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The authors would like to correct the error in the publication of the original article. The corrected detail is published with this erratum for your reading.

Gall Rust Disease Dynamics in *Falcataria falcata* L. Across Elevations in Agusan del Norte, Philippines

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ABSTRACT

Gall rust disease poses a significant threat to falcata (*Falcataria falcata* L.), particularly in different elevation ranges. This study aimed to assess the gall rust disease incidence and severity at low (0–200 masl), moderate (201–400 masl), and high (401–600 masl) elevations. Results showed a significant correlation between gall rust disease incidence and severity and elevation based on Spearman rho correlation analysis. Higher elevations were associated with increased gall rust disease incidence and severity. This suggests that environmental conditions specific to these elevations may aggravate gall rust development. Based on the findings, temperature and relative humidity, which vary with elevation, play a role in gall rust disease incidence. Conversely, light intensity significantly influences gall rust disease severity across elevation ranges. These findings signify the importance of elevation-related factors in disease management strategies in falcata plantations. By identifying the relationship between gall rust disease and elevation, this research provides insightful information that can be used to improve disease management strategies and create focused control measures. The results provide an in-depth understanding of gall rust disease dynamics and offer recommendations for reducing its impact.

1. Introduction

Falcata (*Falcataria falcata* L.) is a common multifunctional legume in Southeast Asia due to its ideal features for humid tropical farm forestry. Increased demand for wood-based products as a substitute for timber supply in the wood industries resulted in the adoption of fast-wood plantations (Rahayu et al. 2024), resulting in the recent depletion of tropical forest resources

(Cossalter and Pye-Smith 2003). In the Philippines, falcata species are among the most commonly cultivated tree species in high demand in local and international markets. Smallholder farmers mostly grow falcata, used by mini-sawmills and plywood processing companies (Paquit and Rojo 2018).

However, diseases related to falcata induce a decrease in timber yield. Timber yield quantity and quality depend on the state of tree health. The disease has caused severe damage to falcata from saplings to mature trees. Several plantations in Malaysia and Indonesia were infected by *U. tepperianum* (the former scientific name of *Uromycladium falcatarium*) (Palma et al. 2020). One of the common diseases of falcata in the Philippines is gall rust. The early symptoms of this air-borne fungal disease caused by *Uromycladium falcatarium* on infected trees are rigid, crooked, bending stems, branches or shoots and greenish to reddish necrotic lesions. The symptoms then developed into large, irregularly shaped, chocolate-brown galls that resembled broccoli or whips that appeared on the stem and branches (Ambrose et al. 2022).

We value and rely on forests for various resources that forest diseases can threaten (Martiansyah et al. 2022). As a result, it is critical to monitor forest health. Proper forest management, early detection, and protective measures can prevent or reduce the effects of disease problems, while more intensive management and control options are available when required. Effective disease monitoring in tree species is essential for the long-term sustainability of plantations, as it enables timely interventions against potential outbreaks (Dahlsjo 2023). Though the application of protection measures and disease management of plantations is not part of the study, the characterization of sites is important because this will provide an in-depth understanding of the forest's health status. Thus, it is wise to know the prevalence and extent of damage caused by a disease to develop effective management strategies for the future. Disease is measured in terms of incidence and severity. Disease incidence generally concerns the number or proportion of diseased plants in a host population, while disease severity concerns the area or proportion of symptomatic plant tissue (Campbell and Neher 1994). In addition, disease severity is defined as the area or volume of plant tissue that is (visibly) diseased, usually relative to the total plant tissue (Madden et al. 1999).

This study aimed to determine several matters: (i) the status of incidence and severity of diseases at different elevation ranges (low, moderate, and high elevation), as previous studies have suggested that elevation can significantly influence gall rust disease (Tulod et al. 2024; Palma et al. 2020); (ii) the relationship between different elevation ranges with disease incidence and disease severity; (iii) the climatic factors and local site conditions in each elevation range; and (iv) the relationship of climatic factors and local site conditions with incidence and severity of gall rust disease. There are still no previous studies on the incidence and severity of falcata gall rust at different elevation ranges in Agusan del Norte province. Thus, this study will serve as baseline information regarding the status of disease incidence and disease severity of falcata gall rust.

2. Materials and Methods

2.1. Gall Rust Disease Incidence and Disease Severity

The incidence and severity of falcata (*Falcataria falcata* L.) gall rust were assessed in three sampling sites in Agusan del Norte for six (6) months. The sites were Brgy. Anticala, Brgy. Pianing and Brgy.Del Pilar, Agusan del Norte. Stratified sampling was followed based on elevation range.

