Universal Journal of Agricultural Research 11(1): 146-157, 2023 http://www.hrpub.org
DOI: 10.13189/ujar.2023.110114

Identification of Climate Influence on Upas Fungus (*Corticium* sp.) Disease Intensity on Rubber Plants (*Hevea brasiliensis* Muell.Arg.)

Helda Syahfari[1,*], A. Syamad Ramayana[2], Ahmad Suhaimi[3], Nur Hafizah[4], M. Taufan Tirkaamiana[5]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas 17 Agustus 1945.
Jl. Ir. H. Juanda 80 Samarinda, 75123,
East Kalimantan, Indonesia
[2]Department of Agrotechnology, Faculty of Agriculture, Universitas Mulawarman.
Jl. Paser Balengkong, Samarinda, 75119,
East Kalimantan, Indonesia
[3]Agribusiness Study Program, Amuntai College of Agriculture Science, Bihman Villa Street 123,
71416 North Hulu Sungai District, South Kalimantan, Indonesia
[4]Agrotechnology Study Program, Amuntai College of Agriculture Science,
Bihman Villa Street 123, 71416 North Hulu Sungai District, South Kalimantan, Indonesia
[5]Department of Forestry, Faculty of Agriculture, Universitas 17 Agustus 1945.
Jl. Ir. H. Juanda 80 Samarinda, 75123,
East Kalimantan, Indonesia

Received December 9, 2022; Revised January 10, 2023; Accepted February 15, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Helda Syahfari, A. Syamad Ramayana, Ahmad Suhaimi, Nur Hafizah, M. Taufan Tirkaamiana , "Identification of Climate Influence on Upas Fungus (Corticium sp.) Disease Intensity on Rubber Plants (Hevea brasiliensis Muell.Arg.)," Universal Journal of Agricultural Research, Vol. 11, No. 1, pp. 146 - 157, 2023. DOI: 10.13189/ujar.2023.110114.*

(b): *Helda Syahfari, A. Syamad Ramayana, Ahmad Suhaimi, Nur Hafizah, M. Taufan Tirkaamiana (2023). Identification of Climate Influence on Upas Fungus (Corticium sp.) Disease Intensity on Rubber Plants (Hevea brasiliensis Muell.Arg.). Universal Journal of Agricultural Research, 11(1), 146 - 157. DOI: 10.13189/ujar.2023.110114.*

Abstract This research aims to determine the influence of climate in West Kutai, Indonesia on the intensity of disease attack Upas Fungus (*Corticium* sp.) pathogen on 4-year-old and 7-year-old rubber plants. The study began in 2015, with a 4-year-old rubber plant and continues in 2018 with a 7-year-old rubber plant. The methodology is to inventory 500 rubber plants in two neighboring locations to determine the incidence and severity of disease caused by Upas Fungus in 2015. The results indicated that an invasion of pathogenic Upas Fungus attacked rubber plants starting at the age of 4 years in 2 places and the age of 4 years in another location. Symptoms included substantial eruptions of tree trunks that finally dried up. The inventory and calculation results indicate that the attack frequency at position 1 is 1.20 % with an attack intensity of 0.90 %, and the attack frequency at location 2 is 2.40 % with an attack intensity of 1.80 %. The correlation test revealed an inverse (negative) relationship between temperature and attack intensity, with a coefficient value of 0.721, and a directly proportional (positive) relationship between humidity and intensity, with a coefficient value of 0.754 and vice versa, between rainfall and intensity there is an inverse (negative) relationship that is not significant with a coefficient value of 0.199 and vice versa.

Keywords Attack Intensity, Disease Effect, *Hevea brasiliensis* Muell. Arg, Latex Loss, Plant Pathology

1. Introduction

Natural rubber is a highly valued and strategically significant biomaterial; unlike the majority of other biopolymers, it cannot be substituted in many of its applications by synthetic materials. For example, heavy-duty tires for trucks, buses, and airplanes, as well as a variety of latex products used in the medical field, cannot be manufactured entirely from synthetic rubber or at a large cost premium. Around 10% of natural rubber is used to make latex, which is used in the manufacture of gloves, condoms, catheters, and other medical items [1], [2].

The rubber tree (*Hevea brasiliensis* Muell. Arg.) is a perennial tropical plant species of the Euphorbiaceae family. Although natural rubber is indigenous to the Amazon basin, its economic value and growing demand have resulted in its widespread domestication in Southeast Asia. To this day, the rubber tree is the sole commercial source of natural rubber, due to its high output and rubber quality [3], [4]. Indonesia has the world's largest area under rubber plantation, surpassing major producers Thailand and Malaysia. Nonetheless, Thailand's annual rubber production exceeds Indonesia's.

Factors that contribute to the low productivity of rubber plants are the presence of pest and disease assault, inadequate understanding of routine care, such as fertilization and insect eradication, and less intensive disease [5]. It is estimated that crop losses caused by pests and diseases range anywhere from 17 to 30 percent across the globe [6]. Pathogenic fungal infections such as Phytophthora-caused aberrant leaf fall (ALF) and shoot rot, Corticium salmonicolor-caused pink disease, Corynespora-caused leaf disease, and powdery mildew (*Oidium* sp.)-caused leaf disease, were difficult to control and pose epidemic hazards to rubber agriculture [7].

In India, the pink disease has been a critical malady, affecting around 30% of all rubber trees [8]. Climatic factors are suspected to be the cause which influence the pattern of cancer because the rainfall pattern influences cancer formation, but humidity does not affect cancer development. Still, perhaps the duration of direct wetting on the host surface facilitates infection, or rain splash helps the release of spores from summer/winter spores in the soil, which affects cancer development. A study showed that the rise in temperature has a negative effect, while rainfall change exerts a positive impact on agricultural productivity [9]. Previous study also considered the maximum progress and spread of infection during the rainy season in pink cancer cases [8].

Effective disease control strategies strive to disrupt the triangle formed by the environment, pathogen, and host. Reduction in disease-related loss is possible, for example, if the host can be made more resistant or immune through plant breeding or genetic engineering. Additionally, the environment could be modified to make it less conducive to disease invasion and more conducive to host plant growth. Finally, the pathogen may be eradicated from the host or prevented from infecting it. These fundamental control approaches can be classified into a variety of cultural, chemical, and biological practices, all of which contribute to disease control [10], [11].

