Survey and Present Status of Soybean Diseases in Central India

Pawan K. Amrate ✉ ID

Dept. of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P. (482 004), India

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Corresponding ✉ pamrate@jnkvv.org

ID 0000-0002-3708-4477

ABSTRACT

The experiment was conducted during *kharif* (July to September), 2018 and 2019 at J.N.K.V.V., Jabalpur, Madhya Pradesh, India to study the current status of soybean diseases in central Indian conditions. A fixed plot survey of nine soybean varieties was carried out at three different growth stages i.e. seedling stage (V_2-V_3), early reproductive stage (R_2-R_4) and late reproductive stage (R_5-R_7). The study found that soybean varieties were infected with fourteen diseases in the current cultivation scenario. Collar rot (0.0–4.88%), root rot (0.63–4.13%) and soybean mosaic (0.0–8.38%) was initially noticed at the seedling stage in the second and third week of July. At early reproductive stages, yellow mosaic (0.0–35.0%), bacterial pustule (0.0–8.0%), and anthracnose (0.00–35.13%) were dominating diseases in the third week of July (yellow mosaic) to the first week of August (bacterial pustule). At late reproductive stage (first week of August to the third week of September), the average range of incidence of aerial blight (1.25–30.63), frog eye leaf spot (0.75–21.13), charcoal rot (0.0–65.13), Pod blight (0.0–10.63), myrothesium leaf spot (0.0–2.88), target leaf spot (0.0–6.13) and alternaria leaf spot (0.0–5.0) were varied from low to high. At maturity, the soybean seeds were infected with purple seed stain (0.38–7.0%). Through incidence and varietal influence patterns, charcoal rot, yellow mosaic, Anthracnose/pod blight, aerial blight, and frog eye leaf spot could be considered significant concerns for soybean cultivation in this region.

KEYWORDS: Appearance, diseases, identification, incidence, leaf spots, soybean, survey

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Soybean [*Glycine max* (L.) Merrill], also designated as "Golden bean" or "Yellow jewel", is a major oilseed crop in India. Soybean originated in China or Eastern Asia and subsequently spread to other parts of the world (Banerjee et al., 2022). In India, the trial for soybean cultivation started in 1963 by using varieties from the USA (Agarwal et al., 2013). Since then, the area under cultivation and production has increased continuously. Due to the availability of high content of protein (31.9–45.0%), edible oil (14.0–21.7%) and several health-beneficial nutritional constituents (Amino acids, Unsaturated fatty acids, Calcium, Potassium, Vitamins A, B, C and D and antioxidants, etc) soybean is considered one of the most popular and valuable seed legumes in the world (Mehra et al., 2020; Finoto et al., 2021; Uikey et al., 2022; Banerjee et al., 2023). Now, soybean is among the world's five most important food crops (Bandara et al., 2020).

The farming of soybean is attractive and lucrative, but simultaneously, its cultivation has several constraints. About 59.9 million metric tonnes of soybean yield losses are accounted for due to the attacks of various diseases in the top eight soybean-producing countries (Wrather et al., 2010). Among these, Anthracnose/pod blight [*Colletotrichum truncatum* (Schw.) Andrus and Moore], Charcoal rot [*Macrophomina phaseolina* (Tassi) Goid], Soybean mosaic (*soybean mosaic virus*), Yellow mosaic [*Mungbean Yellow Mosaic India Virus*], Aerial blight [*Rhizoctonia solani* Kuhn], Frog eye leaf spot [*Cercospora sojina* Hara], Rust (*Phakopsora pachyrhizi* syd. & P. syd.), Bacterial pustule (*Xanthomonas axonopodis* pv. *glycines*) and Target leaf spot [*Corynespora cassicola* (Berk. and Curt.)] are important worldwide disease infect soybean crop every year in India (Mengistu et al., 2011; Wrather et al., 2010; Amrate et al., 2018; Singh and Aravind, 2019; Jahagirdar, 2019; Bandara et al., 2020; Rajput et al., 2021; Amrate and Shrivastava, 2021; Amrate et al., 2023a; Uikey et al., 2022; Tripathi et al., 2022; Lin et al., 2022). Apart from this, other diseases such as Collar rot (*Sclerotium rolfsii* Sacc), Root rot (*Rhizoctonia solani* Kuhn), Myrothesium leaf spot (*Myrothecium roridum* Tode ex. Fries), Alternaria leaf spot [*Alternaria tenuissima* (Kunze ex Pers.) and *A. alternata* (Fr.) Keissler], Brown leaf spot (*Septoria glycine* Hemmi), Cercospora leaf blight/purple seed stain (*Cercospora kikuchii*) are also infect soybean crops with varying intensity at different locations in India (Wrather et al., 2010; Belkar and Gade, 2013; Sajeesh et al., 2014; Kumar et al., 2015; Fagodiya et al., 2021; Tripathi et al., 2022).

In India, central part of the country that includes Madhya Pradesh, Maharashtra and Rajasthan are major contributor of soybean (about 92–93%). Madhya Pradesh, known as the soybean state, has been facing a decline in soybean cultivation and productivity. Continuous attack of several biotic stresses like insect pest and diseases influence the production of soybean in this region (Sharma et al., 2014; Marabi et al., 2017; Amrate and Shrivastava, 2021). The changing weather trend in this region also exaggerates biotic stresses on soybean. Annual occurrence and severity of various diseases in soybean are highly influenced by the changing weather pattern (Amrate et al., 2021; Rajput et al., 2021; Fagodiya et al., 2022; Amrate et al., 2023b). Environmental and varietal scenarios have changed with time, impacting the disease's annual occurrence and severity. There are several reports of the occurrence and prevalence of diseases in soybean at different locations in central India and other parts of country during recent past (Sajeesh et al., 2014; Kumar et al., 2015; Mathpal and Singh, 2017; Rajput et al., 2021; Amrate and Shrivastava, 2021; Uikey et al., 2022; Fagodiya et al., 2021). However, few research articles exhibit the overall scenario of soybean diseases at the exact locations. Considering all this pertinent information, the present investigation was undertaken to reveal the present status of the disease at different growth stages of soybean under changing environmental and varietal scenarios in central India.

