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Correlation coefficient between early blight severity, infection rates and meteorological factors in potato under different fungicidal spray

AJAY KUMAR*, SK SINGH, NARENDER KUMAR[1], VIPIN KUMAR[2], MAHESH SINGH[3] AND HK SINGH

Department of Plant Pathology, ND University of Agriculture and Technology, Kumarganj, Faizabad-224 229, UP, India

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ABSTRACT

Early blight caused by *Alternaria solani* is a severe constraint in potato production. The severity of this disease has been increasing day by day for last few years in India due to changes in weather. Disease severity and area under disease progress curve (AUDPC) was recorded in each treatment plot. The early blight disease had significant negative correlation with maximum relative humidity during 2012-13 and in year 2013-14 minimum temperature was significantly correlated. The severity of early blight showed significant positive correlation with maximum temperature and highly significant positive correlations with sun shine hours in year 2013-14 in all tested treatments. The study showed that minimum temperature and rainfall revealed negative but non-significant correlation in all treatments except untreated control in year 2012-13. The maximum tuber yield 223.70 and 222.00 q/ha in first and second years, respectively, were recorded with spray of Fenamidone @ 0.2% at disease initiation and 2nd spray of Mancozeb @ 0.25% followed by Mancozeb @ 0.25% at 15 days intervals in both respective years.

Key words: Early blight, *Alternaria solani*, Infection rate, Severity, Potato, Fungicides

INTRODUCTION

Potato (*Solanum tuberosum* L.) belongs to family Solanaceae and it is the most important crop among the all vegetables. Potato crop suffers from a number of fungal diseases and causes 20 to 64 per cent losses in yield when favourable condition prevailed. It is attacked by several pathogens, causing serious diseases. Among fungal diseases, early blight is a major one on potato. It is caused by fungus *Alternaria solani* (Ell. and Mart.) Jones and Grout is the most important disease attacking potato plants in different countries of the world. The disease in severe stage can lead to complete defoliation. It is most damaging on potato in regions with heavy dew, rainfall, high humidity, and fairly high temperature (24-29°C). *A. solani* has the capability to grow over a temperature of 4-36°C. Temperature is one of the most important uncontrollable factors affecting crop yield and heat stress is an agricultural problem in many areas in the world (Birch *et al.* 2012).

At global level annual production of potato during 2013 was 453.44 million tonnes covering an area of 19.92 million hectare with the productivity of 22.8 tonnes per hectare. Indian contribution to the world's production was 45.34 million tonnes from 1.99 million hectare area with average productivity of 22.8 tonnes per hectare (Anonymous, 2013).The management of potato crops against this pathogen is important to maximize the crops' yield. The disease occurs throughout the major potato production areas and it is difficult to produce both the crops during the main rainy season without chemical protection measures (Sahu *et al.*, 2013a; Kumar and Shrivastava, 2013). Several components are available on their management. Basically, this disease is controlled with chemicals. Several chemicals, derivatives of chlorothalonil, are more effectiveness for potato late blight control and early blight also, compared to copper based products. A number of control measures for minimizing the disease losses have been recommended by different workers but the use of resistant cultivars remains the most reliable and economical one. Environmental factors play a key role in the development of the disease. The spores remain on the soil surface and on the leaves. Early blight develops more rapidly during periods when environmental conditions alternate between humidity and drought.

In recent years, many studies have been carried out to examine the presence and dispersion of pathogenic fungal spores in crops (Olga *et al.*, 2010). Many authors have developed epidemiological models, in order to predict when the disease will occur and to improve the use of control measures. The correlation between weather and disease severity has been recognized by many authors in different parts of the world (Devi and Chanu, 2012). Atmospheric *Alternaria* spores, temperature and humidity are the factors that most closely correlate with the occurrence of this disease. In the present study, investigation was carried out to elucidate relationship between weather variables and disease progression and evaluate the fungicides in different spray schedules for management of early blight disease. Keeping in view the need of management practices with meteorological factors, the "study on early blight development and infection rates under field conditions" is undertaken with objectives: To

[1]*Department of Plant Pathology, CSAUA&T, Kanpur- 208002, UP, India*
[2]*Department of Plant Pathology, SVBPUT, Meerut-250110, UP, India*
[3]*School of Agriculture, ITM University, Gwalior-475001, MP, India*
*Corresponding Author Email : ajkumar87@rediffmail.com

study the correlation coefficient between early blight severity, infection rates and meteorological factors under different fungicidal spray.

