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Comparative analysis of altered weather parameters on Phoma leaf blight (*Phoma sojicola*) of soybean (*Glycine max*)

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ABSTRACT

Development of a plant disease like Phoma blight (*Phoma sojicola*) of soybean]*Glycine max* (L.) Merr.] in time and space is a variable, largely depending on environmental factors like temperature, precipitation and humidity. Considering importance of this disease, understanding its dynamics via mathematical and statistical models will help in disease forecasting and prevention of yield losses. To serve this objective, present study on epidemiology of Phoma leaf blight of soybean was carried out under natural epiphytotic conditions on 2 soybean cultivars (Shalimar soybean 1 and Kashmir local) at research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir during rainy (*kharif*) season 2019 and 2020. Weather factors significantly influenced disease development irrespective of crop cultivar as revealed by correlation matrix between weekly disease score and weather of preceding one and preceding three weeks. Disease intensity was found positively correlated with RH and rains while as the correlation with temperature was negative. It followed similar trend with all the three sets of weather parameter as weather of preceding one week and that of 3rd and preceding three weeks have contributed to the extent of 57, 50 and 51%, respectively. The study further reveals that optimum temperature for all the events of pathogenesis besides inoculum dispersal in this case lies below 25ºC while as the optimum relative humidity must be above 90% and this all is made possible when it rains at least once a week in the summer.

Keywords: Epidemiology, Phoma blight, *Phoma sojicola*, Soybean, Weather parameters

Soybean [*Glycine max* (L.) Merril] is an important field crop in the world and it was once a significant pulse crop of Jammu and Kashmir in 1940s and 1950s with annual production of 502 tonnes on 702.8 ha (Shurtleff and Aoyagi 2012). However, its cultivation has declined over the years and the biotic stress due to fungal and viral diseases is seen as an important limiting factor that might have affected its yield potential in the region. Fungal leaf blight being wide spread in nature and early appearance of the blight (V-1 stage) in soybean can reach a terminal intensity of 67.16% besides causing 51.72% yield loss (Subaya *et al.* 2022). Ascochyta blight is caused by a coelomycetous fungus called *Phoma sojicola* (Syn. *Ascochyta sojicola*) and it is considered identical to *Phoma pinodella* and *Phoma exigua* var. *exigua* (Kovics *et al.* 1999, Kovics *et al.* 2014). The fungus survives off-season in the form of pycnidia in diseased crop debris and also through dormant mycelium in infected seed. Moreover it is reported to form chlaydospores for off season survival. Conidia are released through natural opening of the pycnidium and the process is facilitated by moisture of any source, i.e. rain, dew etc. Therefore, weather is considered a vital component for the development of diseases in any crop and same is true with soybean blight caused by *Phoma sojicola*. According to earlier reports, Ascochyta blight is particularly favoured by cool temperatures, high relative humidity and the secondary infection within crop canopy during the cropping season occurs due to rain-splashed conidia (Lepoivre and Baudouin 1993, Tivoli and Banniza 2006). However, these epidemiology reports mention only the influence of weeklong weather components on disease development while as its possible influence on early stage pathogenesis like penetration and incubation is largely neglected. Hence, in the present investigation, two weeks weather components were considered to measure their possible influence on disease development taking into account the early stage pathogenesis.

MATERIALS AND METHODS

This experiment was laid to generate baseline data vis-a-vis soybean blight as influenced by host cultivars as well as weather components of variable duration on the disease at research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir during rainy (*kharif*) season 2019 and 2020. The study was carried out on 2 soybean cultivars (Shalimar