Three plots per elevation range (0–200 masl, 201–400 masl, and 401–600 masl) representing low, moderate, and high elevation were sampled, measuring 20m × 20m per lot in three study sites, totaling twenty-seven (27) sampling plots. Gall rust disease incidence and severity were assessed monthly for six (6) months.

2.1.1. Measurement of gall rust disease incidence in falcata [Falcataria falcata L.] plantation

Each falcata plantation was assessed for the presence of gall rust disease. Trees within the plot were closely evaluated. The incidence of gall rust disease was determined by counting the infected trees and dividing by the number of trees per plot. The incidence status was determined using the scale used by Palma et al. (2020) (**Table 1**). Falcata gall rust disease incidence was calculated using Equation 1.

$$DI = \frac{n}{N}\ 100\% \tag{1}$$

where DI is disease incidence for each tree in a plot, and N is the total number of trees.

Table 1. Rating scale for gall rust disease incidence per plot

Percent incidence	Incidence status
< 10	Rare
10 – < 25	Occasional
25 – < 50	Common
50 – < 75	Very Common
≥ 75	Widespread

Note: Adapted from Palma et al. (2020).

2.1.2. Measurement of gall rust disease severity in falcata plantation

The disease severity was measured by counting the number of infected parts of a plant. The severity of gall rust infection per tree was scored using the following rating scale used by Lacandula et al. (2017) (**Table 2**). The disease severity index was computed adopting Equation 2.

$$Severity\ index = \frac{sum\ of\ all\ the\ disease\ rating}{Total\ number\ of\ ratings \times max.\ Disease\ grade}\ x\ 10 \tag{2}$$

Table 2. Rating scale for gall rust disease severity per tree

Rating	Percentage of crown with galls	Qualitative rating
0	No symptoms	Healthy
1	≤ 10%	Lack
2	11–25%	Weak
3	26–60%	Average
4	> 60%	High

Note: Adapted from Lacandula et al. (2017).

2.2. Characterization of Study Sites

As one of the major factors in plant disease development, biophysical factors were characterized to build an in-depth understanding of their possible influence on the incidence and severity of gall rust disease in falcata plantations at different elevation ranges. These factors include the following: micro-climate data (wind speed, temperature, relative humidity, light intensity). A digital anemometer was used to determine the wind speed. A data logger was installed in each elevation range or stratum to determine the temperature and relative humidity. Hemispherical photographs were used at each plot to quantify the light intensity. The photographs were taken at the center of each plot using a camera on a phone installed with a fish-eye lens. The camera system was set up at 1.37 m above ground, with the lens positioned vertically and the top of the resulting image oriented to the north. The estimation of percent light transmission from the hemispherical photos was accomplished using the software package Gap Light Analyzer (GLA version 2) (Frazer et al. 1999) (**Fig. 1**). Hemispherical photographs were taken once a week to assess light intensity. Wind speed was also determined once a week by using an anemometer. A data logger in each elevation range was installed inside the plantation plot to determine the relative humidity and temperature for six months. Microclimate data were recorded at various times throughout the day.