MATERIALS AND METHODS

The experiment was carried out on spray schedules of different fungicides for the management of early blight of potato, cultivars Kufri Bahar was sown on dated 18th November, with three replications and ten treatments in RBD design along with recommended package and practices during 2012-14 at Vegetable Farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (UP) India.

The ten treatments were *viz*: spray with Mancozeb @ 0.25% at disease initiation stage followed by three more spray at 15 days intervals (T_1), Spray with Mancozeb @ 0.25% at disease initiation stage and 2nd spray of Fenamidone @ 0.2% followed by Mancozeb @ 0.25% at 15 days intervals (T_2), Spray with Fenamidone @ 0.2% at disease initiation stage and 2nd spray of Mancozeb @ 0.25% followed by Mancozeb @ 0.25% at 15 days intervals (T_3), Spray with Mancozeb @ 0.25% at disease initiation stage and 2nd spray of Cymoxanil @ 0.2% and 3rd spray of Mancozeb @ 0.25% at 15 days intervals (T_4), Spray with Cymoxanil @ 0.2% at disease initiation stage and 2nd spray of Mancozeb @ 0.25% followed by Mancozeb @ 0.25% at 15 days intervals (T_5) and Spray with Mancozeb @ 0.25% at disease initiation stage and 2nd spray of Dimethomorph @ 0.2% followed by Mancozeb @ 0.25% at 15 days intervals (T_6), Spray with Dimethomorph @ 0.2% at disease initiation stage and 2nd spray of Mancozeb @ 0.25% and 3rd spray of Mancozeb @ 0.25% at 15 days intervals (T_7), Spray with Mancozeb @ 0.25% at disease initiation stage and 2nd spray of Tilt @ 0.2% followed by mancozeb @ 0.25% at 15 days intervals (T_8), Spray with Tilt @ 0.2% at disease initiation stage and 2nd spray of Mancozeb @ 0.25% followed by Mancozeb @ 0.25% at 15 days intervals (T_9) and T_{10} serve as untreated.

The observations on appearance and progression of severity of disease at weekly intervals were recorded. Data of severity were used for calculating area under disease progress curve (AUDPC). Observations on disease severity were recorded on the basis of per cent leaf area affected in newer and older leaves of 10 plants selected randomly in each field using 0-5 rating scale (Kaul, 1983) to early blight. Area under disease progress curve was calculated by the formula given by Forbes *et al.* (2014).

$$AUDPC = \sum_{i=1}^{N} [(Y_{i+1} + Y_i) \times 0.5][T_{i+1} - T_i]$$

Where,

Y_i= Blight severity (%) at the I[st] observation, T_i= Time (days) of the I[st] observation, n= Total number of observations

RESULTS AND DISCUSSION

Correlation coefficient between severity, infection rates and meteorological factors

Data given in Table 1 and 2, revealed that the severity of early blight showed positive but non-significant correlation with maximum temperatures and sunshine hours in 2012-13 in all treatments while, it has showed significant positive correlation with maximum temperature and highly significant positive correlations with sun shine hours in year 2013-14 in all treatments. Mean correlation of maximum, minimum temperature and sunshine hours in 2012-13 and minimum temperature rainfall during 2013-14 showed non-significant positive correlation whereas minimum relative humidity in both years and maximum relative humidity in second year showed non-significant negative correlation. Maximum relative humidity showed significant negative correlation in first year and maximum temperature had showed significant positive correlation in second year.

Mean correlation with sun shine hours showed non-significant positive in first year and significant positive correlation showed in second year. Correlation between infection rates of early blight and maximum temperature showed non-significant positive in 2012-13. Minimum temperature and rainfall showed negative but non-significant correlation in all treatments except T_{10} in year 2012-13 whereas

Table 1: Correlation coefficient between early blight severity and meteorological factors under different fungicidal spray (2012-13) and 2013-14)

