REVIEW OF IMPORTANT VIRUSES INFECTING SOYBEAN [Glycine max L.) ERR]

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SUMMARY

Soybean (Glycine max (L.) Merr) is an important leguminous crop in the Tropics because of its high protein and oil content which are essential for human nutrition. It is also a raw material for use in industries. The crop is susceptible to infection by several viruses, which substantially reduce its yield and quality. This study reviewed ten genera and twelve important soybean viruses with their symptoms, insect vectors, modes of transmission, distribution across regions and the approach to control measures. The most important virus of soybean disease is the genus potyvirus which is associated with four diseases of soybean. However, the other nine genera: Comovirus, carlavirus, begomovirus, nepovirus, letouvirus, alfamovirus, illarvirus, cucumovirus and tospovirus can cause significant yield losses of about 15 % in the field. This review showed that Soybean Mosaic Virus (SMV) and Bean Pod Mottle Virus (BPMV) are the most widely distributed viruses of soybean causing debilitating damages accounting for 8 % to 94 % yield losses in several regions of the world. Control of these economically important viruses should include the use of resistant varieties of soybean, control of insect vectors and maintaining high planting density to reduce the occurrence of virus epidemics on the field.

Keywords: Soybean, viruses, distribution, disease management

INTRODUCTION

Soybean (Glycine max (L.) Merr) is particularly important for its numerous uses. The crop produces a high amount of excellent oil for both local and international market. The crop has high protein content (39-42 %), 18-22 % oil which is 85 % unsaturated and cholesterol-free. It has a calorie value of 30 % carbohydrates and an excellent amount of dietary fibre, essential amino acids, vitamins, and minerals, all of which are required for promotion of human health (Nakamura, 1980., Dugje et al., 2009).

The demand for soybean in Nigeria is on the increase due to the rapid use of the crop in the poultry sector. The crop is a source of raw materials for the industrial and feeds for livestock. It can be produced more cheaply than other leguminous plants and it has longer post-harvest storage life without weevil infestation (Nakamura, 1980). When soybean is included in rotations with cereals it restores the fertility of the soils and these make it an ideal crop for the African farmer (Pandley**,** 1987). The yield of soybean in tropical countries averages 1000 kg per hectare as compared to 2000 kg per hectare in temperate countries (AVRDC, 1987). The lower yield in the tropics, especially in Africa, is attributable to biological and socio-economic factors (Singh and Rachie, 1987). Constraints to the production of the crop include damages caused by insect pests, diseases, nematodes, pod shattering and sensitivity to photoperiodicity (Hartman et al., 1999).

Soybean is susceptible to infection by several viruses, which substantially reduce yield and

quality (Sutic et al., 1999). For example, virus diseases were estimated to have reduced the soybean yield in the United State of America by over 760,000 metric tons in 2002 (Wrather et al., 2003). According to the Department of Crop Sciences University of Illinois at Urbana-Champaign, USA, soybean diseases reduced Illinois soybean yields by 5 to 15 % annually, depending on the diseases involved, the varieties grown, the management practices followed, and various environmental factors. Approximately 15 different viral diseases are responsible for these losses in yield. Virus infection on crops is significant most especially when there is mix infection with other pathogens and nematode. Viral diseases of soybean can give rise to varying degrees of grain yield loss and may result in total crop failure (Shoyinka et al., 1997., Jellis et al.,1998). Seed quality is also significantly reduced by virus infection (Jellis i., 1998). Yield losses of 50 % can be expected when the plant is infected with viruses such as Soybean mosaic virus (SMV), genus Potyvirus (Sinclair, 1998). Crop losses of up to 68 % and 50 % have been recorded in the USA and Morocco respectively due to infection by Bean Pod Mottle Virus (BPMV). Occasionally, complete crop loss has been recorded (Lockhart and Fischer, 1974., Allen and Lenné. 1998).

