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Harsh Kumawat
M.sc, Scholar, Department of Plant Pathology, R. A. K.. College of Agriculture, Sehore, Madhya Pradesh, India

AK Choudhary
Ph.D., Assistant Professor, Department of Plant Pathology R. A. K.. College of Agriculture, Sehore, Madhya Pradesh, India

Lekharam
Ph.D., Assistant Professor, Department of Genetics and Plant Breeding R. A. K. College of Agriculture, Sehore, Madhya Pradesh, India

Vishal Patil
M.Sc. Scholar, Department of Plant Pathology, R. A. K. College of Agriculture, Sehore, Madhya Pradesh, India

Corresponding Author:
Harsh Kumawat
M.sc, Scholar, Department of Plant Pathology, R. A. K.. College of Agriculture, Sehore, Madhya Pradesh, India

Epidemiology of turmeric (*Curcuma longa* L) leaf spot caused by *Colletotrichum capsici* (Butler and Bisby)

Harsh Kumawat, AK Choudhary, Lekharam and Vishal Patil

Abstract
Spices constitute an important group of agricultural commodities, which is considered as low volume and high-value crops. Turmeric (*Curcuma longa* L.) belongs to the family: Zingiberaceae is one of the most important spices of the world, which is commercially cultivated for rhizome, called as “hidden Lilly” or “turmeric of commerce” and “golden spice of life”. Maximum temperature and minimum temperature showed (r= -0.793, r= -0.886) significant negative correlation with the leaf spot of turmeric. This indicates that the disease incidence increased with lowering down of maximum temperature. Rainfall (r= -0.389) reveals that disease severity is negative correlated but not significant. Relative humidity (r= 0.191) showed positive correlation with the disease severity which clearly indicates that the disease increased.

Keywords: Colletotrichum, correlation linear regressions, turmeric, leaf spot

Introduction
One of the most common spices grown for its underground rhizome, often known as "hidden Lilly," is turmeric (*Curcuma longa* L.), also known as "Golden spice" or "hidden lily." The herbaceous perennial plant known as turmeric is a member of the Zingiberaceae family. It suffers from a serious foliar disease i.e. leaf spot caused by *Colletotrichum capsici*. *Vermicularia curcumae* (Syd.) was the name given by McRae in 1917 to the C. capsici caused turmeric leaf spot disease that was initially discovered in the Coimbatore region of Madras. *V. curcumae* was renamed *C. capsici* by Butler and Bisby in 1931 (Ramkrishnana, 1947) [9]. The disease resulted in drastic reduction in rhizome yield. Turmeric was planted on 2.94 lakh ha in India, with a productivity of 6654 kg/ha and an annual production of 11.02 Lakh tones. Turmeric area, production, and productivity in Madhya Pradesh were 0.17053 lakh ha, 0.60 lakh tonnes, and 3518 kg/ha, respectively (Anon. 2021) [1]. Colletotrichum leaf spot is one of the most significant diseases affecting turmeric. It caused mother and finger rhizomes to lose 25.83 to 62.12% of their fresh weight and 42.10 to 62.12% of their dry weight, respectively (Hudge and Ghugul, 2010) [6]. Reported leaf spot symptoms of turmeric were elliptical to oblong spots with variable size on the leaves. In the initial stages, the spot had grayish -white centre having numerous black dot-like structures i.e. the acervuli in concentric rings and such spots were surrounded by a yellow halo, which later coalesced giving blighted appearance (Gaikwad, 2018) [5]. This research was oriented to study the environmental factors that lead to CLS infection and to the need for disease control. The information needed to develop a forecast system for such disease. The knowledge on effect of environmental factors on development and progress of CLS is important in order to device an appropriate and effectual disease management tactic. Hence, efforts were made to study the effect of weather parameters, to know the time/stage of initiation, progress of leaf spot during the entire crop season, susceptible stage of the crop and window period of the disease.