2. MATERIALS AND METHODS

The survey was conducted to determine the incidence of soybean diseases at the different growth stages of the crops in experimental fields at J.N.K.V.V., Jabalpur (Latitude: 23°14 N, Longitude: 79°56 E) during *kharif* 2018 and 2019 (July to September). A total of nine varieties were surveyed during both years. The date of sowing of these varieties was the first fortnight of July. The sizes of fields were varied from 100–10000 m². The entire fields were well drained. All these were grown with recommended packages and practices for soybean cultivation in Madhya Pradesh. Jabalpur has become a hot spot for many soybean diseases in Madhya Pradesh. It was observed that the Incidence, severity, and timing of the appearance of diseases varied at Jabalpur locations and depended on prevailing weather conditions. Fields were visited throughout the cropping season regularly at 7-day intervals.

2.1. Recording of diseases at different stage of soybean methodology of fixed plot survey

Incidence of various disease such as collar rot, soybean mosaic, yellow mosaic, bacterial pustule, was recorded on randomly selected 400 plants at four points in a particular field at V2-V3, R2-R4 and R5-R7 stage during 3rd of week of July (29th SMW), August (34th SMW) and September (38th SMW), respectively. Observations on incidence of purple seed stain were recorded at the time of harvesting on 400 seeds collected from randomly selected pods. Initially diseases such as Collar rot, root rot, soybean mosaic, Yellow

mosaic Bacterial pustule, Anthracnose, Aerial blight, Frog eye leaf spot, Charcoal rot Pod blight, Target leaf spot, Myrothesium leaf spot, Alternaria leaf spot and Purple seed stain were diagnosed on the bases of typical field symptoms (Gupta and Chauhan, 2005; Amrate et al., 2019; Amrate et al., 2020; Amrate et al., 2023a; Amrate and Shrivastava, 2021; Kumari et al., 2021; Fagodiya et al., 2022; Sagarika et al., 2023), and later confirmed under lab conditions for microbial association.

Per cent disease incidence for each disease was calculated by using following formula.

$$\text{Per cent mortality} = \frac{\text{No. of plants affected}}{\text{Total no. of plants observed}} \times 100$$

3. RESULTS AND DISCUSSION

3.1. Year wise incidence of diseases at different stages

3.1.1. Seedling stage (V_2-V_3)

Surveys during 3rd of the week of July 2018 and 2019 revealed that Collar rot, root rot and soybean mosaic disease were predominant at an early stage of soybean growth (V_2-V_3) (Figure 1). However, collar rot and root rot incidence were first noticed in the 2nd week of July, followed by soybean mosaic in the 3rd week of July (Table 1). Collar rot-affected plants showed necrotic constriction around the collar region and whitish fungal growth of pathogen (Figure 1 a and b). Seedling death was recorded in such kind of collar rot-affected plants. Root rot-affected plants showed stunted growth, and the roots of such plants had depressed long, irregular, dark brown necrotic lesions (Figure 1c). Green mosaic was diagnosed by visual symptoms, including mosaic patterns of light and dark islands on leaf lamina, green mottling, and downward curling of leaves. Stunting of the plant was noticed under severe infection conditions (Figure 1d).

The average incidence of collar rot among nine soybean varieties was 1.81 and 2.56% during 2018 and 2019, respectively. It ranged between 0.0–4.25 and 0.0–5.50 in 2018 and 2019, respectively (Figure 2). The maximum incidence (4.25 and 5.50%) was recorded in JS 335 in both years. No infection was recorded in JS 20–34 (2018) and JS 20–69 (2018 and 2019). Similarly, the average incidence of root rot was 1.22 and 2.11% during 2018 and 2019, respectively. Root rot was ranged between 0.00–2.75 and 0.00– 5.50% in 2018 and 2019. The highest root rot incidence was observed in JS 95–60 (5.50%) in 2019. The incidence of soybean mosaic was noticed in most varieties between 0.00–8.25 and 0.00–10.0% during 2018 and 2019, respectively. Green mosaic was higher in RVS 2001-04 (8.25%) and JS 95–60 (10.0%) during 2018 and 2019, respectively. No incidence of green mosaic was noticed
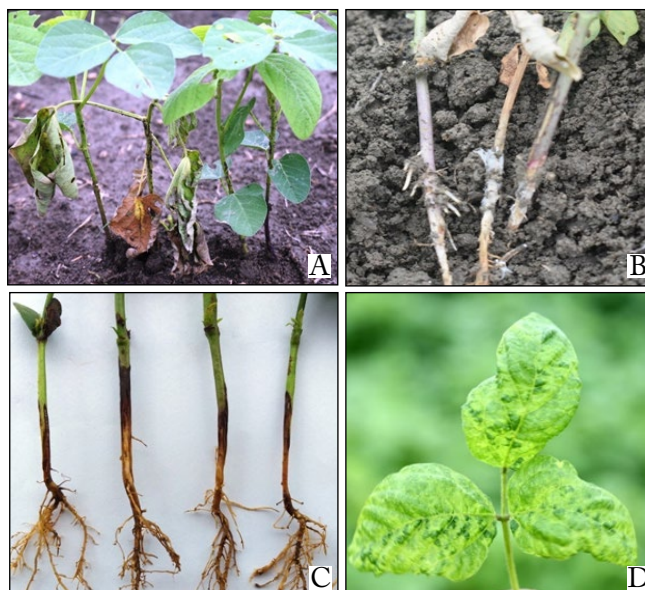

Figure 1: Pictorial depiction of collar rot affected plant and root (A and B), Root rot affected plant (C) and Soybean mosaic disease affected leave (D), respectively at V_2-V_3 stage of soybean
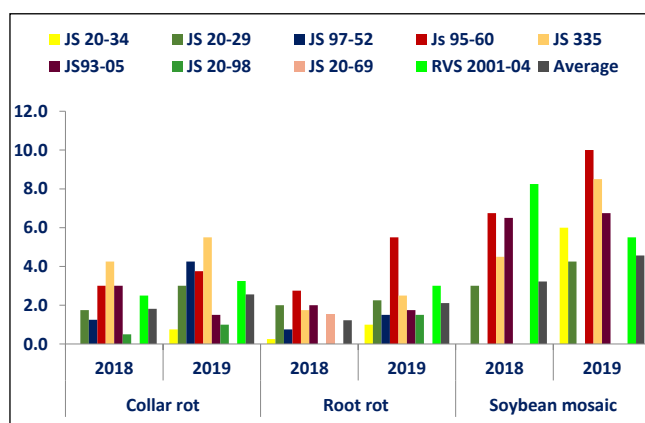

Figure 2: Per cent incidence of collar rot, root rot and soybean mosaic disease among varieties of soybean at V_2-V_3 stage in Jabalpur during *kharif,* 2018 and 2019

in JS 20–34 (2018), JS 20–69 (2018 and 2019), JS 97–52 (2018 and 2019) and JS 20–98 (2018 and 2019). During the observations, the average maximum temperature was 31.4 and 34.9°C, and relative humidity was 70.5 and 87.5% in 2018 and 2019, respectively.

