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# ASSESSMENT OF EARLY BLIGHT RESISTANCE IN INDIAN POTATO CULTIVARS AND ASSOCIATED BIOCHEMICAL CHANGES DURING DISEASE DEVELOPMENT

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**ABSTRACT: Among the twenty-three varieties of potato screened against early blight disease under field conditions during *Rabi* 2020-21 and *Rabi* 2021-22 in Gujarat at Anand agricultural University, Anand, varieties were categorized into resistant (R), moderately resistant (MR), moderately susceptible (MS), susceptible (S) and highly susceptible (HS). For biochemical analysis some varieties disease reaction revealed Kufri Lima as resistant, Kufri Himalini and Kufri Nilkanth as moderately resistant, Kufri Mohan and Kufri Chadramukhi as moderately susceptible Kufri Pukhraj and Kufri Kesar as susceptible and Kufri Lalit as highly susceptible varieties to early blight disease. These varieties biochemical analysis revealed that healthy leaves of resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible varieties showed higher content of moisture, total soluble sugar and total chlorophyll as compared to diseased leaves. While diseased leaves of resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible varieties contained higher content of phenol and true protein compared to healthy leaves.**

**KEYWORDS**: Potato, early blight, phenol, true protein, moisture, chlorophyll, total soluble sugar

## INTRODUCTION

Potato (*Solanum tuberosum* L.) occupies a significant position in vegetable production. China stood first among the potato-growing countries, followed by India. During the 2019-20 period in India, potato production averaged 48,662 MT from 2,055 ha, achieving an average productivity of 23.67 MT per hectare (Anonymous, 2020).Potato production is currently threatened by a number of biotic and abiotic factors.

Protection of the crop is a serious issue as it is attacked by a huge number of pests which includes fungi, bacteria, viruses, nematodes and insect pests followed by never-ending vagaries of nature causing significant yield loss in the field and storage conditions. Early blight [*Alternaria solani* (Ellis and Martin) Jones and Grout] disease is one of the most common and widespread diseases of potatoes. Both foliage and tubers can be affected by the disease, which can result in yield losses of up to 50 per cent (Waals *et al*., 2001). Potato crops severely infected with early blight often produced 30-50 per cent lower yields than those of uninfected (Rouse, 1985). When *Alternaria* attacks the host leaf, morphologically it produces a series of concentric rings around the initial site of the attack. This gives a "target spot" effect that is associated with early blight. Over the decades, the application of pesticides has become a dominant and routine practice of pest management to save crops from devastating pests and diseases. Increasing food demand is another force behind it. However, problems associated with the frequent and heavy use of pesticides are creating many issues. The cost of cultivation is rising, fungicide

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resistance to pathogens is another concern and increased pesticide residues are contaminating soil, water and air. The adverse effects of chemicals used in agriculture over decades have changed the mindset of farmers and consumers who are now producing and buying organic foods for their health (Vyas *et al*., 2019). The use of resistant cultivars for managing the early blight offers an economical and environmentally friendly alternative consistent with the objectives of integrated pest management. Unfortunately, no potato cultivar has been reported to be completely resistant to early blight. Very little work has been done on varietal screening, biochemical factors responsible for disease resistance and eco-safe management of the disease.

## MATERIALS AND METHODS

The experiment was conducted over two consecutive *Rabi* cropping seasons, namely November 2020-21 and November 2021-22 at the Agronomy farm of B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat.

### Screening of potato varieties:

Twenty-two potato varieties were screened (each in two rows -15 tubers planted per row) along with a susceptible check to identify the resistant source. Each plot size was (0.9 × 1.5 m). The experimental area was kept unsprayed without any pesticide and micronutrient spray throughout the crop season. The tubers of different varieties (Table 1 ) along with a susceptible check (K. Lauvkar) were procured from Potato Research Station, SDAU, Deesa, Gujara

From the time the disease first appeared until the crop reached physiological maturity, ten randomly selected and labeled plants from each variety were used to measure the early blight intensity at weekly interval. In results section data of disease intensity is terminal disease intensity. A standard scale (Mayee and Datar, 1986) *i.e*. 0 to 5 (Table 1) was used to record the observations of the percentage disease intensity on ten randomly chosen plants each entry. Three leaves- one from the basal, middle, and top portions of the plants were observed in order to determine the severity of the disease.