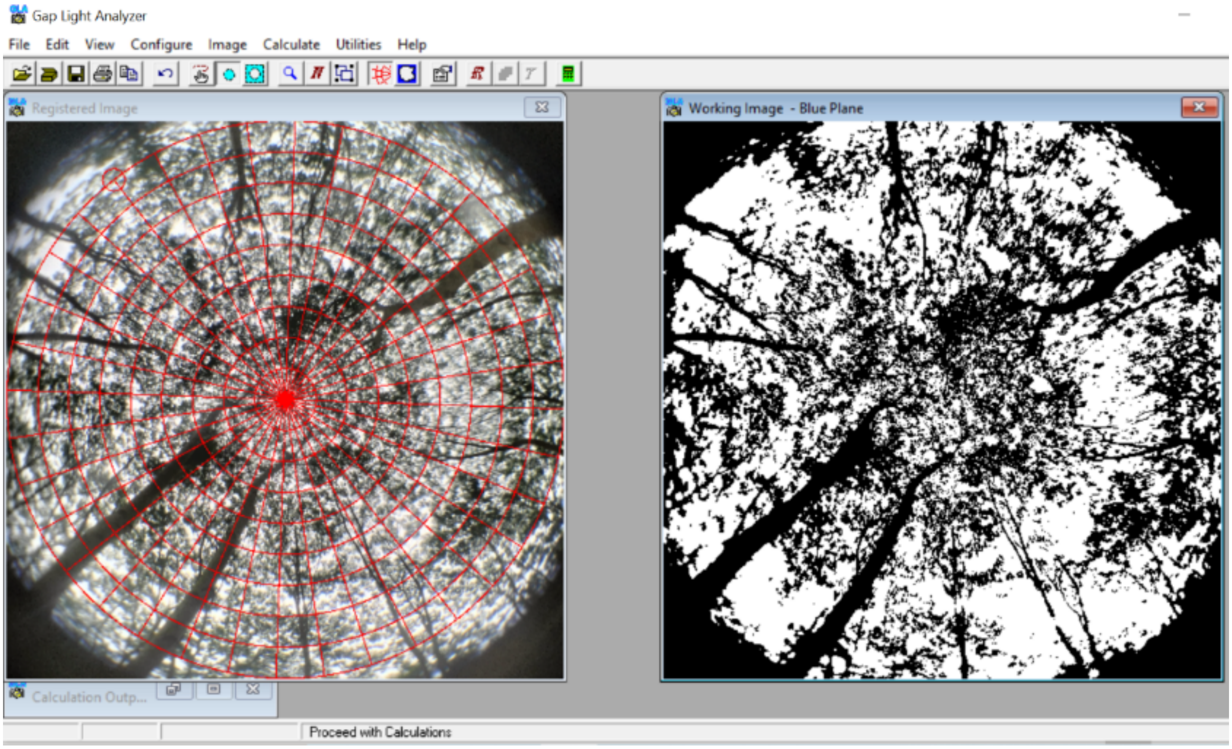

Fig. 1. Gap Light Analyzer software used to analyze hemispherical photographs.

2.3. Stand Density, Spacing, and Age of Trees in the Plantation

Stand density (number of trees) was obtained by counting the falcata trees per plot. Stand density values were used in the Gall Rust Disease Incidence (GRDI) and Gall Rust Disease Severity (GRDS) computations. Meter tape was used to measure the spacing between trees. Information about the age of the plantation was obtained by asking the plantation owners and acquiring information from DENR.

2.4. Data Analysis

The objective of the study aimed to determine if there is a significant influence of different elevation ranges, including climatic factors and local site conditions, on the status of incidence and severity of different diseases in falcata. Since the data was not normally distributed, the non-parametric equivalent of the Pearson r correlation, the Spearman rho correlation, was used to measure the degree of correlation between the variables. Additionally, the non-parametric equivalent of the Analysis of Variance (ANOVA), the Kruskal-Wallis test, was used to determine if there was a significant difference between the groups being studied using variance. Partial correlation was also used to determine the strength of the relationship between two variables while considering the impact of one or more other factors. These formulas applied are as follows:

Spearman Rho Coefficient formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \quad (3)$$

where di is the difference between the ranks of each pair of values, n is the number of data points.

Kruskal-Wallis Test Formula:

$$H = \frac{12}{N(N+1)}\sum_{i=1}^{k}\frac{R_i^2}{n_i} - 3(N+1) \quad (4)$$

where N is the total number of observations across all groups, k is the number of groups, Ri is the sum of ranks in group iii, ni is the number of observations in group iii.

Partial Correlation Formula:

$$r_{XY\cdot Z} = \frac{r_{XY} - r_{XZ}r_{YZ}}{\sqrt{(1-r_{XZ}^2)(1-r_{YZ}^2)}} \quad (5)$$

where rXY is the Pearson correlation between X and Y, rXZ is the Pearson correlation between X and Z, rYZ is the Pearson correlation between Y and Z.

3. Results and Discussion

3.1. Gall Rust Disease Incidence and Severity Status

3.1.1. Gall rust disease incidence status

Table 3 shows the average status of gall rust disease incidence in 3 sites at different elevations in Brgy. Anticala, Pianing, and Del Pilar, Agusan del Norte. The result showed widespread mean gall rust disease incidence in moderate and high elevations. Among the three elevation ranges, low elevation was the lowest regarding mean gall rust disease incidence status. Gall rust disease incidence status in low elevation was common. The mean gall rust disease incidence percentages in low, moderate, and high elevations were 42.95%, 90.75%, and 78.29%, respectively. In terms of site, Brgy. Pianing has the highest gall rust disease incidence (%) in low elevation, with a 70% average. While at moderate elevation, Brgy. Anticala has a 94.52% gall rust disease incidence. Brgy. Pianing also ranked highest in gall rust disease incidence, with a 90.95% average in high elevation. The widespread incidence of gall rust disease can be attributed to environmental conditions. High relative humidity creates the most favorable conditions for developing gall rust disease (Lestari et al. 2013). Based on the result of this study, relative humidity was found to be significantly correlated with gall rust disease incidence and severity. This suggests that the findings of this study align with those of Lestari et al. (2013), which also highlighted the influence of relative humidity on the development of gall rust disease. Gall rust disease is due to fungal pathogens (Orwa et al. 2009). Gall rust is caused by *Uromycladium falcatarium*, previously known as *Uromycladium tepperianum* (Doungsa-ard et al. 2015; Lelana et al. 2022). Gall rust is an airborne fungal disease that spreads through the dispersal of fungal spores (DOST-PCAARRD 2019).