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Soybean 1 and Kashmir Local) each raised over an area of 100 m^2 during rainy (*kharif*) season 2019 at two locations, Sopore (Site-Wadura) and Budgam (Site-Soibugh). However, the experiment was repeated only at Sopore during the subsequent crop season of 2020. To ensure the presence of inoculum, border row plants were inoculated with *Phoma sojicola* spore suspension (5×10^6 conidia/ml) in the evening hours and then maintained unsprayed under natural epiphytotic conditions. The pathogen was brought in axenic culture on PDA using standard tissue bit transfer method (Yadav 2015). Spore mass was harvested from 15 days old colonies and the inoculum load was adjusted by using haemocytometer. Identification of this pathogen was confirmed on the basis of its morpho- cultural characteristics (Subaya *et al.* 2022) in the light of authentic reports of Abramov (1931), Boerema *et al.* (1997), Kovics *et al.* (1999) and Kovics *et al.* (2014). In each cultivar, disease intensity was recorded periodically at weekly intervals through physiological maturity on 30 randomly selected and tagged plants while using 0-9 disease scoring scale (0, No disease; 1, less than 10% diseased plant area; 2, 11–20%; 3, 21–30;% 4, 31–40%; 5, 41–50%; 6, 51–60%; 7, 61–70%; 8, 71–80% and 9, more than 80% diseased plant area) following Subaya *et al.* (2022) and was calculated by using the Mckinney's formula (McKinney 1923). The relevant data on weather variables was procured from Meteorology section of Division of Agronomy. The influence of weather variables, viz. temperature, RH and rain on the disease development was worked out by correlation matrix as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Epidemiology of Phoma blight generated three sets of disease intensities at two locations (Sopore and Budgam) for two consecutive rainy (*kharif*) seasons of 2019 and 2020. The data (Table 1 and Fig 1) revealed that disease development on Shalimar Soybean 1 (SS-1) and Kashmir local (KL) cultivars was alike at Sopore during 2019. Disease intensity of 9.91% in KL cultivar as recorded at 3rd week of June reached to 47.10% by 1st week of August. Similarly, the disease intensity of 7.81% in SS 1, as recorded at 3rd week of June, reached to 35.55% by the 1st week of August. The weekly increase in average disease intensity of two cultivars varied from 4.10–6.11 units and the prevailing temperature, RH, rainfall and number of rainy days during corresponding period ranged from 26.84–31.30ºC, 78.29–86.71%, 1.70–32.80 mm and 1–4 days a week, respectively. In the same year, the data recorded at Budgam revealed that disease development was again alike in both the soybean cultivars (Table 2 and Fig 1). Disease intensity of 9.76% in KL cultivar, as recorded at 3rd week of August, reached to 60.20% by 3rd week of October. Similarly, the disease intensity of 7.86% in SS 1 recorded at 3rd week of August reached to 46.20% during the same two months period. The weekly increase in average disease intensity of two cultivars varied from 3.42–6.90 units and the prevailing temperature, relative humidity, rainfall and number of rainy days during corresponding period ranged from 20.33–31.34ºC, 65.86–88.71%, 0-44.90 mm and 0–4 days a week, respectively. During 2020, disease development in SS 1 at Sopore was much more than that recorded in the previous year as the disease intensity reached 64.75% in the 3rd week of September after starting in 4th week of June (Table 3 and Fig 1). The weekly increase in the disease intensity varied from 1.98 to 8.23 units and the prevailing temperature, relative humidity, rainfall and number of rainy days during corresponding period ranged from 26.63–34.24ºC, 74.71–91%, 0.02–53.40 mm and 0-4 day a week, respectively.

The data sets on weekly increase in disease intensity and weather of preceding one week was subjected to correlation matrix analysis (Table 4). The results revealed that disease intensity was significantly correlated with RH, rainfall and number of rainy days. There was significant and negative correlation of disease with temperature. In order to assess the possible influence of weather on overall pathogenesis and inoculum dispersal, a novel correlation matrix analysis was attempted wherein weekly increase in disease was studied with respect to combined weather of preceding three weeks and also with preceding 3rd week. The results of correlation matrices (Supplementary Table 1) revealed positive and significant influence of weather of three weeks on disease development. However, the influence of temperature was again negative and non-significant. The influence of weather of preceding third week was largely insignificant except the influence of number of rainy days.

