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Epidemiological studies against late blight of potato caused by *Phytophthora infestans* under climate changes in Kanpur district of Uttar Pradesh

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Abstract
Late blight caused by *Phytophthora infestans* (Mont.) de-Bary is the most important and destructive disease of potato causes "Irish Famine" in 1845. The management of the disease is mainly based on cultivation of resistant variety and use of fungicides. However, resistance against pathogen is not a permanent solution and fungicidal is not eco-friendly and economical. Therefore, inquest for IDM modules by using soil application with compost, tuber treatment with *T. harzianum* and foliar spray with fungicides were assessed during the course of present investigation. The co-relation between disease severity with rainfall, maximum temperature, minimum temperature and relative humidity showed that disease severity co-relate negatively with maximum temperature and Relative humidity, representing the value (-0.9693) and (0.5731) during 2016-17 and (-0.9521) and (-0.7454) during 2017-18, respectively, but positively co-relate with rainfall and minimum temperature (0.5884) and (0.9954) respectively.

Keywords: *Phytophthora infestans*, eco-friendly, rainfall, maximum temperature, minimum temperature and relative humidity

Introduction
Potato (*Solanum tuberosum* L.) belongs to the family Solanaceae, considered as "King of vegetables". It is an important tuberous crop cultivated for vegetable, food and several other processed products. It can be grown in wider range of altitude, latitude and climatic conditions. The English word "Potato" comes from Spanish word "patata" (the name used in Spain). Food and Agriculture Organization of UN has declared potato as 'Food for future'. (Hawkes, 1989) [1]. The areas lying between 300 to 1300 m altitude are considered to be grown for potato. However, areas between 300 to 600 m altitudes are suitable for growing winter potato and 600 to 1300 m for winter as well as *kharif* season potato. In India, about 80% potato are grown in north-western Indo-Gangetic plains during winter from October to Februray, about 10% are grown in Himalayas and Nilgiri hills during summer and only 7% in warmer plateau region during rainy season as well as winter. (Bairwa *et al.*, 2017). Potato can grow in any types of soil but they prefer moist, acidic soil (pH slightly less than 6) Van der Zaag (1994) [2].
Potato suffers from a number of diseases caused like, early blight, late blight, leaf spot, dry rot, charcoal rot, black scurf, common scab, soft rot, leaf roll *etc*. Among them, late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important and most destructive disease of potato causes "Irish Famine in 1845". The disease is distributed all over the world like North & South America, Europe, Asian continents (Fry *et al*., 1993; Chowdappa *et al*., 2013) [3, 4]. In last few years, late blight has become a significant epidemic problem in North Africa and Moroco (Sedgui *et al*., 1999; Andrivon *et al*., 2007) [6, 9], Tunisia (Jmour and Hamada, 2006; Harbaoui *et al*., 2013) [7, 8] and Algeria (Corbière *et al*., 2010) [6, 9]. The annual economic losses caused by the disease worldwide have been about 170 billion US dollars (Haverkort *et al*., 2009; Wu *et al*., 2012) [10, 11]. In India, the losses caused by the disease are 10-20% in Uttar Pradesh, 10-15% in West Bengal and Punjab, 10-15% in Karnataka and Uttrakhand also have been reported during 2013-14 (Lal, *et al.*, 2016) [12, 17] but the amount of losses depends on the variety and plant protection measures adopted.

Materials and Methods

Disease severity

Inoculation with *Phytophthora infestans*

At 45 days age, plants were inoculated with spore suspension of pathogen. The concentration of sporangia was maintained at 10^6 sporangia/ml. The spore suspension was prepared from seven days old culture of the pathogen. The homogenized, spore suspension were inoculated on the foliage of each plant. The plants were then covered with polythene bags for 48 hrs to provide suitable moisture and humidity for growth and development of the pathogen.

Measurement of disease severity

Observations for measuring the disease severity were taken after 5 days of pathogen inoculation. The disease severity was recorded on a 0 - 9 scale. Fifty leaves randomly selected from the pot were taken 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

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

Co-relation of disease severity with rainfall, maximum temperature, minimum temperature and relative humidity

The co-relation between disease severity with rainfall, maximum temperature, minimum temperature and relative humidity were calculated by standard statistical calculation.