As the progression of the disease depends heavily on climatic elements such as temperature, humidity, light, precipitation, and wind. In general, Indonesia's climate is ideal for the spread of any kind of rubber disease. The epidemiology of plant diseases is influenced by a number of climatic conditions, but temperature, humidity, and rainfall are particularly significant ones.

Upas fungus (pink disease) caused by the opportunistic fungus Corticium salmonicolor with increasing incidence and host of increasingly diverse plant types has not received proper attention. The purpose and benefit of this research was to analyze the relationship between climate factors and disease development so that disease control can be carried out from the beginning of planting.

However, prior studies have limited information on climate factors and disease development of Upas Fungus in Indonesia [12], [13]. Hence, this study was an attempt to close the gap from previous studies on climate influence on upas fungus (*Corticium* sp.) disease frequency/attack intensity on rubber plants (*Hevea brasiliensis* Muell.Arg.).

This study relevance was about the rubber plants production in Wes Kutai, Indonesia which was affected by Upas Fungus that prior study has limited information on climate influence on the attack intensity of Upas Fungus.

2. Materials and Methods

2.1. Research Location

The research location was conducted in a rubber plantation in Sumber Rejo Village, Sekolaq Darat District, West Kutai Regency, East Kalimantan Province, Indonesia. The research location's coordinates are 0 º 29 ' 79 " – 115 º 77 ' 45 ".

Rubber is the main income for the people of Sekolaq Darat Village, besides Pepper, Coffee, Cloves, Coconut, Cocoa, Cotton, Pecan, Palm and Ginger. So far, the community, especially in the Sekolaq Darat District Area have not been satisfied with the production of rubber that is too low and is not in accordance with basic necessities in Sekolaq Darat District. Many things have caused rubber production such as, disease, climate and other factors that will result in rubber production. As such, the author chooses Sekolaq Darat District as the research location in order to generate better rubber plant treatment, especially for disease control.

2.2. Research Procedures

In the research location, 2 plots were determined. Each plot was 1 hectare in size. Rubber plant samples observed were 1000 plants. At location 1, 500 plants were observed and at location 2, 500 plants were observed. The age of the plants in each location was 4 year in 2015 and 7 year in 2018. All plants were inventoried by studying Upas Fungus disease symptoms and signals on rubber plant stems. The disease manifests itself through symptoms associated with fungal pathogenic disease.

Signs of Upas Fungus harmful diseases were promptly discovered in the field by comparing them to published literature and picture data. Additionally, any symptoms and indicators in the area were noted on the tally sheet. Plants affected by the disease were calculated frequency (F) and attack intensity (AI).

2.3. Data Analysis

The core data set records the Frequency (F) of pathogen assault and the Intensity of the attack (AI). The value (score) of an attack was established by examining the assault symptoms or the status of each rubber plant, as shown in Table 1 and Table 2.

Table 1. The scoring procedure of diseases caused by upas fungus (*Corticium* sp.) on each rubber plant observed

Plant condition (attack symptoms)	**Score**
Healthy (no symptoms)	0
Mildly infected (plants that are infected but still look healthy)	1
Severely infected (the number of stems infected are a lot)	2
Moderately infected (plants are infected and the number of stems infected are a lot more)	3
Dead (all plants damaged or no signs of life)	4

The formula for calculating attack frequency (F) and attack intensity (AI) is as follows:

$$\text{Attack Frequency (AF)} = \frac{\text{number of affected plants}}{\text{number of plant sample}} * 100\% \quad (1)$$

$$\text{Attack Intensity (AI)} = \frac{\text{x1y1 +x2y2 +x3y3 +x4y4}}{\text{xy4}} * 100\% \quad (2)$$

Data were gathered during the study in the form of temperature, relative humidity, and rainfall data. Data analysis of climatic factors related to the disease intensity were tested by correlation at 2 research locations. Unfortunately, at this time, there was no Meterological Station in West Kutai so climate data was obtained from the Samarinda Meteorological Station.

Afterwards, the data was interpreted with the correlation coefficient as shown in Table 3.

In this study, rubber plants observed were given a score depending on the plant condition, and healthy (no symptoms) rubber plants were given 0 score as they were not affected by any disease. However, if plants were infected but still look healthy or refer to “Mildly infected” was given 1 score, while “Severely infected” which was indicated by a lot of stems infected was given 2 score. Moderately infected or more plants were infected and lot of stems infected was given 3 score. Meanwhile, Dead rubber plant or no signs of life was given 4.

After obtaining the AI value, the degree of damage to each plant was evaluated to ascertain the severity of the pathogen attack in the research region. Table 2 showed the criteria for evaluating the condition of plants damaged by assault intensity:

Table 2. Criteria for determining plant conditions due to pathogen based attack intensity

Intensity of attack (%)	Plant condition
0.0 to 10.0	Healthy
11.0 to 25.0	Minor damage
25.1 to 50.0	Moderately damaged
50.1 to 75.0	Heavy damage
75.1 to 100	Very heavy damaged

Table 3. Provide an interpretation of the correlation coefficient

Coefficient interval	Level of relationship
0.00 to 0.19	Very weak
0.20 to 0.39	Weak
0.40 to 0.59	Moderate
0.60 to 0.79	Strong
0.80 to 1.00	Very strong

3. Result and Discussion

Based on the results of the research, the inventory data for the attack of infected plants was tabulated as shown in Table 4 below.

