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Effect of Weather Parameters on the Severity of Sorghum Anthracnose

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ABSTRACT

One of the most important diseases of Sorghum crop with great economic significance is anthracnose caused by *Colletotrichum*. The understanding of weather conditions predisposing for spread and development of the disease is essential to organize Agro Advisory Services (AAS) for the growers to take timely management decisions for anthracnose of sorghum. Experimental area received variable environmental conditions during 2014 and 2015 season. The weather conditions prevailing during mid July to October were the most favorable for occurrence of disease. The study revealed that the temperature, relative humidity and rainfall had a significant role in epidemiology.

Keywords Anthracnose, AAS, Epidemiology, Favorable

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) crop is traditionally grown in an area, where there is high ambient temperature and low soil moisture (Wenzel and Van Rooyen 2001, Machado *et al*. 2002, Gebeyehu *et al*. 2004). It is a tropical crop belongs to the Poaceae family which might have originated from northeast Africa and was supposed to be domesticated about 3000–5000 years ago (Pedersen *et al*. 2003). The crop is best suited to hot and dry agro-ecosystem where other food grains are difficult to grow. These areas can be recognized easily by fragile environments and are frequently under drought-prone condition. More than 35% of the sorghum production is utilized directly for human consumption. The remaining is used for animal feed, industrial products and production of alcohol (Awika and Rooney, 2004).

Sorghum is a cereal crop of warm, temperate and semiarid region which is adapted to latitude ranges from 45°N to 45°S of the equator. It has an outstanding ability to produce grain under conditions too severe for most of the cereals, particularly in hot, dry climates and in soils of relatively low moisture content (Prasad 2012). In India the topmost sorghum producing states are Maharashtra, Karnataka, Gujrat, Rajasthan, Andhra Pradesh, Uttar Pradesh and Madhya Pradesh. Maximum sorghum producer state in India is Maharashtra.

Fungi cause many severe diseases, such as root and stalk rot caused by *Fusarium moniliforme*, *Fusarium thapsinum*, or *Colletotrichum* spp.,

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seedling diseases induced by *Pythium* spp., foliar disease such as leaf blight, caused by *Exserohilum turcicum*, zonate leaf spot by *Gloeocercospora sorghi*, Ergot by *Claviceps sorghi*, sooty stripe by *Ramulispora sorghi*, rust by *Puccinia purpurea* and head smut by *Sporisorium reilianum*, respectively (Waniska *et al.* 2001, Prom *et al*. 2005). Several management strategies towards limiting the effect of anthracnose of sorghum have been used with different achievements on the basis of pathosystems. More diverse types of foliar biocontrol agents need to be evaluated for developing eco-friendly and sustainable approach for management of sorghum anthracnose (Rana *et al.* 2020). Breeding for resistance, which has been found to be the most practical, economical and feasible method for plant disease management is not able to match with the development of more virulent pathogens. It is well known that pathogenic variability creates difficulty for the identification of an effective host resistance and its deployment, which is a reliable and economic practice of plant disease management.

MATERIALS AND METHODS

Field experiments were conducted during the *kharif* season 2014-2015 and 2015-2016 at Livestock Research Center, G.B. Pant University of Agriculture and Technology, Pantnagar.

Effect of weather parameters on disease development

Experiment was conducted in 2014 and 2015 during sorghum growing season at livestock research center, G.B. Pant University of Agriculture and Technology, Pantnagar. The average relative humidity is highest (70–80%) in July – August and December – January, while lowest (35–40 %) in April – May. During the summer, the temperature exceeds 40°C. Average rainfall in this area is about 1400 mm per annum. Correlation analysis was performed using PROC CORR procedure of the SAS computer package to determine relationship among the PDI and weather variables. A similar regression analysis procedure was used by Tarekegn and Tadege (2006). The regression equation was carried out between PDI and weather parameters. The observations were taken at 15 days interval.

Control plots were sprayed with the same volume of water. Observations on PDI was recorded in 1-9 scale after 90 days of sowing. Following formula was used to calculate the percent disease index.

$$\text{Per cent disease index (\%)} = \frac{\text{Sum of numerical rating}}{\text{Total no. of sample} \times \text{Maximum rating grade}} \times 100$$

Formula to calculate Area under disease progress curve (AUDPC) was given by Shaner and Finney (1977).

$$\text{AUDPC} = \frac{\left(\frac{D_1+D_2}{2}\times T\right)+\left(\frac{D_2+D_3}{2}\times T\right)+\left(\frac{D_3+D_4}{2}\times T\right)}{n-1}$$

Where,

D = Per cent disease index at different dates (D_1, D_2, D_3 and so on)

T=Time interval (days) between two observations

n =Total number of observations

RESULTS AND DISCUSSION

Epidemiological studies

Effect of weather parameters on disease development

The understanding of weather conditions predisposing for spread and development of the disease is essential to organize Agro Advisory Services (AAS) for the growers to take timely management decisions for anthracnose of sorghum. Experimental area received variable environmental conditions during 2014 and 2015 season.

