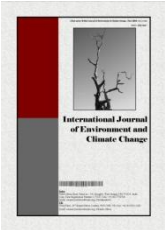

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Epidemiology of Late Blight of Potato, Its Progress and Apparent Rate of Infection

S. Dey [a], A. Chakraborty [a] and N. K. Adhikary [a*]

[a] Department of Plant Pathology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, Nadia, West Bengal, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Late blight of potato caused by *Phytophthora infestans* is one of the most destructive diseases of potato world over. The devastation of the disease is very much related with climatic factors like temperature, relative humidity, fog or dew deposition and also sunshine hours. An experiment was conducted in Indo-Gangetic plains of West Bengal to know the effect of weather parameters on initiation and severity of the disease as well as progress and pattern of development of disease which will ultimately help to develop the effective spray schedule to manage the disease. From the experiment it is observed that 7 days prior to first appearance of late blight disease of potato the average maximum and minimum temperature varied between 24-26˚C and 7-8˚C respectively; average maximum and minimum relative humidity varied between 90-93% and 41-44% respectively; average sunshine hours per day varied between 6-8 hours. Correlation study of late blight disease severity with different weather parameters were also carried out. Maximum and minimum temperature as well as maximum and minimum relative humidity found to be positively correlated with late blight disease build up. While sunshine hour found to be negatively correlated with the disease build up. But only minimum temperature was significant at 0.01 level in all the planting dates and maximum temperature was significant at 0.01 level in two dates of planting. Apparent rate of infection of the disease and area under disease progress curve were calculated for different planting dates of potato. From the results it is evident that late blight of potato progressed almost in an exponential fashion starting from its first appearance. As the crop approached towards maturity and weather became unfavourable for the pathogen the rate of progress declined. This may be due to non-availability of healthy tissue.

**Corresponding author: E-mail: nayan.bckv@gmail.com;*

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1. INTRODUCTION

Late blight, caused by the oomycete *Phytophthora infestans* (Mont.) de Bary, is considered to be the most important and devastating potato foliage and tubers disease worldwide. In West Bengal the disease usually appears between first to third weeks of January in every year. As the *Phytophthora infestans* is a fast spreading pathogen, therefore, its management is still a challenging job to plant pathologist all over the world. The devastation of the disease is very much related with climatic factors like temperature, relative humidity, fog or dew deposition and also sunshine hours. If favourable weather prevails the total crop failure may occur within 2-4 days causing economically loss. The rate of inoculum production and dispersal as well as the viability and infectivity of the inoculum are the crucial factors that govern rates of epidemic development [1]. Though there are lots of management strategies for the disease but till date application of suitable fungicide is the best management strategy inspite of having resistant varieties. But application of fungicides is cost involving and environmental hazardous. It is known that fungicides, it is necessary for the late blight control are effective only if they are applied before and very close to the time of infection [2]. Therefore, judicious application of fungicide is necessary. But for judicious application of fungicide it necessary to know the apparent rate of infection of the disease and also the area under disease progress curve (AUDPC). If we can know how the disease progress within the crop season then it will be possible to develop the effective spray schedule for the management of late blight of potato. Keeping all these in view of mind the present investigation was undertaken to observe the effect of weather variables on the late blight disease as well as pattern of development and apparent rate of infection of the disease in Indo-Gangetic plains of West Bengal.

2. MATERIALS AND METHODS

2.1 Effect of Weather Variables on Late Blight Disease

Late blight disease appearance on plants with different dates of sowing during 2012-2013 was recorded and meteorological data for the total potato growing season were recorded. Correlation studies of late blight disease severity with different weather parameters were also done.

2.2 Apparent Rate of Infection and AUDPC

Studies on progress, apparent rate of infection and AUDPC of potato late blight disease with respect to different dates of sowing under natural field conditions were conducted in two successive crop season *i.e.,* during 2012-2013 and 2013-2014 at Adisaptagram Block Seed Farm, Hooghly, West Bengal. For present investigation the variety used was Kufri Chandramukhi, susceptible to late blight. The disease incidence and intensity per cent were recorded at 7 days interval on the basis of visual symptoms after the first appearance of symptoms due to infection of *Phytophthora infestans*. At each plot per cent disease intensity (PDI) or severity of the disease was recorded following the scale of Horsfall and Barrett [3] as used in modified form (0-11) by a number of researchers [4,5,6]. Finally, PDI values were calculated by using the formula developed by McKinney [7].