Table 4. Result of inventarization pathogen infection and symptoms score, and signs at the researched plot of rubber plants 2015, 2016, 2017, 2018

Number of the trees observed	Location 1 Number of the sick trees				Location 2 Number of the sick trees				Location 1 Score of the sick trees				Location 2 Score of the sick trees			
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
1 to 50	11 15	11 15	11 15	11 15	3	3	3	3	1 2	2 3	3 3	3 3	2 2	2 3	3 3	3 3
51 to100	91	91	91	91	23	23	23	23	1	2	2	3	2 2	2 3	3 3	3 3
101 to 150					131 132	131 132	131 132	131 132					2 2	2 2	3 3	3 3
151 to 200												-				
201 to 250	210	210	210	210	233 243	233 243	233 243	233 243	1	2	2	3	2 2	2 2	3 3	3 3
251 to 300					300	300	300	300					2	3	3	3
301 to 350	317 319	317 319	317 319	317 319	301 -	301 -	301 -	301 -	1 1	2 2	3 3	3 3	2	2	3	3
400 to 450				-	430	430	430	430					2	3	3	3
451 to 500				-	432	432	432	432					2	2	3	3
Total plants affected									6	6	6	6	12	12	12	12

From the research results listed in Table 4, the researcher could calculate the attack frequency (AF) and attack intensity (AI) of *Corticium* sp. on the rubber plant as follows:

3.1. Frequency of Attack (AF)

According to field observations, 6 plants were infected with Upas Fungus out of the 500 observed plants at location 1, and 12 were attacked out of 500 at location 2. The research results were listed in Table 5.

Table 5. Frequency of attack at two location 2015, 2016, 2017, 2018

Location 1	Frequency of attack (AF)
2015	1.20 % of plants affected by disease
2016	1.20 % of plants affected by disease
2017	1.20 % of plants affected by disease
2018	1.20 % of plants affected by disease
Location 2	
2015	2.40 % of plants affected by disease
2016	2.40 % of plants affected by disease
2017	2.40 % of plants affected by disease
2018	2.40 % of plants affected by disease

Note: Example

$$\text{AF at location 1 (2018)} = \frac{\text{6 plants attacked}}{\text{500 plants}} * 100\% = 1.20\ \% \text{ of plants affected by disease} \quad (3)$$

$$\text{AF at location 2 (2018)} = \frac{\text{12 plants attacked}}{\text{500 plants}} * 100\% = 2.40\ \% \text{ of plants affected by disease} \quad (4)$$

Base on the result which can be seen from Table 4, that the frequency of attacks at location 1 was less than at location 2. Microclimatic conditions may promote activity and make fungal infections easier. It further explains that the number of potential hosts, pathogen dispersal, and microclimate differences at the research site were the factors responsible for the difference in attack rates. The microclimate structure was closely related to the stand structure, which was determined by plant phenotype, tree density, leaf surface development, leaf shape, etc. High humidity and rainfall spur the breeding of fungal spores [14].

A pathogenic fungus infects a plant when its spores land on the leaves or stem of a vulnerable host and germinate, each spore creating a germ tube. The tube grows on the host's surface until it encounters an opening; then it enters the host, sprouting branches among the host's cells and forming a mycelial network within the invaded tissue.

Certain fungi created special pressing structures called appressoria, from which a microscopic, needlelike peg presses against and punctures the host's epidermis; upon penetration, a mycelium develops normally. Numerous parasitic fungi obtain nourishment from host cells through hyphal walls that were pushed against the host's interior tissue cell walls. Others created haustoria (specialized absorption structures) that branch off from the intercellular hyphae and enter the cells [15].

The total rainfall was 3 466 mm, the average temperature ranged from 24 ºC to 26 ºC and the dry season was the same, with the relative humidity always high at night (> 95%), with many hours of leaf per night throughout the year, the phenological pattern of young rubber trees following pruning [3], [16].

Without one of the following three fundamental circumstances, infectious illness cannot develop: (i) an appropriate habitat, with the most crucial environmental parameters being the amount and frequency of rainfall or heavy dews, relative humidity, and air and soil temperatures; (ii) the presence of a virulent pathogen; and (iii) a susceptible host [17].

In this case, humidity and temperature were two more ecological variables that influence fungus dispersion. Perhaps the majority of the fungi were mesophilic, with an optimal development temperature of 20 ºC to 30 ºC. Thermophilic species were able to grow at 50 ºC or higher but were unable to produce below 30 ºC. Although the optimum temperature for the growth of most fungi lies at or above 20 ºC, many species could grow close to or below 0 ºC. The so-called snow moulds and the fungi that cause the spoilage of refrigerated foods were examples. Temperature relationships influence the distribution of various species. Other specific effects of temperature were also important factors in determining the habitats of fungi. Many coprophilous (dung-inhabiting) fungi, such as *Pilobolus*, although able to grow at a temperature of 20 ºC to 30 ºC, require a short period at 60 ºC for their spores to germinate [18], [19].

Throughout the late 1970s, worldwide, including northeast India, Vietnam's highlands and coastal parts, southern China, and Brazil's southern plateau, all these places, however, are subject to varying degrees of climate limitations. While they met the majority of the basic growth criteria for rubber production, they also have harsh conditions such as low temperatures and prolonged periods of drought. With the damage and reduced development rate caused by the freezing temperatures, latex production was suspended in these places for around 1–3 months every year [19].

H. brasiliensis grows and produces rubber optimally in hot, humid climates similar to those found in its home location, but it is also frequently cultivated in drier and colder climates worldwide [20], [21]. Governmental checks and regulations were also needed; dealers often sell fake seed varieties that discourage the production and use of original seeds and technological development. However, this PB260 was susceptible to fungal attacks, resulting in leaf-fall caused by *Corynespora cassiicola* sp. [22], [23].

3.2. Attack Intensity (AI)

Calculations based on observations of plant symptoms that appear as scores are reported in Tables 6,7 and 8. Using the score calculation data, the attack intensity can be determined as follows:

Table 6. Plant condition at location 1

The number of plant populations affected	Plant condition	Score
494	Healthy (no symptoms)	0
0	Mildly infected (plants that are infected but still look healthy)	1
0	Severely infected (the number of stems infected are a lot)	2
6	Moderately infected (plants are infected and the number of stems infected are a lot more)	3
0	Dead (all plants damaged or no signs of life)	4

According to the data on rubber plant condition in location 1 above, it can be seen that there were 494 healthy (no symptoms) rubber plants as they are not affected by any disease. Meanwhile, there were 6 Moderately infected rubber plants, and no Mildly infected" or "Severely infected" and Dead rubber plant recorded.

