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Research Paper

Influence of weather parameters on rice blast disease progression in Tamil Nadu, India

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ABSTRACT

Rice cultivation in Madurai district, Tamil Nadu, spans distinct cropping seasons: Kar (May – Jun), Semi-dry (Jul – Aug), Samba/ Late Samba (Aug – Sep), and Navarai (Dec – Jan), each with unique weather conditions and rice varieties. This study explores the correlation between weather parameters temperature, rainfall, humidity, sunshine hours, and wind speed and rice blast disease severity from 2021 to 2023. Using multiple linear regression with ordinary least squares (OLS), the analysis achieves high predictive accuracy ($R^2 = 0.98$). Results show that the maximum temperatures correlated negatively with disease severity (r = -0.869 to -0.892), while rainfall (r = 0.768 to 0.804) and wind speed (r = 0.766 to 0.938) correlated positively during the semi-dry season. Relative humidity exhibits varying impacts across seasons. These findings underscore the importance of tailored disease management strategies, such as targeted fungicidal applications during warmer seasons and optimized water management in others. By elucidating these dynamics, the study enhances understanding of weather-disease interactions, providing actionable insights to optimize disease management and enhance crop resilience in Madurai district.

Keywords: Rice blast disease, Weather parameters, Disease severity, Correlation, Multiple linear regression

Rice cultivation in Madurai district, Tamil Nadu, is pivotal to the region's agricultural economy, characterized by distinct seasonal cycles: Kar (May – Jun), Semi-dry (Jul – Aug), Samba/ Late Samba (Aug – Sep), and Navarai (Dec – Jan). Each season corresponds intricately with specific rice varieties and unique weather conditions. Despite the prosperity of rice farming, farmers encounter a significant challenge in the form of blast disease. This fungal infection predominantly caused by Pyricularia oryzae, manifests in two primary forms: Leaf Blast and Neck Blast posing substantial threats throughout various growth stages of rice (Liang *et al.,* 2019). Blast disease thrives under specific environmental triggers, including airborne spores, upland rice environments, overcast skies, frequent rainfall, high nitrogen levels, elevated humidity, and temperatures ranging between 25-28°C. These factors profoundly influence the onset and severity of rice blast disease, as underscored by Pandit *et al.,* (2023) in their study conducted on the Jammu plains.

Moreover, the cultivation of rice is intricately intertwined with environmental dynamics, where weather parameters such as maximum temperature (Tmax), minimum temperature (Tmin), relative humidity, rainfall, bright sunshine hours, and wind speed play critical roles in shaping disease severity. Prasad *et al.,* (2015) and Nain *et al.,* (2021) emphasize the sensitivity of rice to high temperatures, impacting spikelet fertility and harvest index, thereby highlighting the crucial influence of Tmax and Tmin on crop health. Skamnioti *et al.,* (2009) and Singh and Maurya (2021) underscore the susceptibility of rice to blast disease, exacerbated by fluctuations in humidity, rainfall, and sunshine hours, directly impacting disease severity. The broader implications of climate change on disease patterns are discussed by Chakraborty and Newton (2011) and Rini Pal *et al.,* (2017), emphasizing the pivotal roles of temperature and rainfall in altering disease dynamics. Savary *et al.,* (2019) provide a global perspective on the impact of weather fluctuations on rice pathogens and pests, illustrating their contributions to disease outbreaks and agricultural losses. Additionally, Prasad *et al.,* (2006) explore varietal responses to high temperature stress, further accentuating the influence of environmental factors on rice productivity.

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This study aims to investigate the intricate relationship between weather parameters and rice blast disease severity in Madurai district from 2021 to 2023. Drawing insights from previous research across diverse plant species, such as Singh *et al.,* (2010) on Karnal bunt disease in wheat and Das *et al.,* (2011) on pest-disease interactions in okra, this research seeks to forecast these relationships. Furthermore, insights from Sandhu *et al.,* (2017) on the impact of relative humidity on stripe rust in wheat highlight the critical role of environmental factors in disease management strategies. Leveraging existing knowledge, this study will employ a Multiple Linear Regression Model Using Ordinary Least Squares (OLS) to unravel these complex relationships, offering insights to inform targeted mitigation strategies against this persistent threat to rice cultivation in Madurai district.