**Table 1. Per cent disease intensity and the reactions of varieties against early blight of potato.**

| Per cent leaf area covered | Disease grade | Reactions |
|---|---|---|
| 0 | 0 | Immune (I) |
| 1-5 | 1 | Resistant (R) |
| 6-20 | 2 | Moderately Resistant (MR) |
| 21-40 | 3 | Moderately Susceptible (MS) |
| 41-70 | 4 | Susceptible (S) |
| >70 | 5 | Highly Susceptible (HS) |

### Estimation of biochemical factors responsible for disease resistance

The effect of early blight (*A. solani*) of potato on biochemical constituents *viz*., moisture content, phenol, total sugar, chlorophyll and true protein content were estimated from potato varieties representing different reactions from diseased and healthy leaves when the disease intensity was severe (more than 40%) in the field and susceptible variety was 55% infected.

### Sampling of leaves

Sampling was conducted after 40-45 days after planting in the early morning, selecting five plants exhibiting various responses at random. For biochemical analysis, the top three leaves from both diseased and healthy specimens were chosen from same plants. To preserve enzymatic integrity, the leaves were carefully transferred to polythene bags and transported in an icebox with ice cubes to the laboratory. Standard procedures were

employed to assess biochemical parameters including phenol, true protein, total soluble sugar, total chlorophyll, and moisture content. The biochemical analysis was performed at the Department of Biochemistry, B. A. College of Agriculture, Anand Agricultural University, Anand.

## Phenol content

Using a mortar and pestle, the 1 g leaf sample was homogenized in 80% methanol, resulting in a final volume of 10 ml. The supernatant was collected after the content was centrifuged for 10 min at 10,000 rpm. The extract was used for the assay of total phenol. Phenol content was estimated by following the method of Bray and Thorpe (1954). Glass 10 ml tubes were filled with diluted extracts at varying concentrations, and the total amount was filled up with 1 ml of distilled water and mixed with 1 ml Folin-Ciocalteau (1:2 with water) and after 3 min, After adding 1 ml of 20% $Na_2CO_3$, the tubes were heated to a boiling point for one minute, cooled, and then filled to a full 5 ml with distilled water. The absorbance was measured at 650nm. Phenol content was calculated from the standard curve and expressed as a percentage.

$$\text{Phenol content (\%)} = \frac{\text{Graph factor} \times \text{O.D.} \times \text{Total volume} \times 100 \times 10^{-6}}{\text{Taken volume} \times \text{Sample weight}}$$

## True protein content

The protein content was estimated using the Lowry method (Lowry *et al.*, 1951).A 100 mg leaf sample was weighed, homogenized in 2 ml of 0.1 N NaOH, and then filtered using Whatman No. 1 filter paper. The sample extracts of 0.2 ml were taken and 3 ml volume made with distilled water. 5 ml of alkaline copper solution (50 ml 2% Na2CO3 in 0.1 N NaOH + 1 ml 0.5 % CuS04 in 10 % sodium potassium tartrate) was added. 0.5 ml of the Folin-Ciocalteu reagent solution (1:1 v/v) was added after the content allowed standing at room temperature for 10 min. After 30 min at the room temperature, the material was stored and the absorbance was measured at 750 nm. The protein content was calculated using bovine serum albumin as standard range from 50 - 300 mg. The result was expressed as a percentage.

$$\text{True protein (\%)} = \frac{\text{Graph factor} \times \text{O.D.} \times \text{Total volume} \times 100 \times 10^{-6}}{\text{Taken volume} \times \text{Sample weight}}$$

## Total soluble sugar content

Total soluble sugars (%) were estimated as the method suggested by Bhatnagar *et al*. (2006).

## Sample preparation

A 1 gm sample was dissolved in 10 ml of 80% alcohol and left to incubate on a shaker for two hours. Following centrifugation, 1 ml of the clear solution was collected and dried in a hot water bath. It was mixed with 1 ml of distilled water. The extract was used in the total soluble sugar test.

$$\text{TSS (\%)} = \frac{\text{Graph factor} \times \text{O.D.} \times \text{Total volume} \times 100 \times 10^{-6}}{\text{Taken volume} \times \text{Sample weight}}$$

## Estimation

Working standards (0.2, 0.4, 0.6, 0.8 and 1 ml) were pipetted into a series of test tubes. 0.1 and 0.2 ml of the sample solution were pipetted into two separate test tubes and volume was made up to 1 ml with distilled water. A blank of 1 ml of distilled water was also prepared. Then 1 ml of phenol was added to each test tube followed by 5 ml sulphuric acid (96%) to each test tube and shaken well for 10 min. The test tubes were then placed in a water bath at 25-30 °C for 20 min. The colour development was measured at 490 nm in a spectrophotometer. TSS present in the sample was calculated from the standard graph.

