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Effect of Weather Parameters on Red Rot of Sugarcane

Mitalkumari Ishvarbhai Patel*, Priya John, Shivangi S. Kansara and Kotramma C. Addangadi
Department of Plant Pathology,
N.M. College of Agriculture Navsari, Agricuture University, NAU, Navsari (Gujarat), India.

(Corresponding author: Mitalkumari Ishvarbhai Patel)*
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ABSTRACT: Numerous factors contribute to the disease's incidence, and certain environmental factors are also important in identifying the disease's cause and severity. Therefore, the current study was conducted to determine how weather affects the prevalence of red rot disease, which is caused by *Collectotrichum falcatum* Went. In South Gujarat, red rot has become a significant issue for sugarcane cultivation. Weather plays an important role in disease development. Minimum temperature, morning and evening relative humidity, rain fall and rainy days are more favourable for the progress of the red rot during 27th to 32th MSW (July to August) at Navsari, Gujarat. The stepwise regression analysis highlights that including additional predictor variables improved the model's ability to explain the variance in the disease incidence of red rot. During 2021-22 and 2022 to 2023, the final model added with evening relative humidity to the previous variables (rainy days and wind speed), showed an R^2 value of 0.712 indicating that the inclusion of all three predictors explains 84.4 per cent of the variation in the red rot incidence.

Keywords: Sugarcane, red rot, *Colletotrichum falcatum*, weather parameter, correlation.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L., Family: Gramineae), long duration, a C4, cash propagated plant. It is cultivated in both tropical and subtropical regions globally. The leading sugarcane producing countries are Brazil, India, Thailand, Pakistan, Mexico, and Australia. India has emerged as the world's largest producer and consumer of sugar as well as the world's 2nd largest exporter of sugar after Brazil2021-22 (Anonymous, 2024). It contributes nearly 70 present of world sugar production and provides raw material for many other by products (Gawade *et al.,* 2012). Sugarcane is also used for the manufacture of biofuel, where the cane can be utilized to make ethanol. Red rot disease was first reported from Java/Indonesia by Went in 1893 (Went, 1893) and called the fungus *Colletotrichum falcatum* Went and disease named as het root snot meaning red smut disease. Red rot disease from India was first recorded by Barber (1901). Red rot disease of sugarcane is widely distributed and has been reported in 68 sugarcane growing countries of the world (Bharti *et al.,* 2012). Many factors which are responsible for the development of red rot disease in which weather factors also play a crucial role in determining the cause of the disease. Depending on the weather conditions, different symptoms are observed. If the isolates are virulent, the variety is susceptible and the atmosphere is congenial, the fungus invades the host tissues and causes red rot. About 10 to 15 per cent of the nation's sugar yield is lost due to diseases of sugarcane (Viswanathan and Rao 2011). Thus, the present investigation was carried out to study the effect of weather parameters on incidence of red rot disease in sugarcane. Agro-climatic conditions influence the crop growth and nutrient use efficiency. Climatic factors are impacted by both spread and severity of red rot.

In recent years, the global sugarcane industry has witnessed fluctuations in production and productivity due to various factors, including climate change, pest and disease pressures, and market dynamics. However, fluctuations in weather patterns continue to affect production and productivity in these regions due to red rot. Therefore, weather based models can be an effective scientific tool for forewarning diseases in advance. Forewarning of disease is important for crop production management and taking timely plant protection measures.

MATERIAL AND METHOD

A field experiment was conducted at College farm, N.M.C.A, NAU, Navsari- 396450 during 2021-22 and 2022-2023 with sugarcane CoC 671 variety. The crop were sown with respective dates *i.e.* 04/01/2022 and 06/01/2022, harvested at *i.e.* 28/11/2022 and 01/12/2023, spacing was 90 cm × 90 cm with gross plot size was = 6.3m × 2.7 m (3 row, 30 two eye bud/row = 90 plants) and net plot size was= 5.3 m × 1.8 m (1 row, 18 two eye bud/row = 54 plants) to find out the effect of all the weather factors associated with the disease development of red rot sugarcane.

Fifty sugarcane plants were tagged for observations on red rot. The normal agronomic practices were adopted to raise the crop except spraying of any fungicides.

Observations on meteorological data related to the weather conditions prevailing during crop season regarding temperature (°C), relative humidity (%), rainfall (mm) and sunshine (h) were obtained from Meteorological Department, NMCA, NAU, Navsari. The observation on first appearance of red rot was carefully recorded. Thereafter, progress of the disease development was recorded; incidence was calculated at standard meteorological week during the crop period (planting to harvest) Calculated correlation and stepwise regression.