Results and Discussion

Disease development as a result of susceptible host, virulent pathogen and favourable environmental factors. In the present study also, disease severity was co-related with favourable environmental factors like rainfall, maximum temperature, minimum temperature and relative humidity. The data presented in the (Table-1 and 2) showed that disease severity co-relate negatively with rainfall and maximum temperature, representing the value (-0.1095) and (-0.1259), respectively, but positively co-relate with minimum temperature and relative humidity (0.2004) and (0.2302) during 2016-17. The similar observations have also been found during 2017-18. The disease severity co-relate negatively with rainfall and maximum temperature, representing the value (-0.2232) and (-0.2497), respectively, but positively co-relate with minimum temperature and relative humidity (0.2693) and (0.2137) respectively. Singh (2007) also reported that the optimum temperature required for *P. infestans* lies between 12-13^{0}C (for germination of sporangia by zoospore production) and 24^{0}C (for germination of zoospores) coupled with excessive humidity (above 90% RH), favors maximum spread of disease. Benker *et al.*, (2010) [13] also reported that after heavy rainfall and high soil moisture, the pathogen *P. infestans* grown either from the latently infected seed tuber upwards in the stem or on the surface of the planting tuber sporulate. The fungus sporulates rapidly at relative humidity near to 100% and temperature between 16-22 ^{0}C. Germination of sporangia takes place only when free water or dew is present the leaves and at 10-15 ^{0}C, it may be completed within 0.5-2 hours. After germination period of 2-2.5 hours at 15-25 ^{0}C is required for penetration of germ tube. After penetration, the mycelium develops rapidly 17-21 ^{0}C which is optimal for sporulation (Agrios, 2005) [14]. Ideal condition for late blight infection and development are night temperature 10-16 °C with light rain, fog, next day temperature ranged from 13 to 16 °C with high relative humidity (Kirk, 2009; Kirk *et al*., 2013) [15, 16]. Congenial conditions for appearance and buildup of late blight disease includes 18 to 22°C temperature and 80-100% relative humidity (Fry *et al*., 2001) [3, 4]. (Praveen *et al*., 2017) reported that disease severity early blight of potato co-relate negatively with temperature relative humidity and sunshine hrs. and positively co-relate with relative humidity. (Biswas *et al*., 2013) [17, 18] found late blight of potato first appeared in the 3rd to 4th week December at Kanpur and 3rd week of Faizabad district of U.P. The infection rate rapidly increased during 7 to 9 January at Kanpur and 31st December to 2nd January at Faizabad which might be due to favourable environmental factors like cloudiness slight rainfall high relative humidity and low sunshine hrs. They also found that disease severity negatively co-relate with relative humidity in both Kanpur and Faizabad.

Table 1: Correlation between disease severity to rainfall, maximum temperature, minimum temperature and relative humidity 2016-17

Disease severity	Rainfall	Max. temp.	Min. temp.	Relative humidity
Rainfall	-0.1095	-0.1259	0.2004	0.2302
Max. Temp.	--	0.8603	-0.8385	-0.4880
Min. Temp.	--	--	-0.5448	-0.5295
Relative humidity	--	--	--	0.2761

Table 2: Correlation between disease severity to rainfall, maximum temperature, minimum temperature and relative humidity 2017-18

Disease severity	Rainfall	Max. temp	Min. temp.	Relative humidity
Rainfall	-0.2232	-0.2497	0.2693	0.2137
Max. Temp.	--	0.8819	-0.7883	-0.4042
Min. Temp.	--	--	-0.6088	-0.5043
Relative humidity	--	--	--	0.3350

Conclusion

The co-relation between disease severity with rainfall, maximum temperature, minimum temperature and relative humidity were calculated by standard statistical calculation. Disease severity co-relate negatively with rainfall and maximum temperature, representing the value (-0.1095) and (-0.1259), respectively, but positively co-relate with minimum temperature and relative humidity (0.2004) and (0.2302) during 2016-17. The similar observations have also been found during 2017-18.

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