Int.J.Curr.Res.Aca.Rev.2021; 9(09): 26-36

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 9 Number 09 (September-2021)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2021.909.004

A Review on the Economic Importance, Epidemiology and Management Practices of Soybean Rust (*Phakopsora pachyrhizi)*

Gizachew Hirpa Regasa*

Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Bishoftu, Ethiopia

**Corresponding author*

Abstract

Soybean rust caused by the biotrophic fungus *Phakopsora pachyrhizi*, is one of the major detrimental global concerns and the most challenging foliar diseases of soybean (*Glycine max*) production worldwide. The pathogen is able to survive all year‑round attributable to its polycyclic nature if a host is available and favorable conditions for soybean production are also fortunate for epidemics. This review focuses primarily on economic importance, epidemiology and management strategy of soybean rust (*Phakopsora pachyrhizi*). It is responsible for significant yield reduction up to 90% depending on prevailing weather patterns and the wide distribution of the pathogen makes it the most harmful disease in soybeans production worldwide. Now a days, substantial progress has been made towards understanding the epidemiology, identification of sources of resistance and mapping of soybean loci conferring resistance to *Phakopsora pachyrhizi* since this species is particularly well established and widespread. Besides, host-plant resistance is mainly considered as the most looked for solution from an environmental, economic and cost effective. Furthermore, other disease control approaches such as cultural practices and chemical application are also important and influence rust epidemiology as well as the durability of host plant resistance. Reviews summarize the research in the following areas; a management practices that uses fungicides effectively will afford the primary tool, which in time will hopefully be complemented by some form of host resistance. Development of resistance to fungicides and its ability to overwhelmed resistance genes show that no single management practices will be able to maintain the sustainability of the crop. To sidestep the destruction and yield losses, all management practices must be associated in the form of integrated management.

Article Info

Accepted: 15 August 2021
Available Online: 20 September 2021

Keywords

Epidemiology, Management, *Phakopsora pachyrhizi*, Soybean rust.

Introduction

Soybean (*Glycine max* (L.)) Merrill, is one of the ten most important legume economic crops in the world as a source of protein concentrates and oil (Hartman *et al.*, 2011). *Glycine max* is domesticated species over the 18 known species of the genus *Glycine*, and its diploid number of chromosomes is forty. Soybean is cultivated in temperate and subtropical regions as oil and protein source. It is a legume species that has a great adaptability to different latitudes, climate and soil conditions and grain is important source of protein and vegetable oil for human and animal diet. Soybean contain about 20% oil and 40% protein in the form of essential amino acids. Soybean oil is used mainly for human consumption and as an industrial raw material, and the beans after oil extraction are used for animal feed (Rosa *et al.*, 2015; Murithi *et al.*, 2021).

The soybean seed is highly valued for its high protein content that is used either for fresh green vegetables or processed products such as soyflour, soymilk, roasted soy beverage, fried soynuts and soymeat for human consumption (Hartman *et al.*, 2011). It also contains high oil which is used for making processed food products and industrial products such as cosmetics, plastics and paint removers, among others. Soybean is also an important source of isoflavines, which are used for reducing health risks associated with blood cholesterol and other diseases in human beings. Furthermore, soybean improves soil fertility through biological nitrogen fixation, thereby alleviating soil fertility problems, and when grown in rotation with maize, it reduces *Striga* infestations of maize (De Groote *et al.*, 2010).

Worldwide soybean is cultivated on about 120.48 million hectares in 2016, with production estimated at 351.74 million metric tons (Khurshid *et al.*, 2017). USA is the largest producer with an output of 117.2 million tons followed by Brazil accounts 114 million metric tons and Argentina 57.80 million metric tons (Rosa *et al.*, 2015; Khurshid *et al.*, 2017). In Ethiopia, the production and yield of soybean have become quick at a rate of 30.8%, 45.4% and 11.2% per annum respectively and reached 38,166 ha of land with the production of 812,420 tons of soybean with national average yield of 2.13 tons/ha (CSA, 2016; Gebre-Egziabher, 2019). However, the production and productivity are affected by several constraints including biotic, abiotic and socio-economic stresses (Tefera *et al.*, 2009; Gebre-Egziabher, 2019). The major abiotic constraints in soybean production are weather-related factors for example, extreme temperature, drought, water logging and frost), soil nutrient availability, salinity and photoperiodism. Apart from biotic factors, soybean production is constrained by pests (aphids and thrips), diseases (soybean rust, brown spot, soybean mosaic, downy mildew, frogeye leaf spot and bacterial blight), and weeds are also harmful that reducing the yield. Amongst the biotic constraints, soybean rust is the major limitations that cause of low yields in many areas of the world (Hartman *et al.*, 2011). Soybean rust caused by the biotrophic fungus *Phakopsora pachyrhizi* Sydow, is one of the most devastating foliar diseases affecting soybean production worldwide (Calvo *et al.*, 2008; Murithi *et al.*, 2021). The disease is native to Asia but has spread to Australia, India (Goellner *et al.*, 2010), and Africa where it was first reported in Uganda in 1996 (Levy, 2005). It subsequently spread to Brazil in 2002 (Yorinori *et al.*, 2005) and to USA in 2004 (Schneider *et al.*, 2005). Its introduction into Africa probably occurred through urediniospores blowing from western India to the African east coastal areas by moist north-east monsoon winds (Levy, 2005). The fungus spread rapidly and was reported after its introduction into Uganda on soybean in South Africa in 2001 (Pretorius *et al.*, 2001), in western Cameroon in 2003 (Levy, 2005), and in Ghana and the Democratic Republic of Congo in 2007 (Bandyopadhyay *et al.*, 2007; Ojiambo *et al.*, 2007). The disease was also confirmed in Ethiopia, Malawi, and Tanzania (Murithi *et al.*, 2014, 2015; Tesfaye *et al.*, 2017). A second species causing rust on soybean, *Phakopsora meibomiae*, has not been reported in Africa or elsewhere outside the Americas and it is much less aggressive than *P. pachyrhizi* and therefore does not pose a threat to soybean yield (Hartman *et al.*, 2011).