3.1.2. Early reproductive stage (R_2-R_4)

Survey during 3rd of week of August 2018 and 2019 revealed that yellow mosaic, Bacterial pustules and Anthracnose were major diseases at early reproductive stage (R_2-R_4) in different soybean varieties. Symptoms of yellow mosaic as contrast yellow irregular patches along with mosaic pattern were first noticed on 3rd week (2018) and 4th week (2019) of July (Table 1). Most of the leaf lamina was covered with

Table 1: Growth stage wise first appearance of soybean diseases at Jabalpur during *kharif,* 2018 and 2019

Name of disease	2018		2019	
	GS	Timing	GS	Timing
Collar rot (Coll R)	V_2	2nd week, July	V_1	2nd week, July
Root rot	V_2	2nd week, July	V_2	2nd week, July
SMV	V_2	3rd week, July	V_2	4th week, July
YMV	V_2	3rd week, July	V_2	4th week, July
Anthracnose	V_2	3rd week, July	V_3	1st week, August
BP	R_1	1st week, August	R_2	1st week, August
FLS	R_4	3rd week, August	R_3	2nd week, August
RAB	R_2	1st week, August	R_4	3rd week, August
Charcoal rot (CR)	R_3	4th week, August	R_5	2nd week, September
Pod blight	R_4	1st week, September	R_5	3rd week, September
Myrothesium leaf spot (MLS)	-	-	R_4	3rd week, September
Target leaf spot (TLS)	R_4	3rd week, September	R_5	3rd week, September
Alternaria leaf spot (ALS)	R_5	2nd week, September	R_5	4th week, September
Purple seed stain (PSS)	R_8	3rd week, September	R_8	1st week, October

GS: Growth stages; V_1-V_3: Vegetative stage; R_1: Flower initiation; R_2: Full flowering; R_3: Pod development initiation; R_4: Full pod development; R_5: Seed formation initiation; R_6: Complete seed development; R_7: Maturity initiation; R_8: Complete maturity

contrast yellowing in severely infected plants (Figure 3a). After first appearance of yellow mosaic, it had been spread rapidly during fourth week of July and first fortnight of August in most of the varieties. Whereas in case of bacterial pustule disease, small circular to large irregular red brown spots surrounded by yellow hallow were prominent on the surface of leaf. Small, raised light red to brown pin head like pustules were noticed on the centre of spot (Figure 3b). Bacterial pustules were first noticed during first week of August in both the years. Anthracnose disease was recognized by reddish to dark brown irregular spots or

patches on stem, petiole and pods along with the presence of randomly arranged black fruiting bodies consisting of spiny setae. Complete dark brown blackening of stem of petioles was recorded upon severe infection of Anthracnose (Figure 3c and d). The first symptoms of Anthracnose were noticed in 3rd week of July (2018) and 1st week of August (2019). Thereafter disease progressed continuously in infected plants.
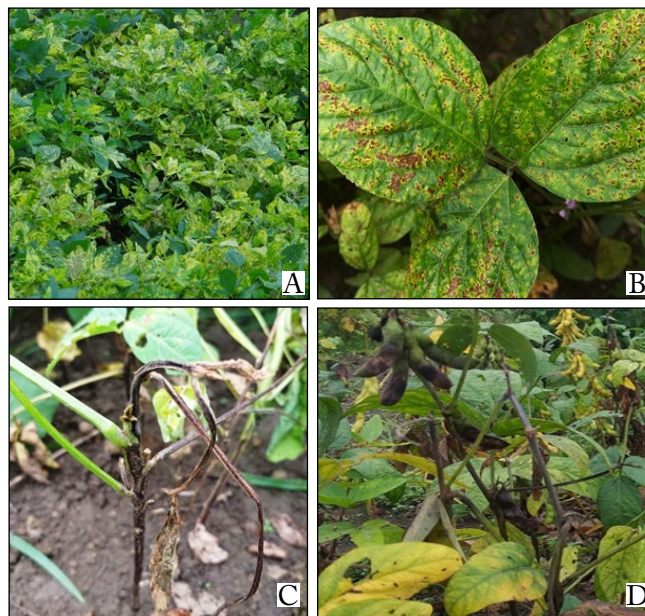

Figure 3: Pictorial depiction of yellow mosaic disease (YMD) (A), Bacterial pustule (B) and Anthracnose at early (C) and pod development (D) during R_2-R_4 stage of soybean

The incidence data indicated that all the varieties were affected with YMD in variable proportions; however, no incidence was recorded in JS 20–69 (Figure 4). The incidence of YMV ranged between 0.0–31.0 and 0.0–42.0% with average of 12.92 and 14.86% during 2018 and 2019,
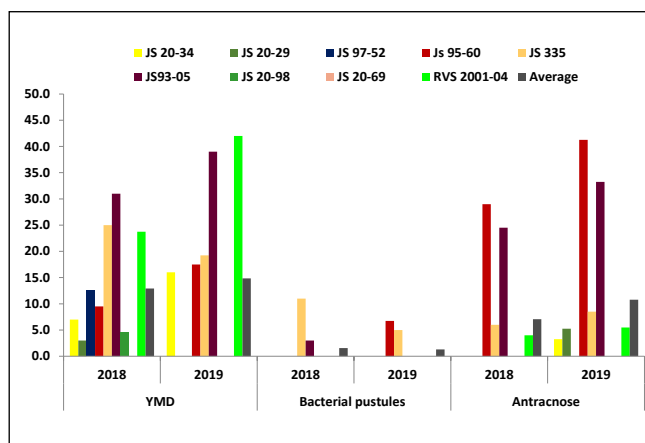