Materials and Methods
To study the effect of different weather parameters on leaf spot of turmeric, a field experiment was conducted during 2021 at Horticulture Department under the R.A.K. College of Agriculture Sehore (M.P.). The normal agronomic practices were adopted to raise the crop except spraying of any fungicides. Turmeric variety Roma was used in the experiment. The plot area 3 × 2 m was divided into four equal quadrates and ten plants from each quadrate were selected randomly and labeled. The intensity of leaf spot was recorded separately on leaves using a 0-9 scale at seven days interval starting from the appearance of diseases (Mayee and Datar, 1986) [7].

The observations on leaf spot intensity were recorded starting from the germination to the harvesting of the crop.

Rating	Leaf area infection (%)
0	No symptoms on plant
1	Small spot on leaves, less than 1% of leaf area diseased
3	Medium six spot on leaves covering 1-10% infected area
5	Spot big, coalescing covering 11-25% of leaf area
7	Spots large, coalescing covering 26-50% of leaf area
9	Spots on leaves covering above 51% of leaf area

The disease intensity (PDI) was calculated according to the formula suggested by Datar and Mayee (1986) [7] given as below

$$PDI = \frac{\text{Sum of all numerical grade}}{\text{No. of leaves observed x Maximum disease grade}} \times 100$$

The absolute disease intensity was calculated as the difference between two successive observations of PDI and correlation coefficient ('r') was computed between the absolute disease intensity and different meteorological factors like maximum and minimum temperature, relative humidity, and rainfall. The significance of correlation coefficient was judged by 't' test as per standard statistical methods.

The data on disease intensity were plotted against meteorological parameters to predict the correlation between disease and environment. Regressions equations were also computed and scatter diagram were drawn.

Data on meteorological observations during the period was obtained from Meteorological Department, Horticulture Department of R.A.K. College of Agriculture on temperature, relative humidity, and rainfall.

Results

Leaf spot intensity was recorded after 81 and 75 days of sowing in susceptible variety Roma which was grown at 1 and 15th July of 2021-2022, respectively. Since then, there was linear progress of the disease during the seasons. It was initiated on 1-7 October (2.11%) and reached at its highest on 12th – 18th February (54.25%) during 2021. There was maximum increase in leaf spot intensity during 12th to 18th November (26.27%) during 2021 (table -2).

Correlation of leaf spot intensity with weather parameters The disease started appearing in the younger stage of the crop and epidemiological studies were performed right from initiation to harvesting of crop. The leaf spot infection insusceptible cv. Roma and corresponding weather parameters at weekly interval were recorded which are presented in tabled progressed up to the harvesting stage continuously. Weekly intervals of meteorological data were kept, and the severities of turmeric leaf spot were calculated for the corresponding week. The correlation studies between individual parameters and the severity of leaf spot were carried out and the data summarized in (Table-2), which shows that the maximum temperature (-0.793**) showed negative correlation at 1 percent of significance with the disease severity. This indicates that the disease incidence increased with lowering down of maximum temperature. Minimum temperature (-0.886**) also showed negative correlation coefficient at 1 percent significance. This indicates that the disease incidence increased with lowering down of minimum temperature also. Rainfall (-0.389) reveals that disease severity is negative correlated but not significant. Relative humidity (0.191) has positive correlation coefficient with the disease severity that indicates that the disease increased with high humidity. All these factors played an important role in the development of disease. It is very clear from the data that young crop (2 to 5 months) mostly remaining free from the infection of leaf spot. The infection starts during August and attained its peak on completion of major rainfall *i.e.* after 37th MSW. During the major progress (37th to 40th MSW), average temperature remains around 28 ºC and 80 percent relative humidity with moderate rainfall. Thus temperature and humidity plays an important role for the development of disease.

