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Incidence and Intensity of Early Blight in Potato under Different Dates of Planting

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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

Aim: The study aims to the progression of the early blight of potato in relation to weather parameters such as maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, and rainfall.
Place and Duration of Study: Epidemiological investigation was conducted during rabi season of 2021-22 at the research field of the All India Coordinated Research Project (AICRP) on potato, OUAT, Bhubaneswar.
Methodology: The trial was laid out in Split Plot Design with different dates of planting (26 November and 16 December), as the main plots and four varieties (Kufri Pukhraj, Kufri Khyati, Kufri Surya, and Kufri Jyoti) as the subplots.
Results: The initial infection of early blight occurred during 52 Standard Meteorological Week (SMW). The highest percentage of disease intensity and incidence occurred in the variety Kufri Pukhraj followed by Kufri Khyati, Kufri Jyoti and Kufri Surya under 26 November planting.

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Conclusion: Minimum and maximum temperatures and minimum relative humidity had a significantly positive correlation with the incidence and intensity of early blight. Stepwise multiple linear regression equations revealed that maximum temperature, maximum and minimum relative humidity, and rainfall was responsible for early blight in potatoes.

Keywords: Early blight; epidemiology; potato; incidence; intensity.

1. INTRODUCTION

Potato (*Solanum berosum* L.) is a major food crop grown worldwide. It is used in the production of starch, foods like potato chips, and stock feed [1]. Potatoes are a great source of carbohydrates and are utilized in both table consumption and processed foods. Potato tubers contain around 80% of water. 20% dry matter. More than 75 % of the dry Starch, protein, fibers, and a negligible quantity of fatty acids make up matter [2]. Additionally, it is abundant in minerals like potassium, phosphorus, and magnesium with B1, B3, and B6 vitamins [3]. The potato also includes Vitamin C and several phenolic compounds that act as strong antioxidants [4].

Potato is the world's 4th important food crop after wheat, rice, and maize because of its great yield potential and high nutritive value [5,6]. China is the world's largest producer and consumer of potato, producing 78.24 Mt in 4.21 m ha^{-1} with a productivity of 18.55 t ha^{-1} followed by India (51.30 Mt production in 2.16 m ha^{-1} with 23.78 t ha^{-1} productivity) and Russia (19.61 Mt in 1.18 m ha^{-1} with a productivity of 16.65 t ha^{-1}) (According to the estimates of 2020, FAO 2021). In India, most of the potato production takes place in Uttar Pradesh (15892 thousand tons production in 622.50 thousand ha^{-1} area) followed by West Bengal (12600 thousand tons in 447 thousand ha^{-1}) and Bihar (9125.80 thousand tons in 330 thousand ha^{-1} area) according to the estimates of 2021, NHB2021.

Currently, Odisha produces 308.22 thousand tons in a 25.91 thousand ha^{-1} area (NHB 2021). Potato is one of the major constituents of the daily diet in Odisha. It is cultivated all districts of the state in the winter season and in kharif season it is cultivated in Phulbani and Koraput districts [7,8].

Early blight symptoms, which are characterized by dark brown to black lesions with concentric rings and produce a "target spot effect," are first noticed on older and senescing leaves [9]. The lesions are frequently encircled by a small chlorotic halo because of the pathogen's toxins, which progress into healthy epidermal cells. Defoliation may occur completely under extreme circumstances, particularly in places with high temperatures (24–29°C), high humidity levels, and semi-arid conditions locations where frequent and protracted dew occurs [10].

Considering the significance of these illnesses as the primary biotic the current study has been limited by factors in the region's potato yield taken to analyze the impact of various meteorological parameters (maximum temperature, minimum temperature, maximum RH, minimum RH, and rainfall, etc.) on the onset and progression of early potato blight.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted during the Rabi season of 2021-2022 at the experimental plots of the All India Coordinated Research Project on Potato, Odisha University of Agriculture and Technology, Bhubaneswar, located at 20° North latitude, 86° East longitude and at about 45 m above MSL consecutively for three years. The soil for the study was sandy loam in texture, acidic (pH 5.56) in reaction, low in organic carbon (0.51 %) and available N (218.4 kg $ha^{-1)}$, medium in both available P (20.8 kg ha^{-1}) and K (96.1 kg ha^{-1}). The treatments were a combination of two planting dates (D) and four varieties (V). The two dates of planting followed in the experiment were 26 November, and 16 December, and the varieties were Kufri Pukhraj, Kufri Khyati , Kufri Surya and Kufri Jyoti in the medium duration groups. The seed tubers of these varieties were kept in a cold store till planting. Well-sprouted foundation seed tubers were planted in 3 m x 2.4 m sized plots at 60 x 20 cm spacing in a Split Plot design with five replications. The present investigations on the development of early blight of potato in relation to weather parameters (maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, and rainfall), The weekly data of weather parameters during the cropping period (26 November to 04

March 2021-22) were collected from the central observatory of the department of Agricultural meteorology, University of Agriculture & Technology University in Bhubaneswar, Odisha.

2.2 Climate

The general climatic condition of Bhubaneswar is hot and humid. The maximum temperature during the crop growth period in 2021-2022 was 31.2°C and the minimum temperature was 10°C. The experimental site is in the eastern coastal plain of India. The mean annual rainfall is approximately 1408mm and annual maximum temperature is 42.2°C and the annual minimum temperature is 11.1°C.