The pathogen is devastating foliar part of the plant primarily that affecting production worldwide (Calvo *et al.*, 2008). It causes up to 90% yield losses depending on prevailing weather patterns (growing season), location, variety and growth of soybean during the time of infection (Godoy *et al.*, 2016). Severe yield reduction due to soybean rust have been reported in Argentina, Asia, Brazil, Paraguay and other parts of Africa under disease-conducive conditions because of its fast-spreading nature (Yorinori *et al.*, 2005). The infected plants undergo defoliation and early maturation in relation to non-infected plants, which causes reduction in weight and quality of the grains. Due to limited availability of resistant varieties, fungicide application is the only management tool available for farmers, which significantly raises the production cost and the risk of environmental and human contamination (Rosa *et al.*, 2015). The yield loss potential of the pathogen is fluctuate depending on the host pathogen susceptibility and favorable environmental conditions, however, the challenges are enormous since no geographic region is free from the occurrence and devastation of soybean rust. The information on this pathogen is limited in our country and less concern about this devastated disease. Therefore, the intention of this paper is to review on the economic importance, epidemiology and management strategy of soybean rust (*Phakopsora pachyrhizi)*.

Overview and Taxonomy of Soybean Rust

Soybean rust is the most devastating foliar disease in soybean growing areas (Li *et al.*, 2012). It is caused by two obligate fungal species, *Phakopsora pachyrhizi* and *Phakopsora meibomiae* (Arthur) Arthur (Bonde *et al.,* 2006). Both pathogens are biotrophic (obligate parasites) and produce no functional survival structures; cannot overwinter in the absence of live host tissue. *Phakopsora meibomiae* is mainly found in the western hemisphere, is less aggressive and does not cause substantial yield losses in soybeans. On the other hand, *Phakopsora pachyrhizi* is more aggressive, and is responsible for significant yield reduction worldwide (Calvo *et al.,* 2008). It has occurred in the eastern hemisphere for decades, predominantly in Asia and Australia, for this reason, the rust on soybean caused by *Phakopsora pachyrhizi* is referred to Asian soybean rust or Australasian soybean rust (Miles *et al.,* 2003).

Geographical Distribution of Soybean Rust

The current global distribution of soybean rust includes several continents and countries of the eastern and western hemisphere. Soybean rust caused by the fungus *Phakopsora pachyrhizi* is firstly reported in Japan in 1902 and later spread throughout the main soybean growing areas of Asia, Australia and India in 1951 (Miles *et al.,* 2003). This disease is primarily spread by spores carried on wind currents (Xun, 2007). The disease later spread to Africa probably through wind (airborne) urediniospores movements; but the date of first appearance on the continent is not well documented (Levy, 2005).

In Africa, soybean rust was first reported in East African countries. Especially, it has been singled out as a noteworthy danger to soybean creation all around, and in Africa has caused significant yield misfortunes (Dean *et al.,* 2012). The disease has been reported in 10 African countries (Murithi *et al.,* 2015) since the first report in Uganda in 1996 and subsequently spread southwards to Zambia and Zimbabwe in 1998, and by 2001 it had reached other Southern African countries i.e., Mozambique and South Africa (Levy, 2003). The disease also spread westwards into Nigeria in 1999 and Ghana in 2007 (Bandyopadhyay, 2007). Soybean rust later moved from Africa to South America, where it was reported first in Paraguay in 2001, Brazil in 2002 and Argentina in 2003 (Bonde *et al.,* 2006). It was reported in the United States of America in 2004 (Garcia *et al.,* 2008). The disease was also confirmed in Ethiopia, Malawi, and Tanzania (Murithi *et al.,* 2015; Tesfaye *et al.,* 2017).

Moreover, soybean rust was first observed and reported in Ethiopia in October 2011 and again in 2015 and 2016. In mid-October 2016, a severe epidemic caused “clouds” of presumable of *Phakopsora pachyrhizi* urediniospores to be observed when walking through fields (Tesfaye *et al.,* 2017). Having this in mind, the wide distribution of the pathogen and severe yield losses it causes, makes it the most harmful disease in soybeans production worldwide. Considering the geographical variability of the pathogen, it is important to identify sources of resistance that can be deployed to effectively control *Phakopsora pachyrhizi* populations (Murithi *et al.,* 2021).

Economic Importance of Soybean Rust

Soybean rust spreads fast, causing severe crop damage, which leads to significant yield and quality losses. Soybean yield losses up to 90% have been reported (Godoy *et al.,* 2016). Kumudini *et al.,* (2008) reported that yield losses are mainly attributed to premature leaf fall, reduced green leaf area in the canopy, reduced dry matter accumulation and reduced harvest index. Bennett (2005) also reported that heavily infected plants had significantly reduced pods/plant, seeds/pod, number of filled pods/plant, 1000 seed weight, seed germination and oil content. The magnitude of yield and quality losses associated to soybean rust has not been quantified in Ethiopia. However, in 2016 samples were collected from Jimma Agricultural Research Center to USDA-ARS Soybean Disease and Pest Laboratory and confirmed for the presence of the pathogen. This is the first confirmed report of *Phakopsora pachyrhizi* causing rust on soybean in Ethiopia. Currently, in Ethiopia soybean production was increasing from time to time at southwest, western and northwestern part of the country. Now a day, the area of production excides 38, 166 ha of land, but this disease was prevalent at most soybean growing areas of the country (Tesfaye *et al.,* 2017; Gebre-Egziabher, 2019).