Table 1: Regression equation of weather parameters with disease severity of leaf spot of turmeric

S. N0	Weather parameters	Regression equation
1	Maximum temperature (˚C)	y = 33.556 + (-0.2076x)
2	Minimum temperature (˚C)	y = 23.282 + (-0.3205x)
3	Relative humidity (%)	y = 84.09 + 0.068x
4	Rainfall (mm)	y = 2.8043 + (-0.0587x)

Linear regression analysis

1. **Maximum temperature:** Maximum temperature was found to have a significant negative correlation with leaf spot of turmeric (r= -0.793). The regression equation showed that severity of leaf spot of turmeric decreased by -0.2076% with the increase of 1^0C maximum temperature (Table-2 and Fig 1).
2. **Minimum temperature:** Minimum temperature was found to have a significant negative correlation with leaf spot of turmeric (r=-0.886). The regression equation showed that leaf spot of turmeric severity decreased by -0.3205% with increase of 1^0C minimum temperature (Table-2 and Fig-2).
3. **Relative humidity:** Maximum humidity was found to have a non-significant correlation with leaf spot of turmeric severity (r=0.191).
4. **Rainfall:** Rainfall (mm) was found to have a non-significant correlation with leaf spot of turmeric (r= -0.389).

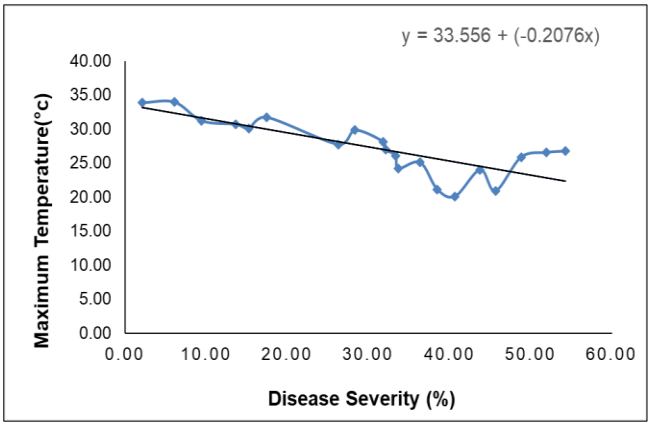

Fig 1: Regression line between disease severity of leaf spot and maximum temperature