Disease assessment

Data revealed that out of twenty genotypes, PDI was highest on susceptible variety PC 23, while min-

Table 1. Weather parameters during 2014 and 2015.

Days after sowing	Temperature (⁰C) Maximum 2014	Maximum 2015	Minimum 2014	Minimum 2015	Relative humidity (%) Morning 2014	Morning 2015	Evening 2014	Evening 2015	Total rainfall (mm) 2014	2015
45DAS	30.52	32.56	26.02	25.40	88.47	85.73	66.93	69.53	103	155.2
60 DAS	32.99	32.10	25.84	25.66	89.87	87.27	68.4	70.83	37.8	123.1
75DAS	33.77	32.31	25.52	25.42	86.60	89.33	62.20	68.78	2.4	40.4
90 DAS	32.83	34.23	23.87	24.77	88.73	86.20	65.40	60.00	34.8	0
105 DAS	32.23	32.27	21.66	21.30	89.93	86.67	59.53	58.53	6.6	112.00

imum on PC5 in both seasons. Data observed at 15 days interval showed remarkable increase in PDI. During 2014, maximum increase of PDI occurred in second fortnight of August when the environmental conditions were ; maximum temperature: 30.52⁰C , minimum temperature: 26.02⁰C, relative humidity (morning): 88.47%, relative humidity (evening): 66.93% and rainfall : 103mm. During 2015, also the disease increased in the mid of August, with maximum temperature : 32.56⁰C, minimum temperature: 25.40⁰C, relative humidity (morning) : 85.73%, relative humidity (evening) : 69.53% and rainfall : 155.2 mm. Data indicated that the disease kept on increasing till the end (Table 1). The disease development seemed to depend on prevailing environmental conditions. In general, the weather conditions prevailing during mid July to October were most favorable for occurrence of disease.

Correlation and regression between PDI and weather parameters

The correlation and regression analysis were done to establish relationship between various weather parameters viz., maximum temperature, minimum temperature, relative humidity and rainfall with PDI.

Correlation Analysis

Correlation studies were carried out to find out

Table 2. Correlation between PDI and weather parameters (2014).

Genotype	Temperature (⁰C) Maximum	Minimum	Relative humidity (%) Morning	Evening	Total rainfall (mm)
ICSB654	-0.2802	-0.6867	0.136623	-0.5979	-0.92546
ICSB2012	-0.36787	-0.78827	0.164504	-0.72054	-0.91832
ICSB474	-0.30941	-0.73707	0.122849	-0.66139	-0.92034
ICSB12015	-0.36731	-0.74946	0.219389	-0.6629	-0.92792
ICSV467	-0.41422	-0.8346	0.163334	-0.73266	-0.86742
ICSV12019	-0.43854	-0.84156	0.202981	-0.73206	-0.87307
IS3089	-34674	-0.86866	0.198061	-0.75554	-0.84674
ICSV12021	-0.3966	-0.80509	0.171334	-0.68365	-0.8719
IS23586	-0.38196	-0.77998	0.195503	-0.67603	-0.90659
PC5	-0.33593	-0.77407	0.106163	-0.68668	-0.88702
IS23521	-0.39351	-0.78491	0.217032	-0.70099	-0.91834
CSV21F	-0.36369	-0.82292	0.103142	-0.8026	-0.90348
IS2095	-0.31958	-0.78045	0.075236	-0.732	-0.90211
SSG 59-3	-0.48873	-0.851	0.284707	-0.72988	-0.87293
IS10302	-0.36277	-0.75015	0.213009	-0.67927	-0.9336
Kekri local	-0.44809	-0.86397	0.149804	-0.73239	-0.79627
IS473	-0.40374	-0.76958	0.236946	-0.61686	-0.88246
ICSB405	-0.47721	-0.83444	0.290605	-0.71999	-0.88378
PC4	-0.30116	-0.73365	0.119665	-0.67832	-0.9349
PC23	-0.44713	-0.84918	0.180595	-0.70449	-0.82048

Table 3. Correlation between PDI and weather parameters (2015).