Symptoms of Soybean Rust

Symptoms of soybean rust can appear on all aboveground plant parts, but they are more significant on leaves. First symptoms could be described as small water-soaked lesions which develop into grey, tan to dark brown, or reddish-brown lesions (uredinia) particularly on the abaxial leaf surface. The symptoms start as small irregularly distributed chlorotic spots that are gradually enlarged. These chlorotic areas gradually increase in size and develop into gray to tan or brown polygonal lesions, usually about 2-5 mm in diameter large and delimited by the leaf veins. The lesions tend to be angular with and may also occur on petioles, pods and stems. The color of the lesions varies with age and with the interaction between the host genotype and the pathogen isolate. The new lesions are initially light brown, becoming darker with the age (Rosa *et al.,* 2015). Individual lesions continue to enlarge and may coalesce; the color of the lesions becomes darker (dark brown to reddish) because of the production of erumpent pustules, which eventually cause necrosis, premature yellowing and defoliation. Uredinia develop in the pustules and release urediniospores through a central pore. Typically, the number or uredinia is higher on the abaxial than on the adaxial leaf surface (Li, 2009b). In most cases, the lesion colour varies depending on the lesion age, pathogen aggressiveness, host plant, and the interaction between the pathogen and the host (Li, 2009a). There are three major types of lesions described as tan, red brown and immune (Bromfield, 1984). Tan-coloured lesions (TAN) indicate a highly susceptible reaction with many urediniospores and high sporulation levels. Reddish brown lesion (RB) on the other hand, is a form of resistance that is characterized by small, irregular lesions without urediniospores, while an immune reaction is a complete resistance without visible symptoms. In some cases, an intermediate response with both TAN and RB lesions has been reported. This reaction is described as mix (MIX) and is attributed to mixtures of *Phakopsora pachyrhizi* races in the inoculum (Bonde *et al.,* 2006)

Life Cycle of Soybean Rust

Rust fungi constitute a group of plant pathogens that attack numerous plant species. They have complex life cycles, which vary according to the genera and species. The complete life cycle of a rust fungi includes five successive spore stages but the complete life cycle of *Phakopsora pachyrhizi* is still not fully understood due to unknown aecia and pycnial stage, as well as the alternate hosts, which also leaves whether the rust is autoecious or heteroecious unknown (Xun Li, 2007).

Based on the reproductive stages, rusts are classified in three groups: (i) macrocyclic, (ii) demicyclic, and (iii) microcyclic. The first group refers to rusts that exhibit all five reproductive stages, the second group to rusts that lack the uredinial stage, and the third group to rusts that lack the aecial and uredinial stages while the teliospores are the only binucleate spores it produces. Rusts that complete the five stages on a single host are called autoecious, while those rusts needing two hosts' species for the completion of their cycle are termed heteroecious. Under natural conditions, the uredinial stage and telial stage of *Phakopsora pachyrhizi* occur and teliospores serve as over seasoning structures but with an unknown status of their role in disease epidemics, i.e., only urediospores seem to serve as inoculum source. This implies that living hosts are necessary for soybean rust pathogen over-seasoning (Xun, 2007). The uredinospores are the primary inoculum of soybean rust. These are asexual, small, lightweight spores, which are removed from uredinia when the infected leaf surface is dry. After removal, the air currents can transport the spores over long distances, which explain its spread from one field to another. In the presence of water and temperature between 21 and 25°C, the urediniospores deposited on the host leaf surface begin the germination process and infection (Rosa *et al.,* 2015).

Epidemiology of Soybean Rust

The existence of a susceptible host, viable pathogen spores and suitable environmental conditions are requisites for the development of a soybean rust epidemic. It requires, high relative humidity in the range of 75% - 80%, a temperature scope of 15°C to 28°C and 6 to 12 hours of dampness are required for spore germination and ailment propagation. Perfect ecological conditions have caused soybean rust illness to end up endemic in most soybean developing zones in tropical Africa (Twizeyimana *et al.,* 2007). Soybean rust (*Phakopsora pachyrhizi)* infection process involves spore germination, formation of appressorium, penetration, development of urediniospores and finally sporulation (Li, 2009b). The pathogen *Phakopsora pachyrhizi* spreads in the field by airborne urediniospores from disease foci. The optimum temperature for urediniospore germination ranges between 12 and 27°C and also germination is greater in darkness, with light either inhibiting or delaying germination.

Urediniospores are the primary source of inoculum of *Phakopsora pachyrhizi* that initiates epidemics. After the initial infection, a single germ tube germinates from each uredinospores, and subsequently forming an appressorium that has a hyphal tube on its bottom part, enabling direct penetration of the epidermal cells through the leaf cuticle. This explains why *Phakopsora pachyrhizi* has a wider range of hosts than most other rust pathogens, which penetrate the leaf via the stomata or wounds (Miles *et al.,* 2003).

Under favourable environmental conditions, new uredinospores are developed in pustules and the first urediniospores are released about 9 days after the initial infection (Kawuki *et al.*, 2003b). Urediniospores may be released continuously for several weeks, depending on the initial inoculum, and the volume of spores produced within the first three weeks. This infection cycle is repeated on the same plant, neighboring plants, of the same or many other legume species, as long as the environmental conditions are suitable and susceptible host plants are available. Basidiospore and teliospores have also been described in the life cycle of *Phakopsora pachyrhizi* but they are not the primary source of inoculum. The telial stage (sexual stage) is not very common but it has been induced under laboratory conditions to produce basidiospore. In the field, telia are sometimes observed towards the end of the growing cycle of soybean plants (Bromfield, 1984).

