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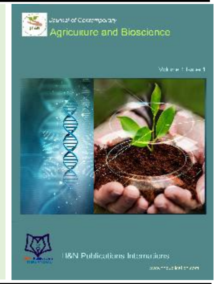

Research Article Open Access

Influence of Environmental Factors on the Incidence and Progression of Major Fungal Diseases in Jute (*Corchorus capsularis*)

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Abstract

The incidence of fungal diseases in jute (*Corchorus capsularis*), specifically anthracnose, black band, and stem rot, varies over time, influenced by the interactions between host and pathogen and environmental conditions. A field experiment was carried out at the Jute Agricultural Experiment Station (JAES), Manikganj, and at the Kishoreganj Regional Research Station (KRRS) of the Bangladesh Jute Research Institute (BJRI) in the years 2022 and 2023 with the specific purpose of looking into the role of temperature, rainfall and humidity in disease development. It was found that the occurrence of diseases increased with time, with respect to stem rot, it was the quickest to spread than the other two diseases; anthracnose and black band. The linear regression showed increasing trends in the incidence of the three diseases studied, while the regression coefficients for the diseases showed a strong positive relationship with the disease progression and the weather variables. There was high collinearity among rain, temperature, and humidity; it may be construed that these parameters and their joint effects were important in the initiation and the manifestation of the fungal infections. The findings of this jute study point towards the major role that environmental factors play in the epidemiology of fungal diseases in jute. Regression coefficients additionally indicated that the changes in temperature, rainfall, and humidity were important and led to the increase in the diseases significantly.

Keywords: Jute, Fungal diseases, Temperature, Rainfall and Humidity

Introduction

Jute (*Corchorus capsularis* L. and *C. olitorius* L.) is considered primary cash crop that has several impacts on the economy of Bangladesh, as it earns around 6-7% of the country's foreign exchange into several jute and jute products for exports (BBS, 2023; Hasan *et al.,* 2014). This crop, that is popularly known as the "golden fiber" is widely used in the textile, packaging, and other industries mainly because it is biodegradable and environmentally friendly (Miah *et al.,* 2011). However, in spite of its economic benefits, jute farming is constrained by a variety of biotic and abiotic factors, with fungal diseases being the major problem (Mahapatra *et al.,* 2009; De, 2019). Jute is plagued by several diseases, and at least ten of these are seed borne. However, among these, more problematic fungal diseases are stem rot, black band, and anthracnose diseases caused by *Macrophomina phaseolina*, *Botryodiplodia theobromae*, and *Colletotrichum corchori*, respectively. These diseases not only affect the amount and quality of the fiber harvested but also transmit via seed-plant-seed cycles (De, 2019; Hasan, 2020).

Jute shows interesting photoperiodic features, since it needs long days for vegetative growth and short days for seed yield (De, 2019). This dependency on photoperiodism leads to the situation where the jute plants are grown in the field for an extended period stretching between the months of March and September, which is a wet inter-monsoon period characterized by drastic changes in weather elements such as temperature, rainfall, and humidity. These climatic factors are key determinants of infection dynamics, particularly in the establishment and spread of fungal diseases (Challinor *et al.,* 2014). The interactions of the host, the pathogen, and the environment stress the importance of understanding disease ecology in jute in a more holistic manner (Hasan *et al.,* 2015).

