

# Epidemiology of late blight of potato, its progress and apparent rate of infection

## 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.

**Keywords:** Climate, correlation, disease, epidemiology, late blight, potato

## 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

### 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.

### 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 scientists [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  $i^{\text{th}}$  observation
- $t_i$  = Time of  $i^{\text{th}}$  observation (days)
- $n$  = Number of scoring dates

## 3. RESULTS AND DISCUSSION

### 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., 19<sup>th</sup> November, 29<sup>th</sup> November, 9<sup>th</sup> December and 19<sup>th</sup> December. Average weather parameters of last seven days were recorded from the date of initiation of the disease for each plot. From meteorological observations (Table 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.

**Table 1. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 19<sup>th</sup> 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

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 19<sup>th</sup> 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 29<sup>th</sup> 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.

**Table 2. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 29<sup>th</sup> 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

In case of 9<sup>th</sup> 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 3. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 9<sup>th</sup> 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

In case of 19<sup>th</sup> 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.

**Table 4. Correlation coefficient of seven days average weather factors and increase of PDI of late blight of potato in seven days on 19<sup>th</sup> 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

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.

### 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 19<sup>th</sup> 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 29<sup>th</sup> November, 9<sup>th</sup> December and 19<sup>th</sup> December planting.

**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 | 19 <sup>th</sup> Nov. | 2.24                                     | 18.45   | 32.00  | 43.56  | –      | –      | –      |
|           | 29 <sup>th</sup> Nov. | 1.88                                     | 16.50   | 28.56  | 43.07  | 55.25  | –      | –      |
|           | 9 <sup>th</sup> Dec.  | 1.64                                     | 14.22   | 23.35  | 42.22  | 54.17  | 66.33  | –      |
|           | 19 <sup>th</sup> Dec. | 1.88                                     | 14.25   | 24.33  | 35.67  | 44.33  | 52.21  | 64.12  |
| 2013-2014 | 23 <sup>rd</sup> Nov. | 2.12                                     | 14.22   | 30.35  | 35.22  | 56.33  | –      | –      |
|           | 3 <sup>rd</sup> Dec.  | 2.00                                     | 12.25   | 21.33  | 29.50  | 43.22  | 65.30  | –      |
|           | 13 <sup>th</sup> 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

In 2013-2014 crop season, the disease progressed gradually in all the dates of planting i.e., in 23<sup>rd</sup> 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 3<sup>rd</sup> 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 13<sup>th</sup> 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 3<sup>rd</sup> December planting.

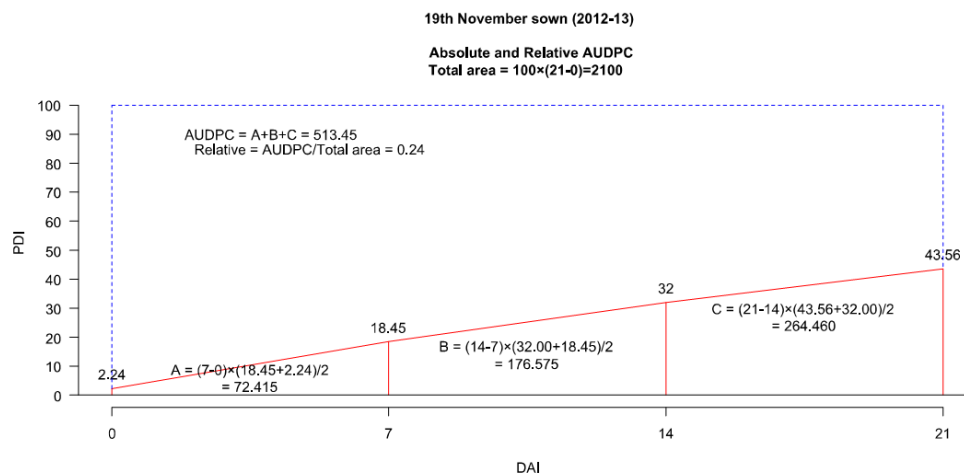
### Apparent rate of infection and AUDPC of late blight of potato in respect of different time of planting