The disease incidence and PDI were recorded carefully and the apparent rate of infection of the disease was calculated by using the following formula developed by Vander Plank [8].

$$r = \frac{1}{t_2 - t_1} log_e \left[\frac{x_2(1-x_1)}{x_1(1-x_2)}\right]$$

where,

r = Apparent infection rate at exponential growth stage
t_1 = Time of the first measurement
t_2 = Time of the final measurement
x_1 = Proportion of infection measured at time t_1
x_2 = Proportion of infection measured at time t_2

For measuring the amount of disease, Area under Disease Progress Curve (AUDPC) was calculated by using the formula outlined by Das et al. [9].

$$AUDPC = \sum_{i=1}^{n} [(x_i + x_{i+1})/2](t_{i+1} - t_i)$$

where,

x_i = PDI at i^{th} observation

t_i = Time of i^{th} observation (days)
n = Number of scoring dates

3. RESULTS AND DISCUSSION

3.1 Effect of Weather Parameters on Initiation and Severity of Late Blight of Potato

To know the effect of various weather parameters on initiation and severity of the disease, the experiment was conducted for two years *viz.,* 2012-2013 and 2013-2014 potato growing seasons. In the year 2012-2013 potato was planted on four different dates *viz*., 19th November, 29th November, 9th December and 19th December. Average weather parameters of last seven days were recorded from the date of initiation of the disease for each plot. From meteorological observations (Tables 1-4) in 7 days prior to first appearance of the disease the average maximum and minimum temperature varied between 24.46°C to 25.17°C and 7.10°C to 7.93°C respectively; average maximum and minimum relative humidity varied between 90.57% to 92.57% and 41.57% to 43.71% respectively; average sunshine hours per day varied between 6.89 to 7.90 hours.

Correlation studies of increase of potato late blight disease severity in seven days with weather parameters such as maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and sunshine hour were also made. It was found that in case of 19th November, 2012 planting, the correlation coefficients between Increase of PDI of late blight disease and minimum temperature was significant at 0.01 level. It had very strong positive impact (r = 0.74) on disease spread. In case of 29th November, 2012 planting, the correlation coefficients between increases of PDI of late blight disease and maximum temperature, minimum temperature and minimum relative humidity were significant at 0.01 level. Maximum temperature and minimum temperature had very strong positive impact (r = 0.71 and 0.82 respectively) and minimum relative humidity had strong positive impact (r = 0.50) on disease spread.

In case of 9th December, 2012 planting, the correlation coefficients between increases of PDI of late blight disease and minimum temperature and maximum relative humidity were significant at 0.01 level and minimum relative humidity was significant at 0.05 level. Minimum temperature had very strong positive impact (r=0.80) and maximum relative humidity and minimum relative humidity had strong positive impact (r = 0.49 and 0.40 respectively) on disease spread.

Table 1. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 19th November, 2012

Date of observation	Increase of PDI in 7 days	Temp. (°C)		RH (%)		Sunshine hour (hr/day)
		Max.	Min.	Max.	Min.	
25.01.2013	2.24	25.11	7.93	92.57	43.71	6.89
01.02.2013	16.21	25.63	10.67	94.43	49.43	6.27
08.02.2013	13.55	29.00	13.29	90.71	49.14	5.67
15.02.2013	11.56	29.81	12.47	89.71	35.71	8.87
r value		0.38	0.74**	0.08	0.34	-0.20

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

Table 2. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 29th November, 2012 sown plant