Jute curtails the adverse effects brought on by three major diseases: stem rot, which attacks the jute trunk or stem, black band and anthracnose disease. All these pathogens are notorious for reducing the crop safety and its yield. Stem rot in jute caused by *Macrophomina phaseolina* is a dangerous disease that causes many yield losses, especially when hot and moist environmental conditions prevail. The pathogen penetrates within the basal stiff of the stem, causing necrotic lesions that may lead to the death of the whole stem, and the plant as a whole collapse (De, 2019). Black band disease, a disease caused by *Botryodiplodia theobromae*, appears as dark, dead-looking patches or lesions on the stalks and branches. This disease causes a softer part of the plant, thus making it easy for the fibers contained in the plant to fall off and lowering the plant's overall fiber quality. Anthracnose in jute due to the pathogen *Colletotrichum corchori* is typically characterized by the presence of dark sunken spots on the foliage and stalks of the plant, often causing loss of leaves and untimely growth of the plant (Miah *et al.,* 2011; Hasan *et al.,* 2014). This pathogen also flourishes under high, moist temperatures and affects the visual and the value of the crop itself. The three diseases have one thing in common, which is that their transmission from seed into a plant and back into a seed creates a cycle of infection that is difficult to manage without advanced measures. The effective management of these diseases entails an integrated approach based on seed health, agroecology, and other concepts (Challinor *et al.,* 2014).

The tropical monsoon climate of Bangladesh in which there are two distinct wet and dry seasons has a great impact on jute farming in the country. The period of March to September is when the plants of jute are left growing in the field for the production of fiber, and this period is associated with changing weather patterns that are likely to encourage diseases. Temperature, rainfall and humidity are the main environmental factors that are responsible for the variation in the prevalence and damage caused by pathogenic fungi on jute plants (Czarnecka *et al.,* 2022). Temperatures encourage the growth and reproduction of pathogens and consequently their ability to attack and infect the host tissues. In the same context, too much rain causes the formation of a wet condition such that all spores resting will set off, causing further extension of the disease. Persistent high humidity, which is often experienced with rain, also aggravates the situation, creating an environment that is ideal for the flourishing of the disease. These meteorological elements are interrelated, thus complicating the understanding of the disease (Khaliq *et al.,* 2022). Where there is increased rainfall, there is usually increased humidity as well, while temperature changes may determine how long and how high the humidity is (Sindt *et al.,* 2016). This kind of combination also explains why rainfall, temperature, and humidity provide a conducive atmosphere for the diseases of jute to spread rapidly.

Understanding the impact of environmental factors on the development of jute fungal diseases becomes imperative considering the threat it poses to sustainable crop production. Although several previous investigations have shown the seed-borne nature of these diseases and their respective effects on jute, they do not provide an elaborative analysis on the effects of changing environmental conditions on the diseases (Fazli and Ahmed, 1960). This presents a challenge in formulating appropriate disease control measures in the face of climate change. In this study, we seek to fill that void by looking at the incidence and progression of the major fungal diseases of jute in relation to some selected environmental parameters. The study will be conducted by carrying out field experiments at the Jute Agricultural Experiment Station (JAES), Manikganj, and the Kishoreganj Regional Research Station (KRRS) of the Bangladesh Jute Research Institute (BJRI) in order to understand host-pathogen-environment interactions.

Materials and Methods

Collection of Seeds

In the jute growing seasons of 2022 and 2023, jute seeds of one capsularis jute cultivar, CVL-1, was obtained from the Central Research and Seed Testing Laboratory, Bangladesh Agricultural Development Corporation (BADC), Dhaka. The obtained seeds were taken for germination and health testing in the laboratory of the Plant Pathology Department, Bangladesh Jute Research Institute (BJRI). This process involved the application of the blotter method in accordance with the guidelines of the International Seed Testing Association (ISTA, 1999). Only those seeds that gave over 80% germination and were free from any fungal infection were taken as experimental materials. These selected seeds were placed in moisture-proof brown paper bags and kept in the Gene Bank of BJRI at 5°C to ensure their viability for use in future research studies.

Experimental Site and Design

Field experiments were conducted at the Jute Agricultural Experiment Station (JAES) in Manikganj and the Kishoreganj Regional Research Station (KRRS) under BJRI. The experiments were carried out during the 2022 and 2023 jute-growing seasons. The experiments were done in RCBD with five replications to make sure that the results obtained are reliable and statistically valid since they have minimal variability, and thus a valid comparison is made between the various treatments. Experimental plots were prepared to standard dimensions, each measuring 3m × 4m, with a 1m gap between blocks to ensure uniform spacing and ease of management. Seeds were sown in the first week of April in both years following a line-sowing method, maintaining a 30 cm line-to-line distance.