The apparent rate of infection and AUDPC of late blight has been presented in table 6 and in fig. 1-7. It is evident from the result that maximum apparent rate of infection (0.1673) observed in 19<sup>th</sup> November planting and minimum (0.1079) in 19<sup>th</sup> December planting in 2012-13 crop season. In 2013-2014 crop season maximum apparent rate of infection (0.1458) observed in 23<sup>rd</sup> November planting followed by 3<sup>rd</sup> December planting (0.1291) and least (0.0976) observed in 13<sup>th</sup> 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.

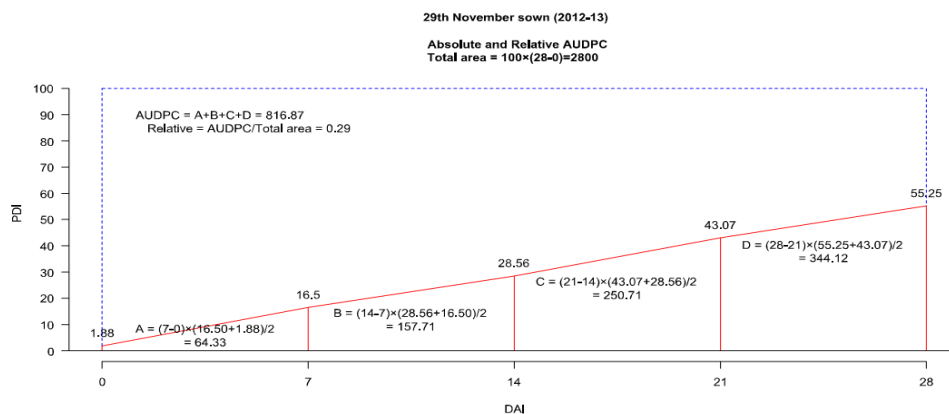
From table 6 and in fig. 1-7, it is also evident that the maximum AUDPC (1426.53) was observed in 19<sup>th</sup> December followed by 9<sup>th</sup> December planting (1175.62) in 2012-2013 crop season and the AUDPC value were declined as the crop sown earlier. In 2013-2014 season same trend was also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

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



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



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

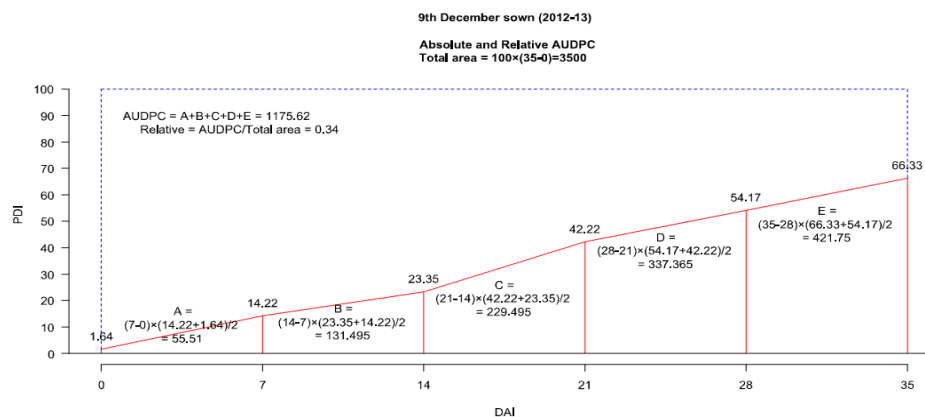


Fig. 3. Area under disease progress curve (AUDPC) of potato late blight on 9<sup>th</sup> December sown plant during 2012-2013.