RESULT AND DISCUSSION

Epidemiological studies are typically categorized into two types: (1) which aim to investigate the influence of a broad range of variables related to the host, pathogen and environment on disease development and (2) focus on a few key variables to explain the majority of factors affecting the epidemic.

Progress of red rot in CoC 671under natural condition during 2021-2022. The crop was sown on 4th January 2022 and harvested on 28th November 2022. The first symptoms of red rot on leaves were observed during 22nd MSW with an initial per cent disease incidence was 2.00 per cent. From the 22ndMSW to 48th MSW, there was linear progress of the disease during the entire crop season (Table 1). The main peak period of the red rot was recorded during 27th MSW to 30th MSW.

Progress of red rot in CoC 671 under natural condition during 2022-2023. The crop was sown on 6th January of 2023 and harvested on 1th December 2023. The first symptoms of red rot on leaves were observed during 27th MSW with an initial per cent disease incidence of 2.00 per cent. From the 26th MSW to 48th MSW, there was linear progress of the disease during the entire crop season (Table 2).The main peak period of the red rot was recorded during 31th MSW to 35th MSW.

Comparatively, red rot incidence was more during 2023 than in 2022. During 31th to 35th standard weeks, there was very fast development of the disease due to congenial condition. Hence, this period can be considered as a window period for the red rot of sugarcane CoC 671 in Navsari condition.

Progress of red tot in CoC 671 under natural condition in pooled. The first symptoms of red rot on leaves were observed during 22th MSW with an initial disease incidence of 1.00 per cent. From the 22th MSW to 48th MSW, there was linear progress of the disease during the entire crop season (Table 3). The main peak period of the red rot was recorded during 27th MSW to 32th MSW.

From the results of the present investigation, it is very clear that red rot of sugarcane is very important and become a major disease in Navsari district. Hence, it causes heavy losses, because its infection starts at the tillering stage so, it directly affects the yield. The infection on tillering to growth phase produced a huge quantity of inoculum in favourable climatic conditions. Due to the presence of a heavy load of inoculum, the pathogen attacked on the economic part at maturity stage to harvesting stage and resulted yield loss.

Correlation of red rot incidence with weather parameters during 2021-2022. Red rot of sugarcane was initiated on 22th MSW. Previous two weeks 20th and 21th MSW were recorded minimum temperature *i.e.,* 27.00 and 27.70°C, morning relative humidity *i.e.,* 83.00 and 81.00 per cent and evening relative humidity *i.e.* 64.00 to 65.00 per cent, respectively. These conditions favoured for initiation of the red rot disease at tillering stage. More favourable weather conditions *viz.*, minimum temperature, morning and evening relative humidity, rain fall with rainy days lead to more progress of the disease during 27th to 33rd MSW.

Correlation matrix worked out (Table 4) showed that maximum temperature (-0.410**) and bright sun shine hours (-0.738*) was found highly significantly and negatively correlated while, minimum temperature (0.419**), morning relative humidity (0.383**), evening relative humidity (0.713**), rain fall (0.702**) and rainy days (0.728**) was found highly significantly and positively correlated. Wind speed (0.272) was found positively correlated. Minimum temperature, morning and evening relative humidity, rainfall and rainy days are very important, playing greater role in the disease development as compared to other weather parameters.

Correlation of red rot incidence with weather parameters during 2022-2023. Red rot of sugarcane was initiated on 27th MSW. Previous two weeks 25th and 26th MSW were recorded with minimum temperature *i.e.,* 27.94 and 23.93°C, morning relative humidity *i.e.,* 82.16 and 98.09 per cent and evening relative humidity *i.e.* 65.57 to 93.17 per cent, respectively. These conditions favoured for initiation of the red rot tillering stage (Table 5). More favourable weather conditions *viz.*, minimum temperature, morning and evening relative humidity, wind speed, rain fall with rainy days lead to more progress of the disease during 31th to 35th MSW.

Correlation matrix worked out showed that minimum temperature (0.415**), morning relative humidity (0.515**), evening relative humidity (0.652**), rain fall (0.296**) and rainy days (0.497**) were found highly significant and positively correlated while wind speed (0.002*) were found significant and negatively correlated. Minimum temperature, morning and evening relative humidity, rain fall and rainy days were very important playing greater role in the disease development compared to other weather parameters.