Disease Development and Data Collection

No chemical treatment in the form of seed treatment or fungicide application was done to allow fungal diseases to develop under natural conditions. Only routine cultural practices, such as weeding and thinning, were done. Three major fungal diseases of jute, namely anthracnose, black band, and stem rot, were considered for study on natural disease development. Data on the incidence of the respective diseases were gathered on a monthly basis from each plot over four observation periods starting one month after sowing until pre-harvest time. Disease incidence for each particular disease was calculated as percent disease incidence, and its particular monthly progress was obtained by subtracting the percent incidence in the last previous month from the cumulative percent disease incidence in the present month.

Meteorological Data Collection

Daily temperature, rainfall, and humidity data of the concerned area were collected from the Meteorological Office, Agargaon, Dhaka. The aforementioned parameters were used for the correlation of the progress of the fungal diseases in the experimental plots.

Statistical Analysis

Regression analyses of disease incidence against various environmental parameters, along with the correlation matrix and regression coefficient, were also worked out. The analyses have been done using the statistical methodologies outlined in Simple Lessons from Biometry by Zaman *et al.,* (1982). Stepwise multiple regression has been done to find out the integrated effect of temperature, rainfall, and humidity on the incidence of the disease. Regression models considered temperature, rainfall, and humidity as factors for the incidence of anthracnose, black band, and stem rot diseases. Analysis of correlation matrix and regression coefficient was done using R programing (R packages: corrgram and agricolae) software.

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Results and Discussion

Time vs. Fungal Disease Incidences

The relationship between the progressions of disease incidences of major fungal diseases in *Corchorus capsularis* variety, CVL-1, recorded with the increase of time showed in figure 1. Respective stem rot infection was visible within one month of sowing, while anthracnose and black band after two months. This indicates that in all the above diseases, the time and diseases incidences are positively related. The progression of fungal diseases in jute varieties CVL-1 demonstrated a positive correlation with time, consistent with earlier findings (De, 2019). These observations therefore indicate that the intensity of a disease is nearer its maximum value at around the pre-mature stage of the plants. These are the most consistent infection foci that increase with time in tandem with the findings of Gopi *et al.,* (2023), reporting that infection foci expand with time, thereby enhancing the spread and survival of pathogens. This, therefore, postulates that in the effective management of fungal diseases in jute, the early detection and control measures have to be initiated before the disease assumes exponential proportions.

