



EPIDEMIOLOGY OF RUST DISEASE IN MAIZE (*Zea mays* L.)

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Abstract

Rust diseases consists of Southern rust, Common rust, and Tropical rust, has contracted causing substantial losses in maize in the world. Disease began to be seen attacking the corn crop in South Denpasar-Bali. The purpose of this study to determine the presence of rust disease on corn, contracted diseases, epidemiology, and weather factors that dominate affect disease progression. The results showed that the type of rust that attacks corn planting area in the south of Denpasar was a kind of Southern Corn Rust, caused by the fungus *Puccinia polysora*. Pathogens can be identified by urediniospora, which is elliptical, there is also a round with no macroscopy symptoms on the leaves are brown reddish yellow. Epidemiology of diseases included in the criteria being the epidemic range from 0.054 to 0.329 per unit per day. The relationship between temperature and humidity with the intensity of the disease were not significantly different, but the relationship temperature with infection rate was significantly different, while relationship humidity with infection rate was significantly different. Multiple regression temperature and humidity with infection rate was highly significant.

Keywords:

Southern rust, common rust, tropical rust, the percentage of disease, the intensity of the disease and the rate of infection.

INTRODUCTION

Corn rust diseases can be categorized into southern corn rust, common corn rust, and tropical corn rust; these fungal diseases affect corn plants after the milk stage. Weather conditions significantly impact the development and spread of the disease [1]. Common rust of corn (caused by the fungus *Puccinia sorghi*) occurs at low levels in Indiana fields annually, whereas southern rust (caused by *P. polysora*) is frequently observed in Indiana [2]. Tropical corn rust is caused by *Physopella zeae* [3; 4].

The initial symptoms appear as small, circular-to-elongated lesions on the leaves, often occurring in rows. As the lesions mature, the fungus erupts through the leaf surface (epidermis), causing the lesions to become more elongated. A yellow halo typically develops at this stage. Reddish-brown pustules are a characteristic symptom on the leaves; these are caused by the urediniospores within the lesions. Unlike southern rust in maize, common rust lesions are distributed across the entire leaf and occur on both the upper and lower leaf surfaces. Spores are wind-dispersed, with new infections occurring every 7 to 14 days. Over time, black

teliospores are produced within the lesions. During this process, a single lesion may produce both reddish-brown urediniospores and black teliospores, though eventually, only black teliospores are observed within the lesion [5].

Based on disease symptoms, the types can be distinguished: tropical corn rust presents with white rust symptoms; southern rust appears only on the upper leaf surface; whereas common rust occurs on both the upper and lower leaf surfaces [5]. To date, this disease has not been reported, and its status and epidemiology remain unknown; therefore, this study aims to address these issues.

MATERIALS AND METHODS

Research Location and Timing

The research, consisting of a disease survey, was conducted in the maize cultivation areas of South Denpasar-Bali; subsequent disease observations were carried out at the Laboratory of Plant Pathology and Agricultural Biotechnology, Faculty of Agriculture, Udayana University, from January to June 2026.

Disease symptoms

The study involved observing disease symptoms in the field; subsequently, samples of diseased leaves were placed in plastic bags to serve as specimens for examining the causative pathogen. Prior to pathogen isolation, the diseased leaves were stored in a refrigerator for 24 hours to inhibit the growth of the pathogen and associated microbes. The number of diseased leaves was counted and compared to the total number of leaves observed to calculate the disease percentage (using the formula provided below).

Pathogen Identification

The pathogens were observed directly under a microscope to examine their microscopic morphology such as fungal spores, conidiophores, and pustules (including pustule size and color) and were photographed using a digital camera. Observations were conducted using the OPTILAB device (manufactured in Yogyakarta), which connects directly to a laptop.

Disease incidence

The disease percentage can be calculated using the formula:

$$P = a/b \times 100\%$$

P = disease percentage (%),

a = number of diseased leaves, and

b = total number of leaves observed.

Disease intensity

To determine the local severity of the disease, it is necessary to calculate the disease intensity using the following formula:

$$IP = \frac{\sum (n \times v)}{N \times V} \times 100\%$$

Where:

IP = disease intensity (%)

n = number of diseased leaves with a specific score; v = numerical scale of the diseased leaf

N = total number of leaves
V = highest numerical scale

Table 1. Numerical scale and infestation criteria

Numerical scale	Information	Infestation criteria
0	Healthy leaves (no rust symptoms)	Healthy
1	≤ 10% of the leaf blade shows symptoms of disease,	Very lightweight
2	>10% - ≤25% of leaf parts show symptoms of disease,	Light
3	>25% - ≤50% of the leaf surface shows symptoms of disease,	Currently
4	>50% - ≤ 75% of the leaf parts show symptoms of disease,	Heavy
5	75% of the leaf area shows symptoms of disease.	Very heavy