Table 3. Average status of gall rust disease incidence in 3 sites at different elevation

Elevation (masl)	GRDI (%) at different sites			Average (%) GRDI	Rating scale
	Anticala	Pianing	Del Pilar		
Low (0–200 masl)	51.65	70.00	7.21	42.95	Common
Moderate (201–400 masl)	94.52	86.98	90.74	90.75	Widespread
High (401–600 masl)	78.87	90.95	65.04	78.29	Widespread

Note: GRDI means gall rust disease incidence.

3.1.2. Gall rust disease severity status

Table 4 shows the average severity of gall rust disease in 3 sites at different elevations in Brgy. Anticala, Pianing, and Del Pilar, Agusan del Norte. The result showed a high mean gall rust disease severity status in moderate elevation (63.53%). Both low and high elevations have average mean gall rust severity status. Although both low and high elevations have an average status, they differ significantly in severity percentage: 31.01% in low elevation and 58.18% in high elevation. Based on the results, higher percentages of gall rust disease severity were found in moderate and high elevation ranges. In terms of site, Brgy. Pianing has the highest gall rust disease severity in low elevation, with a 64.17% average. While at moderate elevation, Brgy. Anticala has the highest gall rust disease severity, with a 70.38% average. Birgy. Pianing also ranked highest regarding gall rust disease severity in high elevation, with a 68.80% average.

Table 4. Average status of gall rust disease severity in 3 sites at different elevation

Elevation (masl)	GRDS (%) at different sites			Average GRDS (%)	Rating scale
	Anticala	Pianing	Del Pilar		
Low (0–200 masl)	19.02	64.17	9.85	31.04	Average
Moderate (201–400 masl)	70.38	60.53	59.67	63.53	High
High (401–600 masl)	58.71	68.80	47.04	58.18	Average

Note: GRDS means gall rust disease severity.

Other than elevation, other factors are considered in disease development. Climatic factors and other local site conditions may influence the higher percentage of gall rust disease severity in moderate elevation compared to high elevation. The average relative humidity in moderate elevation was higher than in high elevation. Relative humidity (≥ 90%) was one of the dominant factors leading to gall rust disease spread in Malaysia (Rahayu et al. 2018). The average wind speed in moderate elevation was slower compared to high elevation. Based on the study of Rahayu et al. (2018), which evaluated the presence of pests and diseases in falcata trees grown in agroforestry systems, it was observed that the severity of gall rust disease decreased with higher wind speeds.

Closer spacing in trees was observed in moderate elevation compared to high elevation. In this study, the average spacing of trees was wider in high elevation compared to moderate elevation. Based on the study of Rahayu et al. (2018), wider spacing provided a more open canopy of trees, reducing the humidity, which is unsuitable for the formation of teliospores of the fungus to cause infection. While the average number of trees in high elevation was older than that in moderate elevation, it has been observed that gall rust disease causes damage throughout all developmental stages, from seedlings to mature trees (Rahayu et al. 2018). Regarding average temperature, 25.99°C and 24.27°C were moderate and high elevation averages, respectively. According to the study of Tulod et al. (2024), temperatures above 24°C, especially at elevations above 600 masl, significantly impact the severity of gall rust disease. However, in this study, moderate elevation (201–400 masl), with an average temperature of 25.99°C, had the highest percentage of gall rust disease severity.

Table 5 shows the relationship between elevation, gall rust disease incidence, and severity in falcata plantations. The result showed a significant difference between gall rust disease incidence and elevation. This means that as the elevation increases, gall rust disease incidence also increases. Gall rust disease severity also has a significant relationship with elevation. This implies that as the elevation increases, the severity of falcata gall rust disease also increases. Similar results were observed in previous studies where heavy gall rust infections increased as the elevation increased. According to the study of Lacandula et al. (2017), the healthy falcata trees decreased significantly at 400 m asl. Severe cases of gall rust were found from 400–600 masl. Similar results were observed by Palma et al. (2020), where the lowest percentage of gall rust incidence in Misamis Oriental was found in 152 masl. This was supported by the study of Lestari et al. (2013) in the community forest of falcata in Malaysia, where gall rust disease incidence decreased with lower elevation. Similarly, Anino (1991) observed that slight infections generally occur at lower elevations ranging from 1–250 masl, and heavy infections occur at elevations ranging from 275–500 m.