MATERIALS AND METHODS

Madurai district, the study area, is situated between 9° 30′ N to 10° 30′ N latitudes and 77° 30′ E to 78° 30′ E longitudes. It includes 13 blocks and 665 revenue villages, spanning a total area of 384,680 hectares. Fig. 1 illustrates the geographical map of Madurai district.

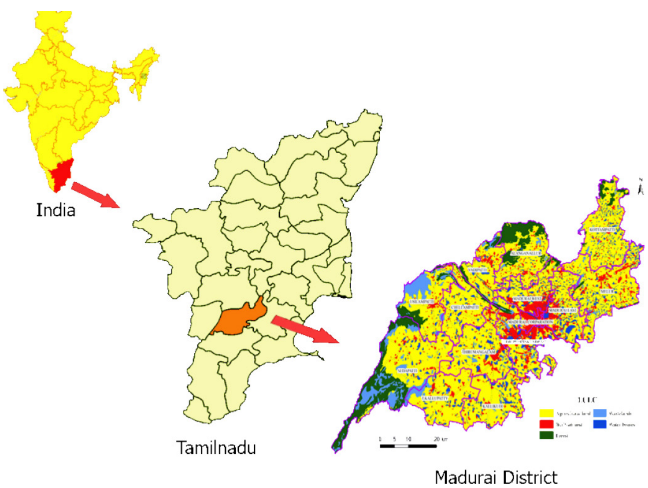

Fig 1: Geographical map of Madurai district

Between 2021 and 2023, studies were conducted in Madurai district, Tamil Nadu, covering the Kar (May – Jun), Semi-dry (Jul – Aug), Samba/ Late Samba (Aug – Sep), and Navarai (Dec – Jan) cropping seasons. Monthly records of blast disease incidence were gathered from various Tamil Nadu government sources such as the Tamil Nadu Agriculture University (TNAU) Architect Portal http://www.agritech.tnau.ac.in/crop_protection/surv _fc_ reports_en.html) and the Tamil Nadu Agriculture web portal (http://tnagriculture.in/).

Meteorological data, including minimum temperature, maximum temperature, rainfall, bright sunshine, relative humidity, and wind speed, were collected throughout different growth seasons of rice. These data were obtained from the India Meteorological Department (IMD) web portal (www.mausam.imd.gov.in), enabling a thorough analysis of the correlation between meteorological parameters and the evolving severity of Rice blast disease.

Disease observation

The monthly data detailing rice blast disease cases was extracted from the "Pest and Disease Surveillance and Forecast Report - Archive" covering the years 2021 to 2023, sourced from the Tamil Nadu Agricultural University's (TNAU) Agritech Portal and the Tamil Nadu Agriculture web portal. This data was subsequently organized into seasonal summaries: Kar (May - Jun), Semi-dry (July - Aug), Samba/Late Samba (Aug - Sep), and Navarai (Dec - Jan). The percent disease severity (PDS) was calculated using the formula:

$$\text{Percent disease severity (PDS)} = \frac{\text{Total disease cases in the season}}{\text{Total cases for the whole period}} \text{ X } 100$$

Analysis of data

Data were analysed using Colab with Python Programming language and its statistical and Graphical packages such as NumPy, Pandas, Matplotlib, Seaborn, SciPy, Scikit-learn, Plotly and Bokeh. Correlation analysis is done to ascertain the impact of various meteorological parameters such as maximum temperature (Tmax, °C), minimum temperature (Tmin, °C), relative humidity (%), rainfall (mm), bright sunshine (Hrs), and wind speed (km s^{-1}) on rice blast disease severity

The meteorological data (weather parameters) were recorded from the seasons such as Kar, Semi-dry, Samba/Late Samba and Navarai during the month intervals May to June, July to August, August to September and December to January. Rice blast disease prediction model was developed based on the pooled disease severity data (2021-2023) and weather parameters using multi linear regression using ordinary least squares (OLS) and was verified using this meteorological data of 2024.