Figure 4: Per cent incidence of yellow mosaic disease (YMD), bacterial pustule and anthracnose among varieties of soybean at R_2-R_4 stage in Jabalpur during *kharif,* 2018 and 2019

respectively. The varieties i.e. JS 20–29 (2019), JS 97–52 (2019), JS 20–98 (2019) and JS 20–69 (2018 & 2019) was free from YMV infection. The maximum infection was noticed in JS 93–05 (31.0%) and 42.0% (RVS 2001–04) in 2018 and 2019, respectively. Infection of bacterial pustule was comparatively low and recorded in JS 335, JS 93-05 and JS 95–60. The maximum incidence (11.0%) of the disease was recorded in JS 335 (2018). The incidence of Anthracnose was recorded in JS 20–34, JS 20–29, JS 95–60, JS 335, JS 93–05, and RVS 2001-04 (Figure 3). Old varieties i.e. JS 95–60 (29.0 and 41.25%) and JS 93-05 (24.50 and 33.25%) were most affected due to Anthracnose in both year (2018 and 2019). During the period of observations average maximum temperature was 28.5 and 29.2°C, and relative humidity 94.0 and 90.0% in 2018 and 2019, respectively.

3.1.3. Late reproductive stage (R_5-R_7)

During late reproductive stage, Rhizoctonia Aerial Blight (RAB), Pod blight and Charcoal rot were predominant in most of the varieties. RAB was first appeared on 1st week of August (2018) and 3rd week of August (2019) (Table 1). Water-soaked greenish brown to reddish brown lesions on the leaves along with web like aerial mycelia were seen on RAB affected plant portions (Figure 5a). Charcoal rot disease was first appeared on 4th week of August (2018) and 2nd week of September (2019). Dropping of leaves and sudden wilting of plants were recorded with the presence of charcoal like blackening on lower stem and root portions of dead plant (Figure 5b). Infection of pod blight was first noticed on 1st week (2018) and 3rd week (2019) of September. It was identified by the presence of light to dark brown lesions, with black dot like minute numerous ascervuli on the infected tissues (Figure 5c). Apart from this the incidence of various leaf spot diseases and purple seed stain (PSS) were also noticed in varieties.

Among leaf spot diseases, frog eye leaf spot (FLS) was first observed on 3rd week (2018) and 2nd week (2019) of August. It was recognized by varying size circular to angular grayish green water-soaked spot with presence of narrow and dark brown margins and absence of yellowing around it. In the later stage, these spots become ashy gray to light brown in the central area (Figure 5d). Target Leaf Spot (TLS) was first appeared 3rd week of September during both year and initially recognized by minute to small chlorotic or reddish-brown spots with yellow halo. Later these spots increased in size and became round to irregular with dark brown center and thick dark brown border, resembling a shooting target (Figure 5e). Alternaria Leaf Spot (ALS) was first noticed on 2nd week (2018) and 4th week (2019) of September. ALS was characterized by presence of brown, necrotic spots with concentric rings, later coalesced and formed large necrotic areas on foliage (Figure 5f). Myrothesium leaf spot (MLS) was only noticed in the year 2019 on 3rd week of September.
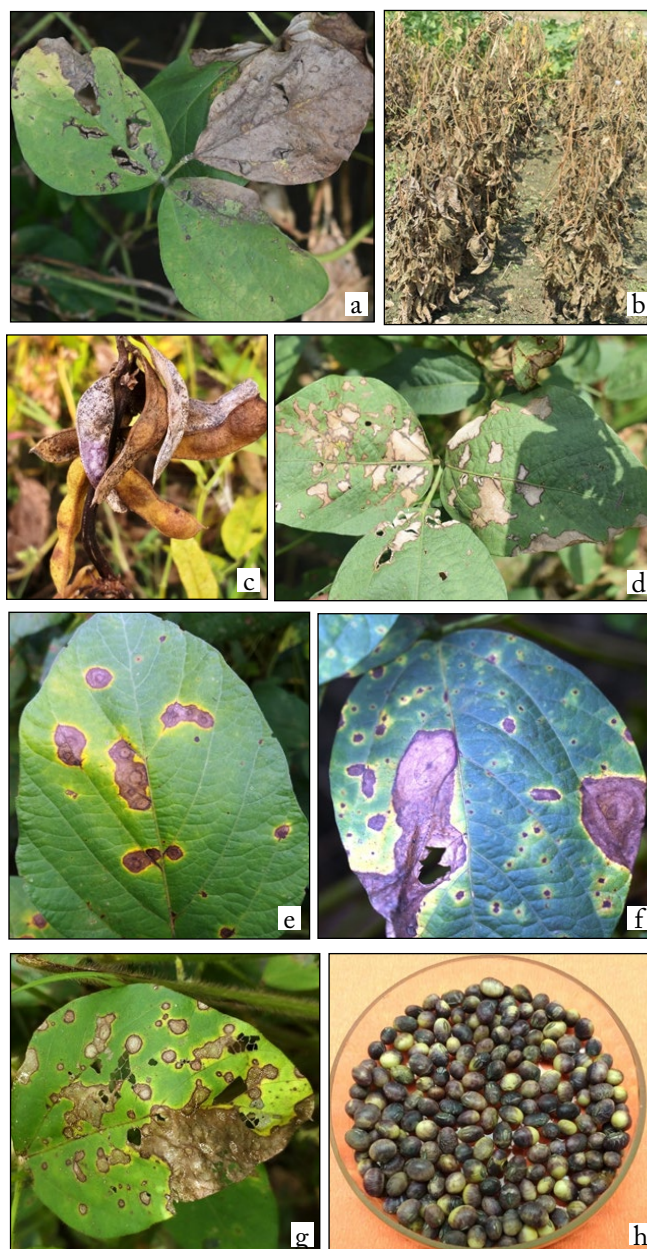

Figure 5: Pictorial depiction of Rhizoctonia aerial blight (RAB) (a), Charcoal rot (b), Pod blight (c), Frog eye leaf spot (FLS) (d), Target leaf spot (TLS) (e), Alternaria leaf spot (ALS) (f), Myrothesium leaf spot (MLS) (g) and Purple seed stain (PSS) (h), respectively at R_5-R_8 stage of soybean

Preliminary MLS was identified by presence of small round dark brown spots with brown or purple margins. Later these spots merged with each other and formed irregular necrotic lesion. Presence of white sporodochia as white erumpent structures was also noticed on translucent zone of the spots (Figure 5g). Purple Seed Stain (PSS) was noticed on 3rd week of September (2019) and 1st week of October (2019) at the time of physiological maturity of soybean (Table 1). PPS affected seeds of soybean exhibited light to dark purple

staining on seed that covered small to whole area of seed coat (Figure 5h)