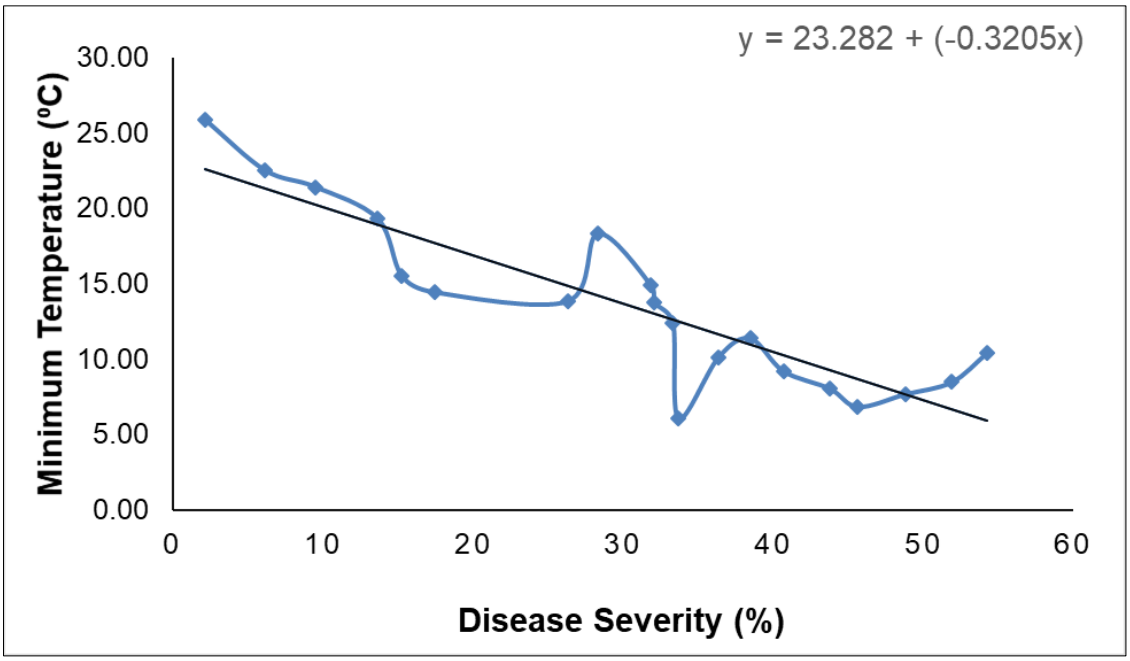

Fig 2: Regression line between disease severity of leaf spot and minimum temperature

Table 2: Climate factors and the severity of turmeric leaf spot

Week Interval	Standard week	Temperature(°C)		Relative Humidity (%)	Rainfall (mm)	Disease Severity (%)
		Maximum	Minimum			
1 Oct.- 7 Oct	40	33.87	25.84	89.43	4.86	2.11
8 Oct.- 14 Oct	41	33.96	22.51	77.43	0.00	6.09
15 Oct.- 21 Oct	42	31.20	21.41	94.00	8.93	9.44
22 Oct.- 28 Oct	43	30.69	19.31	85.00	0.00	13.61
29 Oct- 4 Nov	44	30.11	15.51	84.86	0.00	15.22
5 Nov.-11 Nov	45	31.73	14.43	81.43	0.00	17.42
12 Nov.-18 Nov	46	27.73	13.83	87.71	0.00	26.27
19 Nov.-25 Nov	47	29.84	18.31	90.14	0.00	28.30
26 Nov.-2 Dec.	48	28.11	14.93	84.43	0.07	31.81
3 Dec -9 Dec.	49	26.94	13.73	84.43	0.30	32.08
10 Dec -16 Dec	50	26.09	12.36	87.00	0.00	33.31
17 Dec -23 Dec	51	24.17	6.07	69.14	0.00	33.67
24 Dec -31 Dec	52	25.08	10.14	87.88	0.16	36.35
1 Jan.-7 Jan.	1	21.10	11.37	88.86	1.89	38.45
8 Jan.-14 Jan.	2	20.09	9.20	87.43	4.11	40.67
15 Jan.-21 Jan.	3	23.99	8.06	89.43	0.00	43.75
22 Jan.-28 Jan.	4	20.86	6.84	82.86	0.00	45.63
29 Jan.-4 Feb.	5	25.85	7.67	91.29	0.00	48.79
5 Feb -11 Feb.	6	26.54	8.47	90.43	0.00	51.89
12 Feb -18 Feb	7	26.74	10.40	90.57	0.00	54.25
Correlation coefficient (r)		-0.793**	-0.886**	0.191	-0.389	
Test of Significant (t)		5.52	8.11	0.83	1.80	

Discussion

The correlation studies between individual factors and the severity of leaf spot were carried out during 2021-2022 and the data are summarized, which shows that the maximum temperature (-0.793) exhibited a significant negative correlation coefficient with the severity. This indicates that the disease incidence increased with lowering down of maximum temperature. Minimum temperature (-0.886) also showed negative correlation with the disease indicating that leaf spot increased with lowering down of minimum temperature also. Rainfall (-0.389) disease severity were negatively correlated. Relative humidity (0.191) has positive correlation coefficient with the disease severity that indicates that the disease may be increased with high humidity. According to Ruth *et al*. (2016) [10] The results indicated that disease intensity has significantly negatively correlated with maximum temperature (-0.5138) and minimum temperature (-02539) and positively correlated with morning relative humidity (0.0061) and evening relative humidity (0.1224) the coefficient of multiple determination R2 value was equal to 0.98, which implies that 98 percent variation in the development of leaf spot intensity and evaporation. A strong relationship existed between PDI, the lowest temperature, and rainy days.

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