Table 5. Relationship between elevation and the incidence and severity of gall rust disease of falcata plantations

	Gall rust disease incidence (%)	Gall rust disease severity (%)
Elevation	0.473**	0.511**

Most previous studies only focused on gall rust disease incidence of falcata. Only a few studies included falcata gall rust disease severity as a disease measurement. The study by Lestari et al. (2013) examined gall rust symptoms in falcata trees aged two to five years in different agroforestry patterns within a community forest in Malaysia over five months. The findings indicated a low occurrence of gall rust, with disease severity of 15.74% for PA I, 10.29% for PA II, and 7.41% for PA III. The study also revealed that lower altitude was crucial in reducing the incidence and severity of gall rust disease as a local site condition.

Table 6 shows the microclimate data (relative humidity, temperature, light intensity, wind speed) that were assessed for six (6) months at three different elevation ranges. The spacing and age of trees were also determined.

Table 6. Climatic factors and local site conditions at different elevation ranges

Elevation	Relative humidity (%)	Temperature (°C)	Light intensity (%)	Wind speed (m/s)	Spacing (m)	Age (years)
Low	95.12	25.43	47.23	0.21	4.31	7
Moderate	97.48	25.99	43.3	0.19	4.52	7.67
High	93.52	24.27	41.5	0.23	4.92	8.33

Based on **Table 6**, different climatic factors and local site conditions were assessed at three (3) sites at different elevation ranges. The mean relative humidity in the low, moderate, and high elevation ranges was 95.12%, 97.48%, and 93.52%, respectively. The mean temperature at different elevation ranges was 25.43 degrees Celsius at low elevation, 25.99 degrees Celsius at moderate elevation, and 24.27 degrees Celsius at high elevation. Both relative humidity and temperature were recorded using the installed data logger at each plot. The mean light intensity in the low, moderate, and high elevation ranges was 47.23%, 43.30%, and 41.50%, respectively. Hemispherical photographs were taken per plot and processed in Gap Light Analyzer v. 2.0 (Frazer et al. 1999) to quantify the light intensity. The mean wind speed at different elevation ranges was 0.21 m/s in low elevation, 0.19 m/s in moderate elevation, and 0.23 m/s in high elevation. Wind speed was recorded using a digital anemometer. Both wind speed and light intensity were assessed once a week for six (6) months.

Along with the different climatic factors assessed over six months, local site conditions were also recorded. These local site conditions include spacing between trees and age. The mean spacing between trees at different elevation ranges was 4.31 m in low elevation, 4.52 m in moderate elevation, and 4.92 m in high elevation, respectively. The mean ages of trees at low, moderate, and high elevations were 7, 7.67, and 8.33 years old, respectively.

Table 7 shows the partial correlation between the variables gall rust disease incidence and climatic factors while controlling the age and spacing at different elevation ranges.

Table 7. Relationship between climatic factors and local site conditions with gall rust disease incidence

Control variable in different elevations			Temp.	RH	Light intensity	Wind speed
Age and spacing in low elevation	Gall rust disease incidence	Cor. coeff	−0.044	0.057	0.107	0.095
		Sig. (2-tailed)	0.561	0.452	0.156	0.207
Age and spacing in moderate elevation	Gall rust disease incidence	Cor. coeff	0.321	0.248	−0.011	0.061
		Sig. (2-tailed)	0.000	0.000	0.876	0.382
Age and spacing in high elevation	Gall rust disease incidence	Cor. coeff	0.043	0.287	−0.051	−0.040
		Sig. (2-tailed)	0.535	0.000	0.466	0.564

Notes: Cor. coeff = correlation coefficient, Temp. = temperature, RH = relative humidity, < 0.05 = significant (2-tailed), > 0.05= nonsignificant (2-tailed).