It revealed that late reproductive stage (R_5-R_7) of soybean was more sensitive for pathogenic attack. In present investigation, incidence of eight diseases was recorded in nine soybean varieties during 3rd of week of September at late reproductive stages of soybean (Figure 6). Incidence of Aerial blight was noticed in almost all the varieties and ranged between 0.0–32.0 and 2.5–29.25% with the average of 14.94 and 15.72% during 2018 and 2019, respectively. Variety JS 20–98 was free from infection of aerial blight during 2018. The highest incidence of aerial blight was recorded in JS 335 in both the year. Pod blight ranged between 1.0–8.75 and 0.75–12.50% during 2018 and 2019, respectively. No pod blight infection was seen in JS 97–52 (2018), JS 20–98 (2018), JS 20–69 (2018 and 2019). The maximum numbers of infected pods were recorded in JS 93–05 in both the years. Charcoal rot was severe in different fields and all the varieties, except JS 20–34, were found to be affected. Incidence of charcoal rot ranged between 0.0–69.25 and 0.0–61.00% with the average of 31.72 and 19.67% during 2018 and 2019, respectively. No incidence of charcoal rot was observed in JS 20–98 (2019), JS 20–69 (2019) and JS 20–34 (2018 & 2019). In both the years, the maximum incidence was observed in JS 95–60.
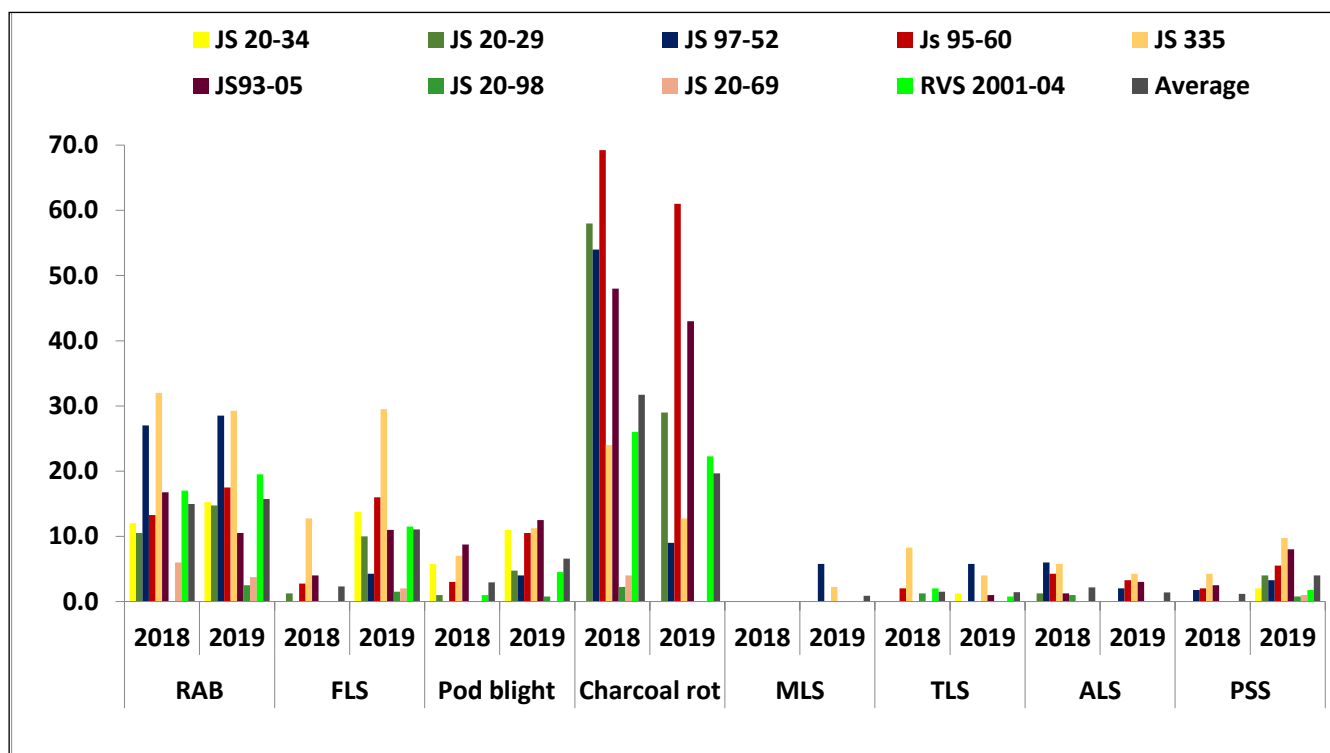

Figure 6: Per cent incidence of Rhizoctonia aerial blight (RAB), Frog eye leaf spot (FLS), Pod blight, Charcoal rot, Myrothesium leaf spot (MLS), Target leaf spot (TLS), Alternaria leaf spot (ALS) and Purple seed stain (PSS) among varieties of soybean at R_5-R_8 stage in Jabalpur during *kharif* 2018 and 2019

Among leaf spots, Frog eye leaf spot was ranged between 0.0–12.75 and 1.50–29.50% with the average incidence of 2.31 and 11.06% during 2018 and 2019, respectively. All the varieties were affected by FLS in 2019 and the highest incidence was recorded in JS 335. Incidence of Target Leaf Spot was ranged between 0.0–8.25 and 0.0–5.75% with the average of 1.50 and 1.42% during 2018 and 2019, respectively. Varieties such as JS 20–34 (2018), JS 20–29 (2018 and 2019), JS 97–52 (2018), JS 95–60 (2019), JS93-05 (2018), JS 20–98 (2019), JS 20–69 (2018 & 2019) were free from TLS disease. The maximum incidence was seen in JS 335 and JS 97–52 during 2018 and 2019. Incidence of alternaria leaf spot was low as compared to other diseases and most of the varieties were free of this disease. The highest incidence was recorded in JS 97–52 (6.00%) and JS 335 (4.25%) during 2018 and 2019, respectively. Incidence of Myrothesium leaf spot was only noticed during 2019 in JS 97–52 (5.75%) and JS 335 (2.25%). At the time of maturity, percentage of seed infected with purple seed stain was varied from 0.0–4.25 and 0.75–9.75 with the average of 1.17 and 4.00% during 2018 and 2019, respectively. Seeds of all the varieties were affected by PSS in 2019 and the highest incidence was seen in JS 335 in both the year. During the observations at late reproductive stage average maximum

temperature was 31.1 and 31.7°C, and relative humidity was 81.1 and 84.5% in 2018 and 2019, respectively.