Correlation of red rot incidence with weather parameters in pooled. The pooled data analysis over two years of field evaluation found that red rot is dominant in Navsari district because of the presence of a pathogen and prevalence of congenial weather conditions (Table 6). Minimum temperature, morning and evening relative humidity, rain fall and rainy days are more favourable for the progress of the red rot during 27th to 32th MSW, respectively.

Correlation matrix worked out showed that maximum temperature (-0.431**) and bright sun shine hours (-0.399**) was found highly significantly and negatively correlated while minimum temperature (0.485**), morning relative humidity (0.583*), evening relative humidity (0.755**), rain fall (0.709**) and rainy days (0.774**) was highly significantly and positively correlated with red rot incidence. Wind speed (0.047) was positively correlated. All these factors played an important role in the development of disease.

Table 1: Epidemiology study on red rot of sugarcane in field condition on CoC 671 during 2021-2022.

MSW	Per cent disease incidence calculated (%)	*Per cent disease incidence cumulative (%)	Tmax (°C)	Tmin (°C)	RH in morning (%)	RH in evening (%)	Ws (km/hrs)	BSSH (h)	Rf (mm)	Rain (days)
1	0.00	0.00	31.90	17.49	93.75	57.51	2.70	5.60	0.00	0.00
2	0.00	0.00	26.43	12.73	90.33	45.76	3.85	6.96	0.00	0.00
3	0.00	0.00	29.80	14.10	87.00	48.00	3.40	8.10	0.00	0.00
4	0.00	0.00	27.00	12.20	82.00	45.00	4.50	7.30	0.00	0.00
5	0.00	0.00	30.20	12.80	92.00	38.00	2.50	9.30	0.00	0.00
6	0.00	0.00	29.60	13.00	95.00	40.00	2.70	8.80	0.00	0.00
7	0.00	0.00	30.60	14.60	90.00	41.00	3.00	9.70	0.00	0.00
8	0.00	0.00	32.70	13.40	95.00	34.00	2.30	9.70	0.00	0.00
9	0.00	0.00	34.90	15.10	85.00	27.00	2.40	9.70	0.00	0.00
10	0.00	0.00	36.80	18.30	76.00	32.00	2.60	7.90	0.00	0.00
11	0.00	0.00	38.70	18.10	68.00	21.00	2.80	9.50	0.00	0.00
12	0.00	0.00	36.90	20.90	75.00	31.00	3.00	7.10	0.00	0.00
13	0.00	0.00	35.50	21.50	95.00	49.00	3.20	8.20	0.00	0.00
14	0.00	0.00	34.80	21.60	98.00	55.00	2.80	9.20	0.00	0.00
15	0.00	0.00	35.90	23.10	93.00	57.00	3.10	8.60	0.00	0.00
16	0.00	0.00	35.20	23.30	89.00	46.00	2.40	9.00	0.00	0.00
17	0.00	0.00	39.50	23.20	75.00	48.00	4.90	10.10	0.00	0.00
18	0.00	0.00	34.80	25.20	90.00	63.00	5.80	10.20	0.00	0.00
19	0.00	0.00	37.20	26.30	88.00	53.00	5.60	8.80	0.00	0.00
20	0.00	0.00	34.30	27.00	83.00	64.00	7.80	8.20	0.00	0.00
21	0.00	0.00	33.90	27.70	81.00	65.00	10.20	6.70	0.00	0.00
22	2.00	2.00	33.90	27.60	83.00	61.00	9.20	6.50	0.00	0.00
23	4.00	2.00	34.60	27.10	85.00	61.00	7.00	8.50	0.00	0.00
24	8.00	4.00	33.10	25.50	93.00	68.00	4.90	7.00	68.00	5.00
25	10.00	2.00	31.80	24.00	95.00	79.00	6.10	4.40	78.00	4.00
26	12.00	2.00	32.80	24.50	94.00	71.00	6.10	5.00	64.00	3.00
27	20.00	8.00	28.80	24.10	98.00	91.00	5.20	0.30	336.00	6.00
28	26.00	6.00	27.90	23.70	95.00	97.00	5.30	0.00	517.00	7.00
29	32.00	4.00	29.40	24.60	96.00	84.00	6.60	2.10	56.00	4.00
30	36.00	4.00	30.50	24.70	94.00	82.00	4.50	2.70	40.00	2.00
31	40.00	2.00	31.80	24.80	92.00	73.00	3.10	5.40	147.00	2.00
32	42.00	2.00	30.70	23.70	94.00	81.00	5.70	2.60	119.00	6.00
33	44.00	2.00	29.70	23.60	91.00	88.00	9.20	1.20	252.00	7.00
34	46.00	2.00	30.40	24.70	93.00	79.00	5.90	3.40	9.00	1.00
35	46.00	0.00	32.20	23.70	94.00	64.00	1.50	6.60	23.00	2.00
36	46.00	0.00	33.20	24.80	95.00	68.00	1.70	5.80	125.00	2.00
37	48.00	2.00	31.40	23.90	98.00	83.00	2.60	2.80	284.00	6.00
38	50.00	2.00	29.40	23.20	97.00	80.00	2.60	2.30	201.00	4.00
39	52.00	2.00	31.40	23.10	96.00	71.00	1.90	4.50	27.00	1.00
40	54.00	2.00	33.50	23.60	93.00	65.00	1.60	7.40	7.00	1.00
41	56.00	2.00	31.30	23.00	92.00	70.00	2.20	4.70	67.00	2.00
42	58.00	2.00	34.60	22.10	79.00	59.00	3.50	8.30	0.00	0.00
43	60.00	2.00	34.70	18.70	86.00	42.00	2.50	9.60	0.00	0.00
44	62.00	2.00	34.60	16.80	80.00	38.00	2.00	9.50	0.00	0.00
45	62.00	0.00	35.40	18.10	90.00	33.00	1.50	9.30	0.00	0.00
46	62.00	0.00	33.80	18.10	84.00	34.00	2.40	8.30	0.00	0.00
47	62.00	0.00	31.80	14.80	75.00	30.00	3.40	9.30	0.00	0.00
48	62.00	0.00	33.29	16.93	79.95	38.70	2.05	8.34	0.00	0.00