IMPORTANT VIRUSES OF SOYBEAN

Viral diseases are major constraints to the production of soybean and legumes in the world, viruses have limited the production of the crop wherever it is grown (Shoyinka et al., 1997). Soybean is susceptible to several viruses such as Soybean mosaic virus (SMV), Bean pod mosaic virus (BPMV), Cowpea mild mottle virus (CPMMV) and many of other important viruses that infect soybean (Krell, 2005). Most viral diseases of soybean result in foliar symptoms, such as mosaic and mottling, thickening/bristling of older leaves, puckering (Gergerich, 1999), leaf distortion, a severe reduction in leaf size and stunting of plants. Other symptoms of viral disease infection include distorted leaves with rolled (downward) leaf margins, rough and puckered leaf surface (rugosity), yellow blotches (mosaic) among green tissues, mottled yellow areas and smaller leaves with dark leaf veins (Gergerich, 1999). Plants with distorted leaves are commonly stunted, produce fewer pods and remain green while other plants in the field mature normally (Alegbejo, 2015). There may be seed coats stained with pigments that originate from seed helium. This "bleeding helium" symptom is associated with virus infection (Adams et al., 2004). Several viruses are associated with the occurrence of green stems at harvest, and these have resulted in lower yield and poor produce with discoloured seed which are more difficult to harvest compared to plants that mature normally (Adams et al., 2004). Proper identification of diseases with obvious symptom expression will help in the diagnosis of the virus. Important viruses of soybean belong to different genera which have different symptoms, insect vectors and modes of action.

Soybean Mosaic Virus (SMV)

The virus SMV belongs to the genus Potyvirus and it is found throughout the world where the crop is grown (Gibbs et al., 2008; Brandes and Wetter, 1959; Hill, 1999). Flexuous rod-shaped particles 760 nm long and yield losses of 8-35 % have been recorded, while losses as high as 86 to 94 % has also been realized under severe condition (Calvert and Ghabrial,1968; Steinlage et al., 2002; Quantz, 1961). The most affected are yield

components such as pods, seed size and seed weight (Hill, 1999). It is transmitted by aphid species belonging to 15 different genera. Aphid glycine can acquire and transmit SMV in a non-persistent manner (Hill, 1999). Seeds from infected SMV plants can be the primary source of inoculum and long-distance dissemination of the virus into the field during planting (Hill and Benner, 1980). The disease symptoms include stunting, premature death, slight mottle and mosaic, pod mottling, necrosis, and poor nodulation (Shoyinka et al., 1998). Soybean mosaic virus causes vein clearing in young leaves which become transparent, while the older leaves develop mosaic symptoms with dark green patches. Leaves with mosaic symptoms also show rugosity around the leaf veins. Some strains of the virus cause necrotic symptoms in some, but not in all, soybean cultivars (Irwin and Schultz, 1981). Seeds from infected soybean plants sometimes show brown mottle symptoms (Mitsuro, 2001). Soybean mosaic virus has a limited host range and infects systemically soybean, azuki bean, some cultivars of kidney beans, and sweet pea with visible symptoms (Mitsuro, 2001). Symptoms are most obvious when temperatures are high up to 90°F (Irwin and Schultz, 1981; Hill, 2003). SMV in mixture with Bean pod mottle virus (BPMV) can create more severe symptoms in plants (Calvert and Ghabrial, 1983).

Bean Pod Mottle Virus (BPMV) Bean pod mottle virus (BPMV) is a member of the genus Comovirus and the family Comoviridae (Hongcang et al., 2005). The virus is single-strand RNA consisting of RNA-1 and RNA-2 which are separately encapsidated in isometric particles 28-30 nm in diameter (Hongcang et al., 2005). Both the particle structures and inclusions are found causing disease in all parts of the host and cells (Gu et al., 2002). BPMV is widespread in major soybean-growing areas in the United States of America infecting soybean, green bean, and many other legumes (Hartman et al., 1999). It has reduced soybean yield to between 3 and 52 % in south and southeast of the United State (Krell et al., 2005). The reduction is more severe when infection occurs in early stages of development, the young leaves of infected plants will turn light green to yellow, with puckering, leaf rugosity, terminal necrosis and ultimate die-back (Gergerich, 1999). BPMV is also associated with seed coat mottling with irregular pattern or streak on helium (Lin, 1985) The deleterious effect of BPMV infections is not limited to only a reduction in seed yield, but also a reduction in seed quality (Hongcang et al., 2005). BPMV is efficiently transmitted within and between soybean fields, by several species of leaf-feeding beetles in the family Chrysomelidae (mainly the genera Ceratoma and Diabrotica). Beetle vectors also occur from the families Coccinellidae, Meloidae and Curulionidae (Hartman et al., 1999). When BPMV interacts synergistically with Soybean mosaic virus (SMV), it can increase the disease and cause a remarkably high reduction in yield and seed quality (Anjos et al., 1992).