Infection rate

The infection rate can be calculated using the [6] formula; the obtained disease percentage value is converted into the proportion of diseased leaves. If the proportion of diseased plants (X) is less than 0.05, the formula used is:

$$R = \frac{2.30259}{t_2 - t_1} \log_{10} \left(\frac{X_t}{X_0} \right) \text{ (per unit per day)}$$

Where:

R = infection rate; 2.30259 = conversion factor from natural logarithm to common logarithm ($\ln X = 2.30259 \log X$);

t = observation time interval (14 days);

X_t = proportion of diseased plants at time t (derived from the disease percentage value at time t);

X₀ = initial proportion of diseased plants.

If the proportion of diseased leaves exceeds 0.05, the formula above requires modification to account for a correction factor specifically, the remaining proportion of healthy leaves ($1 - X$) resulting in the following formula:

$$R = \frac{0,30259}{t_2 - t_1} \times \log_{10} \left(\frac{X_2(1 - X_1)}{X_1(1 - X_2)} \right)$$

Table 2. Infection rate criteria adopted from [6]

No	Infection rate (per unit per day)	Criteria
1	≤ 0.11	Light
2	$> 0.11 - \leq 0.50$	Currently
3	> 0.50	Heavy

Correlation and Regression Analysis

To determine the relationship between disease percentage or intensity and weather factors (temperature and humidity), one can analysis the correlation between the variables. Meanwhile, the relationship between independent and dependent factors can be assessed through regression analysis using Microsoft Excel.

Measuring Weather Factors

Temperature and humidity can be measured using a thermohygrometer placed in the centre of the cornfield. Temperature and humidity are recorded daily until the study is completed.

RESULTS AND DISCUSSION

Disease Study

The observed rust disease exhibits symptoms resembling Southern Corn Rust, caused by *Puccinia polysora* Underw. Symptoms include the formation of pustules primarily on the upper surface of the maize leaves, with only a few appearing on the underside. These pustules are circular to round in shape and range in colour from orange to brown (Figure 1). They are small and tend to coalesce; when they rupture, spores are dispersed by the wind, potentially initiating a new infection cycle. Lesions may also develop on the tissues of the stalk, husks, and leaf sheaths. As the infection progresses and leaves become covered in pustules, premature leaf drop occurs, giving the crop the appearance of being ready for harvest because the disease has killed the plant tissue.

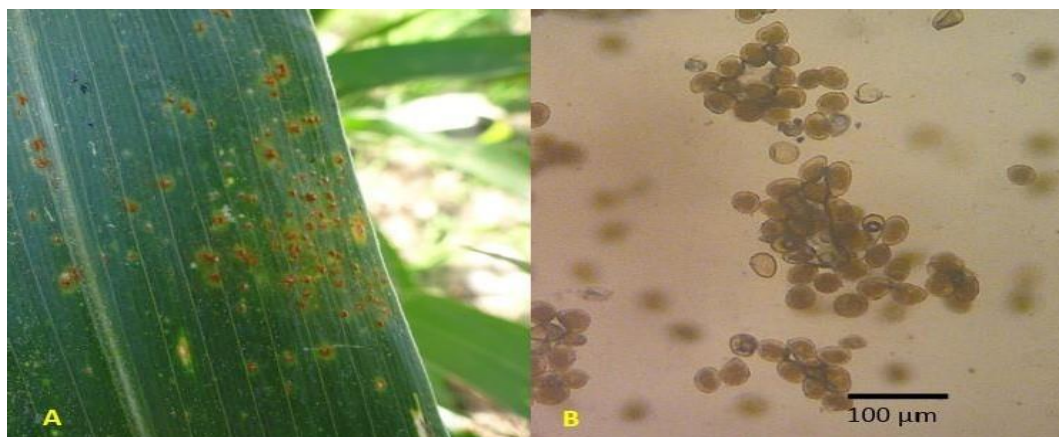


Figure 1. Symptoms of maize rust (A), and (B) urediniospores

Disease Intensity

Observations made during the study revealed disease intensity average ranging from 41.33% to 77.33% (Figure 2), corresponding to severity levels classified as moderate to very severe. The disease affected leaves from the lower levels up to the upper canopy, leaving only the young leaves at the top. These results are associated with humidity, as the disease thrives in moist and shaded conditions (Table 3, Figure 2).

