

Original Research Article

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Epidemiological Studies on Early Blight of Potato under Climate Change and its Co-Relation with Disease Severity

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ABSTRACT

Occurrence and severity of Early blight of potato observed that the disease occurred every year at Kanpur and Faizabad district of Uttar Pradesh. It has observed that the disease was first appeared during 2–3rd weeks of December at Kanpur and 3rd weeks of December to 1st weeks of January at Faizabad district of Uttar Pradesh at the maximum temperature range 17–23°C, minimum temperature 1.8–7.8°C, relative humidity 46–93%, and 0–7.2 sun shine hours. The maximum severity with 28.20 per cent was noted on 24 January, 2012 after 40th days of first appearance of disease at the maximum temperature 23.0°C and minimum temperature 5.6°C, relative humidity ranges 54–85% and sun shine hours 6.9 whereas, in the year 2013, maximum severity of 14.11 per cent on 23 January, 2013 after 41 days first appearance of disease at temperature range between 24.8°C to 8.8, relative humidity 62–90% and 7.0 sun shine hours, respectively. It has also found that infection rate increases with occurrence of rainfall, resulted high relative humidity and low sunshine hours which are optimum for growth and sporulation of the pathogen during both the year. Similar observation has also been recorded at Faizabad district of Uttar Pradesh. The correlation between disease severity with temperature, relative humidity and sunshine hours were calculated by standard statistical calculation and the results showed that disease severity co-relate negatively with temperature (- 0.17845, - 0.51214) and sunshine hours (- 0.04185, - 0.70934) and positive correlation with relative humidity (0.638215, 0.149054) at Kanpur during 2011–2012. Similar observation has also been recorded in both the year at Faizabad.

Keywords

Early blight,
Disease severity,
Weather
parameters,
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Introduction

Potato (*Solanum tuberosum* L.) is the most useful vegetable crop in the world, belonging to the family Solanaceae. It is grown in about 150 countries of the world and is consumed by over a billion of peoples across the globe, of which half are in the developing countries. The United State Organization declared the year 2008 as “International Potato Year” (Shalbala and Pathak, 2008). The global area under potato production during 2011 was

about 19.33 million hectares with a total production of about 321 million tonnes and having productivity of about 17.25 tonnes per hectares.

The intensive and extensive cultivation of potato even under the most favorable environmental conditions, the state failed to provide significant strides in potato yields, because of a number of production

constraints. Among them, early blight caused by *Alternaria solani*, is noted worthy and has been taking heavy loss of the produce.

In Indo-Gangetic plains, depending upon prevailing weather condition, the early appearance of disease may seriously damage the potato crop and causing worry in the midst of potato growers. Yield loss estimates resulting from foliar damage incited by early blight on potato vary by location, cropping season, cultivar, and the stage of potato maturity. The yield reductions of 5 to 40% have been reported in Israel (Rotem and Feldman, 1965) and 20 to 30% in the USA (Christ and Maczuga, 1989; Shtienberg *et al.*, 1990). Early blight may also cause dry rot of tubers, reducing both the quantity and quality of marketable tubers (Nnodu *et al.*, 1982).

Management of the disease can be done through host resistance, cultural adjustments biological and use of fungicides. But there is no doubt that chemicals are best for management of disease. But continuous use of chemicals is not economical and eco-friendly. Therefore, the management practices should be focus on preventive or prophylactic measure that will reduced the initial inoculums resulted slow development of disease. Disease forecasting, may reduce the use of fungicides to minimize the development of disease under changing climatic condition. Therefore, there is urgent need to develop some kind of disease forecasting/warning services for predicting the time of appearance of disease and optimizing use of fungicides without risking the crop and human health. Hence, the study was taken in the present investigations.

Materials and Methods

Survey for ascertaining the prevalence and severity of disease

Survey was conducted at Vegetable Research Farm and Department of Plant Pathology,

Chandra Shakhar Azad University of Agriculture and Technology Kanpur and farmers field at the vicinity area of Kanpur and Faizabad of Uttar Pradesh, during 2011-2012 and 2012-2013, in order to find out the prevalence and intensity of early blight of potato caused by *Alternaria solani*. The weather parameters which influenced the development of disease are also collected to correlate between weather parameters and disease intensity.

Weather data

The daily weather data was collected from weather station Department of Agronomy, C. S. Azad University of Agriculture and Technology Kanpur, Department of Meteorology, N. D. University of Agriculture & Technology, Faizabad, India.