*Percent disease incidence cumulative data use for correlation and stepwise regression

Table 2: Epidemiology study on red rot of sugarcane in field condition on CoC 671 during 2022- 2023.

MSW	Per cent disease incidence calculated (%)	*Per cent disease incidence cumulative (%)	Tmax (°C)	Tmin (°C)	RH in morning (%)	RH in evening (%)	Ws (km/hrs)	BSSH (h)	Rf (mm)	Rain (days)
1	0.00	0.00	29.14	15.23	80.08	40.66	5.31	5.89	0.00	0.00
2	0.00	0.00	29.77	12.81	82.89	34.85	2.78	7.40	0.00	0.00
3	0.00	0.00	29.34	10.91	88.11	38.43	2.12	8.64	0.00	0.00
4	0.00	0.00	27.54	12.71	82.95	35.92	3.78	5.31	0.00	0.00
5	0.00	0.00	30.84	16.73	85.65	42.99	4.56	4.16	0.00	0.00
6	0.00	0.00	33.61	13.59	86.51	29.54	2.43	9.41	0.00	0.00
7	0.00	0.00	35.06	13.47	75.04	19.92	3.08	10.00	0.00	0.00
8	0.00	0.00	36.06	13.74	87.38	24.46	2.16	9.40	0.00	0.00
9	0.00	0.00	35.90	15.43	87.78	26.83	2.01	9.10	0.00	0.00
10	0.00	0.00	36.26	18.56	66.15	31.52	3.59	5.87	0.00	0.00
11	0.00	0.00	36.06	19.99	71.50	39.35	3.75	4.24	0.30	0.00
12	0.00	0.00	30.91	18.96	94.10	55.96	3.67	7.29	0.00	0.00
13	0.00	0.00	32.27	19.81	94.95	44.17	3.66	8.20	0.00	0.00
14	0.00	0.00	34.27	22.93	89.12	40.95	3.46	8.47	0.00	0.00
15	0.00	0.00	39.29	21.87	82.12	28.97	2.75	8.21	0.00	0.00
16	0.00	0.00	36.43	21.03	91.69	48.28	2.84	9.23	5.00	1.00
17	0.00	0.00	35.14	23.01	81.83	60.50	10.27	9.39	0.00	0.00
18	0.00	0.00	33.99	23.20	85.98	48.10	3.36	8.96	0.00	0.00
19	0.00	0.00	36.50	25.41	84.00	54.22	3.42	10.69	0.00	0.00
20	0.00	0.00	35.44	26.30	83.69	60.48	6.86	10.54	0.00	0.00
21	0.00	0.00	33.54	27.29	83.51	60.08	6.76	10.26	0.00	0.00
22	0.00	0.00	36.40	26.74	79.76	54.20	5.75	10.01	0.00	0.00
23	0.00	0.00	34.59	28.07	78.05	59.31	6.98	8.03	0.00	0.00
24	0.00	0.00	34.80	27.17	80.27	65.09	13.45	7.51	13.00	3.00
25	0.00	0.00	33.93	27.94	82.16	65.57	8.03	6.10	0.00	0.00
26	0.00	0.00	29.29	23.93	98.09	93.17	3.96	0.29	384.00	7.00
27	4.00	4.00	30.76	24.89	93.69	83.76	3.49	2.27	254.20	6.00
28	8.00	2.00	28.84	24.46	97.97	94.40	4.78	0.43	167.50	7.00
29	12.00	4.00	29.80	25.26	96.99	91.24	3.46	0.83	72.00	4.00
30	16.00	4.00	29.19	24.70	98.39	87.02	5.15	0.27	517.00	6.00
31	22.00	6.00	29.67	25.21	90.65	87.51	8.09	0.80	41.00	3.00
32	26.00	4.00	30.46	25.70	89.04	77.10	7.68	1.19	11.00	2.00
33	32.00	6.00	30.14	25.41	90.95	77.14	6.15	3.84	4.00	1.00
34	36.00	4.00	30.93	24.89	94.17	78.34	4.32	2.66	12.00	3.00
35	40.00	4.00	32.29	24.41	93.23	58.41	2.69	8.27	1.00	0.00
36	42.00	2.00	32.00	24.24	92.10	69.95	1.63	3.67	57.00	3.00
37	46.00	4.00	31.50	24.97	94.42	74.41	3.06	6.76	16.00	2.00
38	50.00	4.00	30.36	24.49	96.17	83.30	3.07	2.26	93.00	4.00
39	52.00	2.00	32.73	23.41	95.88	71.84	1.04	4.29	123.00	3.00
40	54.00	2.00	33.80	23.90	94.15	65.58	1.00	7.81	0.00	0.00
41	56.00	2.00	34.89	23.16	96.96	57.68	0.43	8.10	0.00	0.00
42	58.00	2.00	35.64	22.27	92.43	43.12	0.79	7.99	0.00	0.00
43	60.00	2.00	36.14	19.63	87.55	34.62	0.49	8.51	0.00	0.00
44	60.00	0.00	35.30	18.10	81.91	30.79	1.02	9.26	0.00	0.00
45	62.00	2.00	35.53	20.26	76.44	36.62	0.98	8.10	0.00	0.00
46	64.00	2.00	34.53	18.94	75.09	37.60	1.71	8.09	0.00	0.00
47	64.00	0.00	34.11	18.73	82.26	39.03	1.56	6.66	0.00	0.00
48	66.00	2.00	28.27	19.16	95.19	72.78	1.91	3.90	42.00	2.00