Bean Yellow Mosaic Virus (BYMV)

Bean yellow mosaic virus belongs to the genus potyvirus and family potyviridae. It is a mono-partite positive single-stranded RNA virus. It is found in most bean producing region of the world. BYMV was found in the southern and middle belt States of Nigeria and the virus is the most prevalent and associated with bean Phaseolus vulgaris Almare (Alegbejo, 2015). Virus-infected plants produce bright yellow mosaic or specks and

develop into large blotches on the leaf lamina, another symptom of BYMV is leaf puckering (Kennedy, 1962). BYMV causes distinct yellow mosaic symptoms and tip necrosis depending on genotype and virus strain. Infected plants produce fewer pods than healthy ones (Alegbejo, 2015). The virus infects soybean and peanut via several aphids in a non-persistent manner, by sap inoculation or through seeds (Alegbejo, 2015; Derks et al., 1980). The form of the virus particles of BYMV has not yet been demonstrated (Grau, 1999).

Peanut Mottle Virus (PeMoV)

Peanut Mottle Virus belongs to the genus Comovirus and family Secoviridae which have bipartite genome encapsulated in icosahedral particles (Gibbs, 2008). The virus causes systemic mottle and necrosis in groundnut (Arachis hypogaea), bean (Phaseolus vulgaris), soybean (Glycine max) and pea (Pisum sativum). The severity of the disease is dependent on host cultivar and virus strain. The economic significance of disease in groundnut was found in the USA where the loss of yield of 25 % was recorded in greenhouse tests (Kuhn, 1965). In Australia, a yield loss of 25 % was also recorded in beans. The virus is transmitted in a non-persistent manner by the aphids Aphis craccivora, A. gossypii, Hyperomyzus lactucae, Myzus persicae and Rhopalosiphum padi.

Peanut Stripe Virus (PStV)

Peanut Stripe Virus is also of genera Comovirus and they generally produce indistinct mottle symptoms on soybean plants but may sometimes produce distinct mosaic or vein-necrosis symptoms. PStV has a wide host range, and infects many leguminous plants, including peanut, with systemic symptoms such as mosaic and vein-necrosis (Mitsuro, 2001). PStV is transmitted by aphids in a non-persistent manner (Mitsuro, 2001). The virus is a filamentous flexuous particle of about 740 nm in length.

Cowpea Mild Mottle Virus (CPMMV)

Cowpea Mild Mottle Virus belongs to the genus Carlavirus and the family Beta-flexiviridae. The Virions are filamentous and slightly flexuous, not enveloped, are 610-690 nm long and 10-15 nm in diameter (Bock and Conti, 1974). CPMM is a single-stranded positive RNA virus, capable of infecting soybean, peanut, and kidney bean. The virus infects and produces yellow mottling, mosaic, rugose mosaic, and crinkle-leaf symptoms. These symptoms vary depending on the cultivar of soybean infected. It also causes local lesions on Chenopodium amaranticolor (Bock and Conti, 1974). CPMMV is transmitted by whitefly Bemisia tabaci, in a semi-persistent manner, while transmission by seed is still unclear because transmission can be dependent on virus isolate and host cultivar (Mitsuro, 2001). The virus was first observed in Ghana (Brunt and Kenten, 1973) but reported in Nigeria in 1980 (IITA,2009). Symptoms observed in Nigeria, include necrotic lesions on primary leaves and severe systemic chlorosis and necrosis on trifoliate leaves. The major effect of mosaic diseases can cause a significant reduction of pods and yield (Adams et al., 2004).

Soybean Severe Stunt Virus (SSSV) Soybean severe stunt virus (SSSV) belongs to the order Picornavirales, in the family Secoviridae and genus nepovirus. There are currently 36 species in this genus including the type species Tobacco ringspot virus (Gibbs et al., 2008). Diseases in association with this genus include soil-borne diseases of

soybeans in which the plants become infected before emergence when roots are 1-2 inches long. The internodes are shortened resulting in severe stunting and superficial dark brown lesions are often seen on the stems (Briddon et al., 2010; Evans, 2004).

Tobacco Ringspot Virus (TRSV) Tobacco ringspot virus (TRSV) belong to genus nepovirus, the virus has a broad host range including soybean, tobacco, snap bean, velvetleaf, and pigweed. A characteristic symptom of this disease is the hooking down and death of the apical meristem. Lateral buds will proliferate excessively, producing many small leaves. Typically, infected plants are delayed in maturing and have underdeveloped pods. Thrips and the dagger nematode are vectors for TRSV and are seed transmittable (Baker and Adkins, 2007).