Measurement of disease severity

The crop was regularly observed for the first appearance of the disease. Progress of the severity of disease was also recorded daily. The observations on date of first appearance and maximum severity per cent of each disease were recorded separately. Disease severity was recorded using a score chart consisting of 0-9 scale as described by Malcolimson, 1976. Fifty leaves were randomly selected from the field for measurement of disease severity. The leaves with 1-9% infection received 1, 10% infection received 2, 11-25% infection received 3, 26-40% infection received 4, 41-60% infection received 5, 61-70% infection received 6, 71-80% infection received 7, 81-90% infection received 8, 91-100% infection received 9 (Malcolimson, 1976). The disease severity of individual plants was calculated by following formula

$$\text{Disease severity PDI} = \frac{\sum \text{Sum of numerical rating}}{\text{Total number of leaves examined} \times \text{maximum rating}} \times 100$$

Correlation of disease severity with temperature, relative humidity and sunshine hours

The correlation between disease severity with temperature, relative humidity and sunshine hours were calculated by standard statistical calculation.

Results and Discussion

Survey and severity of early blight of potato

The observations on occurrence and severity of disease of early blight of potato observed that the disease occur every year at Kanpur and Faizabad of Uttar Pradesh during *rabi* season, 2011-12 and 2012-13.

At Kanpur

The data presented in the tables 1 and 2, showed that the first appearance of early blight was observed on 16th December 2011 with the value of 0.55 per cent at the maximum temperature 21.0, minimum temperature 1.8, maximum relative humidity 93%, minimum relative humidity 39% and 7.2 sun shine hours and maximum severity of 28.20 per cent was noted on 24 January, 2012 after 40th days of first appearance of disease at the maximum temperature 23.0°C and minimum temperature 5.6°C, relative humidity ranges 54 -85% and sun shine hours 6.9 (Table 1). From the table 1, it is cleared that the infection rate is suddenly increased from 23.12.11 to 24.12.11 and 28.12.11 to 29.12.11 which might be due to occurrence of rainfall, resulted high relative humidity and low sunshine hours which are optimum for growth and sporulation of the pathogen. On the other hand, result enumerate in table 2 showed that during second year, the first appearance of early blight was observed on dated 14th December, 2012 with the value of 0.14 per cent at the 17.06^{oC} maximum

temperature and 7.8 minimum temperature, 97 per cent maximum and 79 percent minimum relative humidity and 0 sun shine hours and maximum severity of 14.11 per cent on 23 January, 2013 after 41 days first appearance of disease at temperature range between 24.8°C to 8.8, relative humidity 62-90% and 7.0 sun shine hours, respectively. From table 2, it is cleared that during 2012-13, cloud covered continuously at frequent interval of date but light rainfall occurs on 8th and 9th January, considering favorable condition for development of disease, resulted increased infection rate.

At Faizabad

Two years data of Faizabad district presented in tables 3 and 4 showed that the first appearance of early blight was appeared on 18th December 2011 with the value of 0.42 per cent at maximum temperature 23.5°C and minimum temperature 6.0°C, maximum relative humidity 88%, minimum relative humidity 46%, and sun shine hours 7. The maximum disease severity was recorded on 24th January, 2012 with the value of 29.13% per cent at maximum temperature 24^{oC}, minimum 5^{oC}, maximum relative humidity 90%, minimum 59% and 7.0 sun shine hours (Table 3). From the table 3 it is also cleared that the infection rate was suddenly increased from 1 – 2nd January, 2011 which might be high relative humidity and continuous cloudiness from 28.12.11 to 1.01.2012. During 2012-13, it was evident from table 4 that the first appearance of disease was occur on dated 16th December, 2012 with the value of 0.23 per cent when environmental factors were 23.4°C maximum temperature and 7.8 °C minimum temperature, 98 % maximum relative humidity and 67% minimum relative humidity and 0.0 Octa sun shine hours. The maximum severity of disease 31.23 per cent was noted on 21th January, 2013 after 38 days from first appearance of disease at the maximum temperature 25°C and minimum

0.7 °C, maximum relative humidity 89 % and minimum 38%, 7 sun shine hours, respectively. From table 2 it is cleared that infection rate rapidly increased from 7 - 8th January which might be due to favorable environment factors indicating cloudiness from 6 - 8th January, slight rainfall (3.2 mm) on 8th January followed by high relative humidity (91 per cent) and low sunshine hours.

Correlation between disease severity with temperature, relative humidity and sunshine hours

At Kanpur

The correlation of disease severity with temperature, relative humidity and sunshine hours at Kanpur during 2011-12 has been calculated and data presented in the tables 5 and 6. It has been found that the disease severity showed the negative correlation with temperature (0.3664), (0.72) and positive correlation with relative humidity (-0.493), (-0.042) and the partially significant and negative correlation with sunshine hours (-0.709). During 2012-13, similar observations have also been found from Kanpur area during 2012 - 13. The data from the (Table 6) showed that the negative co-relation of disease severity with temperature (0.55447),(0.19292) positive co-relation with relative humidity (0.00905),(-0.37277) and negative co-relation with sunshine hours (-0.5233) (Figs. 1 & 2).