2.3 Weather Conditions During Crop Growth Season

The weekly mean of maximum temperature, minimum temperature, relative humidity (RH), and bright sunshine hour (BSH) along with total weekly rainfall, and number of rainy days during the crop growth season (26 November to 04 March).

The weekly maximum temperature during the crop growth period ranged from 25.7°C to 33.1°C, with a weekly average of 28.01°C, whereas the weekly minimum temperature ranged from 10°C to 19.8°C, with a weekly average of 16.03^{0}C.

The mean morning relative humidity during the crop growth varied from 86.4 to 95%, while the mean afternoon relative humidity varied from 26 to 84.3%. The mean bright sunshine hour received during the crop growth period varied from 1.3 to 9 hours, with a weekly average of 5.0 hours. The total rainfall received during the crop growth period was142.8 mm.

The weekly mean of maximum temperature, minimum temperature, relative humidity (RH) and bright sunshine hour (BSH) along with total weekly rainfall, number of rainy days during the crop growth season (26 November to 04 March).

2.4 Pathological Observations

Disease incidence and intensity was calculated from the five tagged plants in each plot of the experimental field. Based on the data, the percentage of disease incidence and intensity at weekly intervals, from the date of disease initiation till the crop attained maturity were recorded.

2.4.1 Disease incidence

Percentage of disease incidence was calculated as per the following formula James [11] gave.

Percent disease incidence = No. of diseased leaves / Total No. of leaves examined × 100 (Eq. 1).

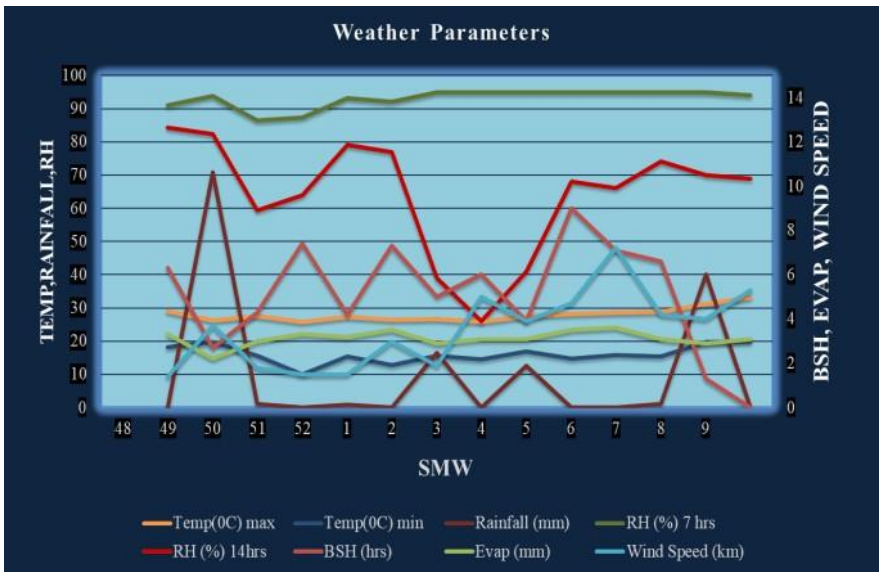

Fig. 1. Weekly mean of maximum temperature, minimum temperature, relative humidity(RH) and bright sunshine hour (BSH)

2.4.2 Disease intensity

According to the Mayer and Datar standard area diagram, Percentage intensity was computed [12].

The Percentage of disease intensity was calculated by using the following formula: -

Percentage of Disease Intensity = Sum of individual ratings / No. of plants observed x Maximum disease rating x100 (Eq.2).

2.5 Methods

2.5.1 Correlation Analysis

Potato early blight Correlation analysis of the disease incidence and intensity (dependent variable) and (independent variable) with weather parameters i.e., maximum and minimum temperature^{0}C, maximum relative humidity (present) before a week from the date of minimum relative humidity (present) and rainfall (mm)) surveillance for early potato blight in 20121–22.

Varieties (Kufri Pukhraj, Kufri Khyati, Kufri Surya, Kufri Jyoti) were conducted to measure the degree of association among the different predictors and response variables in causing the onset and the progress of the disease incidence and intensity of both the dates of planting. The Pearson correlation coefficients (r) were studied to find out the effect of a single as well as a combination of different weather factors on the disease progression of early blight of potato.

2.5.2 Multiple Regression

To predict the disease incidence and intensity of early blight of potato in four varieties, different models were generated with the disease incidence and intensity of both the dates and weather factors by using multiple linear regression.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

Where, Y is the predicted disease incidence and intensity of disease "a" is the intercept, "b_1" to "b_5" are the partial regression coefficients, X_1 is the maximum temperature (°C), X_2 is the minimum temperature (°C), X_3 is the maximum relative humidity (%), X_4 is the minimum relative humidity (%) and X_5 is the total rainfall (mm).