However, importance of telia, teliospores and the basidial stage of *Phakopsora pachyrhizi* in epidemics of Soybean rust are not well understood. If there is an alternate host for the aecial stage of *Phakopsora pachyrhizi*, then it remains to be discovered. The main factors for soybean rust epidemics are a great soybean field extension and the continued monocropping, which favors urediniospores production and dissemination, and accelerates race shifts, fungicide ineffectiveness, high plant density, sowing period from September to January, pathogen survival in volunteer plants of soybean and secondary hosts, are the critical factors that increases efficiency of the disease development (Yorinori and Nunes, 2006).

Factors Affecting Soybean Rust Development

Soybean rust infection process is affected by biotic factors of the host plant and the pathogen, as well as abiotic factors of the environmental conditions (Li, 2009b). Factors affecting development of soybean rust are host range of the pathogen, it has a wide range of hosts. According to Li (2009b), *Phakopsora pachyrhizi* infects more than 150 species from 53 genera of the family Leguminosae. The most susceptible host of *Phakopsora pachyrhizi* is kudzu (*Pueraria lobata* (Wild.), weed species, beans, cowpeas, pigeon pea and peas are the source of inoculum, making soybean rust control a big challenge (Maphosa *et al.*, 2012b).

Environmental factors have play great contribution for the development of soybean rust. The optimal temperature for urediniospore germination ranges between 18 and 25^{0}C (Del Ponte *et al.*, 2006). According to Caldwell *et al.*, (2005), temperatures less than 15^{0}C or greater than 30^{0}C do not support spore viability and infection. Urediniospore germination also requires 6-16 hours of wetness and it is faster in regions with an even rainfall distribution compared to regions with uneven rainfall distribution. Relative humidity of 75-80% is also required for urediniospores germination and infection (Park *et al.*, 2008). The environmental factor also affects both host genotype and the pathogen (*Phakopsora pachyrhizi)* either directly or indirectly, resulting into a complex interaction (Li, 2009a). With the current climate change now a day, Soybean rust is becoming a major concern in Ethiopia (Tesfaye *et al.*, 2017). This is because climate change is likely to transform the host physiology, resistance and the rate at which the pathogen develops (Tukamuhabwa and Maphosa, 2011).

Furthermore, soybean development stages and maturity are also other factors. Soybean phenological stages and maturity duration play an important role in the development of soybean rust. According to Kawuki *et al.*, (2004), soybean plants are susceptible to rust at all developmental stages. However, infections tend to be more severe during the reproductive stages (flowering and pod filling stages) (Maria *et al.*, 2007). With regard to maturity duration, early maturing varieties are heavily infected with higher rates of soybean rust incidences than late maturing varieties by Tschanz *et al.*, (1985).

In contrast, a recent study showed that late maturing varieties are heavily infested by Soybean rust that result into substantial yield losses than early maturing varieties (Oloka *et al.*, 2008).

Management Practices of Soybean Rust

Different control strategies have been suggested, including cultural practices, biological control, fungicide application and host resistance.

Cultural Practices

Cultural practices, such as controlling wild weed hosts, adjusting planting dates, planting early maturing varieties and site selection have been proposed to reduce soybean rust incidences and severity (Xun, 2007). The main challenge with cultural practices is that some of the alternative hosts are perennials, resulting into year-round spore production, thus making cultural practices unsuitable for soybean rust control. Fertilization with potassium, chloride, manganese, and phosphorous may affect the development of fungal diseases. However, their effects on Soybean rust have not been fully explored (Ebelhar *et al.*, 2008).

Biological Control

Biological control of Soybean rust using fungal pathogen has been reported to be an effective method of controlling the disease by various authors. *In vitro* studies, greenhouse and field trials reported protection by beneficial microbes with antagonistic properties to *Phakopsora pachyrhizi*. The fungus *Simplicillium lanosoniveum* preferentially colonizes *Phakopsora pachyrhizi* uredinia on infected soybean leaves and thereby significantly reduces Soybean rust development in the field (Ward *et al.,* 2012). Moreover, several strains of *Bacillus* spp. reduce Soybean rust severity (Dorighello *et al.,* 2015). *Bacillus* strain that is the active ingredient in the organically approved commercial fungicide Ballad R provides Soybean rust control. Besides antagonistic organisms, plant volatiles, such as farnesyl-acetate, can be used for biocontrol of Soybean rust (Mendgen *et al.,* 2006).

Chemical Control

Fungicide is the most effective means for controlling soybean rust now a day. Several systemic and protectant fungicides are used as the primary control measure for managing the pathogen (Levy, 2005). However, the appropriate application of fungicides is locally specific due to differences in the environmental factors (weather patterns), cropping systems and socio-economic factors (availability, equipment, labour and cost). In addition, the fungicide efficacy and timing of application is complicated by the maturity stage of the host and the disease progress. This makes fungicide control measures less applicable in most of the developing countries (Oloka *et al.,* 2008).