Faizabad

The data on disease severity, temperature, and relative humidity and sunshine hours are also collected from Farmer's field of Faizabad district during 2011-12 and 2012-13 and co-relation study was done between them. The data presented in the table 7 showed that

disease severity co-relate negatively with temperature and sunshine hours, representing the value (0.27322), (0.54021) and (-0.59335), (-0.3411) respectively, but positively co-relate with relative humidity (-0.61419), during 2011-12 and similar observations have also been found during 2012-13. The data presented in the table 8 that disease severity showed the partially significant and negative correlation with temperature (0.48844), (0.47148) partially significant and positive correlation with relative humidity(0.023257), (-0.25609) non-significant and negative correlation with sunshine hours (-0.50429) (Figs 3&4).

Environmental factors such as temperature, wetness duration, relative humidity (moisture), sunshine hours, rainfall affect the development of early blight on potato were reported by several workers (Adams and Stevenson, 1990; Harrison *et al.*, 1965; Vloutoglou and Kalogerakis, 2000). Vander Walls *et al.*, (2001) also reported that alternating low and high humidity conditions have also been shown to favour disease development.

Singh (2007) reported that the disease becomes serious when the season begins with abundant moisture or frequent rains followed by warm and dry weather. He also reported that higher mean temperatures (19.2-31.1⁰C), frequent rains but shorter duration of relative humidity above 80%, the absence of dew during most part of the season, longer photoperiod and prolonged senescence of the plants are related to low sporulation, restricted size of lesions, and moderate intensity of the disease.

Troutt and Levetin (2001) also found that there was a strong positive correlation between spore concentration and temperature.

Table.1 Disease severity of early blight of potato (*Alternaria solani*) during 2011-2012 at Kanpur

Date	Disease severity (%)	Temp.		RH. (%)		Sun Shine	Evaporati on	Rainfall	Soil Temp.	
		Max	Min	Max	Min				Max	Min
16.12.2011	0.55	21.0	1.8	93	39	7.2	1.0	0.0	8.0	20.0
17.12.2011	0.60	22.2	1.8	97	51	00	1.0	0.0	8.0	21.0
18.12.2011	0.86	23.0	4.4	94	37	5.7	1.0	0.0	9.4	22.5
19.12.2011	1.32	24.0	5.4	97	48	4.1	1.0	0.0	10.0	21.6
20.12.2011	1.98	24.0	4.6	95	48	6.3	1.0	0.0	10.4	22.0
21.12.2011	1.45	24.0	8.2	94	52	4.1	1.0	0.0	12.2	18.5
22.12.2011	2.45	16.4	14.2	98	91	0	1.0	4.7	16.0	15.0
23.12.2011	3.25	17.0	10.6	98	87	0	1.0	44.4	14.0	15.0
24.12.2011	7.05	20.8	10.8	93	74	0	1.0	0.3	13.5	21.4
25.12.2011	7.85	20.2	9.2	97	69	0	1.0	0.0	13.4	20.2
26.12.2011	8.11	18.4	9.2	97	82	0	1.0	0.0	14.4	20.0
27.12.2011	8.46	15.4	10.2	98	93	0	1.0	0.0	15.0	15.0
28.12.2011	8.50	18.2	12.2	95	77	0	1.0	4.8	14.6	19.0
29.12.2011	10.23	18.6	10.0	95	82	0	1.0	0.0	14.8	16.0
30.12.2011	10.47	14.0	10.4	97	82	0	1.0	0.0	14.8	16.0
31.12.2011	10.88	16.2	6.5	86	69	0	1.0	0.0	11.4	18.0
1.01.2012	11.07	17.8	5.6	89	78	1.5	0.8	0.0	9.8	19.0
2.01.2012	11.36	18.6	6.6	78	78	0	0.8	0	9.6	18.0
3.01.2012	12.43	19.2	6.2	81	75	0	0.8	0	9.0	18.5
4.01.2012	13.87	21.8	6.6	91	56	6.1	0.8	0	8.8	17.4
5.01.2012	13.99	23.8	5.6	78	40	6.7	0.8	0	10.	19.6
6.01.2012	14.33	20.3	9.0	93	61	3.7	0.8	0	12.0	19.6
7.01.2012	15.43	21.8	10.2	97	68	1.0	0.8	0	13.0	19.0
8.01.2012	15.99	16.0	8.0	94	68	0	0.8	0	12.8	18.0
9.01.2012	16.22	17.2	7.6	87	62	0	0.8	0	12.0	17.0
10.01.2012	16.97	18.0	7.4	94	60	0	0.8	00	11.0	18.0
11.01.2012	17.23	18.2	4.6	85	56	0	0.8	0	8.6	18.0
12.01.2012	18.04	20.4	4.0	94	45	7.5	0.8	0	9.4	18.0
13.01.2012	18.98	21.2	4.4	87	79	0	0.8	0	9.4	18.0
14.01.2012	19.12	23.0	4.8	94	33	6.5	0.8	0	10.6	19.5
15.01.2012	20.23	22.0	7.6	94	39	8.5	1.2	0	9.6	19.5
16.01.2012	20.93	23.4	5.5	91	76	7.5	1.2	0	11.6	20.5
17.01.2012	21.47	21.2	6.2	94	72	6.4	1.2	0	11.2	20.5
18.01.2012	22.54	22.0	7.6	94	55	5.5	1.2	0	10.6	20.0
19.01.2012	23.68	21.0	4.6	97	63	5.5	1.2	0	10.5	20.6
20.01.2012	24.19	21.0	4.6	94	61	4.4	1.2	0	9.4	20.8
21.01.2012	25.43	21.4	5.6	97	50	6.1	1.2	0	9.4	20.2
22.01.2012	26.95	21.4	6.4	83	52	3.0	1.2	0	9.4	14.4
23.01.2012	27.86	22.0	7.4	81	48	6.9	1.2	0	10.0	14.4
24.01.2012	28.20	23.0	5.6	88	54	6.9	1.2	0	10.1	14.4