RESULTS AND DISCUSSION

Weather and disease progression during seasons

The analysis of weather data spanning from 2021 to 2023 in Madurai district reveals distinct seasonal trends across the Kar, Semi-dry, Samba/Late Samba, and Navarai periods. Maximum temperatures peaked at 34.4°C during the Kar season in 2023, while the lowest reached was 22.5°C in Navarai during the same year (Table 1). Relative humidity saw a decline from 63 ± 0.5% in Kar 2021 to 62 ± 0.5% in Kar 2023, with Semi-dry increasing from 59 ± 0.5% in 2021 to 68 ± 0.9% in 2022 before returning to 59 ± 0.5% in 2023. Samba/Late Samba witnessed a decrease from 61 ± 0.8% in 2021 to 64 ± 0.8% in 2023, and Navarai fell from 84 ± 1.2% in 2021 to 71.5 ± 0.3% in 2023. Rainfall remained stable in Kar, slightly decreased in Semi-dry, and fluctuated mildly in Samba/Late Samba and Navarai. Bright sunshine hours were consistent overall, peaking at 6.5 hours in Kar 2023. Wind speeds declined from 4.6 km/s in Kar 2021 to 3.6 km s^{-1} in Kar 2023, rose to 5.15 km s^{-1} in Semi-dry 2023, and showed minor variations in other seasons. Rice blast disease severity fluctuated across seasons, with Kar seeing a decrease from 41.76 ± 0.4% in 2021 to 34.38 ± 0.9% in 2023, Semi-dry dropping from 33.52 ± 1.9% in 2021 to 31.07 ± 0.1% in 2022 and then rising to 39.06 ± 4.6% in 2023. Samba/Late Samba experienced slight changes from 38.03 ± 1.1% in 2021 to 38.40 ±

Table 1: Precent disease severity (PDS) and weather parameters recorded in the seasons (2021-2023)

Seasons	Year	Tmax. **(°C)**	Tmin. (°C)	Relative humidity (%)	Rainfall (mm)	Bright sunshine (Hrs)	Wind speed (km s^{-1})	Disease severity (%)
Kar	2021	33.3	26.6	63	62.9	6.1	4.6	41.76 ± 0.6
	2022	33.3	26.6	62	69.8	6.0	3.8	31.07 ± 0.1
	2023	34.4	27.2	62	55.6	6.5	3.6	34.38 ± 0.9
Semi-dry	2021	33.8	26.6	59	92.2	5.9	5.0	33.52 ± 1.9
	2022	31.6	25.5	68	181.7	4.4	4.4	39.06 ± 4.6
	2023	34.4	26.6	59	136.7	5.1	5.1	39.49 ± 4.2
Samba	2021	33.0	26.6	61	99.9	5.7	4.4	38.03 ± 1.1
	2022	31.9	25.0	68	117.1	5.2	4.0	38.59 ± 4.3
	2023	33.6	26.1	64	101.2	5.3	4.2	38.40 ± 3.1
Navarai	2021	27.5	22.7	84	154.4	4.8	3.9	36.84 ± 0.0
	2022	30.0	23.8	72	95.2	5.8	4.2	35.58 ± 1.9
	2023	29.4	22.5	71	55.2	6.4	4.2	35.07 ± 0.2

Table 2: Correlation coefficients between weather parameters and the disease severity