*Per cent disease incidence cumulative data use for correlation and stepwise regression

Table 3: Epidemiology study on red rot of sugarcane in field condition on CoC 671 pooled.

MSW	Per cent disease incidence calculated (%)	*Per cent disease incidence cumulative (%)	Tmax (°C)	Tmin (°C)	RH in morning (%)	RH in evening (%)	Ws (km/hrs)	BSSH (h)	Rf (mm)	Rain (days)
1	0.00	0.00	30.52	16.36	86.91	49.08	4.00	8.14	0.00	0.00
2	0.00	0.00	28.10	12.77	86.61	40.30	3.31	8.75	0.00	0.00
3	0.00	0.00	29.57	12.51	87.56	43.21	2.76	9.18	0.00	0.00
4	0.00	0.00	27.27	12.46	82.47	40.46	4.14	8.66	0.00	0.00
5	0.00	0.00	30.52	14.76	88.83	40.50	3.53	8.66	0.00	0.00
6	0.00	0.00	31.61	13.29	90.76	34.77	2.56	8.16	0.00	0.00
7	0.00	0.00	32.83	14.04	82.52	30.46	3.04	7.90	0.00	0.00
8	0.00	0.00	34.38	13.57	91.19	29.23	2.23	4.99	0.00	0.00
9	0.00	0.00	35.40	15.26	86.39	26.91	2.21	5.99	0.00	0.00
10	0.00	0.00	36.53	18.43	71.07	31.76	3.09	4.16	0.00	0.00
11	0.00	0.00	37.38	19.04	69.75	30.17	3.27	5.16	0.15	0.00
12	0.00	0.00	33.91	19.93	84.55	43.48	3.33	3.69	0.00	0.00
13	0.00	0.00	33.89	20.66	94.97	46.59	3.43	4.50	0.00	0.00
14	0.00	0.00	34.54	22.26	93.56	47.98	3.13	5.19	0.00	0.00
15	0.00	0.00	37.59	22.49	87.56	42.99	2.93	6.22	0.00	0.00
16	0.00	0.00	35.81	22.16	90.34	47.14	2.62	5.83	2.50	0.50
17	0.00	0.00	37.32	23.11	78.41	54.25	7.59	9.19	0.00	0.00
18	0.00	0.00	34.39	24.20	87.99	55.55	4.58	6.94	0.00	0.00
19	0.00	0.00	36.85	25.86	86.00	53.61	4.51	7.78	0.00	0.00
20	0.00	0.00	34.87	26.65	83.35	62.24	7.33	5.23	0.00	0.00
21	0.00	0.00	33.72	27.49	82.25	62.54	8.48	5.49	0.00	0.00
22	1.00	1.00	35.15	27.17	81.38	57.60	7.48	7.16	0.00	0.00
23	2.00	1.00	34.59	27.59	81.52	60.15	6.99	8.30	0.00	0.00
24	4.00	2.00	33.95	26.34	86.64	66.55	9.18	7.49	40.50	4.00
25	5.00	1.00	32.86	25.97	88.58	72.28	7.07	6.46	39.00	2.00
26	6.00	2.00	31.04	24.21	96.05	82.08	5.03	7.13	224.00	5.00
27	12.00	4.00	29.78	24.49	95.84	87.38	4.35	4.20	295.10	6.00
28	17.00	4.00	28.37	24.08	96.48	95.70	5.04	4.04	342.25	7.00
29	22.00	4.00	29.60	24.93	96.49	87.62	5.03	4.38	64.00	4.00
30	26.00	4.00	29.84	24.70	96.19	84.51	4.83	3.30	278.50	4.00
31	31.00	3.00	30.74	25.01	91.32	80.25	5.59	5.40	94.00	2.50