Table.2 Disease severity of early blight of potato (*Alternaria solani*) during 2012-2013 at Kanpur

Date	Disease severity (%)	Temp.		RH. (%)		Sun Shine	Evaporation	Rainfall	Soil Temp.	
		Max	Min	Max	Min				Max	Min
14.12.2012	0.14	17.6	7.8	97	79	0	0.8	0	12.0	18.0
15.12.2012	0.22	12.6	7.2	88	78	0	0.8	0	12.5	20.0
16.12.2012	0.54	15.0	3.8	90	76	0	1.0	0	12.6	14.5
17.12.2012	0.76	16.6	3.8	100	87	0	0.8	0	11.8	16.0
18.12.2012	1.98	10.8	2.8	100	85	0	0.6	0	11.5	20.0
19.12.2012	2.32	12.4	2.0	100	68	0	1.0	0	9.5	17.0
20.12.2012	2.60	18.4	2.2	97	81	6.0	1.0	0	9.5	22.0
21.12.2012	3.13	17.4	5.6	97	59	0	1.2	0	7.5	23.0
22.12.2012	3.89	19.6	3.2	100	53	5.2	1.0	0	8.5	21.0
23.12.2012	4.12	17.6	4.0	100	54	5.0	0.8	0	10.0	22.2
24.12.2012	4.57	12.8	3.87	80	68	2.0	0.8	0	10.5	17.0
25.12.2012	4.99	11.0	1.4	100	85	00	0.8	0	9.0	14.0
26.12.2012	5.11	12.6	2.4	100	76	02.8	0.6	0	9.2	17.0
27.12.2012	5.20	13.4	3.8	94	64	0	0.6	0	9.5	17.5
28.12.2012	5.97	13.0	2.0	93	68	0	0.6	0	8.5	16.6
29.12.2012	6.13	16.4	1.1	100	54	3.0	0.6	0	6.5	17.5
30.12.2012	6.54	19.0	0.4	96	43	6.0	0.6	0	6.0	19.0
31.12.2012	6.87	20.4	3.8	78	46	7.2	1.0	0	8.0	20.5
1.01.2013	7.03	21.8	4.8	74	44	8.5	1.0	0	9.0	22.0
2.01.2013	7.28	21.4	4.7	100	55	0	1.0	0	9.0	21.0
3.01.2013	7.46	25.6	6.7	85	51	0.2	1.0	0	11.0	24.0
4.01.2013	7.85	32.0	7.7	97	68	0	1.0	0	11.5	23.0
5.01.2013	7.95	23.6	6.8	100	58	0	1.0	0	12.0	23.0
6.01.2013	8.00	24.8	11.4	89	60	0	1.0	0	13.5	23.5
7.01.2013	8.10	32.8	12.4	87	59	0	1.0	0	15.0	20.2
8.01.2013	8.40	25.4	12.7	91	74	3.0	1.0	3.5	14.5	20.0
9.01.2013	10.35	19.8	9.4	95	56	8.4	1.0	1.1	12.0	22.2
10.01.2013	10.59	19.4	7.6	92	59	8.9	1.0	0	10.2	22.4
11.01.2013	10.99	16.6	5.4	100	81	4.9	1.0	0	11.0	21.0
12.01.2013	11.05	16.0	4.7	100	75	3.5	0.5	0	11.0	19.2
13.01.2013	11.36	15.8	5.7	100	87	1.3	0.5	0	11.0	18.0
14.01.2013	11.75	17.8	4.8	97	67	5.1	0.5	0	11.0	21.2
15.01.2013	12.06	21.4	5.6	92	52	8.6	1.0	0	8.6	22.5
16.01.2013	12.54	20.6	6.4	84	48	9.0	1.0	0	11.0	22.6
17.01.2013	12.82	21.8	6.8	80	50	8.9	1.0	0	10.5	23.4
18.01.2013	13.36	21.2	3.6	91	49	6.3	1.0	0	9.0	23.0
19.01.2013	13.59	22.0	4.4	91	54	6.1	1.0	0	9.5	22.8
20.01.2013	14.06	22.4	5.6	97	64	4.4	1.0	0	10.0	22.5
21.01.2013	14.18	22.4	4.8	91	58	4.2	1.0	0	10.5	23.0
22.01.2013	14.78	24.4	6.08	92	45	3.7	1.2	0	11.2	24.0
23.01.2013	15.06	24.8	8.8	90	62	7.0	1.2	0	13.0	22.5