### Total chlorophyll content

The quantitative estimation of total chlorophyll content (mg/g fresh weight) was done by using the DMSO method as described by Hiscox and Israelstam (1979).

Fifty mg of the fresh leaf was chopped into small pieces and placed in to test tube containing 10 ml of DMSO. The tubes containing leaf tissue and DMSO were kept in the (oven 65 °C for 3 hrs). During incubation, chlorophyll was extracted into fluid and these were transferred to graduated tubes and making a total volume of 10 ml by adding DMSO. Three ml of the sample of chlorophyll extract was transferred into a cuvette and absorbance or optical density was measured at 663 nm and 645nm using spectrophotometry. Total chlorophyll contents were calculated on a fresh weight basis employing the following formula given by Arnon (1956).

Total Chlorophyll (mg/g fresh wt.) = 22.2 × O.D. at 663 + 8.02 × O.D. at 645

### Moisture content

The moisture content of potato leaves was determined by drying the weighed sample of potato leaf at 105 °C for 5 hrs. and the loss of weight was expressed as moisture content. Five-gram leaf sample from each treatment and calculate the moisture by the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Initial weight - Oven dry weight}}{\text{Oven dry weight}} \times 100$$

## RESULTS AND DISCUSSION

### Screening of Potato Varieties for Resistance Sources against Early Blight Disease under Field Conditions

This study aimed to identify resistant sources against the early blight of potato. During *Rabi* 2020-21 and *Rabi* 2021-22, a total of 23 potato varieties including a susceptible check (K. Lauvkar) were evaluated against early blight disease under field conditions. Based on the per cent disease intensity, varieties were divided into groups with varying degrees of reactions.

The results presented in Table 2 revealed that there were considerabledifferences among the varieties in the level of resistance against the early blight of potato during two years of experimentation.

### *Rabi* 2020-21

Among the twenty-three varieties of potato screened, only one variety (Kufri Lima) showed

**Table 2. Reactions of different potato varieties to early blight disease under field conditions.**

| Sr. No. | Varieties | Disease intensity (%) | | Final reaction |
|---|---|---|---|---|
| | | 2020-21 | 2021-22 | |
| 1 | Kufri Sinduri | 20.00 | 16.33 | MR |
| 2 | Kufri Mohan | 40.00 | 31.00 | MS |
| 3 | Kufri Lalima | 30.67 | 24.00 | MS |
| 4 | Kufri Nilkanth | 18.00 | 19.67 | MR |
| 5 | Kufri Jyoti | 26.00 | 19.33 | MS |
| 6 | Kufri Kesar | 41.00 | 43.33 | S |
| 7 | Kufri Bahar | 33.00 | 17.67 | MS |
| 8 | Kufri Badshah | 19.33 | 14.67 | MR |
| 9 | Kufri Khyati | 30.33 | 27.33 | MS |
| 10 | Kufri Gaurav | 19.00 | 24.33 | MS |
| 11 | Kufri Arun | 17.33 | 18.00 | MR |
| 12 | Kufri Surya | 24.67 | 22.67 | MS |
| 13 | Kufri Chandramukhi | 32.67 | 29.67 | MS |
| 14 | Kufri Himalini | 18.33 | 15.00 | MR |
| 15 | Kufri Garima | 19.00 | 17.00 | MR |
| 16 | Kufri Pukhraj | 43.33 | 42.00 | S |
| 17 | Kufri Anand | 15.00 | 10.33 | MR |
| 18 | Kufri Lima | 5.00 | 4.00 | R |
| 19 | Kufri Lalit | 73.67 | 71.00 | HS |
| 20 | Kufri Ashoka | 15.33 | 21.33 | MS |
| 21 | Kufri Chipsona-1 | 25.67 | 23.00 | MS |
| 22 | Kufri Ganga | 37.67 | 34.00 | MS |
| 23 | K. Lauvkar (Susceptible check) | 84.33 | 86.00 | HS |

a resistant reaction. Nine varieties *viz*., K. Sinduri, K. Nilkanth, K. Badshah, K. Gaurav, K. Arun, K. Himalini, K. Garima, K. Anand and K. Ashoka were showed a moderately resistant reaction and recorded disease intensity ranged from 15.00-20.00%. While nine varieties (K. Mohan, K. Lalima, K. Jyoti, K. Bahar, K. Khyati, K. Surya, K. Chandramukhi, K. Chipsona-1 and K. Ganga) showed moderately susceptible reactions having disease intensity ranged from 24.67-40.00 %. Two varieties *viz*., K. Pukhraj and K. Kesar were found susceptible to disease and recorded disease intensity ranged from 41.00-43.33% while only two varieties *i.e.* K. Lalit and K. Lauvkar were found highly susceptible with a disease intensity of 73.67 and 84.33%, respectively (Tables 2).