The data was also subjected to multiple regression analysis (Supplementary Table 2) for knowing the extent of

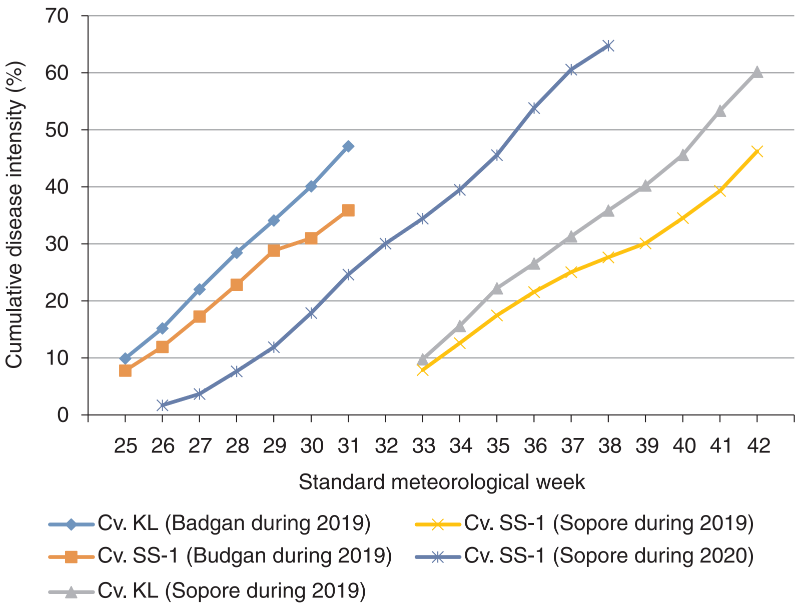

Fig 1 Disease progress curves of Phoma leaf blight of soybean.

Table 1 Effect of weather on Phoma leaf blight of soybean at Sopore during 2019

Date of observation	Weather of preceding one week				Weather of preceding three weeks				Weather of preceding 3rd week				Disease intensity			
													Cumulative (%)		Av. of two cultivars	
	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Cv. KL	Cv. SS 1	Cumulative (%)	Weekly increase
20-06-2019	26.84	81.14	1.70	3	25.78	82.43	84.30	10	24.94	82.00	34.40	3	9.91	7.81	8.86	
27-06-2019	27.24	84.14	15.40	4	26.54	83.29	65.30	11	25.54	85.00	48.20	4	15.2	11.92	13.56	4.70
04-07-2019	30.74	78.29	3.10	2	28.28	81.19	20.20	9	26.84	81.14	1.70	3	22.05	17.29	19.67	6.11
11-07-2019	30.49	80.43	1.70	1	29.49	80.95	20.20	7	27.24	84.14	15.40	4	28.43	22.85	25.64	5.97
18-07-2019	31.13	84.29	25.00	2	30.79	81.00	29.80	5	30.74	78.29	3.10	2	34.10	28.80	31.45	5.81
25-07-2019	31.06	81.43	19.30	3	30.89	82.05	46.00	6	30.49	80.43	1.70	1	40.10	31.00	35.55	4.10
01-08-2019	28.90	86.71	32.80	3	30.36	84.14	77.10	8	31.13	84.29	25.00	2	47.10	35.88	41.49	5.94