Table.3 Disease severity of Early blight of potato (*Alternaria solani*) during 2011-2012 at Faizabad

Date	Disease severity (%)	Temp.		RH. (%)		Sun Shine	Evaporation	Rainfall	Soil Temp.	
		Max	Min	Max	Min				Max	Min
18.12.2011	0.42	23.5	6	88	46	7	1.6	0	12.5	19.0
19.12.2011	0.56	24.5	6.5	78	35	7.5	1.8	0	11.5	24.0
20.12.2011	0.89	25.5	6.5	88	47	7.5	1.2	0	11.5	19.
21.12.2011	1.25	25	6.5	78	56	5	1.	0	13.0	19.0
22.12.2011	1.49	19.5	13.5	98	76	0	1.2	0	15.5	18.0
23.12.2011	1.99	17.9	11.5	91	90	0	0.6	0	14.0	17.0
24.12.2011	3.98	21	13.5	95	81	4	1.6	0	14.5	18.5
25.12.2011	4.72	22	10.5	86	65	4	1.6	0	13.5	25.0
26.12.2011	5.60	17	10.5	83	88	2	1.4	0	14.0	18.0
27.12.2011	6.46	18	9.5	97	62	2	1.8	0	13.0	17.0
28.12.2011	7.22	20.5	13.5	89	81	0	1.7	0	14.5	17.5
29.12.2011	7.22	16	11.5	97	89	0	1.6	0	13.0	17.0
30.12.2011	8.01	13.5	11	91	88	0	1.7	0	15.	15.5
31.12.2011	8.24	16	9.5	97	78	0	1.6	0	13.0	14.0
1.01.2012	8.50	19	6.5	100	62	0	1.8	0	12.0	16.5
2.01.2012	11.50	20	5.5	92	62	2.5	1.6	0	10.5	16.0
3.01.2012	12.10	20	6	87	56	7	1.8	0	09.5	18.0
4.01.2012	12.92	22.5	6	87	59	7	2.2	0	08.5	19.5
5.01.2012	13.10	21	6	90	72	7.5	2.2	0	09.5	20.
6.01.2012	14.87	21.5	10.5	84	57	2	2.2	0	12.5	25.5
7.01.2012	15.63	22	9.5	91	65	2	1.6	0	13.5	19.0
8.01.2012	16.44	21	9.5	98	64	2	2.0	0	12.5	18.5
9.01.2012	17.52	20.5	9	88	72	1.5	2.2	0	12.0	18.0
10.01.2012	17.96	18.5	5.5	90	59	5	2.0	0	11.5	19.5
11.01.2012	18.25	20	5	90	72	7.5	2.4	0	09.5	15.5
12.01.2012	20.42	21	5	87	49	7.5	2.6	0	09.5	20.5
13.01.2012	21.86	22.5	6.5	90	66	8	3.6	0	10.0	19.0
14.01.2012	22.98	24	5	87	59	7.5	3.4	0	10.5	21.5
15.01.2012	23.03	23.5	6	92	45	7	3.0	0	11.5	18.0
16.01.2012	23.42	24	5	87	59	4	2.2	0	10.5	19.0
17.01.2012	24.52	23.5	6	88	45	7	1.6	0	10.5	20.0
18.01.2012	25.84	24	5	88	59	8	2.4	0	11.0	20.0
19.01.2012	26.13	22	5	67	59	8.5	2.2	0	11.0	18.0
20.01.2012	26.98	22.5	4.5	87	43	8	2.4	0	11.5	18.5
21.01.2012	27.15	22	5	97	63	7.5	2.2	0	10.0	20.0
22.01.2012	28.02	22	4.5	84	72	8.0	2.2	0	10.0	22.0
23.01.2012	28.89	22.5	4.4	74	62	7.5	2.4	0	10.0	18.0
24.01.2012	29.13	24	5	90	59	7	2.0	0	10.5	18.5