Seasons	Year	Tmax	Tmin	Relative humidity	Rainfall	Bright sunshine	Wind speed
	2021	-0.869	-0.813	0.856	0.768	-0.882	0.938
Kar	2022	-0.892	-0.858	0.759	0.804	-0.896	0.766
	2023	-0.839	-0.768	0.612	0.745	-0.784	0.964
	2021	-0.903	-0.862	0.897	0.880	-0.920	0.960
Semi-dry	2022	-0.960	-0.892	0.824	0.975	-0.912	0.839
	2023	-0.856	-0.831	0.789	0.910	-0.965	0.947
	2021	-0.885	-0.837	0.872	0.824	-0.844	0.948
Samba	2022	-0.941	-0.883	0.799	0.874	-0.932	0.812
	2023	-0.921	-0.880	0.722	0.827	-0.941	0.895
	2021	-0.883	-0.857	0.942	0.897	-0.960	0.963
Navarai	2022	-0.854	-0.845	0.663	0.817	-0.827	0.696
	2023	-0.909	-0.878	0.643	0.743	-0.741	0.918
Pooled data		-0.890	-0.840	0.790	0.830	-0.870	0.880

3.1% in 2023, while Navarai consistently decreased from 36.84 ± 0.0% in 2021 to 35.07 ± 0.2% in 2023 (Table 1). These findings underscore the variability of rice blast disease severity influenced by seasonal weather dynamics in Madurai district.

Correlation between weather parameters and disease severity

Statistical analysis demonstrates significant correlations between weather parameters and disease severity across different seasons and years, and in the combined analysis, as shown in Table 2. In the Kar season, there is a strong negative correlation between maximum temperature and disease severity, with values ranging from -0.869 to -0.892, indicating that higher maximum temperatures correspond to lower disease severity. Minimum temperature also shows a strong negative correlation with disease severity, ranging from -0.813 to -0.858, suggesting that warmer nights are linked to reduced disease severity. Relative humidity displays a positive correlation, ranging from 0.856 to 0.759, meaning higher humidity levels are associated with increased disease severity. Rainfall has a consistent strong positive correlation with disease severity, ranging from 0.768 to 0.804, indicating that more rainfall is linked to higher disease severity. Bright sunshine hours show a moderate negative correlation with disease severity, ranging from -0.882 to -0.896, implying that more sunshine hours are linked to lower disease severity. Wind speed has a significant positive correlation with disease severity, ranging from 0.938 to 0.766, indicating that higher wind speeds correspond to increased disease severity. Similar patterns are observed in the Semi-dry season, where maximum and minimum temperatures show strong negative correlations with disease severity, while relative humidity, rainfall, bright sunshine hours, and wind speed follow similar correlation patterns.

In the Samba/Late Samba and Navarai seasons, consistent correlations between weather parameters and disease severity are observed. Maximum and minimum temperatures exhibit negative correlations with disease severity, while relative humidity and rainfall consistently show positive correlations. Bright sunshine hours maintain a negative correlation, and wind speed continues to show a positive correlation. The pooled data analysis reinforces these relationships across various seasons and years. These significant associations between weather parameters and disease severity align with existing research findings on rice or paddy diseases. The negative correlations between maximum temperature and disease severity in the Kar season are consistent with Prasad *et al.,* (2015), who studied the impact of weather conditions on rice blast occurrence in Himachal Pradesh. The positive correlations between rainfall and disease severity are similar to findings by Amith *et al.,* (2022), who examined the impact of weather on rice leaf blast progression. The moderate negative correlation between bright sunshine hours and disease severity is supported by Nath