### *Rabi* 2021-22

Out of 23 varieties that were evaluated against early blight, one variety *i.e.* K. Lima still performed better and gave a resistant reaction. The varieties *viz*., K. Sinduri, K. Nilkanth, K. Jyoti, K. Bahar, K. Badshah, K. Arun, K. Himalini, K. Garima and K. Anand showed moderately resistant reactions and recorded disease intensity ranging from 14.67-19.67 %. Nine varieties *viz*., K. Mohan, K. Lalima, K. Khyati, K. Gaurav, K. Surya, K. Chandramukhi, K. Ashoka, K. Chipsona-1 and K. Ganga experienced a moderately susceptible reaction to early blight. Whereas two varieties *viz*., K. Pukhraj and K. Kesar were categorized in susceptible disease reaction and recorded disease intensity ranged from 42.00-43.33% while K. Lalit and K. Lauvkar were found highly susceptible with disease intensity of 71.00 and 86.00%, respectively (Tables 2).

### Final reactions

Based on two years of data, the final disease reaction has been worked out. The final results showed that none of the varieties was immune to early blight, although only one variety *i.e.* K. Lima showed a resistant reaction while seven varieties *viz*., K. Sinduri, K. Nilkanth, K. Badshah, K. Arun, K. Himalini, K. Garima and K. Anand which showed a moderately resistant reaction. The eleven varieties *viz*., K. Lalima, K. Mohan, K. Jyoti, K. Bahar, K. Khyati, K. Gaurav, K. Surya, K. Chandramukhi, K. Ganga and K. Ashoka and K. Chipsona-1 showed as moderately susceptible reactions. Two varieties *viz*., K. Pukhraj and K. Kesar were as susceptible to the disease and K. Lalit and K. Lauvkar emerged as highly susceptible varieties (Tables 2).

Due to disease pressure and congenial environmental factors present at the experimental site, the result indicated significant variation in disease reactivity among potato varieties. The results of the present study revealed a considerable variation in disease reaction among potato varieties.

A similar type of results was also reported by earlier workers *viz*., Ganie and Ghani in Jammu and Kashmir (2013), Singh *et al*. in Faizabad, Uttar Pradesh (2017) and Manjamma in Karnataka (2020) against the early blight of potato.

### Estimation of Biochemical Factors Responsible for Disease Resistance

In recent years, it has been clear that host plants have several natural and induced defence systems that protect them from a wide range of diseases. One such defence mechanism is the presence of pathogen-inhibiting biochemical components. The host's pre-existing, pre-formed or induced compounds play a huge role in the plant's biochemical resistance or susceptibility to disease. The nutritional state and concentration of biochemical elements in plants before infection may be used to estimate the severity of the disease. Phenol, true protein, total soluble sugar, total chlorophyll and moisture are all essential biochemical components in conferring resilience to crop plants (Mahesh, 2024).

In this study, eight varieties were identified based on the final disease reactions to understand more about the biochemical components that trigger such reactions. An attempt was made to determine the impact of biochemical constituents present in potato plants.

Diseased and healthy plant leaves were selected from different varieties showing different reactions and the biochemical variation phenol, true protein, total soluble sugar, total chlorophyll and moisture were estimated. The diseased plant leaves had a lower percentage of moisture, chlorophyll content and total soluble sugar than healthy plant leaves whereas the phenol content and true protein was higher in the diseased plants (Table 3).

## Phenol content

Phenol compounds are well-known antifungal, antibacterial and antiviral compounds occurring in plants. The first step of the defence mechanism in plants involves a rapid accumulation of phenols at the infection site, which restricts or slows the growth of the pathogen. The presence of more phenolic compounds in diseased leaves of potato varieties could be due to several factors, including increased phenolic synthesis or translocation to the site of infection which helped to cease the spread of the pathogen.

The result presented in Table 3 revealed that healthy leaves of resistant (K. Lima: 0.19%) and moderately resistant varieties (K. Himalini: 0.18%, K. Nilkanth: 0.15%) contained a higher amount of total phenol than moderately susceptible (K. Mohan: 0.14%, K. Chandramukhi: 0.13%), susceptible (K. Pukhraj: 0.11%, K. Kesar: 0.11%) and highly susceptible varieties (K. Lalit: 0.10%).

