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Strategies for falcata (*Falcataria falcata* (L.) Greuter and R.Rankin) farmers to mitigate gall rust severity across elevations

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ABSTRACT

The extent of gall rust severity in Falcata plantations across various elevations and locations in the country is insufficiently documented, posing challenges for developing an integrated disease management strategy. This study aimed to assess the conditions favorable for gall rust severity in Falcata plantations at different elevations in Mindanao. Our survey revealed that gall rust severity is significantly higher at elevations exceeding 400 m above sea level (asl), with potential yield losses estimated between 23% and 52% of the total log volume per hectare. Factors contributing to increased severity, regardless of elevation, include low stand density (<1000 trees/ha), extended distances from natural vegetation (>1000 m), low understorey species diversity, and low average temperatures (<24°C). These factors interact significantly with elevation, as higher severity was observed in plantations with greater understorey vegetation diversity and elevated temperatures (>24°C), particularly at elevations over 600 m (asl). Based on our findings, it is recommended to avoid planting Falcata in areas with elevations exceeding 400 m (asl). However, if planting at higher elevations is unavoidable, adequate tree spacing (3 m x 3 m or 3 m x 4 m) should be maintained to achieve a moderate stand density (1000-1500 trees/ha). This practice can help regulate air circulation within the plantation, mitigate pathogen spread, and control understory vegetation growth and temperature impacts. Additionally, establishing and maintaining native vegetation or forest within 1000 m around Falcata plantations is advisable to create a protective buffer zone, thereby reducing gall rust severity.

Keywords: Falcata plantation, gall rust disease, plantation management, industrial tree plantation, Mindanao, Philippines

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INTRODUCTION

The need for an integrated pest and disease management (IPDM) program for industrial tree plantations (ITPs) in the country was identified in 2008 under the ITP Action Program of DOST-PCAARRD. However, this was not implemented due to the absence of comprehensive empirical data to understand the causes of pests and diseases occurrence or infestations in tree plantations. This concern has been raised repeatedly by farmers and sawmill operators in Mindanao especially the problem on gall rust disease infestation in Falcata (*Falcataria falcata* (L.) Greuter and R.Rankin) plantations.

Mindanao is a forerunner in industrial tree plantation development in the Philippines (Paler et al., 1998) but heavily relies on wood sourced from Falcata tree plantations to produce veneer, plywood, and lumber. Falcata is widely cultivated in monoculture and intercropping systems in the country, particularly in Mindanao, providing approximately 70% of the country's total log production (FMB-DENR, 2022). Despite being a fast-growing species, the country's output from Falcata's processed wood materials has not consistently met domestic demand, leading to the importation of wood products such as lumber from Malaysia and veneer and plywood from China (PCAARRD, 2010). The current log production rate in the country is approximately 797,192.27 m^3 or 0.0068 m^3 per capita, significantly lower than its annual average wood consumption of $6x10^6$ m^3 or approximately 0.051 m^3 per capita (FMB-DENR, 2022).

Gall rust disease infestation, caused by *Uromycladium falcatarium* Doungsa-ard, McTaggart and Shivas, is likely a contributing factor to the low production rate of Falcata plantations in the country. The susceptibility of Falcata to gall rust disease is particularly severe at higher elevations, as reported in Malaysia (Rahayu et al., 2018) and the Philippines (Lacandula et al., 2017), because of the foggy conditions and intermittent showers that occur at high altitudes that could induce high levels of spore production (Hoff, 1986; cited by Rahayu et al., 2018). Infected trees exhibit stunted growth and deformities, such as forking and excessive branching (Lacandula et al., 2017), which can negatively affect the quality and quantity of harvestable volume. Factors like high foggy conditions, relative humidity, and wind speed at higher elevations are highly significantly related to gall rust severity (Rahayu et al., 2018). However, current information on the extent of gall rust severity in Falcata plantations at larger spatial scale or across elevation ranges and locations in the country is limited, hindering the development of a comprehensive integrated disease management strategy. Apart from environmental factors, the contribution of management practices, soil conditions, surrounding vegetation, and other factors across elevation ranges on gall rust severity is still poorly understood.