Date of observation	Increase of PDI in 7 days	Temp. (°C)		RH (%)		Sunshine hour (hr/day)
		Max.	Min.	Max.	Min.	
29.01.2013	1.88	24.46	7.10	91.71	41.57	7.81
05.02.2013	14.62	27.94	10.67	94.43	47.71	5.59
12.02.2013	12.06	29.00	12.91	90.57	43.00	7.19
19.02.2013	14.51	27.63	14.37	90.57	51.43	6.27
26.02.2013	12.18	30.97	13.94	91.71	38.57	9.89
r value		0.71**	0.82**	0.14	0.50**	-0.33

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

Table 3. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 9th December, 2012 sown plant

Date of observation	Increase of PDI in 7 days (%)	Temp. (°C)		RH (%)		Sunshine hour (hr/day)
		Max.	Min.	Max.	Min.	
31.01.2013	1.64	25.17	7.17	90.57	41.86	7.30
07.02.2013	12.58	28.87	12.53	92.86	48.57	5.47
14.02.2013	9.13	29.01	12.99	90.00	40.14	7.90
21.02.2013	18.87	27.01	13.61	92.57	55.14	6.27
28.02.2013	11.95	32.24	14.57	90.86	35.43	10.04
07.03.2013	12.16	33.30	14.54	89.43	30.57	9.86
r value		0.32	0.80**	0.49**	0.40*	-0.13

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

Table 4. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 19th December, 2012 sown plant

Date of observation	Increase of PDI in 7 days (%)	Temp. (°C)		RH (%)		Sunshine hour (hr/day)
		Max.	Min.	Max.	Min.	
01.02.2013	1.88	25.13	7.93	90.71	43.71	7.90
08.02.2013	12.37	25.63	10.67	94.43	49.43	6.27
15.02.2013	10.08	29.00	13.29	90.71	49.14	5.67
22.02.2013	11.34	26.73	13.61	93.29	55.57	6.41
01.03.2013	8.66	32.26	14.64	90.29	34.00	10.09
08.03.2013	7.88	34.07	15.11	88.71	31.57	9.56
15.03.2013	11.91	36.00	20.71	90.29	38.57	7.16
r value		0.34*	0.53**	0.29	0.08	-0.29

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

In case of 19th December, 2012 planting, the correlation coefficients between increases of PDI of late blight disease and minimum temperature was significant at 0.01 level and maximum temperature was significant at 0.05 level. Minimum temperature had strong positive impact (r = 0.53) and maximum temperature had moderate positive impact (r = 0.34) on disease spread.

From meteorological observations it is observed that 7 days prior to first appearance of late blight disease of potato, the average maximum and minimum temperature varied between 24-26˚C and 7-8˚C respectively; average maximum and minimum relative humidity varied between 90-93% and 41-44% respectively; average sunshine hours per day varied between 6-8 hours. Maximum and minimum temperature as well as maximum and minimum relative humidity found to be positively correlated with late blight disease build up. While sunshine hour found to be negatively correlated with the disease build up. But only minimum temperature was significant at 0.01 level in all the dates of planting and maximum temperature was significant at 0.01 level in two dates of planting.

3.2 Progress of Late Blight of Potato in Respect of Percent Disease Intensity

The results of the progress of the potato late blight disease with respect to different dates of planting are presented in Table 5. The result indicates that the percent disease intensity (PDI) of late blight increased gradually from the date of disease initiation to 42 days after first appearance of the disease. In 2012-2013 crop season, in case of 19th November planting percent disease intensity progressed as 2.24, 18.45, 32.00 and 43.56% respectively. Not only that, from first initiation to 42 days PDI increased in an exponential fashion and thereafter, as the healthy leaf tissue decreased and weather became unfavourable the disease got restricted. Similar trend was observed in 29th November, 9th December and 19th December planting.

In 2013-2014 crop season, the disease progressed gradually in all the dates of planting *i.e.*, in 23rd November planting, PDI progressed as 2.12, 14.22, 30.35, 35.22 and 56.33% from disease initiation and at 7, 14, 21 and 28 DAI respectively. In 3rd December planting PDI increased as 2.00, 12.25, 21.33, 29.50, 43.22

and 65.30% from disease initiation and at 7, 14, 21 and 28 DAI respectively. Similar trend was followed in case of 13th December planting. Therefore, from the above findings it is evident that the disease progressed with progress of time in all the dates of planting but the progress was more in 3rd December planting.