The phenol amount was increased in resistant, moderately resistant, moderately

**Table 3. Effect of early blight on biochemical parameters in potato.**

| Varieties | Phenol content (%) | | True protein content (%) | | Total soluble sugar (%) | | Total chlorophyll content (mg/g fresh weight) | | Moisture content (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Healthy leaves | Infected leaves | Healthy leaves | Infected leaves | Healthy leaves | Infected leaves | Healthy leaves | Infected leaves | Healthy leaves | Infected leaves |
| Resistant | | | | | | | | | | |
| K. Lima | 0.19 | 0.37 | 1.21 | 1.98 | 4.04 | 3.73 | 2.43 | 2.00 | 87.83 | 80.19 |
| Moderately Resistant | | | | | | | | | | |
| K. Himalini | 0.18 | 0.34 | 0.93 | 1.67 | 3.90 | 3.43 | 2.21 | 1.71 | 85.79 | 79.53 |
| K. Nilkanth | 0.15 | 0.30 | 0.87 | 1.56 | 3.60 | 3.06 | 1.83 | 1.26 | 83.38 | 77.46 |
| Moderately Susceptible | | | | | | | | | | |
| K. Mohan | 0.14 | 0.28 | 0.78 | 1.50 | 3.46 | 2.91 | 1.72 | 1.17 | 82.78 | 77.33 |
| K. Chandramukhi | 0.13 | 0.25 | 0.71 | 1.36 | 3.43 | 2.81 | 1.62 | 1.09 | 79.51 | 74.14 |
| Susceptible | | | | | | | | | | |
| K. Pukhraj | 0.11 | 0.23 | 0.67 | 1.25 | 2.38 | 1.73 | 1.53 | 1.06 | 76.72 | 73.32 |
| K. Kesar | 0.11 | 0.21 | 0.61 | 1.09 | 2.14 | 1.42 | 1.48 | 0.81 | 75.06 | 69.06 |
| Highly Susceptible | | | | | | | | | | |
| K. Lalit | 0.10 | 0.20 | 0.55 | 0.97 | 2.07 | 1.27 | 1.43 | 0.64 | 68.77 | 61.72 |
| S. Em. ± | 0.002 | 0.007 | 0.025 | 0.029 | 0.038 | 0.030 | 0.027 | 0.032 | 1.769 | 0.680 |
| C.D. at 5% | 0.007 | 0.021 | 0.075 | 0.088 | 0.114 | 0.090 | 0.080 | 0.096 | 5.304 | 2.040 |
| C.V. (%) | 2.99 | 4.53 | 5.45 | 3.58 | 2.11 | 2.04 | 2.61 | 4.54 | 3.83 | 1.59 |

susceptible, susceptible and highly susceptible varieties of diseased leaves, but a higher increase of phenol was observed in resistant and moderately resistant varieties, while it was low in highly susceptible varieties.

The current findings are consistent with Shahbazi *et al*. (2010) and Mehboob *et al*. (2013) who reported significant higher phenol activity in potato plants after artificial inoculation with *A. solani*.

Patel *et al*. (2011), Meena *et al*. (2017), Awan *et al*. (2018), Garg *et al*. (2020) and Shoaib *et al*. (2020) remarked a significant increase in total phenol values during *A. solani* infection in tomato.

## True protein content

The result presented in Table 3 revealed that a higher amount of protein content was present in resistant varieties than in susceptible varieties.

The result revealed that protein content was higher in diseased (K. Lima: 1.98% and K. Himalini: 1.67%, K. Nilkanth: 1.56%) as well as healthy leaves (K. Lima: 1.21% and K. Himalini: 0.93%, K. Nilkanth: 0.87%) of resistant and moderately resistant varieties than diseased (K. Pukhraj: 1.25% and K. Kesar: 1.09%, K. Lalima: 0.97%) and healthy leaves of (K. Pukhraj: 0.67% and K. Kesar: 0.61%, K. Lalima: 0.55%) susceptible and highly susceptible varieties.

Many plant pathogens interactions have shown that protein components play a vital role in defense mechanisms under biotic or abiotic stress conditions. Infected plants typically have a high protein content, which could also be linked to respiration. Increased nitrogen intake by sick plants, combined with fast respiration most likely aids in the production of additional amino acids. The information generated in the biochemical study, which presumably triggered some disease symptoms in susceptible tissue and the host-pathogen interaction could help to detect the efficacy of the pathogen.