3.2. Overall incidence of diseases (2018 and 2019)

Based on two-year data of survey it revealed that collar rot, root rot and soybean mosaic were major disease at early vegetative stage of soybean (V_2-V_2) with the incidence ranged of 0.0-4.88, 0.63–4.13 and 0.0–8.38% respectively. The highest incidence of collar rot, root rot and soybean mosaic were recorded in JS 335, JS 95–60 and JS 95–60, respectively (Table 2). Whereas yellow mosaic disease (YMD), Bacterial pustule and Anthracnose were predominant during flowering to pod development stage (R_2-R_4) with the incidence ranged of 0.0–35.0, 0.0–8.0, 0.00–35.13%, respectively. The maximum incidence of YMD, Bacterial pustule and Anthracnose was recorded in JS 93-05, JS 335 and JS 95-60, respectively. During seed development to maturity (R_5-R_7) Aerial blight, charcoal

rot, pod blight and frog eye leaf spot were predominating diseases with the incidence ranged of 1.25–30.63, 0.0–65.13, 0.0–10.63 and 0.75–21.13%, respectively. The varieties such as JS 335 (Aerial blight), JS 95-60 (Charcoal rot), JS 93-05 (pod blight) and JS 335 (frog eye leaf spot) were highly affected by these four diseases. Apart from this, low incidence of Target leaf spot (TLS), Myrothesium leaf spot (MLS) and Alternaria leaf spot (ALS) ranging of 0.0–6.13, 0.0–2.88 and 0.0–5.00% were also recorded during late reproductive stage (R5-R7). At the time of maturity, seed infection of purple seed stain (PSS) was recorded with the range of 0.38–7.00%. The highest seed infection of PSS was noted in JS 335 (Table 2). Overall average incidence among varieties indicated that charcoal rot was most severe (25.69%) disease followed by Aerial blight (15.33%), Yellow mosaic (13.89%), Anthracnose (8.92%), frog eye leaf spot (6.68%) and pod blight (4.76%) at Jabalpur.

Table 2: Average per cent incidence of major disease of soybean at different stage in Jabalpur during *kharif,* 2018 and 2019

Varieties	V_2-V_3 stage			R_2-R_4 stage			R_5-R_7							
	Collar rot	Root rot	Soybean mosaic	YMD	BP	Anthracnose	RAB	FLS	Pod blight	Charcoal rot	MLS	TLS	ALS	PSS
JS 20-34	0.38	0.63	3.00	11.50	0.00	1.63	13.63	6.88	8.38	0.00	0.00	0.63	0.00	1.00
JS 20-29	2.38	2.13	3.63	1.50	0.00	2.63	12.63	5.63	2.88	43.50	0.00	0.00	0.63	2.00
JS 97-52	2.75	1.13	0.00	6.25	0.00	0.00	27.75	2.13	2.00	31.50	2.88	2.88	4.00	2.50
JS 95-60	3.38	4.13	8.38	13.50	3.38	35.13	15.38	9.38	6.75	65.13	0.00	1.00	3.75	3.75
JS 335	4.88	2.13	6.50	22.13	8.00	7.25	30.63	21.13	9.13	18.38	1.13	6.13	5.00	7.00
JS 93-05	2.25	1.88	6.63	35.00	1.50	28.88	13.63	7.50	10.63	45.50	0.00	0.50	2.13	5.25
JS 20-98	0.75	0.75	0.00	2.25	0.00	0.00	1.25	0.75	0.38	1.13	0.00	0.63	0.50	0.38
JS 20-69	0.00	0.75	0.00	0.00	0.00	0.00	4.88	1.00	0.00	2.00	0.00	0.00	0.00	0.50
RVS 2001-04	2.88	1.50	6.88	32.88	0.00	4.75	18.25	5.75	2.75	24.13	0.00	1.38	0.00	0.88
Average	2.18	1.67	3.89	13.89	1.43	8.92	15.33	6.68	4.76	25.69	0.44	1.46	1.78	2.58
Range	0.0-4.88	0.63-4.13	0.0-8.38	0.0-35.0	0.0-8.0	0.00 -35.13	1.25-30.63	0.75-21.13	0.0-10.63	0.0-65.13	0.0-2.88	0.0-6.13	0.0-5.00	0.38-7.00

YMD: Yellow mosaic disease; BP: Bacterial pustule; RAB: Rhizoctonia aerial blight; FLS: Frog eye leaf spot; MLS: Myrothesium leaf spot; TLS: Target leaf spot; ALS: Alternaria leaf spot; PPS: Purple seed stain

India is among the prime (fifth-ranked) soybean-producing countries in the world. Despite this, the country largely depends on other countries to meet its vegetable oil demand. Soybean cultivation faces several diseases that greatly influence the yield potential of soybean in India. High yield losses in soybean (41.0, 64.8 and 100%) upon severe infection of aerial blight, anthracnose/pod blight and charcoal rot (55.6 and 75.2 and 100%, respectively) have been recorded under central Indian conditions (Amrate et al., 2023a; Amrate and Shrivastava, 2021). A severe

disease of soybean called yellow mosaic can cause as high as 85.7% yield reduction upon severe infection in earlier stages of the crop (Amrate et al., 2020). Experimental data reveals that the yield potential of recent varieties of soybean is higher (about 2.1 t ha⁻¹) than the average productivity (1.2 t ha⁻¹) of the country (Agrawal et al., 2013). In this concern, the productivity and sustainability of soybean in central and other parts of the country could be damaged by the fluctuating incidence and severity of several diseases in the crop.