3.3 Apparent Rate of Infection and AUDPC of Late Blight of Potato in Respect of Different Time of Planting

The apparent rate of infection and AUDPC of late blight has been presented in Table 6 and in Figs. 1-7. It is evident from the result that maximum apparent rate of infection (0.1673) observed in 19th November planting and minimum (0.1079) in 19th December planting in 2012-13 crop season. In 2013-2014 crop season maximum apparent rate of infection (0.1458) observed in 23rd November planting followed by 3rd December planting (0.1291) and least (0.0976) observed in 13th December planting. Same trend has been reported by Ghosh et al. [10] in relation to progress and apparent rate of viral diseases of potato in plains of West Bengal.

From Table 6 and in Figs. 1-7, it is also evident that the maximum AUDPC (1426.53) was observed in 19th December followed by 9th December planting (1175.62) in 2012-2013 crop season and the AUDPC value were declined as the crop sown earlier. In 2013-2014 season same trend was also followed. Same trend was also observed in case of relative AUDPC for both the years.

Table 5. Progress of late blight of potato in respect of percent disease intensity

Year	Dates of planting	Disease intensity (%) at 7 days interval						
		DDI*	7 DAI**	14 DAI	21 DAI	28 DAI	35 DAI	42 DAI
2012-2013	19th Nov.	2.24	18.45	32.00	43.56	–	–	–
	29th Nov.	1.88	16.50	28.56	43.07	55.25	–	–
	9th Dec.	1.64	14.22	23.35	42.22	54.17	66.33	–
	19th Dec.	1.88	14.25	24.33	35.67	44.33	52.21	64.12
2013-2014	23rd Nov.	2.12	14.22	30.35	35.22	56.33	–	–
	3rd Dec.	2.00	12.25	21.33	29.50	43.22	65.30	–
	13th Dec.	2.24	14.25	24.33	33.67	44.33	53.21	58.12

** DDI = Date of disease initiation; **DAI = Days after initiation of disease*

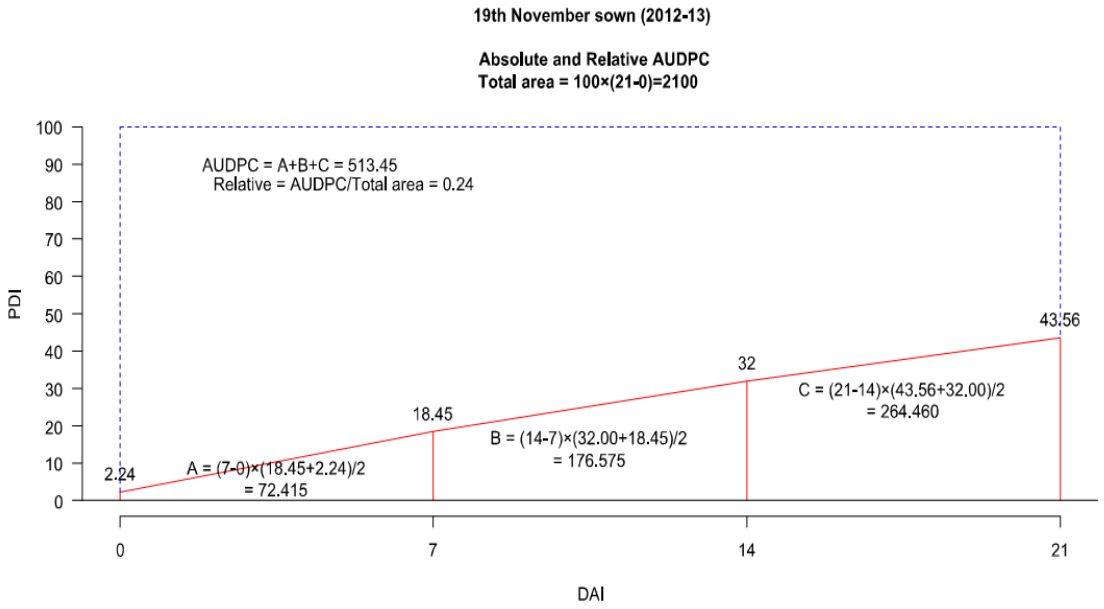

Fig. 1. Area under disease progress curve (AUDPC) of potato late blight on 19th November sown plant during 2012-2013