Table.4 Disease severity of Early blight of potato (*Alternaria solani*) during 2012-2013 at Faizabad

Date	Disease severity (%)	Temp.		RH. (%)		Sun Shine	Evaporation	Rainfall	Soil Temp.	
		Max	Min	Max	Min				Max	Min
16.12.2012	0.23	23.4	7.8	98	67	0	0.9	0	13.5	15.0
17.12.2012	0.45	23.5	7.6	100	77	0	0.8	0	10.0	15.0
18.12.2012	0.63	23.4	7.1	100	86	0	1.4	0	09.0	14.0
19.12.2012	0.79	25.0	7.7	100	88	4.0	1.4	0	09.0	14.0
20.12.2012	1.18	25.0	7.3	100	53	0	1.2	0	09.5	17.0
21.12.2012	1.56	25.0	7.5	78	77	5.0	1.2	0	10.0	15.0
22.12.2012	2.33	21.5	5.5	92	49	5	1.7	0	10.0	21.0
23.12.2012	3.16	22.5	6.0	89	45	4	1.6	0	11.0	21.0
24.12.2012	4.42	14.0	4.0	87	67	2	1.8	0	12.0	16.0
25.12.2012	5.67	12.0	3.5	100	76	0	1.4	0	10.5	15.0
26.12.2012	6.98	9.5	3.0	100	97	0	1.1	0	09.0	13.0
27.12.2012	8.56	11.5	4.5	94	88	0	0.7	0	10.0	12.0
28.12.2012	9.12	9.0	4.0	97	70	0	0.9	0	08.5	11.0
29.12.2012	10.14	12.5	0.4	94	59	0	1.1	0	07.0	14.0
30.12.2012	11.41	15.0	0.3	100	58	0	1.2	0	08.0	16.0
31.12.2012	11.81	19.5	0.2	100	46	1.0	1.3	0	10.	21.0
1.01.2013	12.32	17.5	1.4	97	54	1.5	1.6	0	11.0	21.0
1.01.2013	12.99	20.5	4.0	100	53	2.5	1.4	0	10.5	21.5
2.01.2013	13.76	25.0	5.5	87	41	4.0	1.5	0	09.5	13.0
3.01.2013	14.11	25.0	7.0	97	39	5.0	1.82.0	0	12.0	16.5
4.01.2013	14.96	24.0	6.5	89	45	5.0	1.8	0	11.5	22.5
5.01.2013	15.38	25.0	9.5	89	39	1.0	2.0	0	14.0	23.0
6.01.2013	16.43	24.0	9.5	89	61	0	1.8	00	15.0	21.0
7.01.2013	17.64	23.0	1.4	93	67	0	2.0	0	15.0	22.0
8.01.2013	21.11	20.5	1.3	91	53	0	1.4	3.2	15.0	21.0
9.01.2013	21.40	20.5	8	97	44	6.5	1.6	0	10.0	21.0
10.01.2013	22.06	18.0	7	89	43	4.0	1.8	0	12.0	20.0
11.01.2013	22.47	17	7	97	88	3.0	1.6	0	12.0	19.0
12.01.2013	22.87	14	6	92	67	2.0	1.4	0	10.0	18.0
13.01.2013	22.92	12	5	97	76	0	1.6	0	10.0	14.0
14.01.2013	23.09	16.5	5.5	100	58	2.0	1.5	0	10.0	18.0
15.01.2013	26.55	21	5.0	100	45	5.5	1.5	0	10.5	21.0
16.01.2013	27.44	21	2.5	100	49	5.0	1.6	0	10.0	22.0
17.01.2013	28.39	21.5	4.0	87	45	5.0	2.0	0	11.0	22.5
18.01.2013	29.18	22	4.5	100	45	5.0	2.0	0	10.5	22.0
19.01.2013	30.17	23	2.5	97	58	5.0	1.8	0	10.0	23.0
20.01.2013	30.98	24	4.5	97	61	6.0	2.0	0	10.0	24.0
21.01.2013	31.23	25	7	89	38	7	2.2	0	11.0	24.0

Table.5 Correlation between disease severity with temperature, RH%, Sunshine hours at Kanpur 2011-2012

	Disease severity (%)	Temp max.	Temp min.	RH max.	RH min.	Sun shine
Dsp	1					
Temp max	0.141015	1				
Temp min	-0.17845	-0.51214	1			
RH max	-0.3355	-0.09036	0.278203	1		
RH min	-0.16499	-0.69389	0.638215	0.149054	1	
Sun shine	0.366387	0.720023	-0.49268	-0.04185	-0.70934	1

Table.6 Correlation between disease severity to temperature, RH%, Sunshine hours at Kanpur 2012-2013