This survey revealed that fourteen diseases were infecting soybean varieties with varying level of incidence under present scenario of cultivation in central Indian conditions. In vegetative stage collar rot, root rot and soybean mosaic were dominating with moderate level of incidence. Whereas in early reproductive stage yellow mosaic, Bacterial pustule and Anthracnose were major diseases. At late reproductive stage, aerial blight frog eye leaf spot charcoal rot pod blight, myrothesium leaf spot target leaf spot alternaria leaf spot and purple seed stain were varied from low to high. Previous findings also indicated presence of soybean diseases in India. Varying level of incidence and prevalence of these soybean diseases were also recorded by previous researcher at different locations in India. Sharma et al. (2014) mentioned that these diseases affect soybean crop at different stage of crop in different State of India. Srivastava et al. (2021) recorded varying range of YMD incidence (2.2–84.5%) in Bundelkhand region of Madhya Pradesh. Singh and Aravind (2019) recorded incidence of yellow mosaic and soybean mosaic in sixteen varieties of soybean in Uttarakhand. Rajput et al. (2021) reported that anthracnose disease of soybean was distributed throughout India and incidence was varying at different location and variety. High incidence charcoal rot has been noticed in current growing varieties, germplasm and advanced genotypes of soybean in different trials at JNKVV Jabalpur (Amrate et al. 2019; Amrate and Shrivastava, 2021). Mishra et al. (2021) recorded high severity of frog eye leaf spot (1.9 to 78.8%) among soybean genotypes under northern Indian conditions. Zade et al. (2018) recorded varying incidence (12.5–41.6%) of Alternaria leaf spot in soybean under central region of Vidarbha, Maharashtra. Fagodiya et al. (2021) also recorded incidence of Alternaria leaf spot with varying range (up to 42.35%) in different districts of Rajasthan. Ingle et al. (2016) recorded incidence of Root rot/Charcoal rot, Alternaia leaf spot, bacterial pustule and yellow mosaic virus in vidarbha region of Maharashtra. Bhatt et al. (2022) recorded mean incidence of pod blight (3.96–27.0%) infection in different districts of Uttarakhand. Myrothesium leaf spot was a serious disease in soybean during 1990–2000 decade (Shrivastava and Khan, 1994).

4. CONCLUSION

Charcoal rot (at R5-R7), Yellow mosaic (at R2-R4), Anthracnose/pod blight (at R5-R7), aerial blight (at R5-R7), and frog eye leaf spot (at R5-R7) were major among the fourteen diseases observed during the cropping season.

5. ACKNOWLEDGEMENT

7. REFERENCES

Agarwal, D.K., Billore, S.D., Sharma, A.N., 2013. Soybean: introduction, improvement, and utilization in India-problems and prospects. Agricultural Research 2, 293–300.10.1007/s40003-013-0088-0.

Amrate, P.K., Pancheshwar, D.K., Shrivastava, M.K., 2018. Evaluation of soybean germplasm against charcoal rot, aerial blight and yellow mosaic virus disease in Madhya Pradesh. Plant Disease Research 33(2), 185–190.

Amrate, P.K., Shrivastava, M.K., 2021. Yield response and pathological characterization of promising genotypes of soybean against major diseases in Madhya Pradesh. Journal of Oilseeds Research 38(4), 380–384.

Amrate, P.K., Shrivastava, M.K., Bhale, M.S., 2019. Resistance in soybean varieties against charcoal rot disease caused by *Macrophomina phaseolina*. Plant Disease Research 34(2), 124–128. DOI No. 10.5958/2249-8788.2019.00021.0.

Amrate, P.K., Shrivastava, M.K., Pancheshwar, D.K., 2021. Crop-weather based relation and severity prediction of Aerial blight incited by *Rhizoctonia solani* Kuhn in soybean. Journal of Agrometeorology 23(1), 66–73.

Amrate, P.K., Shrivastava, M.K., Pancheshwar, D.K., Stuti, S., 2020. Charcoal rot and yellow mosaic virus disease of soybean under hot spot condition: symptoms, incidence and resistance characterization. International Journal of Bio-resource and Stress Management 11(3), 268–273. DOI: HTTPS://DOI. ORG/10.23910/1.2020.2104.

Amrate, P.K., Shrivastava, M.K., Singh, G., 2023a. Identification of sources of resistance and yield loss assessment for aerial blight and anthracnose/pod blight diseases in soybean. Legume Research 46(11), 1534–1540. doi: 10.18805/LR-4452.

Amrate, P.K., Shrivastava, M.K., Borah, M., Routhu, G.K., Sharma, S., Nataraj, V., Pancheshwar, D.K., Singh, G., 2023b. Molecular characterization of soybean yellow mosaic virus isolates and identification of stable resistance sources in central India. Australasian Plant Pathology 52, 165–179. https://doi.org/10.1007/s13313-022-00902-8.

Banerjee, J., Shrivastava, M.K., Amrate, P.K., Singh Y., Upadhyay, A., Soni, M., 2022. Genetic variability and association of yield contributing traits in advanced breeding lines of soybean. Electronic Journal of Plant Breeding 13(2), 597–607.

Banerjee, J., Shrivastava, M.K., Singh, Y., Amrate, P.K., 2023. Estimation of genetic divergence and proximate composition in advanced breeding lines of soybean (*Glycine max* (L.) Merrill. Environment and Ecology 41(3C), 1960–1968. https://doi.org/10.60151/envec/VYWE5744.

Bandara, A.Y., Weerasooriya, D.K., Bradley, C.A., Allen, T.W., Esker, P.D., 2020. Dissecting the economic impact of soybean diseases in the United States over two decades. PLOS ONE 15(4), 0231141. https://doi.org/10.1371/journal.pone.0231141.

Belkar, Y.K., Gade, R.M., 2013. Management of root rot and collar rot of soybean by antagonistic microorganism. Journal of Plant Disease Sciences 8(1), 39–42.

Bhatt, P., Singh, K.P., Aravind, T., 2022. Distribution and identification of colletotrichum species associated with soybean anthracnose/pod blight in different geographical locations of Uttarakhand. Legume Research 45(8), 1042–1047. doi: 10.18805/LR-4856.

Fagodiya, R.K., Trivedi, A., Fagodia, B.L., Ratnoo, R.S., 2021. Prevalence and distribution of Alternaria leaf spot in soybean growing areas of Rajasthan. Indian Journal of Agricultural Sciences 91(5), 699–702. https://doi.org/10.56093/ijas.v91i5.112986.

Fagodiya, R.K., Trivedi, A., Fagodia, B.L., 2022. Impact of weather parameters on alternaria leaf spot of soybean incited by *Alternaria alternate*. Scientific Reports 12, 6131. https://doi.org/10.1038/s41598-022-10108-z.