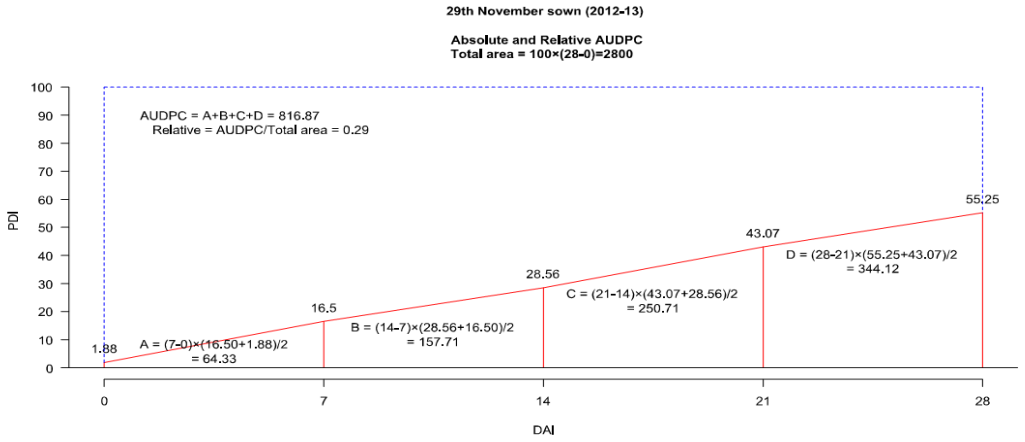

Fig. 2. Area under disease progress curve (AUDPC) of potato late blight on 29th November sown plant during 2012-2013

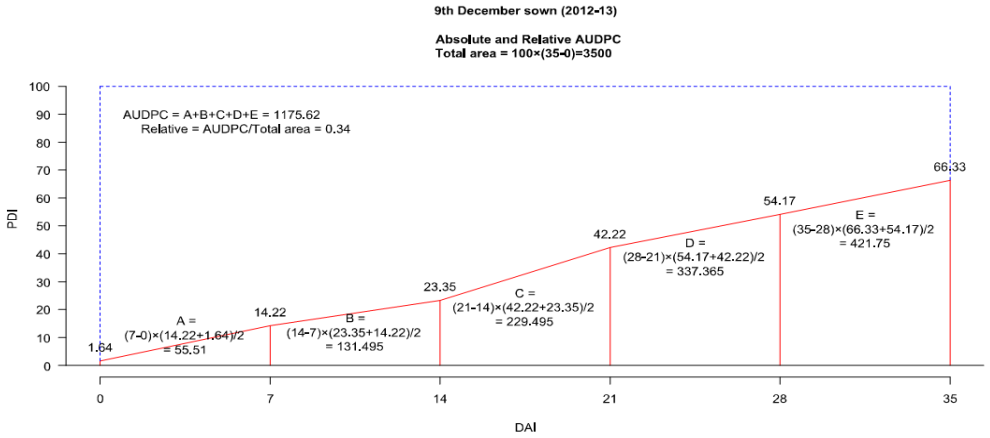

Fig. 3. Area under disease progress curve (AUDPC) of potato late blight on 9th December sown plant during 2012-2013