Table 7. Plant condition at location 2

The number of plant populations affected	Plant condition	Score
488	Healthy (no symptoms)	0
0	Mildly infected (plants that are infected but still look healthy)	1
0	Severely infected (the number of stems infected are a lot)	2
12	Moderately infected (plants are infected and the number of stems infected are a lot more)	3
0	Dead (all plants damaged or no signs of life)	4

Based on the data on location 2 above, it can be seen that there were 484 healthy (no symptoms) rubber plants as they are not affected by any disease. Meanwhile, there were 12 Moderately infected rubber plants. Likewise, as location 1, there was no Mildly infected" or "Severely infected" and Dead rubber plant in location 2.

Table 8. Attack intensity (AI) at two location 2015, 2016, 2017, 2018

Location Month	Attack Intensity (%)				Criteria plant condition
1	*2015*	*2016*	*2017*	*2018*	
January	0.50	0.65	0.70	1.80	Healthy
February	0.50	0.65	0.70	1.80	Healthy
March	0.50	0.65	0.70	1.80	Healthy
April	0.50	0.65	0.70	1.80	Healthy
May	0.50	0.65	0.70	1.80	Healthy
June	0.50	0.65	0.70	1.80	Healthy
July	0.50	0.65	0.70	1.80	Healthy
August	0.50	0.65	0.70	1.80	Healthy
September	0.50	0.65	0.70	1.80	Healthy
October	0.50	0.65	0.70	1.80	Healthy
November	0.51	0.66	0.72	1.81	Healthy
December	0.52	0.67	0.74	1.81	Healthy
2	*2015*	*2016*	*2017*	*2018*	
January	1.20	1.40	1.80	1.80	Healthy
February	1.20	1.40	1.80	1.80	Healthy
March	1.20	1.40	1.80	1.80	Healthy
April	1.20	1.40	1.80	1.80	Healthy
May	1.20	1.40	1.80	1.80	Healthy
June	1.20	1.40	1.80	1.80	Healthy
July	1.20	1.40	1.80	1.80	Healthy
August	1.20	1.40	1.80	1.80	Healthy
September	1.20	1.40	1.80	1.80	Healthy
October	1.20	1.40	1.80	1.80	Healthy
November	1.21	1.41	1.82	1.81	Healthy
December	1.22	1.43	1.83	1.82	Healthy

Note: Example

Location 1.

$$\text{AI (2018)} = \frac{0*1 + 0*2 + 6*3 + 0*4}{500*4} * 100\% = \frac{0+0+18+0}{200} * 100\% = 0.90\ \% \quad (5)$$

Location 2.

$$\text{AI (2018)} = \frac{0*1 + 0*2 + 12*3 + 0*4}{500*4} * 100\% = \frac{0+0+36+0}{200} * 100\% = 1.80\ \% \quad (6)$$

Data for temperature, relative humidity and rainfall at the time of the study were presented in Table 9.

Table 9. Average temperature, relative humidity, rainfall in East Kalimantan (Samarinda Meteorological Station), 2015, 2016, 2017, 2018

Month		Temperature				Relative humidity				Rain fall			
		2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
		(°C)	(°C)	(°C)	(°C)	(%)	(%)	(%)	(%)	(mm)	(mm)	(mm)	(mm)
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	January	26.9	28.18	27.4	27.6	83	78.90	82.0	81	344.8	94.60	160.8	215.9
2	February	27	28.65	27.9	27.6	83	76.41	80.0	82	193	3.40	138.6	97.7
3	March	27.5	28.69	27.6	27.9	81	76.68	81.0	80	197.8	87.60	88.1	154.1
4	April	27	29.60	27.8	27.8	81	79.27	82.0	82	343.7	152.00	343.3	180.2
5	May	27.8	28.38	27.7	27.8	84	81.46	86.0	84	213.5	163.00	309.3	296.3
6	June	27.5	27.14	27.3	27.8	83	81.81	84.0	83	259.2	137.00	421.8	197.0
7	July	27.5	27.02	27.7	27.9	80	79,94	82.0	81	162.7	202.10	160.9	136.9
8	August	28	27.44	27.2	28.0	76	77.35	83.0	78	57.6	106.60	249.7	47.9
9	September	28.5	26.70	27.8	28.1	75	78.31	82.0	77	0	205.80	100.0	127.4
10	October	28.9	26.63	28.3	27.8	74	79.7	77.0	81	73.2	327.20	152.0	151.9
11	November	28.4	27,07	28.1	27.9	80	79.13	81.0	82	60.9	164.60	218.8	126.7
12	December	28.6	-	28.0	28.2	78	-	76.0	80	191.4	230.80	223.1	169.5
	Mean 2015	27.8				80				174.8			
	Mean 2016		27.7				78.98				156.22		
	Mean 2017			27.8				81,3				213.9	
	Mean 2018				24.2				81				158.5

Based on the results of the correlation test in Tables 9, 10, 11, 12 and 13, it can be seen that at locations 1 and 2, there was a positive correlation between the intensity of disease attacks and humidity. As the humidity increases, the intensity of the attack also increases. It can be said that water is needed by the fungi to transport nutrients and also for the diffusion of oxygen for their body cells, in which the structure of the fungi that plays a role in absorbing nutrients is the mycelium because fungi are aerobic. However, at too high a humidity (> 80%), the number of fungi can be reduced. The average relative humidity in 2015-2018 (79.98 to 81.3) was positively correlated with the intensity of disease attacks.

At location 1, the result of the correlation test between temperature and attack intensity reflects an inverse (negative) relationship that was not significant, which means if the temperature increases, the intensity decreases with a coefficient value of 0.721 and vice versa. The correlation between humidity and attack intensity is directly proportional (positive) and not significant, meaning that if the humidity increases, the intensity will increase with a coefficient value of 0.754 and vice versa.

The correlation between rainfall and intensity shows an inverse (negative) relationship that is not significant, which means if rainfall increases, the intensity decreases, with a coefficient value of 0.199 and vice versa. The coefficient value is seen in the coefficient table in the beta column. The significance value is seen in the coefficient table in the Sig column. The results are significant if the value of Sig is <0.05 and not significant if the Sig value is > 0.05.