Treatments	Correlation coefficient											
	2012-13						2013-14					
	Max. Temp	Min. Temp	Max. R.H.	Min. R.H.	Rainfall	Sunshine hour	Max. Temp	Min. Temp	Max. R.H.	Min. R.H.	Rainfall	Sunshine hour
T1	0.731	0.516	-0.373	0.090	-0.141	0.559	0.874	0.819	-0.928	-0.861	-0.124	0.733
T2	0.737	0.447	-0.309	0.034	-0.160	0.533	0.927	0.779	-0.929	-0.862	-0.104	0.728
T3	0.721	0.481	-0.321	0.036	-0.144	0.524	0.916	0.784	-0.926	-0.826	-0.045	0.677
T4	0.726	0.466	-0.297	0.017	-0.148	0.520	0.937	0.734	-0.907	-0.811	-0.032	0.667
T5	0.732	0.460	-0.304	0.032	-0.156	0.529	0.911	0.777	-0.933	-0.837	-0.058	0.710
T6	0.729	0.469	-0.308	0.025	-0.147	0.526	0.913	0.774	-0.935	-0.846	-0.069	0.723
T7	0.717	0.480	-0.296	0.011	-0.139	0.511	0.924	0.750	-0.937	-0.850	-0.071	0.740
T8	0.742	0.581	-0.314	0.057	-0.089	0.569	0.902	0.778	-0.935	-0.853	-0.085	0.743
T9	0.754	0.644	-0.330	0.060	-0.067	0.604	0.918	0.775	-0.938	-0.861	-0.100	0.744
T10	0.740	0.548	-0.367	0.089	-0.126	0.574	0.806	0.821	-0.898	-0.876	-0.198	0.768
Average	0.733	0.509	-0.322	0.045	-0.132	0.545	0.903	0.779	-0.927	-0.848	-0.089	0.723

maximum relative humidity showed non-significant negative correlation in all treatments except control (T_{10}). Correlation between sun shine hours found positive but non-significant in all treatments except T_{10} (non-significant negative) 2012-13.

During 2013-14, maximum, minimum temperature, rainfall and sun shine hours showed non-significant positive correlation in all treatments and non-significant negative correlation found in control plots (T_{10}). Mean correlation with maximum and minimum temperature in first year and minimum relative humidity in second year showed non-significant negative correlation and other parameters had non-significant positive correlation in both years. A higher minimum temperature produced an increase in disease severity.

However, rainfall and minimum relative humidity did not show any significant effect for disease development. Findings of earlier researchers are in close proximity of findings of present study. Bhukal *et al.,* (2015) reported minimum temperature; Pal *et al.,* (2016) maximum temperature 31-34^{0}C; Kaur *et al.,* (2015) minimum temperature, evening relative humidity and rainfall and Singh *et al.,* (2016) found rainfall favoured the sheath blight disease development. A negative correlation of *A. solani* with rainfall and humidity has been observed by Sahu *et al,* (2013b).

Table 2: Correlation coefficient between infection rates of early blight and meteorological factors under different fungicidal schedules (2012-13 and 2013-14)

Treatments	Correlation coefficient 2012-13						Correlation coefficient 2013-14					
	Max. Temp.	Min. Temp.	Max. R.H.	Min. R.H.	Rainfall	Sunshine hour	Max. Temp.	Min. Temp.	Max. R.H.	Min. R.H.	Rainfall	Sunshine hour
T_1	-0.925	-0.840	-0.997	-0.992	0.118	0.581	-0.921	-0.660	-0.999	0.946	0.953	-0.053
T_2	-0.932	-0.858	-0.998	-0.990	0.104	0.573	-0.929	-0.668	-0.999	0.940	0.956	-0.067
T_3	-0.934	-0.862	-0.999	-0.990	0.105	0.569	-0.932	-0.668	-0.999	0.936	0.959	-0.073
T_4	-0.938	-0.864	-0.999	-0.992	0.106	0.560	-0.937	-0.679	-0.998	0.933	0.951	-0.082
T_5	-0.938	-0.866	-0.999	-0.991	0.105	0.559	-0.937	-0.679	-0.998	0.933	0.958	-0.085
T_6	-0.943	-0.868	-0.999	-0.994	0.107	0.547	-0.941	-0.686	-0.998	0.932	0.957	-0.090
T_7	-0.944	-0.870	-0.999	-0.993	0.106	0.541	-0.942	-0.688	-0.998	0.931	0.957	-0.094
T_8	-0.944	-0.867	-0.999	-0.994	0.114	0.543	-0.943	-0.689	-0.998	0.930	0.957	-0.097
T_9	-0.946	-0.869	-0.999	-0.994	0.114	0.540	-0.945	-0.691	-0.997	0.929	0.957	-0.100
T_{10}	0.948	0.872	0.999	0.994	0.110	0.536	0.945	0.689	0.997	0.930	0.955	0.104
Average	-0.939	-0.863	-0.999	-0.992	0.109	0.555	-0.937	-0.680	-0.998	0.934	0.957	-0.084