In Brazil, at least three fungicide applications are needed per season thus raising costs of US$2 billion for soybean disease control annually (Godoy *et al.,* 2015). Scherm *et al.,* (2009) studied the efficacy of several fungicides on a soybean crop in Brazil showed that triazole fungicides had significantly efficiency than strobilurins classes. The combination of triazoles with strobilurins improved disease control and yield gain compared with triazoles or strobilurins alone. However, the combination of triazoles with a benzimidazole fungicide did not improve the disease control when compared with triazoles alone. They either concluded that the two fungicides with the best disease control efficacy were combinations of two active ingredients as flusilazole + carbendazim and azoxystrobin + cyproconazole. Early research in Asia also indicated that mancozeb and, to a more limited extent the benzimidazole fungicides suppressed soybean rust but required 3-5 applications to be effective. The disease control was significantly improved after the introduction of the triazole fungicides (Scherm *et al.,* 2009).

As stated above, using fungicide is currently the most widely employed method for management of the pathogen, although fungicides are not easily accessible to many smallholder farmers in developing countries. In other hand, if the fungicide is available, their use significantly increases production costs, cause environmental risks, and result in fungicide resistance of the pathogen, especially when single-site mode fungicides are used over a long time. Such resistance has been reported in South America and efforts are now directed to combine single-site fungicides with different modes of action or with multisite fungicides (Godoy *et al.,* 2016). As a conclusion, the number and timing of applications are critical for the control of soybean rust. The most efficient applications are applied during early reproductive growth, which allow protection through to crop maturity. The exact number of applications will depend on the length of the reproductive phase of the crop, duration of the compound and severity of the epidemic. Fungicide applications in early vegetative stages, although effective in reducing disease severity, have not been shown to be effective in protecting yield.

Host plant Resistance

Host plant resistance is more affordable method and the most economical, long term and environmentally friendly method for managing soybean rust (Pham *et al.,* 2010). For this reason, considerable efforts have been directed towards screening soybean germplasm for resistance to *Phakopsora pachyrhizi* for many years. Ultimately, it is increasingly recognized that deployment of resistant soybean cultivars is a better disease control method because it is economical, safe, environmentally friendly, and complements other control methods. At least 200 germplasm accessions and breeding lines with resistance to soybean rust have been screened and seven resistance loci, designated *Rpp* (for resistance to *P. pachyrhizi*) have been characterized. None of them where resistance genes were effective against all currently known soybean rust pathotypes (Childs *et al.,* 2018).

Fig.1 Taxonomy of soybean rust (*Phakopsora pachyrhizi)* which belongs to;

Domain Eukaryota

Kingdom Fungi

Phylum Basidiomycota

Order Uredinales

Class Urediniomycetes

Family Phakopsoraceae

Genus *Phakopsora*

Species *pachyrhizi*

Fig.2 Reaction to soybean rust at field conditions (a, b), soybean rust symptoms observed on soybean leaves (c) and Lesions on a soybean leaf (d)

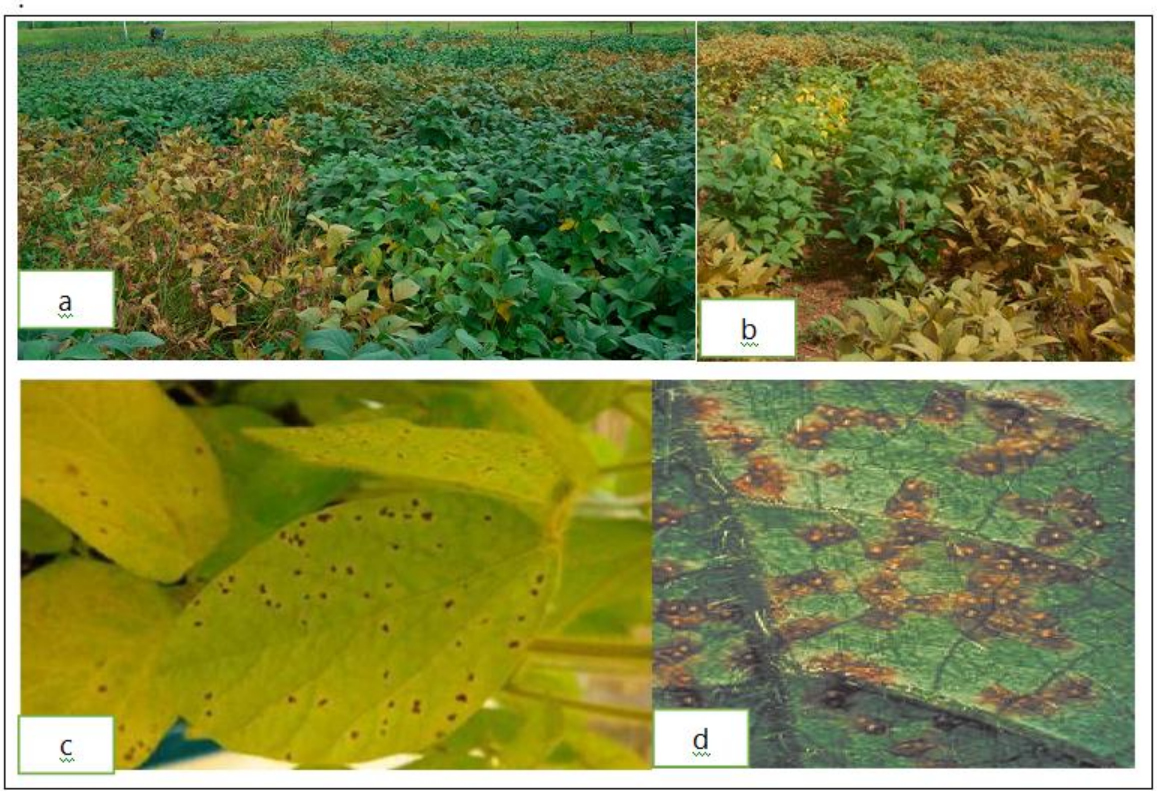
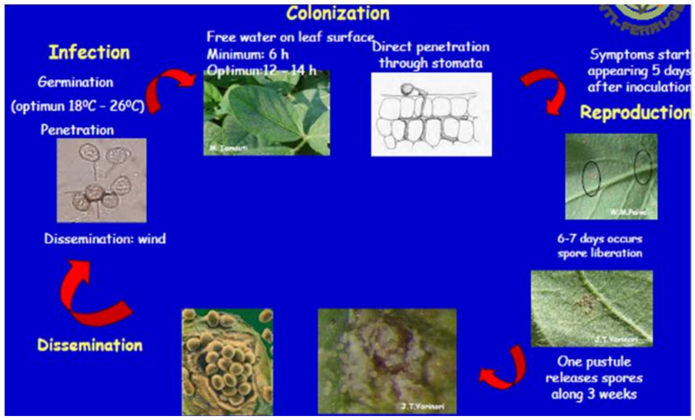