At location 2, the result of the correlation test between temperature and intensity shows an inverse (negative) relationship that is not significant, which means if the temperature increases, the intensity decreases with a coefficient value of 0.666 and vice versa. Relative humidity and attack intensity have a directly proportional correlation (positive) which is not significant, meaning that if the humidity increases, the intensity will increase with a coefficient value of 0.764 and vice versa.

The correlation between rainfall and intensity has an inverse (negative) relationship that is not significant, which means if rainfall increases, the intensity decreases, with a coefficient value of 0.058 and vice versa.

Table 10. Result of statistical analysis of the correlation between attack intensity and weather at location 1 in 2015, 2016, 2017, 2018

Model summary[a]

Model	R	R Square	Adjusted R Square	Std.Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	183[a]	.033	-.033	.14687	.033	.506	3	44	.680	.086

a. Predictors: (Constant), Rain_Fall, Temperature, Relative Humidity

b. Dependent Variable: Intensity of attack location1

Table 11. Correlation coefficient Intensity of attack location 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.724	.163		4.432	.000
	Temperature	-.026	.023	-.721	-1.119	.269
	Relative_Humidity	.009	.008	.754	1.184	.243
	Rain Fall	.000	.000	-.199	-.994	.326

Dependent Variable: Intensity of attack location 1

$$Y = -0.721X1 + 0,754\ X2 - 0,199X3 \quad (7)$$

X1 = Temperature (°C)

X2 = Relative Humidity (%)

X3 = Rain Fall (mm)

Table 12. Result of statistical analysis of the correlation between attack intensity and weather at location 2 in 2015, 2016, 2017, 2018

Model summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.215[a]	.046	-.019	.26540	.046	.713	3	44	.550	.067

a. Predictors: (Constant), Rain_Fall, Temperature, Relative Humidity

b. Dependent Variable: Intensity of attack location 2

Table 13. Correlation coefficient Intensity of attack location 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.428	.295		4.837	.000
	Temperature	-.043	.042	-.666	-1.041	.304
	Relative Humidity	.017	.014	.764	1.209	.233
	Rain Fall	.000	.001	-.058	-.293	.771

a. Dependent Variable: Intensity of attack location 2

$$Y = -0.666X1 + 0,764X2 - 0,058X3 \quad (8)$$

X1 = Temperature (°C)

X2 = Relative Humidity (%)

X3 = Rain Fall (mm)

Climate change affects the life cycle of pathogens-their virulence (infectiousness), transmission, and reproduction, and the level of the genome, cellular, plant physiological processes, and pathogens. Each stage of the pathogen's life cycle was affected by temperature, from the budding of the spores to the entry of the parent into new sporulation and transfer of spores.

The development of the disease can start from inoculation, penetration, infection, and invasion, namely the development of pathogens in the host plant tissue. In the case of diseases caused by fungi, the effect of humidity occurs on the germination of spores, which require a water film on the tissue to germinate. In addition, it also affects the release of spores from the sporophores, whose spores can only be released when conditions are moist.

The main variable of Indonesia's climate was not temperature or air pressure, but rainfall. The area's relative humidity ranges between 70 % and 90 %. East Kalimantan has a fairly high rainfall value with high humidity and a temperature conducive to the growth of fungi. At locations 1 and 2, between 2015 and 2018, the average temperature was 24.2 ºC to 27.8 ºC, relative humidity 78.98 % to 81.3 %, and rainfall 156.22 mm to 213.9 mm.

The severity of the Upas Fungus disease attack in two spots on the 4-year-old rubber plant indicates that the plant's general health was still intact. The infected stems of the Upas Fungus are identified by an eruption of the tree, which eventually dies. As the plant matures and gets stunted, the bark grows thinner and the tree expels black sap, eventually ceasing to produce latex entirely. The rubber tree is a tropical crop that can grow well in regions having rainfall between 1 500 mm to 3 000 mm per year, with even distribution.

According to Kennelly et al. [12], plant-nutrient-pathogen interactions are complicated and poorly understood. Although nutrition was frequently overlooked, it has always been a critical component in illness prevention. The majority of the soils and settings where plants were cultivated were infested with disease pathogens. At the most fundamental level, nutritionally stressed plants will be less robust and more prone to disease. Even so, all nutrients have an effect on plant disease in this way, some have a greater direct and indirect effect than others.

Disease resistance in plants was primarily a function of genetics. However, the ability of a plant to express its genetic potential for disease resistance can be affected by mineral nutrition. Plant species or varieties with high genetic resistance to disease are likely to be less affected by changes in nutrition than plants only tolerant of conditions, on Eucalyptus clonal plantations in Andhra Pradesh, Kerala, and Tamil Nadu (South India). Eucalyptus was studied relative to the attack of the disease pathogen pink [24].

It infects areal parts of various crop species as *Coffea* spp., *Camellia sinensis* (L.) Kuntze., *Diospyros kaki* Thunb., *Pipper nigrum* L., *Theobroma cacao* L., *Citrus* spp., *Zingiber officinale* Roscoe, Trans. Linn. Soc., *Mangifera indica* L. and *Hevea brasiliensis* Muell. Arg [25].

The pink disease can attack saplings and mature trees. Using too many chemical fungicides can lead to land degradation and insecticide resistance of insects. To cope with this problem, controlling disease by biological methods is attracting more attention, and some studies have recently been done [7]. Endophytes were considered to be one of the most important target organisms isolated and screened for the bioproducts used to prevent fungal diseases [26].

The application of nanoparticles has anti-fungal solid activity against various plant pathogens such as Phytophthora and C. *salmonicolor*. However, antimicrobial studies of copper nanoparticles have received more attention recently because they are much less expensive than silver or gold nanoparticles. This advantage could offer antifungal applications of copper nanoparticles in agriculture [27], [28].

In addition, what has been explained is that disease attacks also turn out to affect the production of latex produced. As shown in Table 14 below, we can see Latex Production that the production at location 1 is higher than at location 2. The results of the calculations are presented in Table 14 below.