32	34.00	3.00	30.58	24.70	91.52	79.05	6.69	2.60	65.00	4.00
33	38.00	1.00	29.92	24.51	90.97	82.57	7.67	1.20	128.00	4.00
34	41.00	1.00	30.66	24.79	93.58	78.67	5.11	3.40	10.50	2.00
35	43.00	4.00	32.24	24.06	93.61	61.20	2.09	6.60	12.00	1.00
36	44.00	1.00	32.60	24.52	93.55	68.98	1.66	5.80	91.00	2.50
37	47.00	3.00	31.45	24.44	96.21	78.71	2.83	2.80	150.00	4.00
38	50.00	3.00	29.88	23.84	96.59	81.65	2.84	2.30	147.00	4.00
39	52.00	2.00	32.06	23.26	95.94	71.42	1.47	4.50	75.00	2.00
40	54.00	2.00	33.65	23.75	93.58	65.29	1.30	7.40	3.50	0.50
41	56.00	2.00	33.09	23.08	94.48	63.84	1.31	4.70	33.50	1.00
42	58.00	3.00	35.12	22.19	85.72	51.06	2.15	8.30	0.00	0.00
43	60.00	1.00	35.42	19.16	86.77	38.31	1.50	9.60	0.00	0.00
44	61.00	1.00	34.95	17.45	80.96	34.39	1.51	9.50	0.00	0.00
45	62.00	1.00	35.46	19.18	83.22	34.81	1.24	9.30	0.00	0.00
46	63.00	1.00	34.16	18.52	79.54	35.80	2.05	8.30	0.00	0.00
47	63.00	0.00	32.96	16.76	78.63	34.51	2.48	9.30	0.00	0.00
48	64.00	1.00	30.78	18.04	87.57	55.74	1.98	8.34	21.00	1.00

*Per cent disease incidence cumulative data use for correlation and stepwise regression

Table 4: Correlation of per cent disease incidence and weather parameters on red rot of sugarcane 2021-22.

Per cent disease incidence	Atmospheric temperature (°C)		Relative humidity (%)		Wind Speed (km/h)	Bright sun shine(hours)	Rainfall (mm)	Rain (Days)
	Maximum	Minimum	RH in Morning	RH in Evening				
Correlation coefficient	-0.410**	0.419**	0.383**	0.713**	0.272	-0.738**	0.702**	0.728**

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level

Table 5: Correlation of per cent disease incidence and weather parameters on red rot of sugarcane 2022-23.

Per cent disease incidence	Atmospheric temperature (°C)		Relative humidity (%)		Wind Speed (km/h)	Bright sun shine (hours)	Rainfall (mm)	Rain Days
	Maximum	Minimum	RH in Morning	RH in Evening				
Correlation coefficient	-0.441**	0.415*	0.515**	0.652**	-0.002	-0.613**	0.296**	0.497**

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level

Table 6: Correlation of per cent disease incidence and weather parameters on red rot of sugarcane (Pooled).