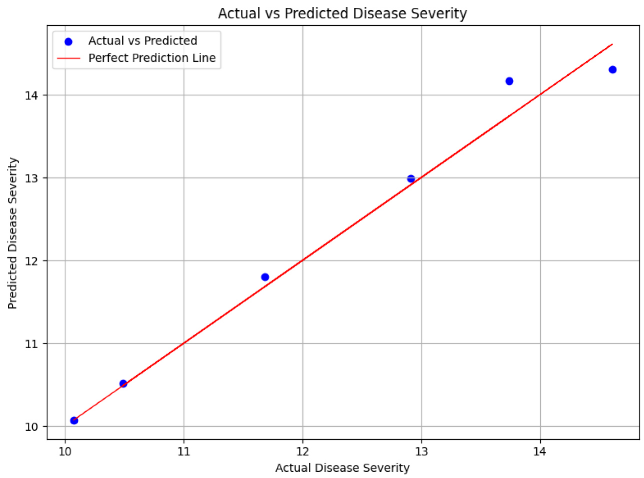

Fig 2: Comparison of Actual vs. Predicted Disease Severity Values

et al., (2023), who researched the effects of weather on rice leaf blast disease in West Bengal. Additionally, the significant positive correlation between wind speed and disease severity aligns with Calvero Jr *et al.,* (1996), who developed predictive models for rice blast using weather variables. These studies highlight the complex relationship between weather parameters and disease severity in rice cultivation, offering valuable insights into rice-related disease dynamics under different environmental conditions.

Development of regression models

Using pooled data of disease severity for the three years (2021, 2022 and 2023) in both the cropping seasons (Kar, Semi-dry, Samba/ Late Samba and Navarai), the multiple linear regression analysis was performed using ordinary least squares (OLS) method to estimate the prediction model equation of Rice blast disease severity in terms of percentage as detailed below

$$Y = 0.01 + 0.14(Tmax) + 0.08(Tmin) + 0.06(RH) + 0.97(Rainfall) - 0.38 (BSS) + 0.38(WS)$$

($R^2 = 0.98$; Adj. R^2: 0.978)

where, Y= Rice blast disease severity percentage, T_{max}= Maximum temperature, T_{min}= Minimum temperature, RH = Relative humidity, BSS = Bright sunshine hours, WS = Wind speed.

The validation of the regression equation utilized meteorological data from the Kar, Semi-dry, Samba/Late Samba, and Navarai cropping seasons in 2023 (Fig. 2), revealing distinct ranges of disease severity: 0.82% to 1.73% during the Kar season and 0.41% to 4.29% in Navarai. Analysis of observed and predicted disease severity across three years and multiple seasons indicated that 98.0% of the variability could be accounted for by key variables such as temperatures, rainfall, sunshine, humidity, and wind speed. Stepwise linear regression analysis underscored the significant impact of temperature, rainfall, and humidity, collectively explaining up to 98% of the variability with an impressive R^2 value of 0.98.

The statistical correlations drawn from the data highlighted robust associations between disease severity and weather parameters. Higher temperatures were consistently linked to reduced severity, while increased rainfall and wind speed correlated with elevated disease levels. Seasonal variations were particularly notable, with distinct patterns observed in the Kar and Semi-dry seasons, where fluctuations in temperature and rainfall played pivotal roles. In contrast, the Samba/Late Samba and Navarai seasons exhibited more stable conditions in terms of disease severity.

CONCLUSION

The study highlights the significant influence of weather parameters temperature, rainfall, humidity, sunshine hours, and wind speed on rice blast disease severity in Madurai district, Tamil Nadu, spanning from 2021 to 2023 across Kar, Semi-dry, Samba/ Late Samba, and Navarai cropping periods. It reveals that higher temperatures correspond to reduced disease severity, while increased rainfall and wind speed are associated with heightened disease levels during the semi-dry season. The multiple linear regression model, achieving an impressive R^2 value of 0.98, demonstrates strong predictive accuracy in forecasting disease severity based on meteorological data. This capability supports timely interventions tailored to seasonal variations, recommending proactive measures like targeted fungicidal applications during the warmer Kar season and efficient water management strategies in the Semi-dry and Kar seasons. These insights offer practical guidance for farmers to optimize disease management strategies aligned with observed weather dynamics, emphasizing the model's role in enhancing crop protection and productivity through informed agricultural planning and proactive disease management protocols.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Data Availability: Indicates the availability of data upon request from the corresponding author.

Author's Contribution: **B. Johnson**: Conceptualization, writing draft, reviewing; **T.Chandrakumar** : Conceptualization, supervision, editing, reviewing.

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