3. RESULTS AND DISCUSSION

3.1 Incidence of Early Blight

3.1.1 Effect of weather parameters on the incidence of early blight of potato in under different dates of planting

Incidence of early blight of potato varied from 2.2 to 23% in all the selected varieties of potato. The disease was first observed at 52 Standard Meteorological Week (30 days after planting) in Kufri Pukhraj (3.00%), Kufri Khyati (2.7%) Kufri Surya (2.2%), and Kufri Jyoti (2.5%). The weather parameters during the preceding week were maximum and minimum temperatures of 27.3^{0}C and 15.4^{0}C, maximum and minimum relative humidity 93.1% and 79.1%, and rainfall of 0.8 mm. Singh, et al. [13] reported a similar observation that maximum temperature and relative humidity had a significant effect on early blight incidence. The disease incidence progressed gradually and showed progression from 4.80 to 17.5%, 3.25 to 10.25%, 3.2 to 7.8%, and 5.5 to 15.6% in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, respectively during 1st to 3rd SMW (37 to 53 DAP). During the period, maximum and minimum temperatures were 26.7^{0}C and 12.8 ^{0}C, maximum and minimum relative humidity 94% and 26% and rainfall 16.5 mm. At the maturity , (60 DAP) in 4th SMW, maximum disease incidence was recorded in Kufri Pukhraj (23%) followed by Kufri Jyoti (15.6%), Kufri Khyati (13.50%) and Kufri Surya (9.8%), when maximum temperature was 27.5 ^{0}C, minimum temperature 16.9 ^{0}C, maximum relative humidity 95% and minimum relative humidity 41 %. In second date of planting (16 December)incidence of early blight of potato varied from 1.1 to 12.40% in all the selected varieties of potato (Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti). The disease was first observed at 2nd Standard Meteorological Week (30 days after planting) in Kufri Pukhraj (1.25%), Kufri Khyati (1.50%) Kufri Surya (1.4%) and Kufri Jyoti (1.1%). The weather parameters during the preceding week were maximum and minimum temperature of 26.7^{0}C and 15.7^{0}C, maximum and minimum relative humidity 94% and 39% and rainfall of 16.5mm. The findings of Alternating low and high humidity conditions have also been shown to favour disease development [14]. The disease varies from 2.25 to 10.20%, 2.50 to 7.40%, 1.8 to 6.8% and 3.2 to 9.6 in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, respectively during 3rd to 5th SMW (37 to 53 DAP). During the period,

maximum and minimum temperatures were 28.2^{0}C and 14.6^{0}C, maximum and minimum relative humidity 95% and 26% and rainfall 12.6mm. At the maturity stage, (60 DAP) in 6th SMW, maximum disease incidence was recorded in Kufri Pukhraj (12.40%) followed by Kufri Jyoti (11%), Kufri Khyati (8.25%) and Kufri Surya (7.5%), when maximum temperature was 28.7^{0}C, minimum temperature 15.8^{0}C, maximum relative humidity 95% and minimum relative humidity 66 %.The highest disease incidence (23.0 and 12.40%) was reported in Kufri Pukhraj followed by 15.6 and 11.0% in Kufri Jyoti, whereas the minimum disease incidence was observed in Kufri Surya and Kufri Khayati (9.8 and 7.5%), in first and second date of planting, respectively. The variation in disease incidence might be due to the response of different varieties against the disease and planting under different environmental conditions. The present study showed that the maximum incidence of early blight of potato was recorded in all selected varieties under the first date of planting as compared to the second date of planting which might be due to the older and senescence leaves, more susceptible to the development of early blight disease. Similar results were also found by Vander-Walls et al. [9]. Changes in weather variables the and amount of initial inoculum of *A. solani* may be responsible for varying disease intensities at different locations.

The results of the field trial conducted in this study indicate that the incidence and intensity of early blight in potatoes can vary depending on the date of planting [15]. Specifically, it was found that early-planted potatoes had a higher incidence and intensity of early blight compared to those planted at mid-season or late. This is likely due to the fact that early-planted potatoes are exposed to favorable conditions for the development of the fungus, such as high humidity and warm temperatures [16]. These findings are consistent with previous research on early blight in potatoes, which has also shown that the timing of planting can have a significant impact on disease incidence and severity. Meno et al. [17] reported that early-planted potato crops are more susceptible to early blight due to prolonged exposure to cool and wet conditions that are favorable for the fungus. Similarly, Nasr-Esfahani [18]. found that early planting can increase the risk of early blight, as the fungus can infect the crop before the plants have reached their full canopy and are better able to tolerate the disease.

3.1.2 Correlation of weather parameters on the incidence of early blight of potato in under different dates of planting

The maximum temperature was non-significant with the disease incidence of early blight of potato, in all the varieties under 26 November planting (Table 3). The maximum temperature was a positively and significant correlation with the incidence of early blight of potato, having (r =0.885, 0.91,0.925, and 0.881) in all the selected varieties under on 16 December planting, which showed that an increase in temperature leads to an increase in disease incidence. The results were similar to those of Tiwari et al. [19] who reported that maximum temperature and relative humidity had a significant effect on early blight, indicating that higher Alternaria spore concentration was recorded at a higher temperature. Morning relative humidity had also a significant positive correlation with disease incidence (r = 0.899, and 0.881) in, Kufri Khyati, and Kufri Surya potato varieties on 26th November planting. And Morning relative humidity was non-significant with the disease incidence of early blight of potato in Kufri Pukhraj and Kufri Jyoti on 26th November

Table 1. Disease intensity scale for early blight of potato

Scale	Description of the symptoms	Reaction
0	Leaves free from infection	Highly resistant
1	Small irregular spots covering <5% leaf area	Resistant
2	Small irregular brown spots with concentric ringscovering 5.1-10% leaf area	Moderately resistant
3	Lesions enlarging, irregular brown with concentricrings covering 10.1-25% leaf area	Moderately susceptible
4	Lesions coalesce to form irregular and appears as atypical blight symptom covering 25.1-50% leaf area	Susceptible
5	Lesions coalesce to form irregular and appears as atypical blight symptom covering >50% leaf area	Highly susceptible