Genotypes	Temperature (^{0}C) Maximum	Relative humidity (%) Minimum	Morning	Evening	Total Rainfall (mm)
ICSB654	0.339055	-0.7466	0.125248	-0.86528	-0.60168
ICSB2012	0.223431	-0.66463	0.269258	-0.73069	-0.59153
ICSB474	0.248561	-0.63997	0.279279	-0.72524	-0.62097
ICSB12015	0.259772	-0.65392	0.269789	-0.74382	-0.62575
ICSV467	0.179033	-0.62578	0.346872	-0.67404	-0.60048
ICSV12019	0.142624	-0.63311	0.34969	-0.65814	-0.56784
IS3089	0.226952	-0.62528	0.322653	-0.70172	-0.6295
ICSV12021	0.147015	-0.67512	0.325314	-0.69615	-0.55775
IS23586	0.247927	-0.65202	0.281853	-0.73557	-0.62278
PC5	0.226375	-0.62943	0.333692	-0.7057	-0.63665
IS23521	0.158494	-0.63985	0.350364	-0.6739	-0.58405
CSV21F	0.257247	-0.68426	0.242081	-0.76713	-0.60565
IS2095	0.137995	-0.71795	0.271396	-0.72476	-0.51378
SSG 59-3	0.231417	-0.63053	0.302792	-0.70783	-0.62039
IS10302	0.247008	-0.59268	0.308488	-0.68466	-0.63662
Kekri local	0.075483	-0.765	0.267301	-0.72719	-0.45215
IS473	0.20545	-0.65635	0.339663	-0.71674	-0.62203
ICSB405	0.268158	-0.63593	0.320695	-0.73646	-0.66695
PC4	0.210358	-0.67384	0.285836	-0.73172	-0.59103
PC23	0.168853	-0.61711	0.373313	-0.66181	-0.60831

whether the factors selected are positively or negatively related or there is no relation between them. Correlation coefficient means that : For unit change with independent variable i.e., weather parameters, how much change takes place in case of dependent variable i.e., PDI.

In the present study PDI of anthracnose of sor-

Table 4. Multiple linear regression equation of per cent disease index and weather parameters (2014).

Genotypes	R^2 Coefficient of determination	Multiple regression equation
ICSB654	0.925	$Y= 291.275-6.068_{X1}-0.168_{X2}-0.273_{X3}$
ICSB2012	0.978	$Y= 648.544-11.987_{X1}+2.048_{X2}-0.263_{X3}$
ICSB474	0.940	$Y= 316.514-5.507_{X1}-0.934_{X2}-0.147_{X3}$
ICSB12015	0.983	$Y= 283.178-6.771_{X1}+0.095_{X2}-0.252_{X3}$
ICSV467	0.954	$Y=957.981-16.809X_{X1}-3.835_{X2}-0.240_{X3}$
ICSV12019	0.969	$Y=869.602-16.008_{X1}-3.155_{X2}-0.248_{X3}$
IS3089	0.969	$Y=1060.147-18.648_{X1}-4.201_{X2}-0.232_{X3}$
ICSV12021	0.930	$Y=828.803-14.898_{X1}-3.012_{X2}-0.252_{X3}$
IS23586	0.960	$Y=480.459-9.155_{X1}-1.166_{X2}-0.221_{X3}$
PC5	0.922	$Y=473.567-7.909_{X1}+-1.878_{X2}-0.140_{X3}$
IS23521	0.986	$Y=437.197-9.296_{X1}-0.828_{X2}-0.247_{X3}$
CSV21F	0.991	$Y=981.062-16.366_{X1}-4.212_{X2}-0.244_{X3}$
IS2095	0.951	$Y=923.952-15.142_{X1}-3.967_{X2}-0.255_{X3}$
SSG 59-3	0.993	$Y=591.093-11.789_{X1}-1.428_{X2}-0.213_{X3}$
IS10302	0.990	$Y=285.887-6.657_{X1}+0.031_{X2}-0.248_{X3}$
Kekri local	0.921	$Y=1427.223-24.048_{X1}-6.389_{X2}-0.234_{X3}$
IS473	0.929	$Y=419.161-9.143_{X1}-0.592_{X2}-0.242_{X3}$
ICSB405	0.996	$Y=432.880-8.858_{X1}-0.743_{X2}-0.186_{X3}$
PC4	0.961	$Y=438.524-7.632_{X1}-1.208_{X2}-0.035_{X3}$
PC23	0.919	$Y=1195.182-20.583_{X1}-4.866_{X2}-0.243_{X3}$

Table 5. Multiple linear regression equation of per cent disease index and weather parameters (2015).