Fig.3 Soybean rust (*Phakopsora pachyrhizi)* disease cycle (Source: Xun, 2007)



Resistance or susceptibility of soybean to *P. pachyrhizi* is determined by the infection types that eventually develop upon challenge with the fungus. Both reddish-brown (RB) and immune (IM) infection types imply that the interaction between the particular soybean accession and the rust fungus is incompatible (Goellner *et al.,* 2010). In this case the sporulation levels are low, the soybean plant is resistant, and *P. pachyrhizi* is avirulent. The formation of tan-coloured (TAN) lesions with abundant sporulation implies compatibility, with the soybean accession being susceptible and the fungal pathotype being virulent (Goellner *et al.,* 2010). It should be noted that even highly effective single *Rpp* genes generally provide partial resistance, which is characterized by the development of RB lesions having one to three uredinia and showing low levels of sporulation. Several studies have been conducted to identify effective genes that can be used in breeding programmes to provide durable resistance. For instance, over 16,000 soybean genotypes were screened in 2006 in the USA, using a mixture of four different rust isolates sourced from Brazil, Paraguay, Thailand, and Zimbabwe. Out of these genotypes, about 805 were identified as a potential source of resistance (Miles *et al.,* 2006). In 2008, 530 genotypes, which were a subset of the 805 genotypes, were screened in Paraguay under field conditions and about 16 of these genotypes were found to be resistant (Miles *et al.,* 2008). In the USA, 64 resistant genotypes were identified among 576 genotypes evaluated at seven locations (Walker *et al.,* 2011). In Africa, screening of soybean genotypes for resistance to the local *P. pachyrhizi* population has been conducted in only a few countries (Murithi *et al.,* 2021).

Due to the high variability among *P. pachyrhizi* pathotypes, which includes shifts in virulence, resistant soybean varieties that were, for example, commercially available in Brazil, rapidly succumbed to the pathogen (Godoy *et al.,* 2016). Furthermore, *P. pachyrhizi* has a broad host range and appears to evolve different pathotypes, even in the absence of selection pressure exerted by the extensive deployment of particular soybean resistance genes against this fungus. Continuous screening of germplasm for resistance to soybean rust is important, as it will aid in the identification of effective resistance genes to be used in breeding programs (Murithi *et al.,* 2021).

Soybean rust is the most destructive fungi that affect vegetative growth, reproductive stage, yield and seed quality of soybean. *Soybean rust is caused by Phakopsora pachyrhizi* which is major threat to global soybean production. Yield losses caused by soybean rust *(Phakopsora pachyrhizi*) depending on the host susceptibility, inoculum quantity, and conductive environmental conditions. The high capacity of spore dispersion over long distances and wide distribution of soybean rust makes it the most harmful and virulent disease throughout the worldwide. The main factors for soybean rust epidemics are great expansion of soybean field and the continued monoculture, fungicide ineffectiveness, high plant density, pathogen survival in volunteer plants of soybean and secondary hosts. An integrated approach exploiting different measures is likely to provide the best possible means for the effective control soybean rust and promise for sustainable soybean production in the future. Generally, this review paper can be useful for creating awareness of this devastated foliar disease of soybean production constraints. Strongly, I recommended that further study or integrated surveillance to detect the pathogen and its current distribution status will be needed in our country Ethiopia and timely develop management strategies.

References

Bandyopadhyay, R., P. S. Ojiambo, M. Twizeyimana, B. Asafo-Adjei, R. D. Frederick, K. F. Pedley, C. L. Stone and G. L. Hartman 2007. Disease notes: First report of soybean rust caused by *Phakopsora pachyrhizi* in Ghana. Plant Disease 91:1057.

Bennett, R. A. 2005. Integration of soybean rust research - USDA perspective [Online]. Available by Agricultural Outlook Forum. US Department of Agriculture. http://ageconsearch.umn. edu/ bitstream/32799/1/fo05be02.pdf. Verified 30 November, 2012.

Bonde, M. R., S. E. Nester, C. N. Austin, C. L. Stone, R. D. Frederick, G. L. Hartman, and M. R. Miles. 2006. Evaluation of virulence of *Phakopsora pachyrhizi* and *P. meibomiae* isolates. Plant Disease 90:708-716.

Borém A. 1999. Melhoramento de espécies cultivadas. Viçosa, Brasil: Universidade Federal de Viçosa.

Bromfield, K. R. 1984. Soybean rust. Monograph No 11. The American Phytopathological Society, St. Paul, MN, USA. 65 pp.