Table 3. Diseases intensity during the observation

Repeat			Amount	Average
I	II	III		
42	40	42	124	41,33
43	48	48	139	46,33
52	53	57	162	54
68	62	65	195	65
68	71	72	211	70,33
75	79	78	232	77,33

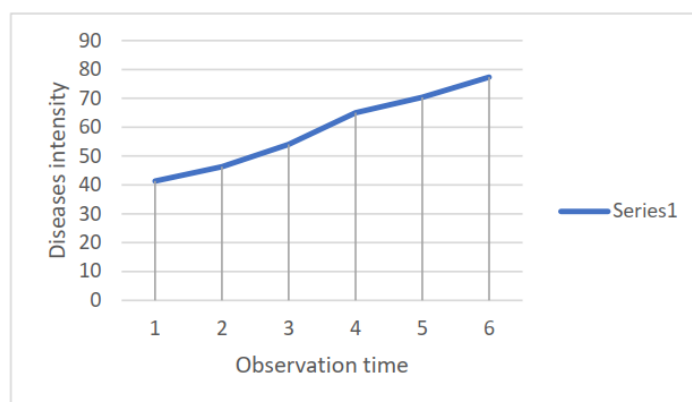


Figure 2. Development of maize leaf rust disease intensity

Puccinia polysora does not survive on infected plant debris left in the field. Infections during the growing season depend on windborne spores. Urediniospores serve as the primary inoculum, both at the onset and throughout the growing season. Continuous maize cultivation and the presence of infected wild maize into the subsequent growing season create a source of initial disease inoculum. Urediniospores are dispersed by wind and rain splash onto healthy maize plants. Under favourable conditions, Polysora rust can spread rapidly, with new infections occurring within seven days. A small number of spores are capable of long-distance dispersal, traveling hundreds of kilometers [7].

Infection Rate

The infection rate is derived from the proportion of diseased plants (disease percentage), calculated weekly in accordance with disease progression. The disease rate ranges from 0.066 to 0.405 per unit per day. This means that out of one thousand leaves, 66 to 405 become infected daily (Table 4, Figure 3).

Rust requires six hours or more of relative humidity $\geq 95\%$ or wet leaves for spore germination and infection, though the optimal temperature ranges differ. Urediniospores are produced in pustules, enabling recurring secondary infections and potentially abundant spore production. Southern rust tends to cause greater yield losses than common rust losses of up to 45% have been reported. Severe epidemics of Southern rust are rare in Nebraska; the 2006 epidemic may have been driven by a combination of above-normal nighttime temperatures and excessive rainfall in August. Severe infections can impact yield by damaging leaves, leading to defoliation and premature leaf drop, although the disease often progresses slowly during the season. Younger leaf tissue is more susceptible to infection, and plants with a longer remaining period for grain fill are more vulnerable to damage. Late-planted corn is more prone to yield loss from rust, particularly Southern rust [8].

Table 3. Infection rate per replicate (per unit per day)

Repeat			Amount	Average	T (°C)	RH (%)
I	II	III				
0,296	0,218	0,405	0,919	0,4595	27,43	92,67
0,066	0,329	0,138	0,533	0,2665	27	94
0,329	0,329	0,329	0,987	0,4935	26,47	92,67
0,329	0,329	0,329	0,987	0,4935	27,1	92,33
0,329	0,329	0,329	0,987	0,4935	27,7	86,67
0,329	0,329	0,329	0,987	0,4935	26,9	91,33
0,296	0,218	0,405	0,919	0,4595	27,43	92,67

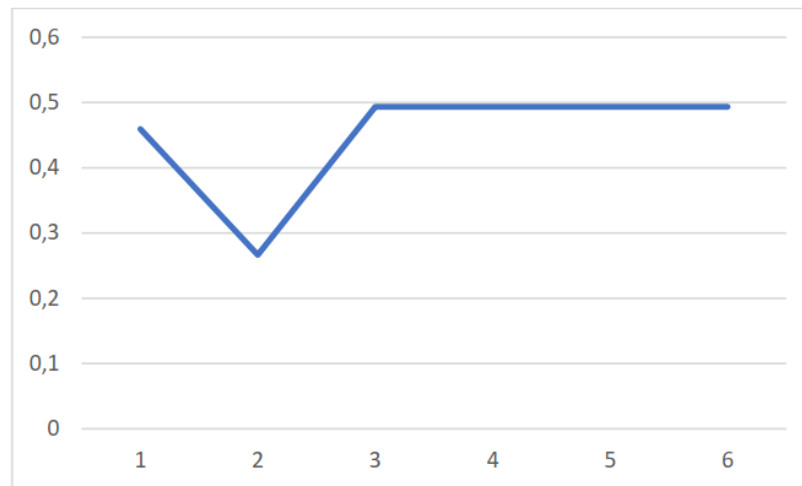


Figure 3. Progression of the infection rate

Relationship Between Temperature, Humidity, and Infection Rate

The regression analysis between temperature and infection rate shows a highly significant relationship, described by the equation $Y = 1.327 - 0.040 X1^{**}$ ($r = -0.7365$). The temperature range of 25.2–28.8°C is highly favourable for the development of rust disease. The graph of the equation is presented in Figure 4.