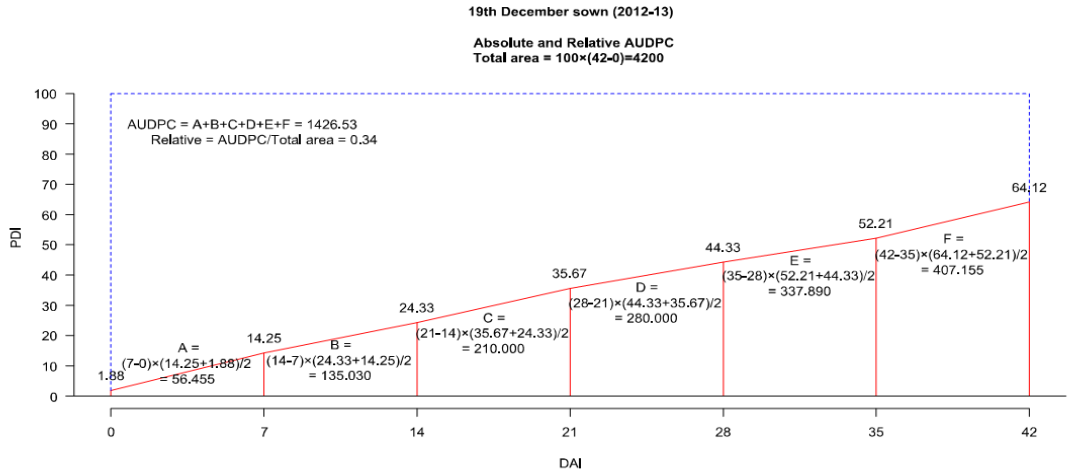

Fig. 4. Area under disease progress curve (AUDPC) of potato late blight on 19th December sown plant during 2012-2013

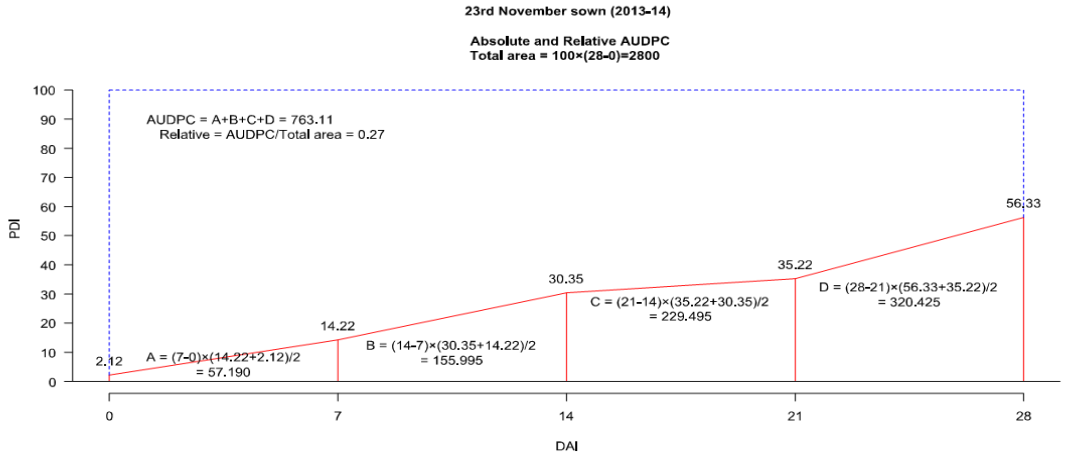

Fig. 5. Area under disease progress curve (AUDPC) of potato late blight on 23rd November sown plant during 2013-2014