Meteorological parameters

In order to ascertain the role of various meteorological factors in disease development, an attempt was made to correlate the apparent infection rate with prevailing temperature, relative humidity (RH) and precipitation during the year 2012-14. Weekly data on mean temperature, relative humidity, precipitation and apparent infection rate (unit/day) recorded are presented in the Table 3 and Table 4. In crop season 2012-13 minimum infection rates 0.227 (unit per day) was recorded in treatment third while, maximum infection rates 0.725 noted on control plots. Over all the infection rates was maximum in between 4th and 5th standard week in 2013. During the higher infection rates, minimum and maximum temperature ranged between 6.05 to 8.40^{0}C and 17.40 to 22.00^{0}C, evening and

Table 3: Effect of meteorological factors on infection rates of early blight of potato under different fungicidal spray (2012-13)

Standard weeks	Temperature (0^{0}C)		Relative humidity (%)		Rainfall (mm)	Sunshine (hrs)	Per day infection rate in different treatments										
	Max.	Min.	Morning	Evening			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Average
1-2	17.40	6.05	93.90	59.35	0	2.4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.349	0.034
2-3	16.30	7.05	94.20	52.05	0	1.2	0.286	0.037	0.102	0.012	0.080	0.142	0.082	0.217	0.176	0.564	0.125
3-4	18.90	8.80	94.20	55.30	3.70	2.5	0.399	0.125	0.082	0.164	0.119	0.247	0.207	0.370	0.340	0.659	0.271
4-5	19.40	8.80	93.70	55.70	12.50	2.8	0.473	0.213	0.188	0.250	0.213	0.315	0.284	0.448	0.422	0.721	0.352
5-6	20.30	9.20	92.05	55.80	8.80	4.8	0.609	0.361	0.344	0.399	0.375	0.441	0.420	0.589	0.576	0.851	0.496
6-7	21.50	9.40	91.20	55.80	0	5.7	0.734	0.501	0.493	0.534	0.519	0.564	0.551	0.668	0.629	0.949	0.614
7-8	22.00	8.40	90.90	55.08	**0**	4.8	0.776	0.623	0.586	0.649	0.637	0.667	0.653	0.722	0.670	0.985	0.696
Average	19.4	8.24	92.87	55.58	3.57	3.45	0.468	0.255	0.227	0.286	0.254	0.339	0.313	0.430	0.401	0.725	

morning RH ranged between 52.08-59.05 and 90.90-94.20 per cent, respectively and rainfall was occurred between 3.7-12.50 mm. Whereas, sunshine hours were ranged between 1.20 to 5.70 hours per day at that time.

In crop season 2013-14, infection rates of disease was affected by different treatments and found minimum i.e., 0.378 unit per day in treatment third while, maximum infection rates 0.656 noted on control plots. Over all the infection rates was recorded maximum in between last and 1st standard week of 4th and 5th in 2014.

During the higher infection rates minimum and maximum temperature ranged between 5.40 to 11.40 ^{0}C and 19.50 to 26.80 ^{0}C, evening and morning RH ranged between 41.40 - 68.25 and 80.40 - 90.85 per cent, respectively, whereas sunshine hours were ranged between 3.65 to 10.50 hours per day at that time. The present study is in agreement with Kumar *et al.* (2017) who reported that availability of abundant moisture during the growth period followed by warm and dry weather conditions are most conducive for early blight development of potato. Similar results were in accordance of Kaur *et al.*, (2015); Yadav and Pathak (2011).