Table 2. Effect of weather parameters on the incidence of early blight of potato underdifferent dates of planting

SMW	Disease Incidence %								Weather parameters				
	1st Date of planting(26.11.2021)				2nd Date of planting(16.12.2021)								
	K. Pukhraj	K. Khyati	K. Surya	K. Jyoti	K. Pukhraj	K. Khyati	K. Surya	K. Jyoti	Max. Te m. (°C)	Mi n. Temp. (°C)	RH(%) 7 hrs	RH(%) 14 hrs	Rain fall (mm)
52	3.00	2.70	2.2	2.5	0	0	0	0	27.3	15.4	93.1	79.1	0.8
1	4.80	3.25	3.2	5.5	0	0	0	0	26.4	12.8	92	77	0.0
2	9.20	6.75	5.4	9.2	1.25	1.50	1.4	1.1	26.7	15.7	94	39	16.5
3	17.50	10.25	7.8	11.5	2.25	2.50	1.8	3.2	25.7	14.6	95	26	0.0
4	23.00	13.50	9.8	15.6	3.80	5.20	3.8	5.8	27.5	16.9	95	41	12.6
5	-	-	-	-	10.20	7.40	6.8	9.6	28.2	14.7	95	68	0.0
6	-	-	-	-	12.40	8.25	7.5	11	28.7	15.8	95	66	0.0

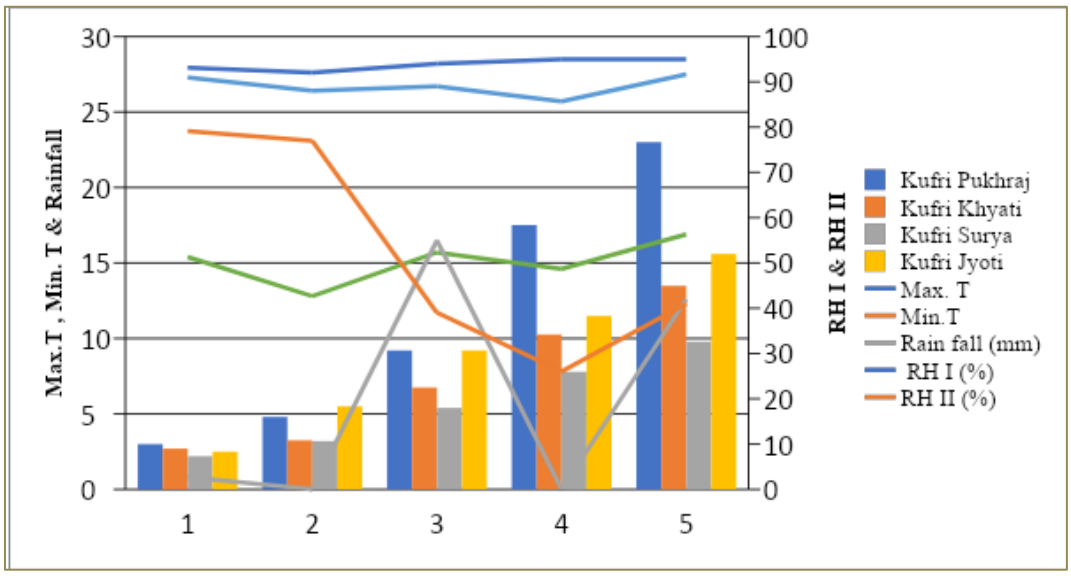

Fig. 2. Disease Incidence% (D1)

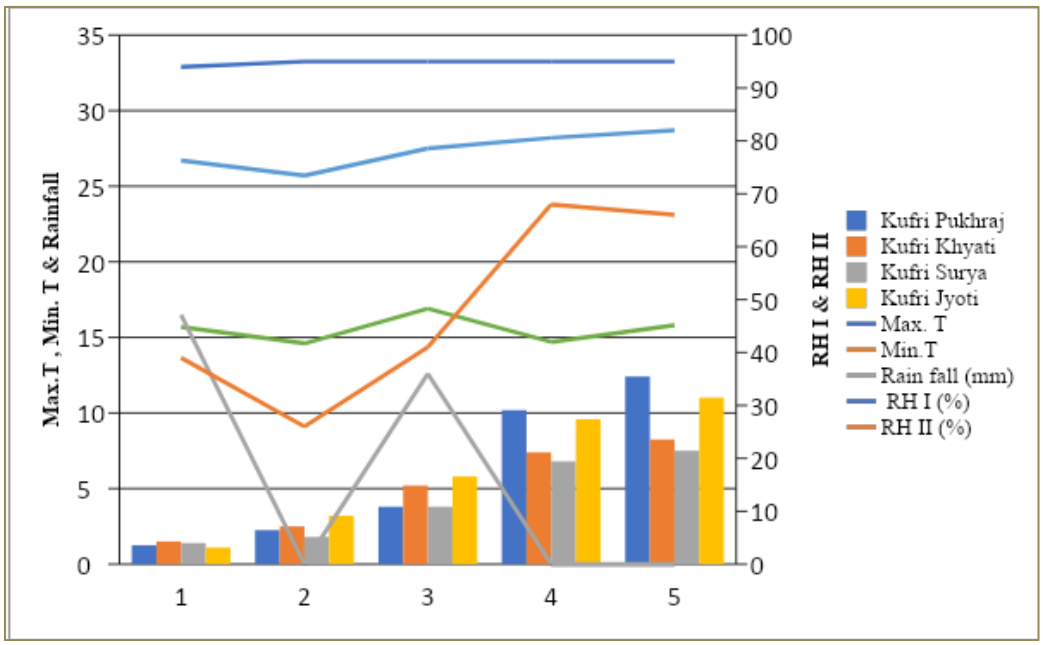

Fig. 3. Disease Incidence% (D2)