Table 14. Average result of rubber production at two location, 2018

Production (kg ha^{-1} mo^{-1})	
Location 1	Location 2
mo 1 = 530	mo 1 = 390
mo 2 = 520	mo 2 = 410
mo 3 = 540	mo 3 = 400
mo 4 = 530	mo 4 = 400
Average = 530	*Average = 400*

Latex production at location 1 rather than location 2 was due to farmers at location 1 have been intensively providing NPK fertilization and weed eradication since the beginning of planting/nursing. As is known, Nitrogen is a basic part of plants as a fundamental unit of proteins, nucleic acids, and chlorophyll, which makes leaves green. Phosphorus (P) is the key to plant life. P is an essential nutrient for plants with a function of transfer of energy to the gene aspect, which cannot be replaced by other nutrients. And Potassium (K) is an essential element used in almost all processes to support plant life. It is the third major nutrient after N and P. In general, potassium acts as a catalyst in protein formation, neutralizes reactions in cells, especially from organic acids, regulates stomatal movement, and makes plants more resistant to pests and diseases.

According to Singha et al. [29] Phosphorus (P) was one of the macronutrients required for the growth and development of the plant. Generally, plants need phosphorus in 2 000 µg g-1 dry weight or 0.2 %.

Phosphorus is the component of nucleic acids, phospholipids, and adenosine triphosphate (ATP). However, phosphate ion was also absorbed by soil particles or fixed by other elements such as calcium (Ca), magnesium (Mg), aluminium (Al), and iron (Fe) [20], [30]. The rubber yield starts at 3 to 4 years of age and peaks at 10 years from planting. Interestingly, the decline of the tree growth rate was steeper than that of the rubber yield rate. The sink strength of growth could be greater than the rubber production during the tree's young phase, a pattern that would reverse during its mature phase. This trend is caused by rubber tapping, which stimulates the tree to produce more rubber. As a result, the biomass allocated to rubber consistently increases from 5 % at three years of age to 40 % at 20 years [20], [31].

Because most of the rubber plantations were located in high rainfall areas, water is frequently not considered a limiting factor [15]. To understand how best to control plant diseases to improve food security in the context of climate change, plant protection professionals must work with societal change, defining its key processes and influencers to effect change. Specifically, there was a key role to play in improving food security [32]. Plant pests and diseases could potentially deprive humanity of up to 82 % of the attainable yield in the case of cotton and over 50 % for other major crops will also be sufficient to enable the crop to maximize disease resistance. However, there were cases where higher-than-needed nutrient applications for optimum growth can improve disease resistance [18].

A correct understanding of the trade-offs and synergies between ecosystem services was great significance for improving the overall benefits of the latter and achieving a "win-win" situation for regional development and ecological protection [33], [34]. Host disease resistance was one of the most sustainable approaches to plant disease management, and the coordination of structured plant breeding networks when propagating resistance genes may reduce the likelihood of pathogens overcoming resistance [35]. As is the case that occurs in India that the tea plant the penetration of a fungus like *Cortiicium theae* Bernard into initiates subcuticular intramural colonization and causes rapid spread throughout the tissue with inter- and intracellular hyphae that kill cells and tissues of plants' leaves and branches [29].

Solar radiation, rainfall, and temperature, in general, have a rather dominant role in growth and production, while air humidity has a direct effect on several types of plants, but is indirectly closely related to the development of plant pests and diseases. A too high air humidity throughout the year was a potential condition for the emergence of pests and plant diseases, especially humidity conditions around plants. Branches that were attacked may die or break easily. Rubber biosynthesis is a well-characterized isoprenoid metabolic process in laticifer cells; however, little is known about the positive feedback regulation induced by latex loss caused by tapping [36]. The theory of complex adaptive systems aims to develop a policy framework for plant breeding networks for the spread of these resistance genes to adapt to global changes in climate and land use [32], the emergence of new diseases, and breeding technologies [36], [37].

The economical management strategies play a vital role in efficient disease management in rubber plantations. To develop a tool to integrated disease management approach, different bio-agents, plant extracts, and fungicides were tested [38], [39]. On the other hand, the inoculation research of *Enterobacter* sp. and arbuscular mycorrhizal fungi with silicon have the potential to suppress *Rigidoporus microporous* (Sw.) Overeem fungi that cause white root rot and increase the growth of rubber seedlings under greenhouse conditions and co-inoculation with silicon also significantly increased the silicon content of the roots and shoots and the nutritional content of the leaves (N, P, and K) [40], [41].

4. Conclusions

This study's findings indicate that the inventory result for Upas Fungus pathogen assault is 1.20 % at location 1 and 2.40 % at location 2, while the attack intensity (AI) is 0.90 % at location 1 and 1.80 % at location 2. The result of the correlation test between temperature and attack intensity reflects an inverse (negative) relationship, with a coefficient value of 0.721. Between humidity and intensity, there is a directly proportional (positive) correlation with a coefficient value of 0.754 and vice versa. Rainfall and intensity have an inverse (negative) relationship that is not significant with a coefficient value of 0.199 and vice versa. Latex output is 530 kg ha^{-1} mo^{-1} at location 1, and 400 kg ha^{-1} mo^{-1} at location 2. Current plant disease control strategies include, first and foremost, non-chemical treatments that are mostly preventative and primarily cultural, such as the adoption of disease-resistant plants.

Novelty Statement

There has been no data on the frequency and intensity of Upas fungus infection on rubber plants in West Kutai (East Kalimantan), Indonesia; thus, this research can be used as a basis for controlling rubber plant diseases right from the planting step, by using resistant varieties, fertilizer application, fungicides usage, and weed control.

Author Contribution

HS: Conceptualized and designed the study, elaborated the intellectual content, performed literature search, data acquisition, data analysis, manuscript preparation, and manuscript revision.

ASR, AS, NH and MTT: carried out experimental studies and manuscript review, elaborated the intellectual content, performed literature search, and manuscript review.

All the authors have read and approved the final manuscript.

Conflict of Interest

The authors have no conflict of interest.

REFERENCES

[1] FEO, "Root Zone Microflora is Responsible for Suppressiveness of the White Root Rot Disease in Akwete Rubber Plantations," *J. Plant Pathol. Microbiol.*, vol. 03, no. 07, 2012, doi: 10.4172/2157-7471.1000151.