Table 4: Effect of meteorological factors on infection rates of early blight of potato under different fungicidal spray (2013-14)

Standard weeks	Temperature (0^0C)		Relative humidity (%)		Rainfall (mm)	Sunshine (hrs)	Per day infection rate in different treatments										
	Max.	Min.	Morning	Evening			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Average
2-3	19.50	7.50	90.85	68.25	0.35	3.65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.169	0.016
3-4	21.75	6.70	87.65	59.30	0.1	5.60	0.259	0.116	0.053	0.091	0.047	0.238	0.184	0.228	0.233	0.513	0.185
4-5	22.80	5.40	86.65	54.40	0.0	7.05	0.456	0.389	0.282	0.358	0.365	0.445	0.446	0.453	0.443	0.597	0.423
5-6	22.80	5.80	85.40	61.35	1.1	6.35	0.561	0.498	0.481	0.513	0.519	0.556	0.548	0.553	0.537	0.670	0.543
6-7	23.65	7.95	83.20	59.80	1.25	10.50	0.644	0.595	0.584	0.605	0.599	0.626	0.618	0.614	0.613	0.735	0.623
7-8	26.15	10.05	82.85	49.05	0.15	6.20	0.734	0.690	0.664	0.689	0.684	0.707	0.703	0.704	0.698	0.875	0.714
8-9	26.80	11.4	80.40	41.40	0.0	7.95	0.833	0.733	0.692	0.673	0.735	0.758	0.752	0.777	0.765	1.033	0.775
Average	23.35	7.82	85.28	56.22	0.42	6.75	0.498	0.431	0.378	0.418	0.421	0.475	0.464	0.475	0.469	0.656	

Disease severity, Area Under Disease Progress Curve and Yield Attribute

In crop season 2012-13 earliest disease appeared during first week of January 2013 in control and treated plots, respectively. The per cent disease severity increased gradually till maturity and reached its maximum i.e. 8.93, 10.06, 10.50, 10.90, 11.00, 11.49, 11.50, 13.62, 16.20 and 32.50 per cent on cultivar K. Bahar in treatment third, second, fifth, fourth, seven, six, nine, eight, first and ten, respectively. Among the treated plots minimum AUDPCs was 173.35 noted in treatment third while maximum AUDPCs 355.39 recorded in treatment first. In the control plots maximum AUDPCs 741.16 was noted on cultivar Kufari Bahar (Table 5).

Table 5: Effect of different fungicidal spray on appearance and progress of early blight in potato cv. Kufri Bahar (2012-13)

Treatment	Appearance Date	DAS	Per cent disease severity at weekly intervals								AUDPC
			04. 01.13	11. 01.13	18.01.13	25.01.13	01.02.13	08.02.13	15.02.13	22.02.13	
T_1	03.01.2013	40	0.80	2.79	3.93	5.20	6.35	9.70	14.30	16.20	355.39
T_2	03.01.2013	40	0.40	1.50	2.10	2.70	3.20	4.80	7.00	10.06	185.71
T_3	09.01.2013	46	0.00	1.40	1.90	2.50	3.04	4.60	6.86	8.93	173.35
T_4	09.01.2013	46	0.00	1.63	2.25	2.93	3.50	5.30	7.70	10.90	201.32
T_5	07.01.2013	44	0.00	1.40	2.00	2.70	3.20	5.00	7.40	10.50	189.11
T_6	03.01.2013	40	0.60	2.13	2.81	3.50	4.10	5.91	8.41	11.49	231.42
T_7	09.01.2013	46	0.00	1.90	2.50	3.21	3.79	5.60	8.10	11.00	215.92
T_8	06.01.2013	43	0.00	2.50	3.30	4.90	5.90	9.13	11.50	13.62	336.28
T_9	06.01.2013	43	0.00	1.90	3.24	4.48	5.50	8.80	10.12	11.50	319.48
T_{10}	03.01.2013	40	1.70	5.80	8.42	11.20	13.56	20.90	28.90	32.50	741.16

During 2013-14 progression of the disease severity was noted at weekly intervals. The per cent disease severity increased gradually till maturity of the crop in February and reached up to 11.50, 12.30, 14.07, 14.20, 15.00, 15.30, 15.67, 16.27, 19.63 and 38.53 per cent on cultivar Kufari Bahar in treatment fourth, third, second, fifth, seven, six, nine, eight, first and ten, respectively. Among the treated plots, minimum AUDPCs was 288.96 noted in treatment third while, maximum

AUDPCs 391.96 was recorded in treatment first. Maximum reduction percentage of disease over control was found in treatment third followed by treatment fourth in both crop seasons (Table 6).