Caldwell, P. M., A. Nunkumar, Z. A. Pretorius, and J. M. C. Fernandes. 2005. Development of *Phakopsora pachyrhizi* at different temperatures, relative humidities and leaf wetness duration. In, the International Workshop on Plant Disease Epidemiology, 9th, 2005. Landerneau, France.

Calvo, E. S., R. A. S. Kiihil, A. Garcia, A. Harada, and D. M. Hiromoto. 2008. Two major recessive soybean genes conferring soybean rust resistance. Crop Science 48:1350-1354.

Childs, S. P., Buck, J. W. & Li, Z. 2018. Breeding soybeans with resistance to soybean rust (*Phakopsora pachyrhizi*). *Plant Breeding*, 137, 250–261.

Dean R, Van Kan J A, Pretorius Z A, Hammond-Kosack K E, Di Pietro A, Spanu P D, *et al.*, 2012. The Top 10 fungal pathogens in molecular plant pathology. Mol Plant Pathol.; 13:414-430.

Del Ponte, E. M., C. V. Godoy, M. G. Canteri, E. M. Reis, and X. B. Yang. 2006. Models and applications for risk assessment and prediction of Asian soybean rust epidemics. Fitopatologia Brasileira 31:533-544.

Dorighello, D. V., Bettiol, W., Maia, N. B., and deCampos Leite, R. M. V. B. 2015. Controlling Asian soybean rust (*Phakopsora pachyrhizi*) with *Bacillus* spp. and coffee oil. *Crop Prot.* 67, 59–65.doi: 10.1016/j.cropro.2014.09.017.

Ebelhar, S. A., J. D. Hernandez, C. D. Hart, and J. Bond. 2008. Effect of nutrient management and fungicides on soybeans in Southern Illinois. http://frec.ifca.com. Verified 16 November, 2012.

Garcia, A., E. S. Calvo, R. A. S. Kiihl, A. Harada, D. M. Hiromoto, and L. G. E. Vieira. 2008. Molecular mapping of soybean rust (*Phakopsora pachyrhizi*) resistance genes: discovery of a novel locus and alleles. Theoretical and Applied Genetics 117:545-553.

Gebre-Egziabher Fentahun, 2019. Production and Marketing Trends of Soybean in Ethiopia 2001-2017. Journal of Marketing and Consumer Research, ISSN 2422-8451. Vol.59, Pp9-14. DOI: 10.7176/JMCR

Godoy, C. V., Bueno, A. F., and Gazziero, D. L. P. 2015. Brazilian soybean pest management and threats to its sustainability. *Outlooks PestManag.* 26, 113–117. doi: 10.1564/v26 jun 06.

Godoy, C. V., Seixas, C. D. S., Soares, R. M., Marcelino-Guimaraes, F. C., Meyer, M. C. & Costamilan, L. M. 2016. Asian soybean rust in Brazil: past, present, and future. *Pesquisa Agropecuária Brasileira*, 51, 407–421.

Goellner, K. and Langenbach, C. 2010. 'Phakopsora pachyrhizi, the causal agent of Asian soybean rust: Pathogen profile', (February 2014). doi: 10.1111/j.1364-3703.2009.00589. x.

Hartman, G. L., E. D. West, and T. K. Herman. 2011. Crops that feed the World 2. Soybean worldwide production, use, and constraints caused by pathogens and pests. Food Security 3:5-17.

Ivancovich, A. 2005. Soybean rust in Argentina. Plant Disease 89:667-668.

Kawuki, R. S., E. Adipala, J. Lamo, and P. Tukamuhabwa. 2003b. Responding to the soybean rust epidemic in Sub-Saharan Africa: A Review. African Crop Science 11:301-318.

Kawuki, R. S., P. Tukamuhabwa, and E. Adipala. 2004. Soybean rust severity, rate of rust development and tolerance as influenced by maturity period and season. Crop Protection 23:447-455.

Kumudini, S., E. Prior, J. Omielan, and T. Tollenaar. 2008. Impact of *Phakopsora pachyrhizi* infection on soybean leaf photosynthesis and radiation absorption. Crop Science 48:2343-2350.

Levy, C. 2003. Measures to control soybean rust in Southern Africa and an initial investigation of meteorological factors that favour its development. Phytopathology 93: S103.

Levy, C. 2005. Epidemiology and chemical control of soybean rust in Southern Africa. Plant Disease 89:669-674.

Li, S. 2009a. Identification of new sources of resistance to soybean rust. Recent Developments in Management of Plant Disease 1:357-373.

Li, S. 2009b. Reaction of soybean rust resistant line identified in Paraguay to Mississippi isolates of *Phakopsora pachyrhizi*. Crop Science 49:887-894.

Li, S., J. R. Smith, J. D. Ray, and R. D. Frederick. 2012. Identification of a new soybean rust resistance gene in PI 567102B. Theoretical and Applied Genetics 125:133-142.

Maphosa, M., H. Talwana, P. Gibson, and P. Tukamuhabwa. 2012b. Combining ability for resistance to soybean rust in F2 and F3 soybean populations. Field Crops Research 130:1-7.

Maria, J. M., A. M. Missaoui, D. V. Phillips, D. R. Walker, and H. R. Boerma. 2007. Mapping and confirmation of the 'Hyuuga' red brown-lesions resistance gene for Asian soybean rust. Crop Science 47:829-836.

Mendgen, K., Wirsel, S. G. R., Jux, A., Hoffmann, J., and Boland, W. 2006. Volatiles modulate the development of plant pathogenic rust fungi. *Planta* 224, 1353–1361. doi:10.1007/s00425-006-0320-2.