Table 2 Effect of weather on Phoma leaf blight of soybean at Budgam during 2019

Date of observation	Weather of preceding one week				Weather of preceding three weeks				Weather of preceding 3rd week				Disease intensity			
													Cumulative (%)		Av. of two cultivars	
	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Av. tem. (°C)	RH (%)	Rain (mm)	Rainy days (No.)	Cv. KL	Cv. SS 1	Cumula-tive (%)	Weekly increase
16-08-2019	29.47	86.43	44.90	3	29.57	88.00	98.00	12	31.00	85.00	52.40	7	9.76	7.86	8.81	
23-08-2019	27.34	79.00	5.30	3	29.51	84.00	55.90	8	31.73	86.57	5.70	2	15.62	12.60	14.11	5.30
30-08-2019	29.97	81.86	0.30	1	28.93	82.43	50.50	7	29.47	86.43	44.90	3	22.21	17.45	19.83	5.72
06-09-2019	31.23	77.43	0.20	1	29.51	79.43	5.80	5	27.34	79.00	5.30	3	26.54	21.54	24.04	4.21
13-09-2019	31.34	74.57	0.00	0	30.85	77.95	0.50	2	29.97	81.86	0.30	1	31.32	25.04	28.18	4.14
20-09-2019	30.97	73.57	0.00	0	31.18	75.19	0.20	1	31.23	77.43	0.20	1	35.85	27.65	31.75	3.57
27-09-2019	29.86	65.86	0.00	0	30.72	71.33	0.00	0	31.34	74.57	0.00	0	40.23	30.11	35.17	3.42
04-10-2019	25.60	84.57	14.70	3	28.81	74.67	14.70	3	30.97	73.57	0.00	0	45.61	34.53	40.07	4.90
11-10-2019	20.33	89.14	8.90	4	25.26	79.86	23.60	7	29.86	65.86	0.00	0	53.32	39.28	46.30	6.23
18-10-2019	25.56	88.71	13.20	1	23.83	87.48	36.80	8	25.60	84.57	14.70	3	60.20	46.20	53.20	6.90

Table 3 Effect of weather on Phoma leaf blight of soybean at Sopore during 2020

Date of observation	Weather of preceding one week				Weather of preceding three weeks				Weather of preceding 3rd week				Disease intensity on cv. SS 1	
	Av. Tem. (ºC)	RH (%)	Rain (mm)	Rainy days (No.)	Av. Tem. (ºC)	RH (%)	Rain (mm)	Rainy days (No.)	Av. Tem. (ºC)	RH (%)	Rain (mm)	Rainy days (No.)	Cumulative (%)	Weekly increase
26-06-2020	30.69	74.71	4.20	4	29.46	78.33	34.60	10	28.17	83.86	28.40	5	1.72	
03-07-2020	32.19	75.14	0.20	1	30.80	75.43	6.40	6	29.51	76.43	2.00	1	3.70	1.98
10-07-2020	32.24	75.29	5.30	2	31.70	75.05	9.70	7	30.69	74.71	4.20	4	7.67	3.97
17-07-2020	31.70	75.00	1.30	2	32.04	75.14	6.80	5	32.19	75.14	0.20	1	11.90	4.23
24-07-2020	30.53	83.00	1.47	3	31.49	77.76	8.07	7	32.24	75.29	5.30	2	17.88	5.98
31-07-2020	33.06	83.00	5.90	2	31.76	80.33	8.67	7	31.7	75.00	1.30	2	24.63	6.75
07-08-2020	33.49	82.00	0.90	2	32.36	82.67	8.27	7	30.53	83.00	1.47	3	30.04	5.41
14-08-2020	34.24	82.14	3.10	2	33.60	82.38	9.90	6	33.06	83.00	5.90	2	34.44	4.40
21-08-2020	32.60	83.43	13.20	4	33.44	82.52	17.20	8	33.49	82.00	0.90	2	39.47	5.03
28-08-2020	28.50	84.00	53.40	3	31.78	83.19	69.70	9	34.24	82.14	3.10	2	45.58	6.11
04-09-2020	26.63	91.00	17.60	5	29.24	86.14	84.20	12	32.6	83.43	13.20	4	53.81	8.23
11-09-2020	29.34	89.43	20.80	2	28.16	88.14	91.80	10	28.5	84.00	53.40	3	60.54	6.73
18-09-2020	30.77	84.71	0.00	0	28.91	88.38	12.80	2	26.63	91.00	17.60	5	64.75	4.21