[2] P. Venkatachalam, N. Geetha, P. Sangeetha, and A. Thulaseedharan, "Natural rubber producing plants: An overview," *African J. Biotechnol.*, vol. 12, no. 12, 2013, [Online]. Available: https://www.ajol.info/index.php/ajb/article/view/128414

[3] J. Guyot and V. Le Guen, "A review of a century of studies on South American leaf blight of the rubber tree," *Plant Disease*, vol. 102, no. 6. 2018. doi: 10.1094/PDIS-04-17-0592-FE.

[4] Z. Zou *et al.*, "Genome-wide identification of rubber tree (Hevea brasiliensis Muell. Arg.) aquaporin genes and their response to ethephon stimulation in the laticifer, a rubber-producing tissue," *BMC Genomics*, vol. 16, no. 1, 2015, doi: 10.1186/s12864-015-2152-6.

[5] Ramadiani, M. Syahrir Ramadhani, M. L. Jundillah, and Azainil, "Rubber plant disease diagnostic system using technique for order preference by similarity to ideal solution," in *Procedia Computer Science*, 2019, vol. 161. doi: 10.1016/j.procs.2019.11.148.

[6] S. Leontopoulos, K. Petrotos, C. Papaioannou, and I. Vasilakoglou, "Effectiveness of Olive Fruit Polyphenol Extract Combined with Aqueous Extracts of Solid Wastes of Pomegranate or/and Orange Juice Against Important Plant Pathogens—Part 2 (in vivo studies)," *Universal Journal of Agricultural Research*, vol. 9, pp. 23–38, 2021, doi: https://doi.org/10.13189/ujar.2021.090201.

[7] N. Chaendaekattu and K. Mydin, "Sustainability of yield during summer stress among certain hybrids of drought tolerant clones of Hevea brasiliensis," 2014.

[8] J. Kumar, S. Watpade, K. K. Pramanick, A. K. Shukla, and M. M. Singh, "Status of smoky blight (Botryosphaeria obtusa), pink (Corticium salmonicolor) and nail head (Nummularia discreta) canker diseases of apple (Malus domestica) in Himachal Pradesh," *Indian Phytopathol.*, vol. 69, no. 4s, pp. 225–229, 2016, [Online]. Available: https://epubs.icar.org.in/index.php/IPPJ/article/view/71289

[9] T. H. Sam *et al.*, "A Review of Climate Change Impacts on Agribusiness Value Chain in Nigeria," 2021, *Universal Journal of Agricultural Research*, doi: https://doi.org/10.13189/ujar.2021.090403.

[10] M. Kennelly, J. O'Mara, C. Rivard, G. L. Miller, and D. Smith, "Introduction to Abiotic Disorders in Plants," *Plant Heal. Instr.*, 2012, doi: 10.1094/phi-i-2012-10-29-01.

[11] L. Sujandi, "Penyakit karet lengkap dan pengendaliannya," *Kompasiana.com*, 2015. [Online]. Available: https://www.kompasiana.com/logi/54f6ea4aa3331119158b476d/penyakit-karet-lengkap-dan-pengendaliannya

[12] S. Rahayu, "Perubahan iklim global dan perkembangan hama penyakit hutan di indonesia, tantangan, dan antisipasi ke depan," *J. Ilmu Kehutan.*, vol. 10, no. 1, pp. 1–3, 2016, [Online]. Available: https://jurnal.ugm.ac.id/jikfkt/article/view/12729/0

[13] T. R. Febbiyanti, "Pengaruh Faktor Abiotik Terhadap Perkembangan Penyakit Karet dan Metode Peramalan Epidemi," *War. Perkaretan*, vol. 39, no. 2, pp. 95–114, 2020, doi: https://doi.org/10.22302/ppk.wp.v39i2.729.

[14] H. Syahfari, A. A. Bratawinata, M. Sutisna, and D. Mardji, "Physiological Process of Acacia mangium Willd. Plant of Six Months Old Attacked by Black Spots Disease in PT Itci Hutani Manunggal Terunen," *Int. J. Sci. Eng.*, vol. 5, no. 1, 2013, doi: 10.12777/ijse.5.1.15-18.

[15] T. Wijaya, "Monitoring and climatic data use for rubber plantation management," in *IOP Conference Series: Earth and Environmental Science*, 2019, vol. 399, no. 1. doi: 10.1088/1755-1315/399/1/012079.

[16] J. Guyot, V. Condina, F. Doaré, C. Cilas, and I. Sache, "Role of ascospores and conidia in the initiation and spread of South American leaf blight in a rubber tree plantation," *Plant Pathol.*, vol. 63, no. 3, 2014, doi: 10.1111/ppa.12126.

[17] X. Cao, X. Xu, H. Che, J. S. West, and D. Luo, "Effects of temperature and leaf age on conidial germination and disease development of powdery mildew on rubber tree," *Plant Pathol.*, vol. 70, no. 2, 2021, doi: 10.1111/ppa.13281.

[18] S. Chakraborty and A. C. Newton, "Climate change, plant diseases and food security: An overview," *Plant Pathology*, vol. 60, no. 1. 2011. doi: 10.1111/j.1365-3059.2010.02411.x.

[19] Schwob, M. Ducher, and A. Coudret, "Effects of climatic factors on native arbuscular mycorrhizae and Meloidogyne exigua in a Brazilian rubber tree (Hevea brasiliensis) plantation," *Plant Pathol.*, vol. 48, no. 1, 1999, doi: 10.1046/j.1365-3059.1999.00300.x.

[20] K. Sone, N. Watanabe, M. Takase, T. Hosaka, and K. Gyokusen, "Carbon sequestration, tree biomass growth and rubber yield of PB260 clone of rubber tree (hevea brasiliensis) in north Sumatra," *J. Rubber Res.*, vol. 17, no. 2, 2014.

[21] L. M. Souza *et al.*, "QTL Mapping of Growth-Related Traits in a Full-Sib Family of Rubber Tree (Hevea brasiliensis) Evaluated in a Sub-Tropical Climate," *PLoS One*, vol. 8, no. 4, 2013, doi: 10.1371/journal.pone.0061238.