Miles, M. R., Frederick, R. D., and Hartman, G. L. 2003. Soybean rust: Is the U.S. soybean crop at risk. The American Phytopathological Society. Online publication.

Miles, M. R., Frederick, R. D. & Hartman, G. L. 2006. Evaluation of soybean germplasm for resistance to *Phakopsora pachyrhizi*. *Plant Health Progress*, 7. doi: 10.1094/PHP-2006- 0104-01-RS.

Miles, M.R., Morel, W., Ray, J.D., Smith, J.R., Frederick, R.D. & Hartman, G.L. 2008. Adult plant evaluation of soybean accessions for resistance to *Phakopsora pachyrhizi* in the field and greenhouse in Paraguay. *Plant Disease*, 92, 96–105.

Mohammad, S. K., A. Ali, and A. Salam. 2003. Production constraints of soybean in Upland Balochistan. Asian Journal of Plant Science 2:388-381.

Murithi, Beed, Tukamuhabwa, Thomma and Joosten. 2015. Soybean production in eastern and southern Africa and threat of yield loss due to soybean rust caused by *Phakopsora pachyrhizi*. Plant Pathology. 65:176–188.

Oloka, H. K., P. Tukamuhabwa, T. Sengooba, and S. Shanmugasundram. 2008. Reaction of exotic soybean germplasm to *Phakopsora pachyrhizi* in Uganda. Plant Disease 92:1493- 1496.

Park, S., Z. Y. Chen, A. K. Chanda, R. W. Schneider, and C.A. Hollier. 2008. Viability of *Phakopsora pachyrhizi* urediniospores under simulated southern Louisiana winter temperature conditions. Plant Disease 92:1456-1462.

Pham, T. A., C. B. Hill, M. R. Miles, B. T. Nguyen, T. T. Vud, T. D. Vuonge, T. T. VanToaif, H. T. Nguyene, and G. L. Hartman. 2010. Evaluation of soybean for resistance to soybean rust in Vietnam. Field Crops Research 117:131-138.

Rosa C R E, Spehar C R, Liu J Q. 2015. Asian Soybean Rust Resistance: An Overview. J Plant Pathol Microb 6: 307. doi:10.4172/2157-7471.1000307.

Scherm, H.; Christiano, R. S. C.; Esker, P. D.; Del Ponte, E. M.; Godoy, C. V. 2009. Quantitative review of fungicide efficacy trials for managing soybean rust in Brazil. *Crop Protection*, Vol. 28, pp. 774-782.

Tefera, H., R. Bandyopadhyay, R. A. Adeleke, O. Boukar, and M. Ishaq. 2009. Grain yields of rust resistant promiscuous soybean lines in the Guinea savanna of Nigeria. African Crop Science Conference Proceedings 9:129-134.

Tesfaye. A, Belachew. K, S. Haudenshield and G. L. Hartman. 2017. First Report of *Phakopsora pachyrhizi* Causing Rust on Soybean in Ethiopia. Plant Disease "First Look" paper *http://dx.doi.org/10.1094/PDIS-11-16-1692-PDN • posted 01/17/2017.*

Tschanz, A. T., and S. Shanmugasundaram. 1985. Soybean rust, pp. 562-567, *In* R. Shibles, (ed.) Proceedings of the 3rd world soybean research conference, Ames, I A.

Tukamuhabwa, P. and M. Maphosa. 2011. State of knowledge on breeding for durable resistance to soybean rust disease in the developing world. FAO plant production and protection paper 204. ISBN 978-92-5-106425-2.

Twizeyimana M, Ojiambo PS, Ikotun T, Paul C, Hartman G L, Bandyopadhyay R, *et al.*, 2007. Comparison of field, greenhouse, and detached-leaf evaluations of soybean germplasm for resistance to *Phakopsora pachyrhizi*. Plant Dis; 91:1161-1169.

USDA. 2015. World Agricultural Production. Foreign Agricultural Service. United States Department of Agriculture: USDA circular series

Walker, D. R., Boerma, H. R., Harris, D. K., Schneider, R. W., Buckley, J. B., Shipe, E. R. *et al.*, 2011. Evaluation of USDA soybean germplasm accessions for resistance to soybean rust in the southern United States. *Crop Science*, 51, 678–693.

Ward, N. A., C. L. Robertson, A. K. Chanda, and R. W. Schneider. 2012. Effects of *Simplicillium lanosoniveum* on *Phakopsora pachyrhizi*, the soybean rust pathogen, and its use as a biological control agent. Phytopathology 102:749-760.

Xun Li. 2007. Soybean rust in the United States: assess its potential epidemic ranges and frequency based on disease limiting factors, disease attributes, and comparative epidemiology. Retrospective PhD Dissertations. Paper 15973. *Iowa State University*. USA

Yorinori J T, Nunes Junior J. 2006. Soybean germplasm with resistance and tolerance to "Asian" rust and screening methods. In: South American Workshop on Soybean Rust. Londrina, Brasil: Embrapa Soybean, p: 13.

Yorinori, J. T., W. M. Paiva, R. D. Frederick, L. M. Costamilan, P. F. Bertagnolli, G. L. Hartman, C. V. Godoy, and J. Nunes. 2005. Epidemics of soybean rust (*Phakopsora pachyrhizi*) in Brazil and Paraguay from 2001-2003. Plant Disease 89:675-677.

How to cite this article:

Gizachew Hirpa Regasa. 2021. A Review on the Economic Importance, Epidemiology and Management Practices of Soybean Rust (*Phakopsora pachyrhizi*). *Int.J.Curr.Res.Aca.Rev*. 9(09), 26-36.
doi: https://doi.org/10.20546/ijcrar.2021.909.004