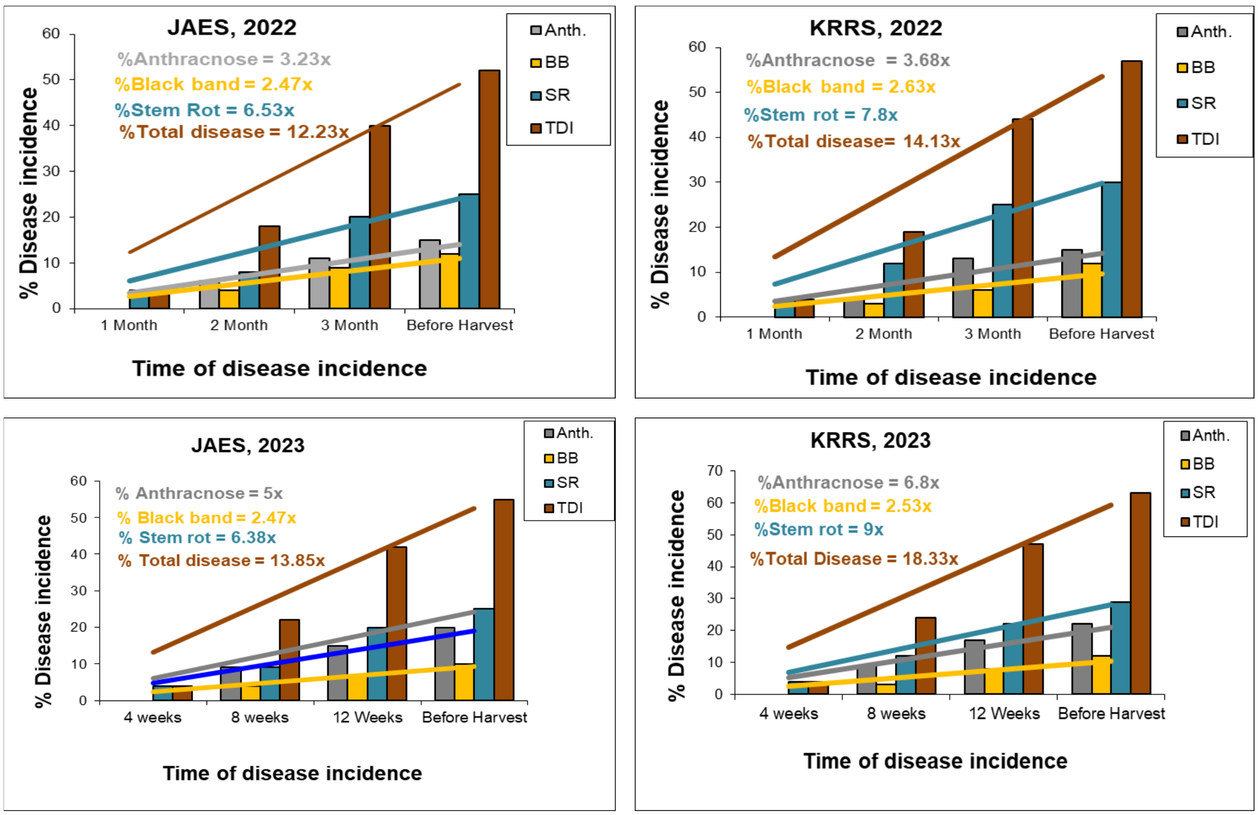

Figure 1. Relationship between increase of time and fungal disease incidences in *Capsularis* jute. Abbreviation: JAES= Jute Agricultural Experiment Station, KRRS=Kishoreganj Regional Research Station

Temperature Correlated with Fungal Diseases

Figure 2 showed that the relation of temperature is always positive regarding the incidence of all major fungal diseases of jute. The correlation between temperature and stem rot, which is the minimum, is 0.44 and the maximum, 0.66, is related to temperature and anthracnose. The strong positive correlation of all of them indicates that an increased temperature is favorable for the proliferation of fungal pathogens in jute. This may be because of the effect of temperature on spore germination of fungi and establishment of the pathogen, as has been further supported by Kaur *et al.,* (2022). Hence, temperature becomes one of the most important environmental factors governing disease development (Yan and Nelson, 2022).

Correlation of Rainfall with Fungal Diseases

It is seen that rainfall also showed a positive correlation with fungal disease incidences from Figure 2. The lowest correlation (0.49) was noted between rainfall and black band, while the highest (0.67) was observed between rainfall and stem rot. The correlation values emphasize that rainfall facilitates fungal disease development. High rainfall levels create favorable conditions for spore dispersal and infection establishment. This finding confirms the findings of the earlier workers that reported the availability of water favors the proliferation of the pathogen and success of infection (Mahapatra *et al.,* 2009; Khaliq *et al.,* 2022).

Correlation of Humidity with Fungal Diseases

All the incidences of fungal diseases were positively influenced by humidity. In Figure 2, the magnitude of correlation varied from 0.65 (humidity × stem rot) to 0.83 (humidity × black band). This positive correlation indicates that high humidity is favoring the growth and development of fungal pathogens (Escuredo *et al.,* 2019). The findings agree with Saharan and Saharan (2004), who reported a significant positive correlation between alternaria blight severity and humidity in cluster bean *Cyamopsis tetragonoloba*. These findings, therefore, gave an indication that high-humidity conditions were an essential factor considered for the reduction of fungal disease incidences in the jute crop.