influence of both preceding one week and preceding three weeks on disease development. The coefficients of preceding single week for temperature, RH, rainfall and number of rainy days were -0.027, 0.160, 0.002 and 0.043, respectively, and all the meteorological factors together contributed 57% towards Phoma blight development. Likewise, the coefficients for temperature, RH, rainfall and number of rainy days of preceding three weeks were -0.081, 0.083, 0.002 and 0.192 and all these factors together contributed 51% towards the disease development. The coefficient of number of rainy days of preceding 3rd week was 0.507 though weather factors of this week together contributed 50% towards the disease development.

Considering all the three data sets with respect to periodic increase in disease intensity and the weather of preceding one week and three weeks, the correlation analysis revealed adverse influence of higher temperature on disease. Basically the temperature has a major influence on the mycelial growth and pycnidial formation (Kasier 1973) and according to Roger *et al*. (1999), temperature influences pycnidiospore germination, appressoria formation and the germ-tube penetration in the leaf cuticle. The influence of rains and number of rainy days on disease development was significant and positive. It could be due to direct involvement of rain splashes in inoculum dispersal which was also indicated by correlation matrix as attempted between disease score and weather of preceding 3rd week. Role of rains in lowering temperature and becoming a source for rising relative humidity in the crop canopy can't be denied either. When compared with preceding one week, the correlation matrix of disease with preceding three week's rainfall and that of rainy days is more reliable as it is with due respect to the fact that disease development in a population is the result of all pre- and post-infection processes. The underlying reasons can be no more than the role of these factors in inoculum dispersal and post-rain favourable environment (low temperature and ensured leaf wetness). Our findings are supported by Kaur *et al*. (2011) who reported positive and significant correlation of rainy days with Ascochyta blight intensity of chickpea. Khaliq *et al*. (2020) also reported positive correlation of Ascochyta blight of chickpea with rainfall. Positive correlation with rainfall and rainy days reveals that rain should be facilitating secondary spread and subsequent infection. Coventry (2012) also reported that only wet pycnidia can release spores, so during rains, pycnidia imbibe water which generates hydrostatic pressure that forces conidia in the pycnidia to exude through the ostiole in the form of chain (cirrhus). When a raindrop strikes the cirrhus, the kinetic energy breaks up the spore mass and disperses the conidia to nearby healthy plants, thus ensures spreading of the disease. With more number of rainy days more will be the secondary spread as frequency of rain is critical for determining surface wetness and pathogen dispersal in plant population through splashing and trickling. Positive correlation of RH with Phoma blight observed in the present investigation may be due to its influence on sporulation and persistence of wetness as reported by Royle and Butlar (1986) earlier in a relevant investigation.

The present findings and all the above previous records support the idea of considering the three week's as well as preceding 3rd week's weather for assessing its influence on weekly dynamics of a disease like Phoma leaf blight. More frequent rains (9-12 days per 3 weeks period) help in inoculum dispersal as well as in lowering the diurnal temperature below 30ºC during cropping season coupled with relative humidity (80% and above) and this all can be a favourable weather set for maximum disease development in susceptible cultivars of soybean like Cv. SS 1 and Cv. KL. The influence of rain splashes on inoculum dispersal from an infection focus is well supported by the outcome of correlation and regression analysis when disease development was seen as dependant variable in relation with weather of preceding 3rd week. Insight of the data reveals that weekly average maximum temperature was mostly above 25ºC and RH was below 90%. In this context, the significant and negative correlation of temperature with disease development reflects that the optimum temperature range is somewhere below 25ºC. Similarly, the significant and positive correlation of RH reflects that optimum level of RH for proliferation of *Phoma sojicola* and subsequent disease development can be somewhere above 90%. Based on this study it is concluded that dry spells during the crop season will help contain this disease of soybean. This also hints at the possibility of managing this disease by altering sowing date such that most or some of the early growth stages receive less frequent rains.

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