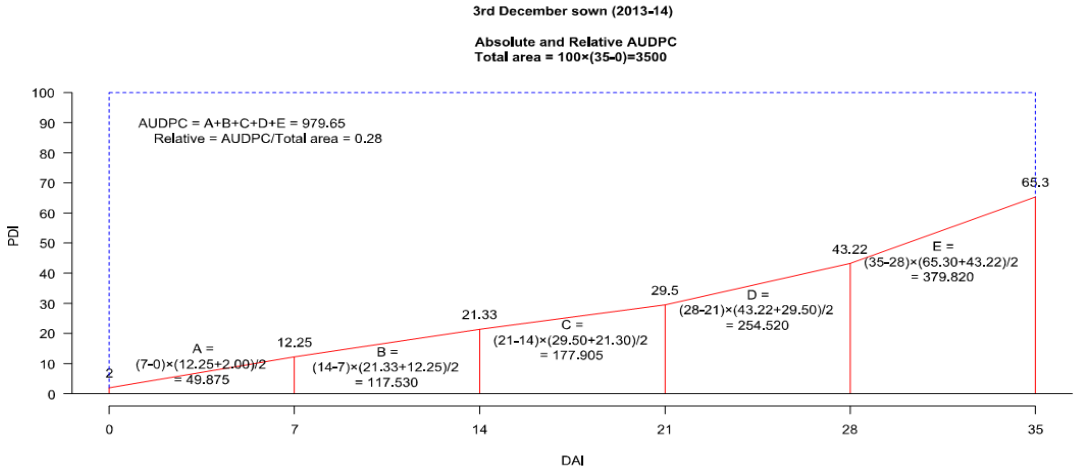

Fig. 6. Area under disease progress curve (AUDPC) of potato late blight on 3rd December sown plant during 2013-2014

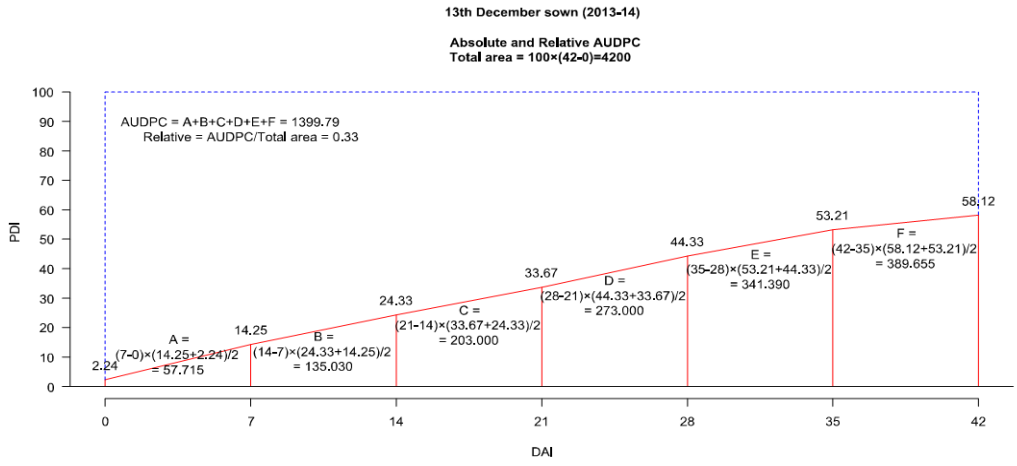

Fig. 7. Area under disease progress curve (AUDPC) of potato late blight on 13th December sown plant during 2013-2014.

Table 6. Apparent rate of infection and AUDPC of late blight of potato in respect of different dates of planting

Year	Dates of planting	Per cent disease intensity (PDI)				AUDPC value	Relative AUDPC
		PDI at 1st observation	Max. PDI at final observation	Periods (day) taken to reach max. PDI	Apparent infection rate/day		
2012-2013	19th Nov.	2.24	43.56	21	0.1673	513.45	0.24
	29th Nov.	1.88	55.25	28	0.1486	816.87	0.29
	9th Dec.	1.64	66.33	35	0.1362	1175.62	0.34
	19th Dec.	1.88	64.12	42	0.1079	1426.53	0.34
2013-2014	23rd Nov.	2.12	56.33	28	0.1458	763.11	0.27
	3rd Dec.	2.00	65.30	35	0.1291	979.65	0.28
	13th Dec.	2.24	58.12	42	0.0976	1399.79	0.33

4. CONCLUSION

Therefore, from above findings it is evident that late blight of potato progressed almost in an exponential fashion starting from its first appearance. As the crop approached towards maturity and weather became unfavourable the rate of progress declined. This may be due to death of healthy tissue and unfavourable weather conditions for the pathogen. Therefore, it may be concluded from the above findings that for proper management of late blight disease the apparent rate of infection or inoculum build up should be kept under check by application of suitable fungicides.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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