planting. Under 16thDecember planting night relative humidity had significant (r = 0.929, 0.887, 0.938, and 0.881) with all the selected varieties which showed that night relative humidity less than 80% exerted negative impact on disease incidence. Temperature and relative humidity played a major role in the dispersion of Alternaria spores [20,21]. Sabariego et al. [22] reported negative correlation of early blight of potato with humidity and rainfall. Sukrutha Herle and Kamanna [23] also reported that early blight of potato was negatively correlated with minimum temperature, and relative humidity (maximum and minimum), while positively correlated with maximum temperature. was also reported by Escuredo et al. [24], indicating that higher Alternaria spore concentrations were recorded at higher temperature.

It is also important to consider that other factors, such as weather conditions and cultural practices, can also affect the incidence and intensity of early blight in potato. Meno et al. [17] noted that the disease is more severe in

regions with high rainfall [25-27] and moderate temperatures and that cultural practices such as high plant populations and reduced crop rotation can also increase the risk of early blight. Therefore, the timing of planting should be considered in conjunction with other factors that may influence the development of the disease.

The multiple linear regression model(Table 4)indicated among different independent variables that morning relative humidity (X3) was responsible for 76.38%, 80.89%, 77.62%, and 68.72% variations for the early blight of potato in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, respectively under 26 November date of planting. And the multiple linear regression indicates the relationship between disease incidence and weather parameters of early blight of potato in under 16 December planting where maximum temperature (X1), maximum relative humidity (X3), minimum humidity (X4), rainfall (X5) had contributed86.27%, 99.98%, 98.53% and 97.82% in the incidence of early blight of potato Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti respectively. Similar results were also found by Behera [28] the study on regression coefficient in relation to disease incidence indicated that maximum temperature had a significant impact on the early blight of potato. Among all the weather parameters the contribution of rainfall was maximum (39.1 %) on the disease incidence.

Table 3. Correlation of weather parameters on the incidence of early blight of potato in under different dates of planting

Weather parameters	1st Date of planting (26.11.2021)				2nd Date of planting (16.12.2021)			
	Varieties				Varieties			
	Kufri Pukhraj	Kufri Khyati	Kufri Surya	Kufri Jyoti	Kufri Pukhraj	Kufri Khyati	Kufri Surya	Kufri Jyoti
$T_{max.}$ (^oC)	0.004^{NS}	0.035^{NS}	-0.018^{NS}	-0.004^{NS}	0.885^{*}	0.911^{*}	0.925^{*}	0.881^{*}
$T_{Min.}$ (^oC)	0.563^{NS}	0.617^{NS}	0.566^{NS}	0.543^{NS}	-0.111^{NS}	0.080^{NS}	-0.006^{NS}	-0.009^{NS}
RH_{7hrs} (%)	0.877^{NS}	0.899^{*}	0.881^{*}	0.829^{NS}	0.529^{NS}	0.657^{NS}	0.571^{NS}	0.675^{NS}
RH_{14hrs} (%)	-0.791^{NS}	-0.818^{NS}	-0.832^{NS}	-0.820^{NS}	0.929^{*}	0.887^{*}	0.938^{*}	0.881^{*}
Rainfall (mm)	-0.369^{NS}	0.448^{NS}	0.444^{NS}	0.526^{NS}	-0.652^{NS}	-0.569^{NS}	-0.585^{NS}	-0.647^{NS}

$T_{Max.}$ = Temperature maximum; $T_{Min.}$ = Temperature minimum; RH_{7hrs} = Maximum Relative humidity; RH_{14hrs} = Minimum Relative humidity

**Significant at 5% level **Significant at 1% level*

Table 4. Multiple linear regression weather parameters on the incidence of early blightof potato in under different dates of planting

Date of sowing	Varieties	Stepwise Regression Equation	R^2	P value
1st Date of planting (26.11.2021)	Kufri Pukhraj	$Y= -861.59+9.34868*X_3$	0.7638	0.0527
	Kufri Khyati	$Y= -294.45+3.21616* X_3$	0.8089	0.0377
	KufriSurya	$Y= -196.58+2.15584* X_3$	0.7762	0.0484
	KufriJyoti	$Y= -299.13+3.28279* X_3$	0.6872	0.0827
2nd Date of planting (16.12.2021)	Kufri Pukhraj	$Y= -6.2119+0.254* X_4$	0.8627	0.0226
	Kufri Khyati	$Y= -228.78+1.93065*X_1+1.91231* X_3+0.624*X_5$	0.9998	0.0178
	KufriSurya	$Y= -202.86+2.11935* X_3+0.12939* X_4$	0.9853	0.0147
	KufriJyoti	$Y= -416.18+4.36792* X_3+0.17174* X_4$	0.9782	0.0218