[22] F. Oktavia, "Identification and diversity analysis of cassiicolin-encoding gene of corynespora Cassiicola isolates from rubber tree in Indonesia," *Biodiversitas*, vol. 21, no. 8, 2020, doi: 10.13057/biodiv/d210811.

[23] W. P. K. Silva, B. J. Deverall, and B. R. Lyon, "Molecular,

physiological and pathological characterization of corynespora leaf spot fungi from rubber plantations in Sri Lanka," *Plant Pathol.*, vol. 47, no. 3, 1998, doi: 10.1046/j.1365-3059.1998.00245.x.

[24] V. Mohan and P. Manokaran, "Assessment of disease problems in different clonal plantations of Eucalyptus spp. in South India," *J Acad Ind Res*, vol. 1, pp. 514–524, 2013, [Online]. Available: http://www.jairjp.com/FEBRUARY 2013/01 MOHAN.pdf

[25] N. Dechassa, "Occurrence, Distribution, Biology and Management of Coffee Thread Blight (Corticium koleroga (Cke) Hoehnel): A Review," *J. Environ. Earth Sci.*, vol. 9, no. 2, pp. 1–6, 2019, doi: 10.7176/jees/9-2-01.

[26] N. Van Minh, M. H. Phuc, D. N. Linh, T. T. A. Ni, T. K. Duc, and N. A. Nghia, "Screening of endophytes from rubber trees (hevea brasiliensis) for biological control of Corticium salmonicolor," *Eng. Technol.*, vol. 8, no. 2, 2020, doi: 10.46223/hcmcoujs.tech.en.8.2.345.2018.

[27] D. van Phu *et al.*, "Synthesis and antimicrobial effects of colloidal silver nanoparticles in chitosan by γ-irradiation," *J. Exp. Nanosci.*, vol. 5, no. 2, 2010, doi: 10.1080/17458080903383324.

[28] P. Ponmurugan, K. Manjukarunambika, V. Elango, and B. M. Gnanamangai, "Antifungal activity of biosynthesised copper nanoparticles evaluated against red root-rot disease in tea plants," *J. Exp. Nanosci.*, vol. 11, no. 13, 2016, doi: 10.1080/17458080.2016.1184766.

[29] S. K. Singha, I. Ahmad, R. Uddin, and M. S. Islam, "Study on the Survival Condition of Black Rot (Corticium theae) Disease of Tea in Different Habitant," *Asian J. Res. Bot.*, pp. 68–75, 2020, [Online]. Available: https://journalajrib.com/index.php/AJRIB/article/view/301 26

[30] Promwee, M. Issarakraisila, W. Intana, C. Chamswarng, and P. Yenjit, "Phosphate Solubilization and Growth Promotion of Rubber Tree (Hevea brasiliensis Muell. Arg.) by Trichoderma Strains," *J. Agric. Sci.*, vol. 6, no. 9, 2014, doi: 10.5539/jas.v6n9p8.

[31] M. H. Sitepu and A. McKay, "Socio-technical analysis of natural rubber plantation in North Sumatera: Possibilities for sustaining supply," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 801, no. 1. doi: 10.1088/1757-899X/801/1/012114.

[32] X. Cao, X. Xu, H. Che, J. S. West, and D. Q. Luo, "Three colletotrichum species, including a new species, are associated to leaf anthracnose of rubber tree in hainan, China," *Plant Dis.*, vol. 103, no. 1, 2019, doi: 10.1094/PDIS-02-18-0374-RE.

[33] C. L. Washbourne, M. A. Goddard, G. Le Provost, D. A. C. Manning, and P. Manning, "Trade-offs and synergies in the ecosystem service demand of urban brownfield stakeholders," *Ecosyst. Serv.*, vol. 42, 2020, doi: 10.1016/j.ecoser.2020.101074.

[34] M. D. Staudinger *et al.*, "Biodiversity in a changing climate: A synthesis of current and projected trends in the US," *Frontiers in Ecology and the Environment*, vol. 11, no. 9. 2013. doi: 10.1890/120272.

[35] Y. J. Zhou, J. H. Li, C. R. Friedman, and H. F. Wang, "Variation of soil bacterial communities in a chronosequence of rubber tree (Hevea brasiliensis) plantations," *Front. Plant Sci.*, vol. 8, 2017, doi: 10.3389/fpls.2017.00849.

[36] X. Deng *et al.*, "Jasmonate signalling in the regulation of rubber biosynthesis in laticifer cells of rubber tree, Hevea brasiliensis," *J. Exp. Bot.*, vol. 69, no. 15, 2018, doi: 10.1093/jxb/ery169.

[37] P. S. Ojiambo, J. Yuen, F. Van Den Bosch, and L. V. Madden, "Epidemiology: Past, present, and future impacts on understanding disease dynamics and improving plant disease management — A summary of focus issue articles," *Phytopathology*, vol. 107, no. 10. 2017. doi: 10.1094/PHYTO-07-17-0248-FI.

[38] K. Raymaekers, L. Ponet, D. Holtappels, B. Berckmans, and B. P. A. Cammue, "Screening for novel biocontrol agents applicable in plant disease management – A review," *Biological Control*, vol. 144. 2020. doi: 10.1016/j.biocontrol.2020.104240.

[39] M. J. Manju *et al.*, "Evaluation of different fungi toxicants against Corynespora cassiicola causing Corynespora Leaf Fall (CLF) disease of rubber [Hevea brasiliensis Muell. Arg.,]," *Int. J. Curr. Microbiol. App. Sci*, vol. 8, no. 2, pp. 1640–1647, 2019, doi: https://doi.org/10.20546/ijcmas.2019.802.193.

[40] Shabbir *et al.*, "White root rot disease suppression in rubber plant with microbial co-inoculants and silicon addition," *Rhizosphere*, vol. 15, 2020, doi: 10.1016/j.rhisph.2020.100221.

[41] S. I. Khattak, M. S. Baloch, K. Naveed, and E. A. Khan, "Improving Farmers Income and Nitrogen Use Efficiency of Dry Land Wheat through Soil and Foliar Application of N-Fertilizer," *Sarhad J. Agric.*, vol. 33, no. 3, 2017, doi: 10.17582/journal.sja/2017/33.3.344.349.