	Dsp	Temp max.	Temp min.	RH max.	RH min.	Sun shine
Dsp	1					
Temp max	0.519258	1				
Temp min	0.318911	0.662035	1			
RH max	-0.20731	-0.30333	-0.29188	1		
RH min	-0.43293	-0.49168	-0.0617	0.476215	1	
Sun shine	0.554468	0.192925	0.009051	-0.37277	-0.5233	1

Table.7 Correlation between disease severity with temperature, RH%, sunshine hours at Faizabad during 2011-2012

	Dsp	Temp max.	Temp min.	RH max.	RH min.	Sun shine
Dsp	1					
Temp max	0.20812	1				
Temp min	-0.20813	-0.32455	1			
RH max	-0.26344	-0.00971	0.248176	1		
RH min	-0.42618	-0.53674	0.804576	0.350474	1	
Sun shine	0.27322	0.540208	-0.59335	-0.3411	-0.61419	1

Table.8 Correlation between disease severity to temperature, RH%, Sunshine hours at Faizabad 2012-2013

	Dsp	Temp max.	Temp min.	RH max.	RH min.	Sun shine
Dsp	1					
Temp max	0.050787	1				
Temp min	-0.15587	0.463563	1			
RH max	-0.00569	-0.22408	0.24917	1		
RH min	-0.42169	-0.44179	0.00531	0.229462	1	
Sunshine	0.488436	0.471475	0.23057	-0.25609	0.50429	1

Fig.1 Disease severity curve correlated with Temperature, Relative humidity, and Sunshine hour at Kanpur during 2011-12

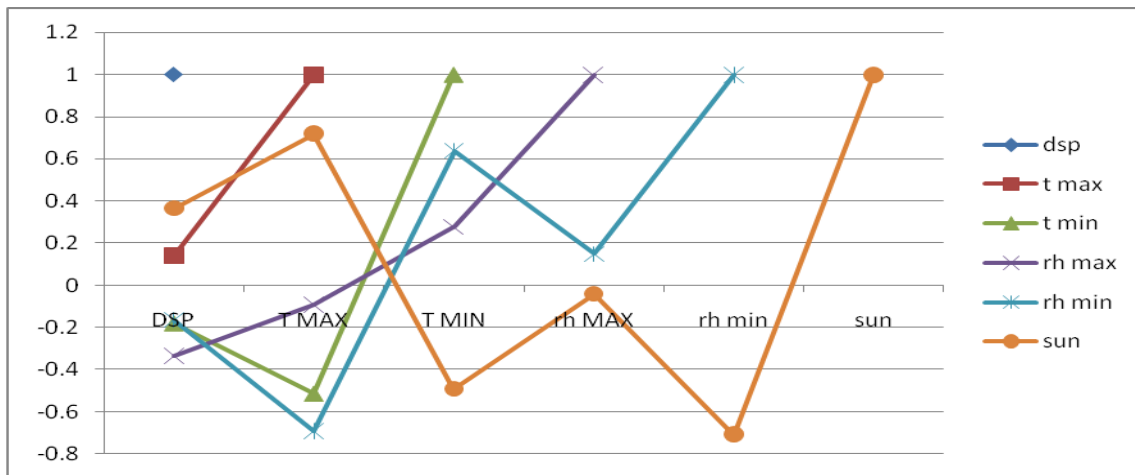


Fig.2 Disease severity curve correlated with Temperature, Relative humidity, and Sunshine hour at Kanpur during 2012-13

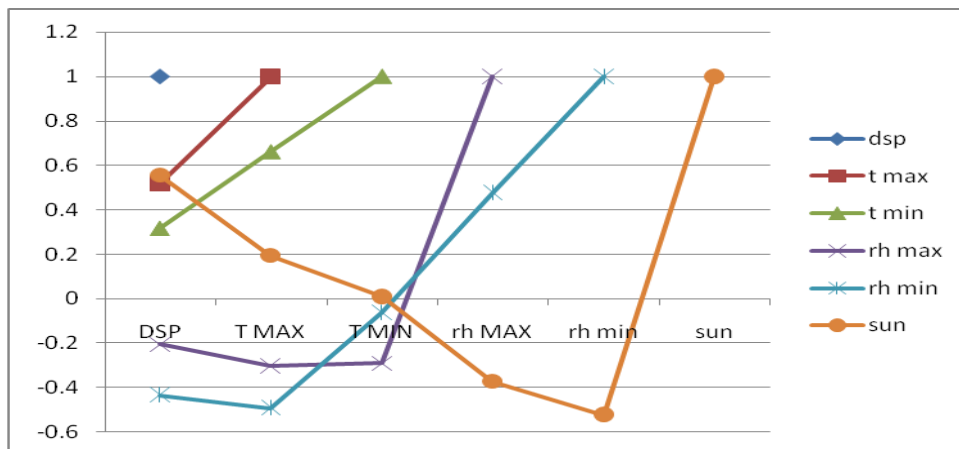


Fig.3 Disease severity curve correlated with temperature, relative humidity, and sunshine hour at Faizabad during 2011-12