African Soybean Dwarf Virus (ASDV)

African soybean dwarf virus belongs to the genus Luteovirus, family Luteoviridae. The name luteovirus arises from the Latin luteus, which is yellow. Luteovirus was given the name due to the symptomatic yellowing of the plant that occurs because of infection (Rossel and Thottappilly, 1983; Rossel et al., 1988). There are currently eight species in this genus including the type species Barley yellow dwarf virus-PAV. This virus causes severe stunting of the soybean plant. Leaves are puckered and show interveinal yellowing. The severity of symptoms depends on the soybean cultivar and virus strain. Disease incidence of about 50 % in the field can result in total yield reduction as much as 40 %. The virus was first discovered in Nigeria (Rossel and Thottappilly). ASDV has not been characterized but it is transmitted by whitefly Bemisia tabaci in a persistent manner and soybean plants are natural hosts (Rossel et al., 1988). Its symptoms include yellowing of older leaves and reduction in leave size. In Nigeria, the virus is a potential constraint to soybean production, when susceptible varieties are grown (Rossel and Thottappilly). This disease occurs in low frequency in the fields. The leaves and shoots of infected plants are severely stunted with a severe reduction in leaf stamina. Infected plants do not produce any pod (Ewardson and Christie, 1999).

Tobacco Streak Virus (TSV)

Tobacco streak virus (TSV) belongs to the genus Ilarvirus, family Bromoviridae. There are currently 19 species in this genus including Tobacco streak virus. Viruses in Ilarvirus are non-enveloped, with icosahedral and Quasi-spherical geometries, and 29 nm in diameter (Van Regenmortel et al., 2009). TSV is a multipartite (three particles), isometric, RNA virus of about 27, 30, and 35 nm in diameter (Brunt et al., 1996). TSV can infect most legumes like soybeans and snap beans, cowpea, lima bean, peas, and groundnut. TSV can show symptoms with a hooked top and absence of symptoms on young plants. Other symptoms include the development of mosaic symptoms and necrotic streaks at the nodes accompanied by reduced pod number and delayed seed maturation (Fagbenle and Ford, 1970). TSV is seed transmitted and the virus can also be transmitted by thrips (Edwardson and Christie, 1999).

Peanut Stunt Virus (PSV) Peanut Stunt Virus (PSV) belongs to the genus Cucumovirus, the family Bromoviridae and one of the members of this genus is the Cucumber mosaic virus. The virus is positive-stranded RNA and the particles are isometric or spherical in shape (Choopanya and Halpin, 1968). PSV is an economically important pathogen of plants in the family Leguminosae.

In addition to beans, peanuts, and clover (7 different species of Trifolium), PSV has been reported to naturally infect peas (Pisum sativum), soybeans (Glycine max), alfalfa (Medicago sativa) and lupine (Lupinus luteus) (Kaper et al., 1978). In 2002, PSV was reported to infect rhizoma or perennial peanut (Arachis glabrata) in Northern Florida and Southern Georgia (Blount et al., 2002). The virus can be transmitted from plant to plant or by several species of aphids (Aphis craccivora, A. spiraecola and Myzus persicae) in a style-borne manner. It is also transmitted through mechanical inoculation (Pietersen, 1993). It has also been found to be transmitted by seeds in peanuts at an extremely low level (Troutman et al., 1967). It can be spread during harvesting (mechanical transmission) or through root grafting (Choopanya and Halpin, 1968). The virus induces symptoms which include general chlorosis, stunting and fern-leaf symptoms.

Soybean Vein Necrosis Virus (SVNV)

Soybean vein necrosis virus (previously known as Soybean vein necrosis associated virus SVNaV) belongs to the genus tospovirus, a negative-stranded virus belonging to the family Bunyaviridae. The genus got its name from Tomato spotted wilt virus (TSWV) which was discovered in Australia in 1915 (Groves et al., 2003; Moritz, 2001). SVNV is a relatively new virus, which was discovered in Tennessee in 2008 and has recently been identified in other parts of the United State of America (Zhou et al., 2011; Zhou and Tzanetakis, 2013; Smith et al., 2013). This pathogen can cause venial chlorosis (yellowing) in leaves. The early symptom of this virus is light green to yellow (chlorotic) patches near main leaf veins on susceptible varieties. The chlorosis can progress to necrotic tissue and eventual desiccation and total death of leaves (Zhou and Tzanetakis, 2013). In soybean resistant varieties, lesions may be restricted or progress slowly with most of the varieties showing moderate symptoms while a few show severe leaf necrosis and canopy droppings (Zhou et al., 2011). Soybean thrips (Neohydato-thrips variabilis) is the only known vector of SVNV. The virus can be harboured in virus-infected weeds or crop hosts (Whitfield et al., 2005). The thrips feed at the underside of leaves along the veins. Dry hot weather increases the threat of damage and environmental conditions that favour thrips growth and reproduction favour disease development (Yu et al., 2018).

