosaic virus. Available at http://www.planthealth.info/smv_basics.htm#

North Central Soybean Research Program-Plant Health Initiative. 2012c. Tobacco ringspot virus. Available at http://www.planthealth.info/trsv_basics.htm

North Central Soybean Research Program-Plant Health Initiative. 2012d. Tobacco ringspot virus. Available at http://www.planthealth.info/trsv_mgmnt.htm

Semancik, J.S. 1972. Bean pod mottle virus. Descriptions of Plant Viruses. No. 108. Association of Applied Biologists. http://www.dpvweb.net/dpv/showdpv.php?dpvno=108

Stace-Smith, R. 1985. Tobacco ringspot virus. Descriptions of Plant Viruses. No. 309. Association of Applied Biologists. http://www.dpvweb.net/dpv/showdpv.php?dpvno=309

Strunk, C.L. 2005. BPMV effects on ten experimental soybean lines and cultivars. Master's thesis. South Dakota State University, Brookings, SD.

Werner, G.J., R.K. Krell, L.P. Pedigo, and J.H. Hill. 2003. The soybean leaf miner (Coleoptera: Chrysomelidae) as a vector of bean pod mottle virus. J. Kansas Entom. Soc. 76:643-644.

Wickizer, S.L., and R.C. Gergerich. 2007. First report of Japanese Beetle (Popillia japonica) as a vector of Southern bean mosaic virus and Bean pod mottle virus. Plant Dis. 91:637

Yang, A.F., and R.I. Hamiliton. 1974. The mechanism of seed transmission of tobacco ringspot virus in soybean. Virology 62:26-37.

Zaumeyer, W.J., and H.R. Thomas. 1948. Pod mottle, a virus disease of beans. Journal of Agricultural Research 77: 81-96.

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Langham M.A.C., and C.L. Strunk. 2013. Viral diseases of soybeans. In Clay, D.E., C.G. Carlson, S.A. Clay, L. Wagner, D. Deneke, and C. Hay (eds). iGrow Soybeans: Best Management Practices for Soybean Production. South Dakota State University, SDSU Extension, Brookings, SD.