3.2 Intensity of Early Blight

3.2.1 Effect of Weather parameters on the intensity of early blight of potato in under different dates of planting

In early blight of potato, intensity of early blight of potato varied from 2.40 to 21.23% in all the selected varieties of potato (Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti) in under 26th November planting (Table 5). The result showed that disease initiation occurred under field condition on 52SWM, in Kufri Pukhraj (2.81%), Kufri Khyati (2.40%) Kufri Surya (2.50%) and Kufri Jyoti (3.50%). The weather parameters during the preceding week were maximum and minimum temperature of 27.3^{0}C and 15.4^{0}C, maximum and minimum relative humidity 93.1% and 79.1% and rainfall of 0.8mm. Abuley [29] reported that temperature from 10 to 35^{0}C were more favorable for early blight epidemic. The disease intensity progressed gradually and showed progression varies from 4.31 to 15.5%, 3.12 to 9.82%, 3.4 to 8.0% and 6.5 to 12.5% in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, respectively during 1st to 3rd SMW (37 to 53 DAP). During the period, maximum and minimum temperatures were 26.7^{0}C and 12.8^{0}C, maximum and minimum relative humidity 94% and 26% and rainfall 16.5mm.At the maturity stage, (60 DAP) in 4th SMW, maximum disease intensity was recorded in Kufri Pukhraj (21.23%) followed by Kufri Jyoti (16.8%), Kufri Khyati (12.84%) and Kufri Surya (10.2%), when maximum temperature was 27.5^{0}C minimum temperature 16.9 ^{0}C, maximum relative humidity 95% and minimum relative humidity 4%.In second date of planting (16 December) disease intensity was first observed at 2nd Standard Meteorological Week (30 days after planting) in Kufri Pukhraj (1.25%), Kufri Khyati (1.30%) Kufri Surya (1.5%) and Kufri Jyoti (1.3). The weather parameters during the preceding week were maximum and minimum temperature of 26.7^{0}C and 15.7^{0}C, maximum and minimum relative humidity 94% and 39% and rainfall of 16.5mm. These findings agree with the findings of Mehboob et al. [30] who observed that maximum disease intensity occurred at maximum temperature of 17 to 20ºC and minimum temperature of 6 to 9ºC. Rotem [31] also reported that availability of water in the form of relative humidity, rainfall or dew increased conidial germination of *A. solani*. The disease intensity progressed gradually and showed progression from 2.14 to 10.7%, 2.30 to 6.84%, 2.0 to 7.0% and 3.6 to 10.2% in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, respectively during 3rd to 5th SMW (37 to 53 DAP). During the period, maximum and minimum temperatures were 28.2^{0}C and 14.6^{0}C, maximum and minimum relative humidity 95% and 26% and rainfall 12.6mm.At the maturity stage, (60 DAP) in 6th SMW, maximum disease intensity was recorded in Kufri Pukhraj (11.80%) followed by Kufri Jyoti (11.2%), Kufri Surya (8.5%), and Kufri Khyati (7.20%) when maximum temperature was 28.7^{0}C, minimum temperature 15.8^{0}C, maximum relative humidity 95% and minimum relative humidity 66 %.The highest disease intensity (21.23 and 11.80%) was reported in Kufri Pukhraj followed by 16.8 and 11.2% in Kufri Jyoti, whereas minimum disease intensity was observed in Kufri Surya and Kufri Khayati (10.20 and 7.20%), in first and second date of planting, respectively. The variation in disease intensity might be due to the response of different varieties against the disease and planting under different environmental conditions. Our results show that maximum intensity of early blight of potato was recorded in all selected varieties under first date of planting as compared to second date of planting which may be due to that older and senescence leaves are more susceptible for development of early blight disease. Similar results were also found by R. Chaerani and Voorrips [32] reported that initially progress of early blight was slow but accelerated as plants attain maturity showing sigmoid disease curve.

Fungi thrive in moist environments, and certain environmental conditions such as high humidity [33], heavy rainfall [34], and warm temperatures can lead to an increase in fungal growth and infection in crops [35]. Poor drainage [36], overcrowding [33], and compacted soil [37] can also contribute to the appearance of fungi in crops [38]. Additionally, certain crops may be more susceptible to fungal infections than others. Cultural practices such as crop rotation, proper irrigation, and the use of fungicides can help to prevent or reduce fungal infections in crops [39].

3.2.2 Correlation and multiple linear regressions on the intensity of early blight of potato in under different dates of planting

Maximum temperature was non- significant with the disease intensity of early blight of potato, in all the selected varieties under 26November planting (Table 6). Maximum temperature was positively and significant correlated with the

intensity of early blight of potato, having r =0.879, 0.901 and 0.921, in Kufri Pukhraj, Kufri Khyati, and Kufri Surya, respectively. On 16 December planting, which showed that increase in temperature leads to increase in disease intensity. Significantly positive correlation between temperature and the Alternaria spore concentration significant at 5% level also reported by Escuredo et al. [24], indicating that higher Alternaria spore concentration was recorded at higher temperature. Morning relative humidity had also significant positive correlation with disease intensity (r = 0.884,0,894, and 0.884) in Kufri Pukhraj, Kufri Khyati, and Kufri Surya potato varieties on 26 November planting. And Morning relative humidity was non-significant with the disease intensity of early blight of potato in all the selected varieties under on 16 December planting. Under 16 December planting night relative humidity had r = 0.942, and 0.924 in Kufri Pukhraj, and Kufri Surya which showed that night relative humidity less than 80% exerted negative impact on disease intensity. Temperature and relative humidity played a major role in the dispersion of Alternaria spores [20,21]. Sabariego et al. [22] reported negative correlation of early blight of potato with humidity and rainfall. SukruthaHerle and Kamanna [23] also reported that early blight of potato was negatively correlated with minimum temperature, and relative humidity (maximum and minimum), while positively correlated with maximum temperature. was also reported by Escuredo et al. [24], indicating that higher Alternaria spore concentration were recorded at higher temperature.