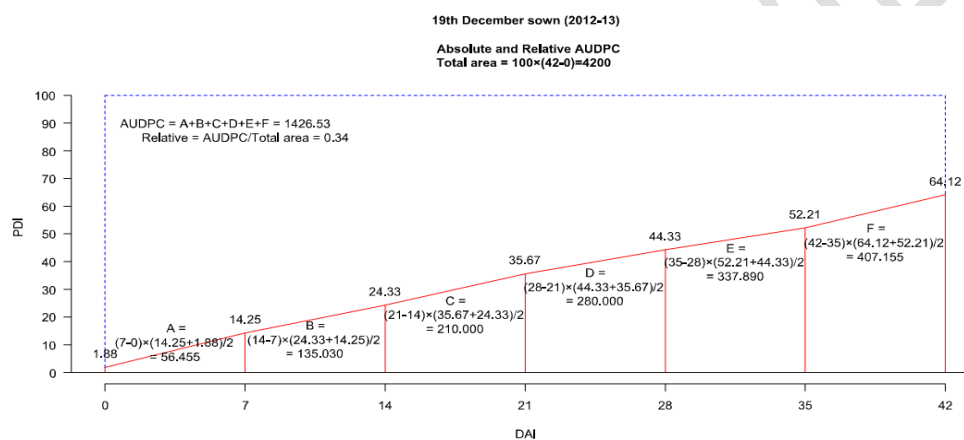


Fig. 4. Area under disease progress curve (AUDPC) of potato late blight on 19<sup>th</sup> December sown plant during 2012-2013.

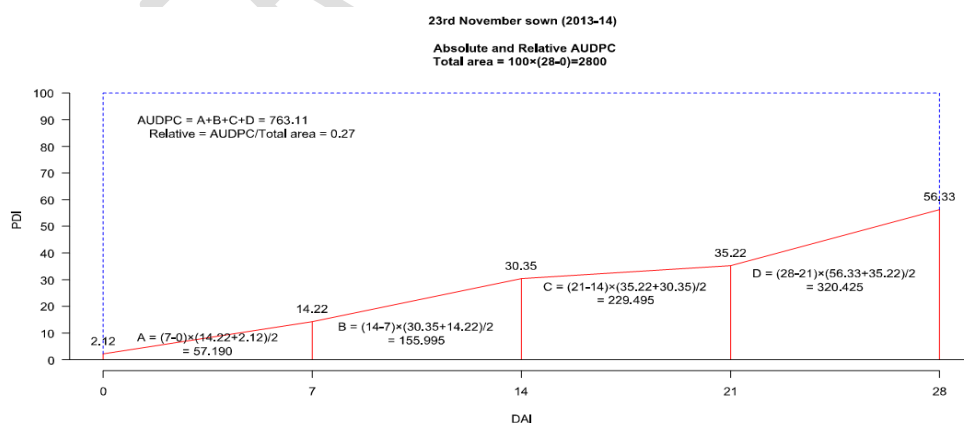


Fig. 5. Area under disease progress curve (AUDPC) of potato late blight on 23<sup>rd</sup> November sown plant during 2013-2014.

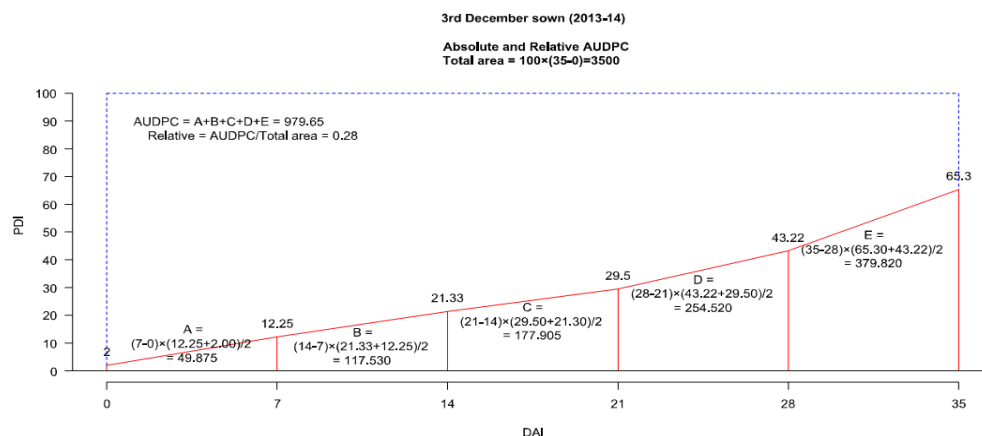


Fig. 6. Area under disease progress curve (AUDPC) of potato late blight on 3<sup>rd</sup> December sown plant during 2013-2014.