Based on **Table 7**, the climatic factors significantly related to gall rust disease are temperature and relative humidity at moderate elevations. In high elevations, the only climatic factor with a significant relationship with gall rust disease incidence was relative humidity, while all the climatic factors in low elevations have no significant relationship with gall rust disease incidence. The highest percentage of gall rust disease incidence was found in moderate and high elevations. Also, the results based on correlation coefficients showed a moderate positive correlation between gall rust disease incidence and temperature, while a weak positive correlation was observed between gall rust disease incidence and humidity when age and spacing were controlled. This means there was a moderate association between gall rust disease incidence and temperature. This means that as the temperature increased, the gall rust incidence also increased moderately. A weak association was observed between gall rust disease incidence and relative humidity. This means that the gall rust incidence also increased weakly as the relative humidity increased. In high elevation, the results based on the correlation coefficient showed a weak positive correlation between gall rust incidence and the relative humidity when the age and spacing were being controlled. This means there was a weak association between the gall rust disease incidence and relative humidity. This indicates that the gall rust incidence also increased weakly as the relative humidity increased.

The climatic factors significantly related to gall rust disease incidence were temperature and relative humidity. Various factors can influence the length of the disease cycle, one being temperature (Bowen 2003). Most fungi thrive within a temperature range of 5–35°C, with their optimal growth occurring between 25 and 30°C. It is worth noting that some fungi can even grow near or below 0°C, while others display tolerance to higher temperatures and can thrive above 40°C (Dix and Webster 1995). On the other hand, when relative humidity levels reach or exceed 90%, it becomes a prominent factor contributing to the spread of gall rust disease in Malaysia (Rahayu et al. 2018).

Table 8 shows the partial correlation of the gall rust disease severity and climatic factors while controlling the age and spacing at different elevation ranges. Based on the table, the result show that only light intensity significantly correlates with gall rust disease severity among all elevation ranges. Also, the results based on correlation coefficients in **Table 8** showed that there was a weak positive correlation between gall rust disease severity and light intensity when the age and spacing were controlled in low elevations. This means there was a weak association between gall rust disease severity and light intensity. This implied that as the light intensity increased, the severity of gall rust disease also increased weakly. Based on the findings of the study of Palma et al. (2020) in the agroforestry systems of Misamis Oriental, Philippines, falcata gall rust disease increases with tree age. Another study, however, has shown that this disease also infects young falcata trees, including the seedling and sapling stages. This suggests that gall rust may impact falcata at different stages of development (Rahayu et al. 2018).

Table 8. Relationship between climatic factors and local site conditions with gall rust disease severity

Control variable in different elevations			**Temp.**	**RH**	**Light intensity**	**Wind speed**
Age and spacing in low elevation	Gall rust disease severity	Cor. coeff	- 0.131	0.120	0.189	0.062
		Sig. (2-tailed)	0.082	0.110	0.011	0.413
Age and spacing in moderate elevation	Gall rust disease severity	Cor. coeff	0.082	0.066	- 0.314	0.009
		Sig. (2-tailed)	0.240	0.350	0.000	0.897
Age and spacing in high elevation	Gall rust disease severity	Cor. coeff	0.020	0.133	- 0.212	- 0.097
		Sig. (2-tailed)	0.769	0.053	0.002	0.162

Notes: Cor. coeff = correlation coefficient Temp. = temperature; RH = relative humidity; < 0.05 = significant (2-tailed); > 0.05= nonsignificant (2-tailed).

Also, based on the findings of the study of Palma et al. (2020), spacing is weak and negatively correlated with gall rust disease. As the spacing between trees increases, gall rust disease decreases, but weakly. In other words, closer spacing facilitates the spread of gall rust, while wider spacing may reduce its spread. However, the correlation is not strong enough.

A moderate negative correlation between gall rust disease severity and light intensity was observed in moderate elevation when age and spacing were controlled. This means that there was a moderate inverse association between gall rust disease severity and light intensity. This implied that as the light intensity increased, the gall rust disease severity decreased moderately, and vice versa. A weak negative correlation between gall rust disease severity and light intensity was found in high elevations when age and spacing were controlled. This means there was a weak inverse association between gall rust disease severity and light intensity. This implied that as the light intensity increased, the gall rust disease severity decreased weakly, and vice versa. Light intensity was the only climatic factor that has a significant relationship with gall rust disease severity among all elevation ranges in this study.