Correlation among Weather Parameters

The correlation between the weather parameters, which were highly inter-correlated, ranging from 0.61 (temperature × rainfall) to 0.96 (rainfall × humidity) presented in table 1. Maximum correlation was between rainfall and humidity, which ranges from 0.85 to 0.96, followed by temperature and rainfall ranging from 0.61 to 0.95, and humidity and temperature that range from 0.76 to 0.85. This is highly inter-correlated and proves the dependency of these environmental variables on one another with respect to influencing fungal disease development (Shakya *et al.,* 2015; Sindt *et al.,* 2016; Songy *et al.,* 2019).

Table 1. Correlation among the weather parameters

Correlation between	Correlation Matrix (r)			
	2022		2023	
	JAES	KRRS	JAES	KRRS
Temperature X Rainfall	0.93	0.92	0.61	0.95
Rainfall X Humidity	0.85	0.96	0.95	0.94
Humidity X Temperature	0.82	0.85	0.76	0.83

Influence of Weather Variables on Fungal Diseases of jute

Regression analyses given in tables 2 provide more insights into the impact of these weather parameters on the development of disease. In fact, the results underlined the role of temperature, rainfall, and humidity variables as carriers of disease incidents for a good number of fungal diseases and varieties. Through regression coefficients, temperature (0.533699) and humidity (0.262105) significantly contributed to the development of anthracnose disease in CVL-1. Temperature (0.515819), rainfall (-0.004017) and humidity (0.314072) were significant contributors to the black band disease. Rainfall (0.007458) and humidity (0.173682) significantly influenced the advancement of the stem rot disease.

In this respect, the present findings have established the multidimensional role of environmental factors in fungal disease development. High humidity and temperature are the critical drivers, mostly working in tandem, while the contribution of rainfall is according to the nature of the disease and locality. Temperature, rainfall, and humidity have been identified as some of the most critical environmental variables associated with fungal diseases emergence in jute (Picornell *et al.,* 2022).

Table 2. Regression coefficients between weather variables and incidence of fungal diseases in jute

Disease	R^2	Regression coefficient		
		Temperature	Rainfall	Humidity
Anthracnose	0.7239	0.533699***	0.001759	0.262105***
Black Band	0.8066	0.515819***	-0.004017 **	0.314072***
Stem Rot	0.543	0.032853	0.007458 **	0.173682**
Total Disease Incidence	0.7706	1.108529**	0.005252	0.748025***