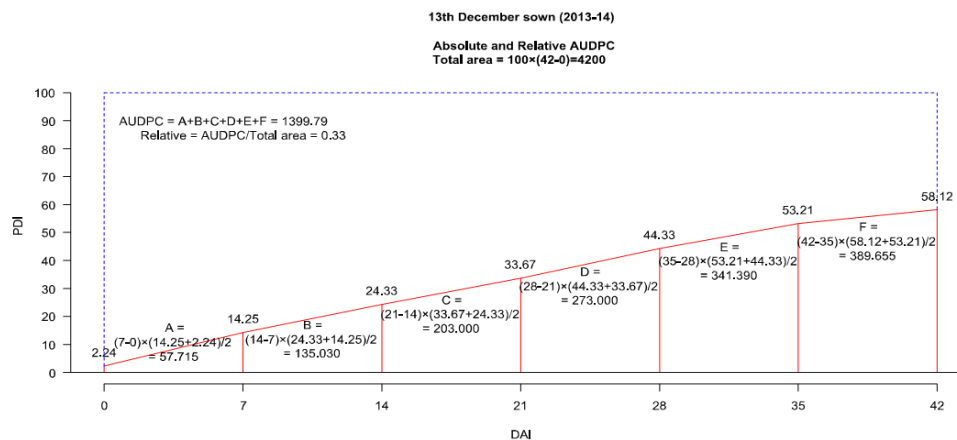


Fig. 7. Area under disease progress curve (AUDPC) of potato late blight on 13<sup>th</sup> December sown plant during 2013-2014.

#### 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.

#### REFERENCES

1. Bashi E, Ben-Joseph Y, Rotem, J. Inoculum potential of *Phytophthora infestans* and the development of potato late blight epidemic. Phytopathology. 1982; 72: 1043-47.
2. Bødker L, Nielsen BJ. Preventive and curative affect of fungicides against late blight under field conditions. PPO-Special Report. 2001; 7: 261-265.



3. Horsfall JG, Barratt RW. An improved grading system for measuring plant diseases. *Phytopathology*. 1945; 35: 655.
4. Shields EJ, Hygnstrom JR, Curwen D, Stevenson WR, Wyman JA, Binning LK. Pest management for potatoes in Wisconsin - a pilot program. *Am J Potato Res*. 1984; 61(8): 508-515.
5. Tek AL, Stevenson WR, Helgeson JP, Jiang J. Transfer of tuber soft rot and early blight resistances from *Solanum brevidens* into cultivated potato. *Theor Appl Genet*. 2004; 109: 249-254.
6. Bock CH, Gottwald TR, Parker PE, Cook AZ, Ferrandino F, Parnell S, van den Bosch F. The Horsfall-Barratt scale and severity estimates of citrus canker. *Eur J Plant Pathology*. 2009; 125: 23-38.
7. McKinney HH. Influence of soil temperature and moisture on infection of wheat seedling by *Helminthosporium sativum*. *J Agric Res*. 1923; 26: 195-217.
8. Vander Plank JE. *Plant Diseases: Epidemics and Control*. Academic Press, New York. 1963; pp. 349.
9. Das MK, Rajaram S, Mundt CC, Kronstad WE. Inheritance of slow rusting resistance to leaf rust in wheat. *Crop Sci*. 1992; 32: 1452-56.
10. Ghosh S, Chakraborty A, De, BK. Progress and apparent rate of infection of viral diseases of potato in the plains of West Bengal. *J Mycopathol Res*. 2010; 48(1): 137-140.