DISTRIBUTION OF SOYBEAN VIRAL DISEASES

The occurrence of viral diseases on soybean plants varies with location and regions across the world (Tavasoli et al., 2007). A viral disease that is most prevalent in the temperate regions may not be so in the tropics. In Iran, Cowpea mild mottle virus (CPMMV) has been reported to infect soybean (Tavasoli et al., 2007). Recently disease-causing stem necrosis in Brazil and Argentina have also been attributed to CPMMV or a related carlavirus (Almeida et al., 2005; Laguna et al., 2006). Soybean mosaic virus (SMV) can be found throughout the world wherever soybean crop is grown. Bean pod mottle virus (BPMV) is another important virus disease of soybean that has been found infecting the crop in different continents of the world where soybean is grown (Krell et al., 2005). In Southeast Asia, the virus (BPMV) was found in every country where soybean is grown (Mitsuro, 2001).

In Golestan and Mazandaran provinces of Iran, Tobacco ringspot virus (TRSV) and Tobacco streak virus (TSV), was found to cause pod set failure syndrome (PSF), and this was a great concern to farmers in the area. Mechanical inoculation and grafting of the affected plants on healthy soybean have resulted in the same symptoms (Rahimian et al., 1995). Soybean mosaic virus (SMV) has also been reported infecting the crop in Iran (Karimi and Noaparast, 1989). A survey conducted in Ontario soybean field in 2003 showed the presence of Alfafa mosaic virus (AMV), Bean Pod mottle virus (BPMV), Soybean mosaic virus (SMV), and Tobacco ringspot virus (TRSV). The viruses occurred most in commercial farms due to increase in seed-borne infection or insect vectors such as aphid and leaf beetles. In Africa, soybean mosaic virus is the most widespread viral disease of soybean and can cause up to 60 % yield loss (IITA, 2009). It is widespread throughout many parts of the world and is considered the most destructive foliar diseases of soybean (IITA, 2009). Over 30 viruses have been found in Africa to infect soybean and of all of these, more than ten of these occur naturally (Shoyinka et al., 1988).

MANAGEMENT OF VIRAL DISEASES OF SOYBEAN

A comprehensive and integrated disease-management program includes the use of disease-resistant varieties, high-quality disease-free seeds, a well-drained good and fertile soil, crop rotations, various tillage practices, effective control of insects and weed with the use of insecticide and herbicide (Pietersen, 1993). Maintaining a full soybean canopy lessens aphid activity, which in turn could reduce the incidence of Alfafa mosaic virus (AMV) and Soybean mosaic virus (SMV) infected plants (Grau, 1999). Other important practices include cultural practices, early rouging of the infected plant can help to reduce natural spread within the crop (Shoyinka et al., 1988). Planting soybean at the recommended date and in narrow row spacing helps the plant to develop canopy fast and this can reduce aphid activity and virus transmission (Grau, 1999). Management of early-season populations of bean leaf beetles is also critical to the control of bean pod mottle virus. Thus, planting date is important in controlling bean leaf beetle and soybean aphid. Many viruses infecting legume species are seed-borne and may be transmitted at varying rates depending on the crop and variety as well as the virus. In many cases, the primary mechanism of control with seed-borne viruses is the use of "clean" seed. The virus-free seeds that are produced away from sources of infection may be certified or farmers may simply self-save seeds from healthy-looking plants. Although the latter runs the risk of potentially virus-infected seeds being collected, it is certainly more effective than using seeds bought, for example in a market, where their provenance and disease status is unknown. Due to a lack of an effective direct control method, control options are aimed at reducing infection sources from within or outside the crop. This is often achieved using virus-free seeds or breeding for resistance to seed disease transmission (Bowers and Goodman, 1982).

In Nigeria, the most economical, practicable, and effective method of control of soybean viruses is by using seeds of resistant varieties. Sources of resistance have also been identified in soybean (Lim, 1982; Lim, 1985; Rossel, 1985). Several of the soybean viruses can be transmitted by beetles, aphids or other vectors. But the use of horizontal resistance to vector

transmission in breeding programs has been suggested to control these vectors (Shoyinka et al., 1997). Control of leguminous weeds that may harbour the virus and the use of trap crops have been practiced for the management of virus disease.

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