* $P < 0.001$, R^2 = coefficient of determination

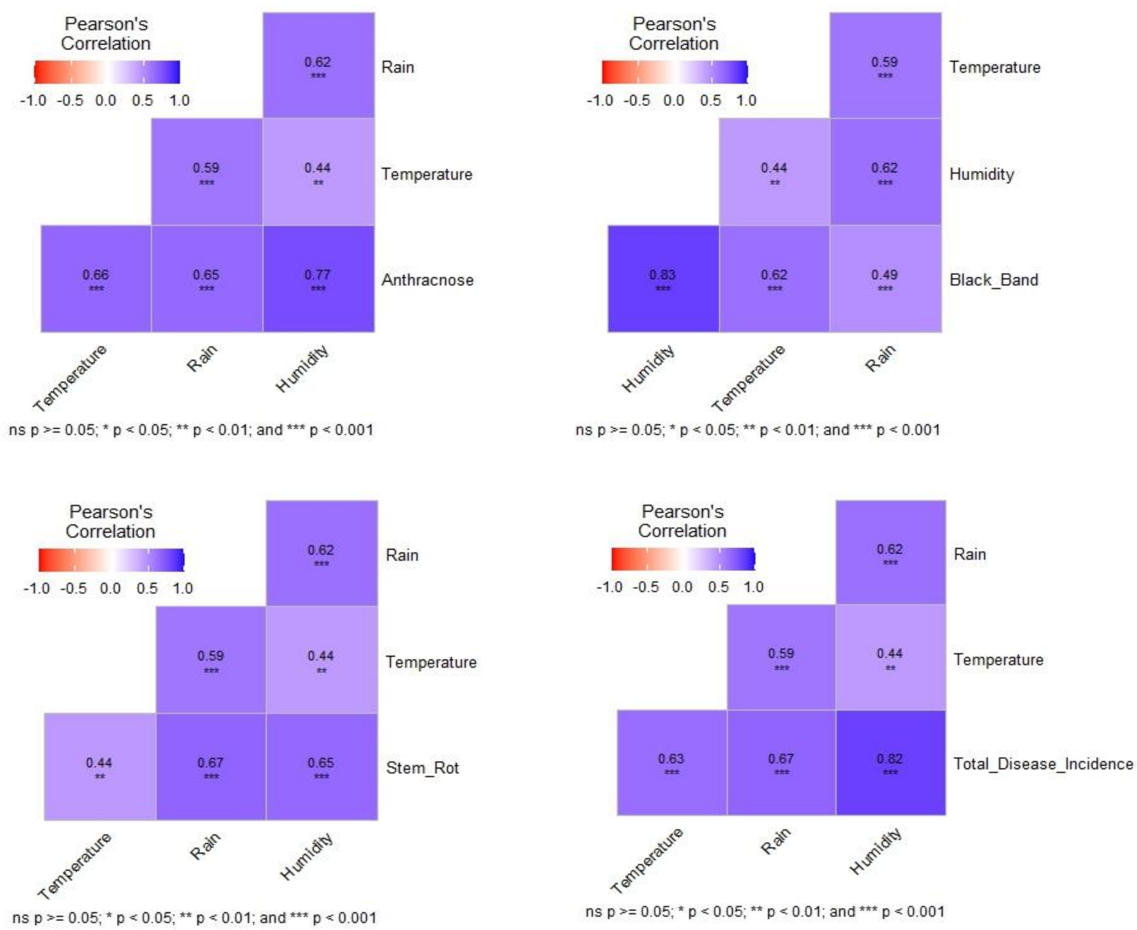

Figure 2. Correlation of Temperature, Rainfall and humidity with fungal disease of jute

Temporally, disease incidences increase up to the pre-harvest stage due to increased infection foci. It demonstrates the positive relationship of temperature, rainfall, and humidity to all major fungal diseases; there is a faster disease progress of stem rot compared to anthracose and black band. Strong indications from regression analyses show the major contribution of humidity and rainfall to the disease progress. These findings are in concurrence with literature such as that by Pramunadipta *et al.,* (2022), Zadoks and Schein (1977), where disease epidemiology is defined by interaction between the pathogen biology and environmental conditions.

Conclusion

The present study has, therefore, pointed out the environmental influences, such as temperature, rainfall, and humidity, on the development and severity of the major fungal diseases of the *Corchorus capsularis*. The results present a good relation of such weather parameters with disease incidence, showing a temporal build-up of fungal infection through the pre-harvest stage. The major environmental variables governing the advancement of diseases are temperature and humidity, though rainfall differs with respect to disease type and geographical locations. High temperatures, in particular, favored the spread of the pathogen causing anthracnose and black band, while the three diseases were favored by humidity. Though subsidiary in effect, rainfall reinforced this favorable environment through spore dispersal and establishment of the pathogen. This therefore underlines the urgent need to consider all environmental conditions for early intervention in disease management strategies. Estimation of the critical window of disease escalation—a prematurity to mature growth stage-will enable more focused control measures. The contribution of this research finding lies in developing deeper insight into the complex relationship of environmental factors with fungal dynamics of disease in jute.

Conflicts of interest

There is no Conflict of interest exists among the authors.

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