The gall rust disease severity in the low, moderate, and high elevation ranges was 31.01%, 63.53%, and 58.18%, respectively. In light intensity, low elevation was ranked as the highest with an average of 47.23%, followed by moderate elevation with 43.3% and 41.5% in high elevation with the lowest light intensity. According to Rahayu (2018) and Lestari et al. 2013, high light intensity creates an unfavorable condition for gall rust development. However, in this study, gall rust severity was highest (63.53%) in moderate elevation despite having a higher (43.3%) light intensity compared to a lower (41.5%) light intensity in the high elevation range. According to the study by Brian et al. 2021, several species of fungi thrive better in moderate-to-high-light settings (Starke 2020). This conclusion contradicts current studies on the topic, which indicate that fungi often grow best in low-light conditions (Idnurm 2005; Simon et al. 2013)

Research by Lestari et al. 2013 indicates that under high relative humidity (90% RH), the teliospores of *Uromycladium falcatarium* germinate to produce basidiospores on the host surface. Within 10 hours, the basidiospores form, and after another 6 hours, a penetration peg develops, allowing direct penetration through the epidermis. This explains the role of relative humidity in inducing spore germination and infection, which can influence the spread of gall rust disease. Based on the study of Talley et al. (2002), high relative humidity and several hours of free surface water are critical for both spore germination and successful infection.

4. Conclusions

According to the study's findings, the incidence and severity of gall rust disease were observed to be different based on the strata of elevation ranges. Compared to low elevation (0-200 masl) with the lowest incidence and severity, moderate elevation (201-400 masl) and high elevation (401-600 masl) exhibited higher levels of gall rust disease. The elevation was significantly positively correlated with the disease incidence and severity, with a more substantial impact at higher elevations. The effect of climatic factors, such as temperature and relative humidity, on disease incidence was significant, especially at moderate elevations. In contrast, relative humidity had a significant relation with the disease incidence at high elevations. The light intensity determined the influence of climatic variables on disease severity. A correlation between light intensity and disease severity was established at all elevational ranges, implying that lower light intensity in moderate and high elevations contributed to increased disease severity. The results indicated that low elevation (0-200 masl) is conducive to lower disease incidence and severity in falcata plantations, making it the ideal planting site. The result of the study can also be used for future research, such as creating mapping sites indicating low, moderate, or high percentages of incidence and severity of gall rust diseases, along with data on wind speed and direction.

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References

Ambrose, A., Liam, J., and Terhem, R. 2022. New and Emerging Disease Threats to Forest Plantations in Sarawak, Borneo, Malaysia. *IntechOpen*. London, UK. DOI: 10.5772/intechopen.107027

Anino, O. 1991. Gall Rust Incidence on *Falcataria moluccana* (Miq.) Barneby & J.W. Grimes at Various Elevations in Mindanao. *Philippine Journal of Forestry* 17(2): 55–67.

Bowen, K. L. 2003. *Plant Disease Epidemiology*. CRC Press. London, UK.

Brian A., Mariam A., Jennifer D., and Ellah M. 2021. Effect of Light Conditions on Abundance of Fungi Growth. *The Expedition* 10: 1–12.

Campbell, C. L., and Neher, D. A. 1994. *Estimating Disease Severity and Incidence*. In: Epidemiology and Management of Root Diseases. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-642-85063-9_5

Cossalter, C., and Pye-Smith, C. 2003. *Fast-Wood Forestry: Myths and Realities*. CIFOR, Bogor, Indonesia.

Dahlsjo, C. 2023. *Strategies to Manage Tree Pest and Disease Outbreaks: A Balancing Act. BMC Ecology and Evolution* 23(1). DOI: 10.1186/s12862-023-02184-0

Dix, N. J., and Webster, J. 1995. *Fungal Ecology and Biology*. Springer Dordrecht. Dordrecht.

DOST-PCAARRD. 2019. *DOST-PCAARRD Nods on Project to Document Gall Rust Disease in Falcata Trees in ComVal Province.* <https://pcaarrd.dost.gov.ph>(Oct. 31, 2024).

Doungsa-ard, C., McTaggart, A. R., Geering, A. D. W., and Others. 2015. *Uromycladium falcatarium* sp. nov., The Cause of Gall Rust on *Paraserianthes falcataria* in South-East Asia. *Australasian Plant Pathology* 44(1): 25–30.DOI: 10.1007/s13313-014-0301-z

Frazer, G. W., Canham, C. D., and Lertzman, K. P. 1999. *Gap Light Analyzer (GLA), Version 2.0: Imaging Software to Extract Canopy Structure and Gap Light Transmission Indices from True Colour Fisheye Photographs, User Manual and Program Documentation*. Simon Fraser University, Burnaby, British Columbia, and the Institute of Ecosystem Studies, Millbrook, New York.