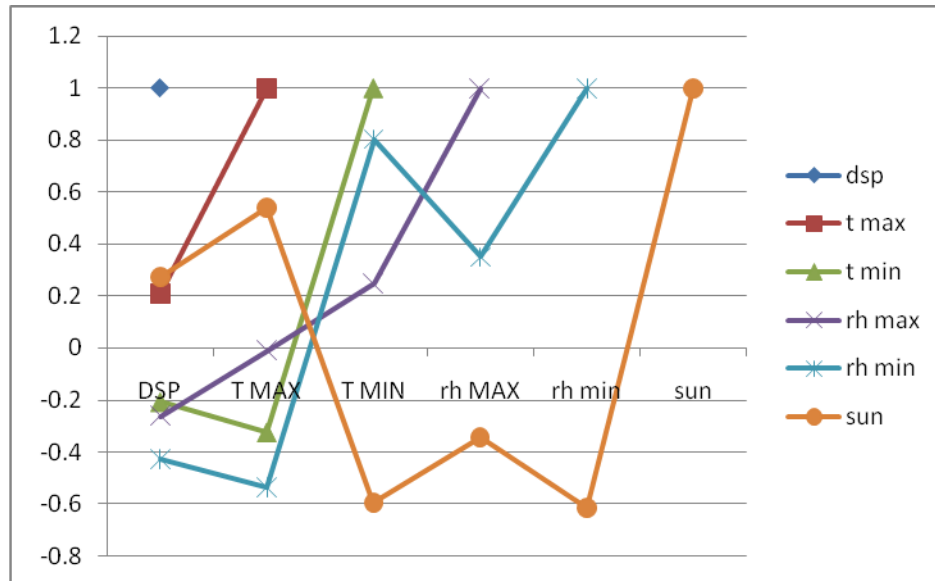
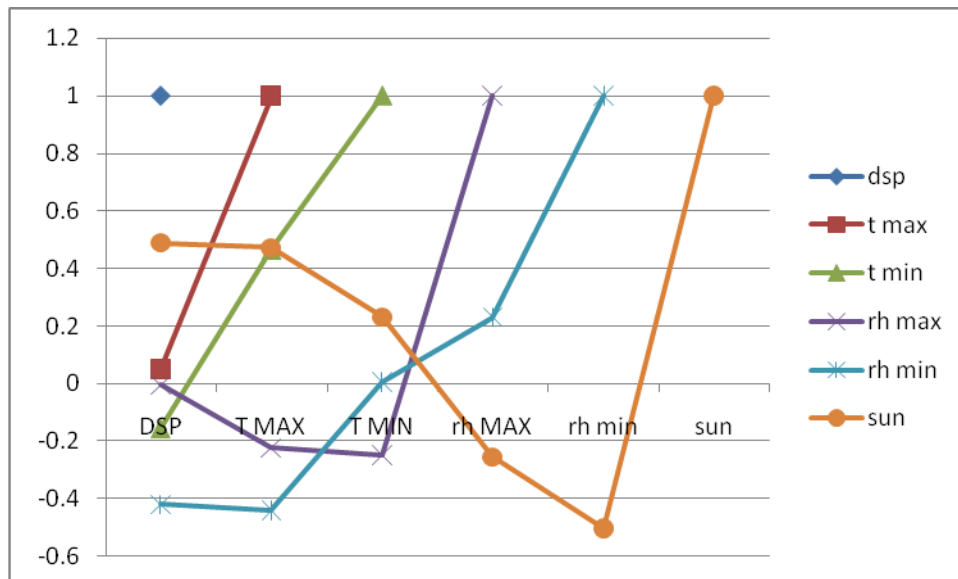


Fig.4 Disease severity curve correlated with temperature, relative humidity, and sunshine hour at Faizabad during 2012-13



The spore content in the atmosphere increases when the mean, maximum and minimum temperatures increases, making *Alternaria* a temperature-dependent fungus. Hjelmroos, (1993) reported that *Alternaria* is a saprophytic genus with an optimal development shown to occur in the temperature ranges of 22–28°C.

The co-relation between disease severity with temperature, relative humidity and sunshine hours were calculated by standard statistical calculation and the results showed that disease severity co-relate negatively with temperature and sunshine hours, representing the value (-0.3984) and (-0.4509), respectively, but positively co-relate with

relative humidity (0.5814) (Biswas *et al.*, 2013).

Angulo-Romero *et al.*, (1999) found that the most conidia appear in the atmosphere when minimum temperatures are over 10°C, maximum temperatures are under 30°C and mean temperatures are between 20 and 25°C.

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