Finoto, E.L., Soares, M.B., Neto, L.M., Dona, S., 2021. Sowing times in adaptation, stability, productivity and oil and protein contents of soybean genotypes. Revista Caatinga 34(4), 799–812.

Gupta, G.K., Chauhan, G.S., 2005. Symptoms, identification and management of soybean diseases. Technical Bulletin 10. National Research Centre for Soybean, Indore, India.

Ingle, V.Y., Chandankar, G.D., Patil, P.V., Patil, C.U., 2016. Evaluation of advance lines of soybean for resistance to major diseases under natural field conditions. Indian Journal of Agricultural Research 50(1), 84–87. doi: 10.18805/ijare.v50i1.8590.

Jahagirdar, S., 2019. Present status and future research dimensions of soybean diseases for sustainable productivity of soybean in India. Indian Phytopathology 72, 3–14. https://doi.org/10.1007/s42360-018-0102-3.

Kumar, S., Chand, G.A., Kumar, S., Singh, K.K., 2015. Occurrence and progression of some foliar diseases of Soybean [*Glycine max* (L.) Merrill]. Annals of Plant Protection Sciences 23(2), 308–312.

Kumari, S., Singh, K.P., Singh, N.K., Aravind, T., 2021. Assessment of genetic diversity among soybean genotypes differing in response to aerial blight using SSR markers. Journal of Phytopathology 169(1), 37–44.

Lin, F., Chhapekar, S.S., Vieira, C.C., 2022. Breeding for disease resistance in soybean: a global perspective. Theoretical and Applied Genetics 135, 3773–3872. https://doi.org/10.1007/s00122-022-04101-3.

Marabi, R.S., Chaukikar, K., Das, S.B., Bhowmick, A.K., 2017. Population dynamics of Whitefly, *Bemisia tabaci* and incidence of mungbean yellow mosaic India virus (MYMIV) on blackgram. International Journal of Bio-resource and Stress Management 8(6), 846–852.

Mathpal, M., Singh, K.P., 2017. Prevalence and severity of Rhizoctonia aerial blight of soybean in Uttarakhand. Indian Journal of Ecology 44(2), 417–419.

Mehra, S., Shrivastava, M.K., Amrate, P.K., Yadav, R.B., 2020. Studies on variability, correlation coefficient and path analysis for yield associated traits in soybean [*Glycine max* (L.) Merrill]. Journal of Oilseeds Research 37(1), 56–59.

Mengistu, A., Smith, J.R., Ray, J.D., Bellaloui, N., 2011. Seasonal progress of charcoal rot and its impact on soybean productivity. Plant Disease 95, 1159–1166. https://doi.org/10.1094/PDIS-02-11-0100 PMID:30732064.

Mishra, K.K., Bhartiya, A., Kant, L., 2021. Identification of resistance sources against frogeye leaf spot (FLS) disease of soybean caused by *Cercospora sojina* under hot spot conditions of Uttarakhand hills. Indian Phytopathology 74, 1117–1121. https://doi.org/10.1007/s42360-021-00399-z

Rajput, L., Nataraj, V., Kumar, S., Amrate, P.K., Jahagirdar, S., Huilgol, S.N., Chakruno, P., Singh, A., Maranna, S., Ratnaparkhe, M.B., Borah, M., Singh, K.P., Gupta, S., Khandekar, N., 2021. WAASB index revealed stable resistance sources for soybean anthracnose in India. Journal of Agricultural Science 159(9–10), 710–720. doi:10.1017/S0021859622000016.

Sajeesh, P.K., Rao, M.S.L., Jahagirdar, S., 2014. Screening of soybean [*Glycine max* (L.) Merill] genotypes against purple seed stain and anthracnose diseases. Environment and Ecology 32(3A), 1092–1095.

Sharma, A.N., Gupta, G.K., Varma, R.K., Sharma, O.P., Bhagat, S., Amaresan, N., Saini, M.R., Chattopadhyay, C., Sushil, S.N., Ram, A., Kapoor, K.S., Satyagopal, K., Jeyakumar, P., 2014. Integrated pest management for soybean. Director National Centre for Integrated Pest Management, IARI Campus, New Delhi, 41.

Shrivastava, S.K., Khan, S.U., 1994. Impact of host age at infection time on the severity of myrothecium leaf spot disease of soybean. Indian Phytopathology 47(2), 190–191.

Sagarika, M., Amrate, P.K., Yadav, V.K., Shrivastava, M.K., 2023. Exploring potential of new generation fungicides as seed dresser in combating early infection of *Macrophomina phaseolina* in soybean. Indian

Phytopathology 76, 1045–1053 https://doi.org/10.1007/s42360-023-00680-3.

Singh, K.P., Aravind, T., 2019. Identification of resistant sources against soybean yellow mosaic and soybean mosaic diseases in field evaluation of soybean (*Glycine max* (L.) Merr.) genotypes. Indian Phytopathology 72, 519–521. https://doi.org/10.1007/ s42360-019-00168-z.

Srivastava, A.K., Marabi, R.S., Bal, L.M., Yogranjan, 2021. Weather based rules for yellow mosaic disease prediction on soybean in Madhya Pradesh. Indian Journal of Biochemistry and Biophysics 58, 486–497.

Tripathi, N., Tripathi, M.K., Tiwari, S., Payasi, D.K., 2022. Molecular breeding to overcome biotic stresses in soybean: update. Plants 11, 1967. https://doi.org/10.3390/ plants1115196.

Uikey, S., Sharma, S., Amrate, P.K., Shrivastava, M.K., 2022. Identification of rich oil-protein and disease resistance genotypes in soybean [*Glycine max* (L.) Merrill]. International Journal of Bio-resource and Stress Management 13(5), 497–506. DOI: HTTPS://DOI.ORG/10.23910/1.2022.2478.

Wrather, A., Shannon, G., Balardin, R., Carregal, L., Escobar, R., Gupta, G.K., Ma, Z., Morel, W., Ploper, D., Tenuta, A., 2010. Effect of diseases on soybean yield in the top eight producing countries in 2006. Plant Health Progress, doi:10.1094/PHP-2010-0125-01-RS.

Zade, S.B., Ingle, Y.V., Mane, S.S., Gathe, A.G., 2018. Survey of alternaria leaf spot of soybean in central Vidarbha. Journal of Plant Disease Science 13(2), 17–20.