Idnurm, A. 2005. Fungal Growth under Low-Light Conditions. *Fungal Biology Reviews* 19(3): 112–123. DOI: 10.1016/j.fbr.2005.01.004

Lacandula, J. M., Anunciado, A. V., and Raluto, W. G. 2017. Evaluation of Disease Severity of Gall Rust in *Falcataria moluccana* (Miq.) Barneby and J.W. Grimes in Bukidnon, Philippines. *The Philippine Journal of Science* 146(1): 53–64.

Lelana, M., Calibo, R.L., and Rellin, D.C. 2022. Fungi Associated with Falcata [*Falcataria moluccana* (Miq.) Barneby & J. W. Grimes] Gall Rust Disease in Mindanao, Philippines. *Forest Pathology* 52(4): e12767. DOI: 10.1111/efp.12767

Lestari, P., Rahayu, S., and Widiyatno. 2013. Dynamics of Gall Rust Disease on Sengon (*Falcataria moluccana*) in Various Agroforestry Patterns. *Procedia Environmental Sciences* 17: 300–307. DOI: 10.1016/j.proenv.2013.02.025

Madden, L. V., and Hughes, G. 1999. Sampling for Plant Disease Incidence. *Phytopathology* 89(11): 1088–1093. DOI: 10.1094/phyto.1999.89.11.1088

Martiansyah, I., Zulkarnaen, R. N., Hariri, M. R., Hutabarat, P. W. K., and Wardani, F. F. 2022. Tree Health Monitoring of Risky Trees in the Hotel Open Space: A Case Study in Rancamaya, Bogor. *Jurnal Sylva Lestari* 10(2): 180–201. DOI: 10.23960/jsl. v10i2.570

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., and Anthony, S. 2009. *Agroforestry Database: A Tree Reference and Selection Guide Version 4.0*. World Agroforestry Centre, Kenya.

Palma, R. A., Tiongco, L. E., Canencia, O. P., Boniao, R. D., Florida, E. J., and Dagonio, J. Y. 2020. Gall Rust Disease Incidence of Falcata (*Paraserianthes falcataria* (L.) Nielsen) in Falcata-Based Agroforestry Systems in Misamis Oriental, Philippines. *IOP Conference Series: Earth and Environmental Science* 449(1): 012035. DOI: 10.1088/1755-1315/449/1/012035

Paquit, J. C., and Rojo, M. J. A. 2018. Assessing Suitable Sites for Falcata *(Paraserianthes falcataria Nielsen*) Plantation in Bukidnon, Philippines using GIS. *International Journal of Biosciences* 12(2): 317–325. DOI: 10.12692/ijb/12.2.317-325

Rahayu, I., Khoerudin, R., Wahyuningtyas, I., Prihatini, E., and Ismail, R. 2024. Quality Evaluation of Fast-Growing Wood Impregnated with Nano-Silica Synthesized from Betung Bamboo Stems. *Jurnal Sylva Lestari* 12(3): 684–711. DOI: 10.23960/jsl.v12i3.926

Rahayu, S., See, L. S., Shukor, N. A. A., and Saleh, G. 2018. Environmental Factors Related to Gall Rust Disease Development on *Falcataria moluccana* (Miq.) Barneby & J. W. Grimes at Brumas estate, Tawau, Sabah, Malaysia. DOI: 10.15666/aeer/1606_74857499

Simon, R. R., Borzelleca, J. F., DeLuca, H. F., and Weaver, C. M. 2013. Safety Assessment of the Post-Harvest Treatment of Button Mushrooms (*Agaricus bisporus*) using Ultraviolet Light. *Food and Chemicals Toxicology* 56: 278–289. DOI: 10.1016/j.fct.2013.02.009

Starke, R., Capek, P., Morais, D., Callister, S. J., and Jehmlich, N. 2020. The Total Microbiome Functions in Bacteria and Fungi. *Journal of Proteomics* 213(20): 103623. DOI: /10.1016/j.jprot.2019.103623

Talley, S. M., Coley, P. D., and Kursar, T. A. 2002. The Effects of Weather on Fungal Abundance and Richness among 25 Communities in The Intermountain West. *BMC Ecology* 2(1): 1–11 DOI: 10.1186/1472-6785-2-7

Tulod, A. M., Casas, J. V., Rojo, M. J. A., Marin, R. A., Talisay, B. A. M., Bruno, E. N., and Gilbero, D. M. 2024. Strategies for Falcata (*Falcataria falcata* (L.) Greuter and R. Rankin) Farmers to Mitigate Gall Rust Severity Across Elevations. *Davao Research Journal* 15(3): 45–50. DOI: 10.59120/drj.v15i3.241