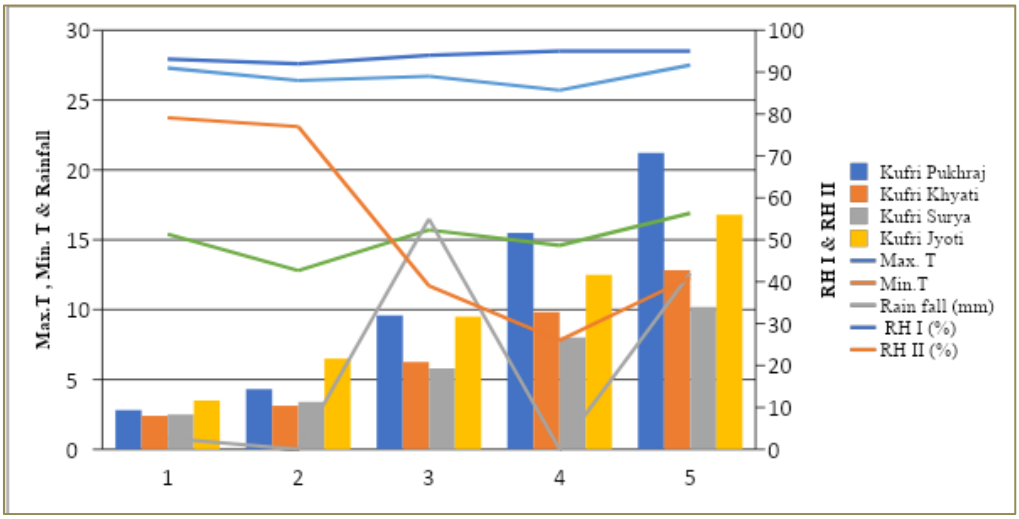

Fig. 4. Disease Intensity% (D1)

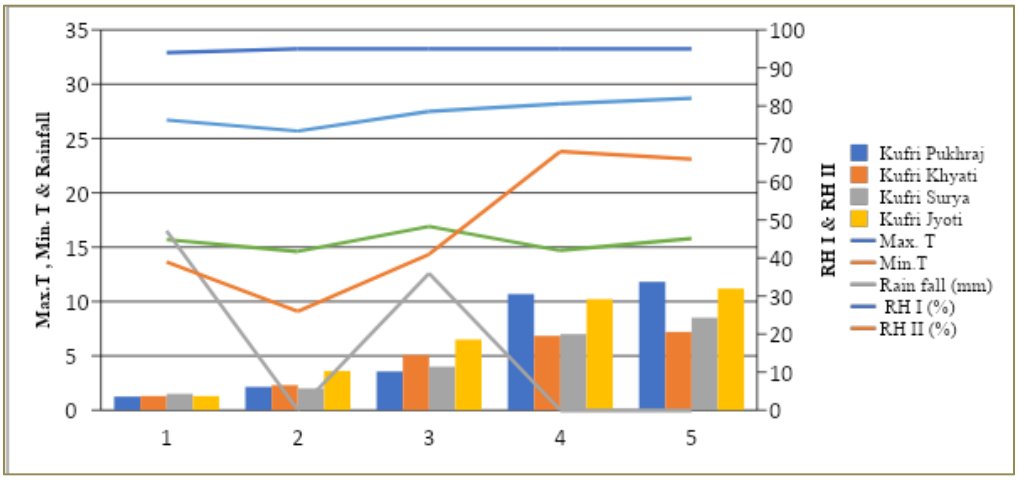

Fig. 5. Disease Intensity% (D2)

Table 5. Effect of weather parameters on the intensity of early blight of potato in underdifferent dates of planting

SMW	Disease intensity %								Weather parameters				
	1st Date of planting (26.11.2021)				2nd Date of planting (16.12.2021)								
	Kufri Pukhraj	KufriKhyati	Kufri Surya	Kufri Jyoti	Kufri Pukhraj	Kufri Khyati	Kufri Surya	Kufri Jyoti	Max. Temp.	Min. Temp.	RH (%) 7 hrs	RH (%) 14 hrs	Rain fall (mm)
52	2.81	2.40	2.5	3.5	0	0	0	0	27.3	15.4	93.1	79.1	0.8
1	4.31	3.12	3.4	6.5	0	0	0	0	26.4	12.8	92	77	0.0
2	9.57	6.24	5.8	9.5	1.25	1.30	1.5	1.3	26.7	15.7	94	39	16.5
3	15.50	9.82	8.0	12.5	2.14	2.30	2.0	3.6	25.7	14.6	95	26	0.0
4	21.23	12.84	10.2	16.8	3.56	5.06	4.0	6.5	27.5	16.9	95	41	12.6
5	-	-	-	-	10.70	6.84	7.0	10.2	28.2	14.7	95	68	0.0
6	-	-	-	-	11.80	7.20	8.5	11.2	28.7	15.8	95	66	0.0

Table 6. Correlation of weather parameters on the intensity of early blight of potato in under different dates of planting