Genotypes	R^2 Coefficient of determination	Multiple regression equation
ICSB654	0.996	$Y= 4868.939-64.193_{X1}-30.212_{X2}-0.970_{X3}$
ICSB2012	0.986	$Y=4350.286-58.880_{X1}-26.290_{X2}-0.877_{X3}$
ICSB474	0.984	$Y= 3497.015-47.396_{X1}-21.148_{X2}-0.713_{X3}$
ICSB12015	0.991	$Y=4254.092-57.516_{X1}-25.773_{X2}-0.867_{X3}$
ICSV467	0.981	$Y=3834.367-52.713_{X1}-22.862_{X2}-0.784_{X3}$
ICSV12019	0.974	$Y=5050.443-69.787_{X1}-30.141_{X2}-1.027_{X3}$
IS3089	0.986	$Y=4334.322-59.142_{X1}-25.972_{X2}-0.890_{X3}$
ICSV12021	0.989	$Y=3620.889-49.623_{X1}-21.630_{X1}-0.728_{X3}$
IS23586	0.991	$Y=4072-55.1179_{X1}-24.5777_{X2}-0.8289_{X3}$
PC5	0.992	$Y=2463.964-33.642_{X1}-14.721_{X2}-0.5077_{X3}$
IS23521	0.983	$Y=3202.650-43.970_{X1}-19.020_{X2}-0.650_{X3}$
CSV21F	0.995	$Y=4142.119+-55.705_{X1}-25.163_{X1}-0.835_{X3}$
IS2095	0.990	$Y=4541.540-61.914_{X1}-27.409_{X2}-0.899_{X3}$
SSG 59-3	0.983	$Y=3422.909-46.2709_{X1}-20.4585_{X2}-0.6949_{X3}$
IS10302	0.968	$Y=3983.473-54.215_{X1}-23.945_{X2}-0.820_{X3}$
Kekri local	0.997	$Y=4686.2115-64.051_{X1}-28.231_{X2}+-0.914_{X3}$
IS473	0.998	$Y=4183.295-57.378_{X1}-25.022_{X2}-0.859_{X3}$
ICSB405	0.999	$Y=3662.781-49.652_{X1}-21.908_{X1}-0.757_{X3}$
PC4	0.992	$Y=3577.051-48.349_{X1}-21.458_{X1}-0.719_{X3}$
PC23	0.984	$Y=3170.284-43.419_{X1}+-0.011_{X1}+0.445_{X3}$

ghum was found to be greatly affected by weather parameters which prevailed during crop growth period. The relationship between PDI and weather factors during 2014 and 2015 indicated significant results. During first experimental season 2014, significant positive correlation between morning relative humidity and PDI was found (Table 2). However, other parameters i.e., maximum temperature, minimum temperature and evening relative humidity were negatively correlated with PDI whereas during 2015, significant positive correlation between maximum temperature, morning relative humidity and PDI was found (Table 3). However, minimum temperature, evening relative humidity and rainfall were negatively correlated with PDI.

Regression analysis

Regression analysis is a mathematical tool which is used to quantify the established relationship (by correlation studies) between the studied factors. These equations explain that with one unit increase or decrease of one factor there is certain amount of change with other factors. Based on multiple regression coefficient, multiple equations were designed for the prediction of PDI depending on weather parameters.

Multiple regression analysis

Under present investigation multiple regression was run between weather parameters (independent variables) and PDI (dependent variable). The multiple regression equation was fitted to the data and the equations derived for the weather parameters in two crop seasons 2014 and 2015 were presented in (Tables 4 and 5) . Very high values of R^2 indicates a high significant level between the factors studied. Therefore, from the above study it can be concluded that temperatue, relative humidity and rainfall had a significant role in epidemiology. PDI is directly related to the weather parameters. The correlation between independent and dependent variables generated a very important information which can be used in disease prediction.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$

Where,

a	=	Intercept
Y	=	Percent Disease Index
X_1	=	Maximum temperature
X_2	=	Relative Humidity
X_3	=	Rainfall

Chambers (1969) found that high humidity and prolonged leaf wetness were more important than amount of rainfall, they are necessary factors for infection of anthracnose in Lama bean. Singh *et al*. (2009) observed that relative humidity was positively correlated with disease development of anthracnose of guava whereas rainfall and number of rainy days had non-significant correlation with the per cent disease index. These factors may help in increasing the relative humidity of the atmosphere which indirectly help in further disease development of anthracnose disease. Chala *et al.,* (2010) studied disease severity and relationship between weather parameters and disease severity of anthracnose on resistant (2001 PWColl No. 022 and 2001 hararghie Coll NO. 12) and susceptible (BT×623 and AL70) lines of sorghum. The Ethiopian genotype 2001 PWColl No. 022 had lowest disease severity regardless the growing season. The disease appeared late and progressed slowly on this genotype whereas disease severity was maximum on BT×623. The correlation and regression analysis showed strong relationship between rainfall and anthracnose, while there was no effect of temperature on disease severity. Erpelding and Louis (2004) investigated sorghum germplasm from West Africa to identify sources of resistance against anthracnose. Resistance response was found with 245 accessions during dry season and 215 in wet season which indicates that wet season is more favorable for disease development. Kulkarni and Benagi (2012) correlated weather factors with disease severity of *Colletotrichum truncatum*. The maximum and minimum temperature had negative correlation with disease severity in the year 2007 and 2008. However, non significant positive correlation was found with relative humidity and rainfall.

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