Per cent disease incidence	Atmospheric temperature (°C)		Relative humidity (%)		Wind Speed (km/h)	Bright sun shine (hours)	Rainfall (mm)	Rain Days
	Maximum	Minimum	RH in Morning	RH in Evening				
Correlation coefficient	-0.431**	0.485**	0.583**	0.755**	0.047	-0.399**	0.709**	0.774**

*Correlation is significant at the 0.05 level**Correlation is significant at the 0.01 level

Stepwise regression equations for sugarcane red rot on different weather parameters. The regression coefficient based on stepwise regression analysis for per cent red rot incidence of sugarcane with respect to weather parameters have been worked out and presented in Table 7-9. The stepwise linear regression analysis was performed to determine the relationship between the per cent disease incidence of red rot and the predictor variables. The dependent variable in this analysis is the per cent disease incidence.

Stepwise regression equations for sugarcane red rot on different weather parameters during 2021-2022. The regression equation along with Multiple R and R^2 values are summarized in the Table 7.

Table 7: Stepwise regression equation for sugarcane red rot on different weather parameters during 2021-2022.

Dependent variable	Multiple linear regression equation $\hat{Y}= a+b_1X_1+ b_2X_2+.... b_nX_n$	Multiple R	Co-efficient of determination (R^2)
Per cent disease incidence of red rot	$\hat{Y}$=4.275+(-0.454) X_1	0.738	0.544
	$\hat{Y}$=2.950+(-0.298) X_1+ (0.005)X_2	0.766	0.587

$\hat{Y}$= Predicted per cent disease incidence; X_1= Bright sun shine hours; X_2= Rain fall (mm)

In the initial model, a single predictor variable (X_1) was used, yielding a multiple R of 0.738 and R^2 of 0.544. This indicated that X_1 alone accounts for 54.4 per cent of the variance in the disease incidence of red rot.

In the second model which included two predictor variables X1 and X2, the multiple R improved to 0.766 and the R^2 increased to 0.568. This showed that together, X1 and X2 explained 56.80 per cent variance in disease incidence of red rot.

Overall, the stepwise regression analysis demonstrates that the inclusion of additional predictor variables enhances the model's ability to explain the variance in the disease incidence of red rot. The final model, incorporating two predictor variables, provides the best fit with the highest R^2 value of 0.766. It has been observed that R-value was 0.766 per cent indicating association between per cent disease incidence to bright sun shine hours and rain fall.

Stepwise regression equations for sugarcane red rot on different weather parameters during 2022-23. The regression equation, along with the corresponding Multiple R and R^2 values, is summarized in the Table 8.

Table 8: Stepwise regression equation for sugarcane red rot on different weather parameters during 2022-2023.

Dependent variable	Multiple linear regression equation $\hat{Y}= a+b_1X_1+ b_2X_2+.... b_nX_n$	Multiple R	Co-efficient of determination (R^2)
Per cent disease incidence of red rot	$\hat{Y}$= -1.828+(0.057)X_1	0.652	0.425
	$\hat{Y}$= -1.579+(0.065)X_1+(-0.183)X_2	0.698	0.487

$\hat{Y}$= Predicted per cent disease incidence; X_1=Relative humidity evening; X_2= Wind speed (km/hrs)

In the initial model, a single predictor variable (X_1) was used, yielding a multiple R of 0.652 and an R^2 of 0.425. This indicated that X_1 alone accounts for 42.5 per cent of the variance in the disease incidence of red rot.

In the second model which included two predictor variables X1 and X2, the multiple R improved to 0.698 and the R^2 increased to 0.487. This showed that together, X1 and X2 explained 48.7 per cent variance in disease incidence of red rot.

Overall, the stepwise regression analysis demonstrates that the inclusion of additional predictor variables enhances the model's ability to explain the variance in the disease incidence of red rot. The final model, incorporating two predictor variables, provides the best fit with the highest R^2 value of 0.698. It has been observed that R-value was 0.698 per cent indicating association between per cent disease incidence to evening relative humidity and wind speed.

Stepwise regression equations for sugarcane red rot on different weather parameters (Pooled). The regression equation, along with the corresponding Multiple R and R^2 values, is summarized in the Table 9.

Table 9: Stepwise regression equation for sugarcane red rot on different weather parameters in pooled.