Table 6: Effect of different fungicidal spray on appearance and progress of early blight in potato cv. Kufri Bahar (2013-14)

	Appearance		Per cent disease severity at weekly intervals								AUDPC
Treatment	Date	DAS	07.01.14	14.01.14	21.01.14	28.01.14	04.02.14	11.02.14	18.02.14	25.02.14	
T_1	10.01.2014	47	0.90	2.60	3.70	6.30	8.27	10.66	14.20	19.63	391.96
T_2	11.01.2014	48	0.00	1.60	3.00	5.30	6.87	9.20	12.37	14.07	317.62
T_3	11.01.2014	48	0.00	1.30	2.30	4.10	6.70	8.87	11.36	12.30	288.96
T_4	11.01.2014	48	0.00	1.60	2.80	4.90	7.26	9.47	12.30	11.50	319.06
T_5	09.01.2014	46	0.00	1.50	2.60	5.10	7.37	9.26	12.10	14.20	315.12
T_6	09.12.2014	46	0.80	2.30	3.60	6.10	8.17	10.07	13.00	15.30	360.32
T_7	10.01.2014	47	0.00	1.80	3.40	6.20	7.96	9.80	12.87	15.00	347.41
T_8	10.01.2014	47	0.60	2.30	3.50	6.30	8.07	9.67	12.90	16.27	358.23
T_9	11.01.2014	48	0.00	2.40	3.50	6.10	7.67	9.67	12.67	15.67	347.62
T_{10}	06.01.2014	43	1.30	4.30	7.40	9.20	11.56	14.20	22.67	38.53	624.15

The maximum tuber yield 223.70 and 222.00 q/ha in first and second years, respectively, were recorded with T_3 *i.e.*, spray with Fenamidone @ 0.2% at disease initiation and 2nd spray of Mancozeb @ 0.25% followed by Mancozeb @ 0.25% at 15 days intervals in both respective years whereas, minimum tuber yield 178.50 and 175.00 q/ha and among the treated plot minimum tuber yields 194.00 and 190.50 q/ha in first and second years, respectively, were noted in T_{10} and T_1 *i.e.*, untreated and spray with Mancozeb @ 0.25% at disease initiation followed by three more spray at 15 days intervals (Table 7).

Table 7: Effect of fungicidal spray on disease severity (%) and tuber yield (q/ha) in potato (2012-13 and 2013-14)

Treat-	Early blight severity (%)			Yield (q/ha)		
ments	2012-13	2013-14	Mean	2012-13	2013-14	Mean
T_1	16.20	19.63	17.69	194.00	190.50	192.25
T_2	10.06	14.07	12.07	203.90	197.00	200.45
T_3	8.93	12.30	10.62	223.70	222.00	222.85
T_4	10.90	11.50	10.70	220.10	219.70	219.90
T_5	10.50	14.20	12.35	221.90	220.50	221.20
T_6	11.49	15.30	13.66	218.70	215.00	216.85
T_7	11.00	15.00	13.00	220.12	218.90	219.51
T_8	13.62	16.27	16.94	207.50	203.20	205.35
T_9	11.50	15.67	16.25	218.00	213.20	215.60
T_{10}	32.50	38.53	40.01	178.50	175.00	176.75
S.Em±	0.37	0.43		1.09	1.87	
CD at 5%	1.09	1.20		1.89	3.25	

A similar phenomenon was observed by Pazderu and Hamouz (2017); Pal *et al.* (2016); Mirkarimi *et al.* (2013). These observations are in accordance with Kapsa (2010) reported that the effectiveness of new chemicals *viz.*, Curzate, Fenamidone, Acrobat to management of early and late blight. A significant increase in the number of tubers under influence of heat stresses acting in the second, third and fourth period in conditions of favourable soil moisture was found. An increase in the number of tubers as a result of high temperature stress was also found in the earlier study (Rykaczewska 2015).

CONCLUSION

The present studies give us an insight into the status of early blight disease of potato in relation to different weather variables, its infection rates as well as its progression and development in Eastern Uttar Pradesh. It can be concluded that the severity of early blight showed significant positive correlation with maximum temperature and highly significant positive correlations with sun shine hours in all treatments. Mean infection rates showed numerically positive association with maximum and minimum temperatures.

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