According to Veeramohan and Ramaswamy (1995), *A. solani* infection in chilli leaves increased protein content drastically.

The present findings are also in harmony with the similar studies carried out on the activity of protein changes due to *A. solani* infection in tomato by Awan *et al*. (2018), Garg *et al*. (2020) and Shoaib *et al*. (2020).

## Total soluble sugar content

In healthy leaves of resistant (K. Lima: 4.04%) and moderately resistant varieties (K. Himalini: 3.90%; K. Nilkanth: 3.60%), a higher amount of total soluble sugars content was estimated for early blight than in infected leaves (K. Lima: 3.73% and K. Himalini: 3.43%; K. Nilkanth: 3.06%), as shown in Table 3. The lowest total soluble sugars were found in infected leaves of susceptible (K. Pukhraj: 1.73%, K. Kesar: 1.42%) and highly susceptible varieties (K. Lalit: 1.27%).

Since *Alternaria* spp. thrive in low-sugar environments (Abuley *et al*., 2019). healthy leaves have higher sugar content. Sugars are important in inhibiting the pathogen's essential pectinolytic and cellulolytic enzymes. Sugars are also precursors to phenolic compounds, which are highly toxic to varieties. When plants become infected with pathogens, the respiratory rate generally increases. This means that infected tissues consume fewer carbohydrates than healthy tissues. These may be the probable reasons for higher sugar content in healthy leaves of resistant varieties. In diseased leaves, their amount was decreased in resistant and susceptible varieties. Nevertheless, this decrease in sugar content was at higher rates in susceptible varieties compared to resistant varieties.

According to Veeramohan *et al*. (1994), *A. solani* infection in chilli caused a reduction in total sugar content.

Various scientists, including Meena *et al*. (2017), Parmar (2019) and Garg *et al*. (2020) have also came to similar conclusions. They reported high sugar content in resistant genotypes compared to susceptible genotypes in tomato.

### Total chlorophyll content

Total chlorophyll and the proportions of its components were shown to influence plant development stages and biological processes. In healthy leaves of resistant (K. Lima: 2.43 mg/g fresh weight) and moderately resistant varieties (K. Himalini: 2.21 and K. Nilkanth: 1.83 mg/g fresh weight), the total chlorophyll content was higher than in infected leaves. Lower chlorophyll content was found in the healthy leaves of susceptible (K. Pukhraj: 1.53, K. Kesar: 1.48 mg/g fresh weight) and highly susceptible varieties (K. Lalit: 1.43 mg/g fresh weight). Infected leaves of susceptible (K. Pukhraj: 1.06, K. Kesar: 0.81 mg/g fresh weight) and highly susceptible varieties (K. Lalit: 0.64 mg/g fresh weight) had the lowest chlorophyll content and the loss of chlorophyll due to foliar infection caused by pathogens must have a significant impact on the photosynthetic area. The establishment, spread and rapid cell changes may have contributed to the accumulation of reactive oxygen species, which may have resulted in thylakoid membrane disruption.

A similar result was also confirmed by Ginoya (2014), Meena *et al*. (2017), Garg *et al*. (2020) and Shoiab *et al*. (2020) in solanaceous crops. Srivastava and Kumar (2012) found a difference in biochemical changes in diseased and healthy leaves of potato and concluded that chlorophyll content in potato leaves was reduced due to early blight disease.

### Moisture content

The data presented in Table 3 revealed that infection of early blight in potato with *A. solani* results in a loss of moisture. Healthy leaves of all varieties contained a higher amount of moisture per cent than diseased leaves. Moisture content was found higher in healthy leaves (87.83%) of resistant variety (K. Lima) followed by 85.79 and 83.38% in moderately resistant varieties *i.e.* K. Himalini and K. Nilkanth. Moderately susceptible varieties *i.e.* K. Mohan and K. Chandramukhi contained 82.78 and 79.51% moisture, respectively. Susceptible varieties *i.e.* K. Pukhraj and K. Kesar contained 76.72 and 75.06% moisture, respectively. The lowest moisture content of 68.77% was recorded in highly susceptible variety (K. Lalit). Diseased leaves contained 80.19% of moisture in the resistant variety (K. Lima) followed by 79.53% in the moderately resistant variety (K. Himalini) and 77.33% in the moderately susceptible variety (K. Mohan) and 73.32% in the susceptible variety (K. Pukhraj). Lowest moisture content recorded in highly susceptible variety (K. Lallit.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

## ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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