Dependent variable	Multiple linear regression equation $\hat{Y}= a+b_1X_1+ b_2X_2+.... b_nX_n$	Multiple R	Co-efficient of determination (R^2)
Per cent disease incidence of red rot	$\hat{Y}$=0.453+(0.561) X_1	0.774	0.600
	$\hat{Y}$=0.900+(0.603) X_1+(-0.127)X_2	0.797	0.635
	$\hat{Y}$=-0.724+(0.272) X_1+(0.208)X_2+(0.042)X_3	0.844	0.712

$\hat{Y}$= Predicted per cent disease incidence; X_1= Rainy days; X_2= Wind speed (km/hrs); X_3= Relative humidity evening (mm)

The analysis reveals that the first model, with an R^2 value of 0.445, shows a significant association between the percentage disease incidence and rainy days. This indicates that rainy days alone accounts for 44.50 per cent of the variation in the red rot incidence.

In the second model, which includes both rainy days and wind speed, the R^2 value increased to 0.635. This suggests that these two variables together explain 79.7 per cent of the variation in the red rot index.

The final model added with evening relative humidity to the previous variables (rainy days and wind speed), showed an R^2 value of 0.712. This indicates that the inclusion of all three predictors explains 84.4 per cent of the variation in the red rot incidence.

Overall, the stepwise regression analysis highlights that including additional predictor variables improved the model's ability to explain the variance in the disease incidence of red rot. The final model, with the inclusion of relative humidity, provided the best fit with the highest R^2 value of 0.712.

Thus, actual observed red rot incidence and predicted red rot incidence found closely related and regression equation established may be most reliable and useful for forecasting of the sugarcane red rot. The loss caused by the red rot can be saved by forewarning to the farmers and thereby controlling the same at the proper time.

It is very clear from the present study that favorable environmental condition for susceptible variety infected more in sugarcane. The weather prevailing during crop season is most congenial for red rot. Thus, rainy days, wind speed and evening relative humidity found to play an important role in the disease development. The results are very useful to formulate weather-based forecasting model, 4 to 5 years further study is suggested.

Moreover, it is suggested to evolve resistant variety, and escape the period of red rot infection, through a change in sowing date, because red rot disease infection initiates at a tillering to harvesting stage, as these all other practices discourage the pathogen for infection and disease development. The management measures must be taken prior to infection get started to avoid huge losses.

These results are supported by many workers. Tiwari *et al*. (2010) reported high humidity and ideal temperature during crop season was responsible for havoc condition in North Western part of the country. Khan *et al*. (2011) reported that rainy season and 25° to 30°C temperature favour the development of disease. Shailbala *et al*. (2019) studied the factor for red rot pathogen epidemic. The dormant infections appeared in the form of disease in the month of July (more favorable environmental condition), after that red rot pathogen created havoc conditions in field. This condition during pre-monsoon and monsoon period led to formation of resting structure of pathogen on crop debris and produced number of acervuli due to recurrent rains during monsoon season. Water logging situation during July to September increased the infection at nodal region, especially at the air water interface. Temperature ranged from 25° to 30°C and high humidity favoured the development of disease and finally affected the juice quality and cane yield.

CONCLUSIONS

Around the world, sugarcane production is still seriously threatened by the red rot disease. Thus, it can be said that the development and occurrence of red rot disease in sugarcane are significantly influenced by the various weather factors. Minimum temperature, morning and evening relative humidity, rain fall and rainy days are more favorable for the progress of the red rot during 28^{th} to 34^{th} MSW(July to August), respectively also consider as main peak period of the red.

Correlation matrix worked out showed that minimum temperature (0.485^{**}), morning relative humidity (0.583^{*}), evening relative humidity (0.755^{**}), rain fall (0.709^{**}) and rainy days (0.774^{**}) was highly significantly and positively correlated with red rot incidence. Wind speed (0.047) was positively correlated. All these factors played an important role in the development of disease. The regression coefficient based on stepwise regression analysis for per cent red rot incidence of sugarcane with evening relative humidity to the previous variables (rainy days and wind speed), showed an R^2 value of 0.712. This indicates that the inclusion of all three predictors explains 84.4 per cent of the variation in the red rot incidence.

Thus it can be concluded that the different weather parameters i.e. rainy days, wind speed , rain fall and evening relative humidity found to play an important role in the disease development and incidence of red rot disease in sugarcane.

FUTURE SCOPE

The present findings would be helpful during planning of suitable management strategies and formulate weather-based forecasting model, for that 4 to 5 years further study is suggested.

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Conflict of interest. None.

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