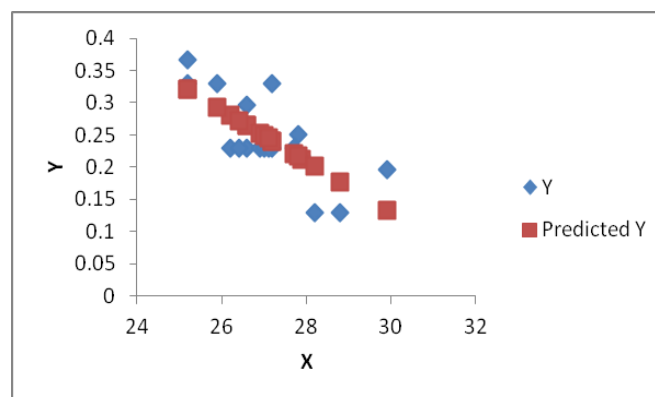


Figure 4. Regression relationship between temperature and rust infection rate.

The regression relationship between relative humidity and the infection rate was statistically significant, with the regression equation $Y = -0.092 + 0.0038 X2^*$ ($r = 0.3599^*$). This indicates that as humidity increases, the infection rate also increases up to a certain limit (Figure 5).

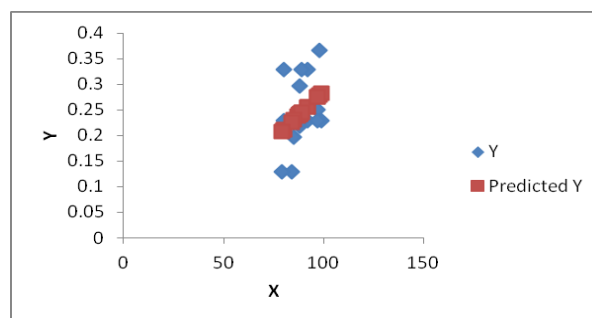


Figure 5. Regression relationship between humidity and infection rate

The multiple regression relationship between temperature and humidity and the infection rate was highly significant, represented by the regression equation $Y = 1.060 - 0.037 X_1 + 0.002 X_2$. This indicates that the infection rate was strongly determined by changes in temperature and humidity during the study; higher temperatures resulted in a lower infection rate, whereas increased humidity led to a higher infection rate.

Southern corn rust is caused by the fungus *Puccinia polysora*. The pathogen cannot overwinter in the Midwest (Corn Belt) but survives the season in the southern United States and Mexico, from where it can be transported northward to the Corn Belt each year in early summer. Disease occurrence depends on wind dispersal; therefore, an infection in a given year does not imply that southern rust will occur annually. Conditions highly favorable to the disease include high humidity and temperatures between 26.5°C and 31.5°C. Under favorable conditions, new infections can occur every seven days. Corn varieties differ in their susceptibility to the disease [1].

The uredia are paraphysis-free, circular, and reddish-orange, developing on both leaf surfaces. The golden-brown-yellow urediospores are oblong to ovoid, measuring $23\text{--}20 \times 29\text{--}36 \mu\text{m}$; the lateral wall, apical wall, and pedicel measure $1.5 \mu\text{m}$, $1.5\text{--}2.5 \mu\text{m}$, and $30 \mu\text{m}$, respectively. The telia are erumpent, and the teliospores which feature pointed tips and relatively thick apical walls distinguish *P. polysora* from *P. sorghi*. *P. polysora* propagates primarily through the repetition of the uredial stage; the teliospores are not known to be functional. The pathogen overwinters on its host and relies on wind dispersal to spread spores into areas where it cannot otherwise survive between seasons [9].

Moist conditions are required for the survival and dissemination of *P. polysora*. Urediniospores exhibit a narrow optimal temperature range approximately 23°C to 28°C for germination, and the pathogen cannot survive for long at 20°C. *Puccinia polysora* primarily spreads within tropical or subtropical regions, largely due to its temperature sensitivity; however, under favorable conditions and with abundant inoculum, it can spread from tropical areas to temperate regions [9].

ACKNOWLEDGEMENTS

Acknowledgements are extended to the Rector of Udayana University, the Head of the Institute for Research and Community Service, and the Dean of the Faculty of Agriculture at Udayana University for the opportunity to serve as a researcher, thereby enabling this research to be realized.

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