Weather parameters	1st Date of planting (26.11.2021)				2nd Date of planting (16.12.2021)			
	Varieties				Varieties			
	Kufri Pukhraj	Kufri Khyati	Kufri Surya	Kufri Jyoti	Kufri Pukhraj	Kufri Khyati	Kufri Surya	Kufri Jyoti
$T_{max.}$ (^{0}C)	-0.036^{NS}	0.021^{NS}	0.005^{NS}	0.008^{NS}	0.879*	0.901*	0.921*	0.875^{NS}
$T_{Min.}$ (^{0}C)	0.601^{NS}	0.600^{NS}	0.587^{NS}	0.534^{NS}	-0.154^{NS}	0.106^{NS}	0.011^{NS}	0.001^{NS}
RH_{7hrs}(%)	0.884*	0.894*	0.884*	0.823^{NS}	0.521^{NS}	0.683^{NS}	0.564^{NS}	0.697^{NS}
RH 14 hrs (%)	-0.805^{NS}	-0.816^{NS}	-0.830^{NS}	-0.795^{NS}	0.942*	0.869^{NS}	0.924*	0.872^{NS}
Rainfall (mm)	0.441^{NS}	0.431^{NS}	0.467^{NS}	0.483^{NS}	-0.658^{NS}	-0.547^{NS}	-0.591^{NS}	-0.641^{NS}

$T_{Max.}$ = Temperature maximum; $T_{Min.}$ = Temperature minimum; RH_{7hrs} = Maximum Relative humidity; RH_{14hrs} = Minimum Relative humidity
**Significant at 5% level **Significant at 1% level*

Table 7. Multiple linear regression weather parameters on the intensity of early blight of potato in under different dates of planting

Date of sowing	Varieties Diseaseintensity	Stepwise Regression Equation	R^2	P value
1st Date of sowing (26.11.2021)	Kufri Pukhraj	Y= -816.07+8.8549*X_3	0.7817	0.0465
	Kufri Khyati	Y= -281.8+3.07696* X_3	0.7989	0.0409
	Kufri Surya	Y= -199.1+2.18592* X_3	0.7807	0.0468
	Kufri Jyoti	Y= -299.78+3.29934* X_3	0.6766	0.0179
2nd Date of sowing (16.12.2021)	Kufri Pukhraj	Y= -3.4761+0.22007* X_4-0.2057*X_5	0.9821	0.0072
	Kufri Khyati	Y= -293.27+1.69386*X_1+2.65257*X_3	0.9928	0.0193
	Kufri Surya	Y= -2.844+0.15508* X_4	0.8536	0.0249
	Kufri Jyoti	Y=-309.82+2.56774*X_1+2.60484* X_3-0.1387* X_5	0.9994	0.0307

The multiple linear regression model indicated among different independent variables, morning relative humidity (X3) was responsible that 78.17%, 79.89%, 78.07%, and 67.66% variations for the early blight of potato in Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti, under 26 November date of planting, respectively. And the multiple linear regression indicated the relationship between disease intensity and weather parameters of early blight of potato in under 16 December planting that the maximum temperature (X1), maximum relative humidity (X3), minimum humidity (X4), rainfall (X5) had contributed 98.21%, 99.28%, 85.36% and 99.94 % in the intensity of early blight of potato Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti respectively. Similar findings by Gupta et al., 2020 early blight of tomato appeared in the 12th SMW and had a steep increase throughout the cropping period. Maximum and minimum temperatures had a significantly positive correlation, whereas maximum and minimum relative humidity along with rainfall had a negative correlation with the PDI of early blight of tomato. The stepwise regression model explained that 83 percent variation in the PDI of the disease was due to maximum temperature.

4. CONCLUSION

The result of correlation analysis in Kufri Khyati, and Kufri Surya that maximum relative humidity had a positive and highly significant correlation with the disease under 26th November planting. Kufri Pukhraj, Kufri Khyati, Kufri Surya and Kufri Jyoti maximum temperature had a positive and highly significant correlation with disease incidence. Whereas minimum relative humidity

significantly positive correlation with the disease incidence, in all the varieties potato under 16th December planting. Stepwise multiple regression analysis among different independent variables that maximum relative humidity (X3) was highly significant in Kufri Pukhraj, Kufri Khyati, Kufri Surya, and Kufri Jyoti under 26th November planting. Under 16th December planting Minimum humidity(X_4) was highly significant in Kufri Pukhraj followed by Kufri Khyati where maximum temperature (X1), maximum relative humidity (X3) and rainfall (X5) were highly significant, and in Kufri Surya, and Kufri Jyoti maximum relative humidity (X3) and minimum humidity(X_4) was highly significant.

The relationship between the intensity of early blight of potato and weather parameters produces a result that Kufri Pukhraj, Kufri Khyati, and Kufri Surya varieties of potatoes disease intensity is positive and highly significant with maximum relative humidity. In all the four potato varieties under 26 November plantings disease intensity of Kufri Pukhraj, Kufri Khyati, and Kufri Surya had positive and highly significant with maximum temperature. Whereas Kufri Pukhraj, and Kufri Surya disease intensity was a significantly positive correlation with minimum relative humidity under 16 December planting. Stepwise multiple regression analysis among different independent variables, maximum relative humidity (X3) was highly significant in Kufri Pukhraj, Kufri Khyati, Kufri Surya, and Kufri Jyoti varieties under on 26 November planting. In conclusion, this study highlights the importance of considering the timing of planting when managing early blight in potatoes. Planting potatoes early in the season may increase the risk of early blight, and growers should consider this when deciding when to plant their crops. Further research is needed to investigate the specific weather conditions and cultural practices that may contribute to the development of early blight under different planting dates.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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