Approaches and results

The severity of gall rust disease was assessed through surveys of Falcata plantations at different elevation ranges (i.e., 0-200 m, >200-400 m, >400-600 m, > 600-800 m, >800 m above sea level) across five regions in Mindanao (i.e., Regions 9, 10, 11, 12, and 13) (Figure 1). Within each region, 25 plantations were assessed using three (3) randomly established sampling plots in each plantation or a total of 125 plantations (equivalent to 375 sampling plots) for the five regions. The severity of gall rust per tree was scored using the rating scale appliedin similar studies (e.g., Lacandula et al., 2017; Tulod et al.). The variables that were measured at each plot include microclimate, soil physicochemical properties, topography, type of surrounding vegetation, distance to the road and to nearest native vegetation, management practices, age of the plantation, stand density, biomass density of understory vegetation, and insect diversity.

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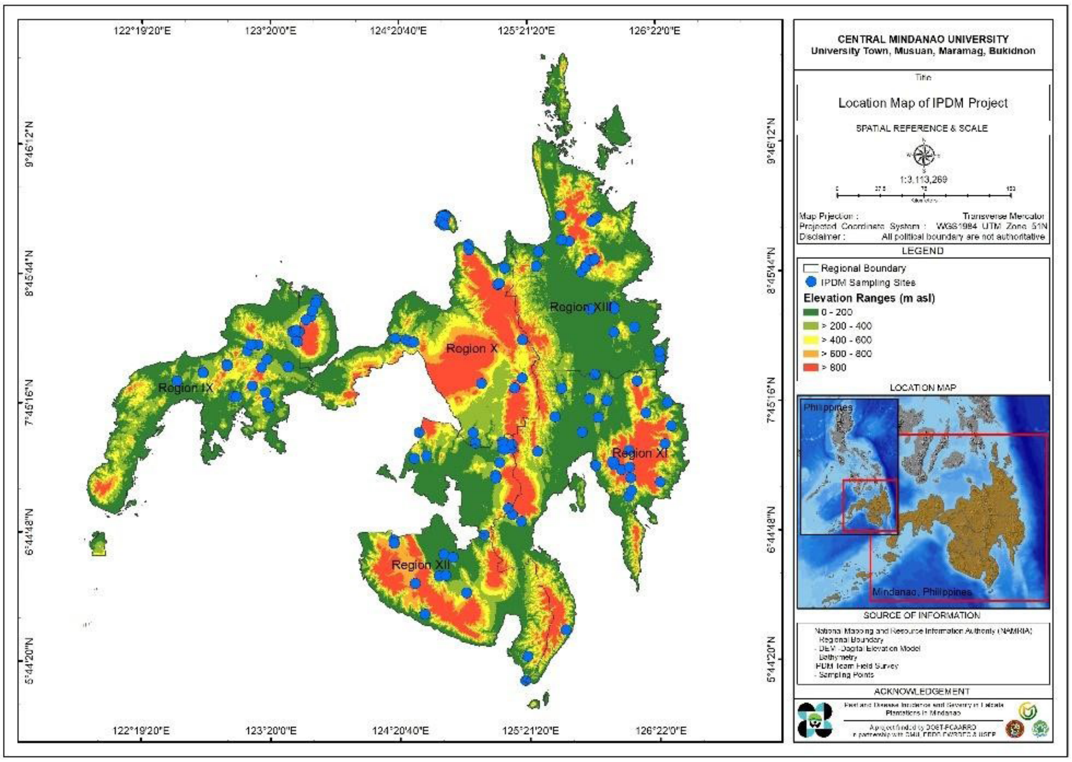

Figure 1. Sampling sites across different elevations in five regions of Mindanao, Philippines.

The percentage severity data was analyzed in relation to elevation, site variables, and the interaction of these variables with elevation. Linear mixed effects model was used in the analysis, with the plantation serving as the random effect. To avoid multicollinearity between any two variables, package DAAG in R (R Core Team, 2022) was used to perform variance inflation factor (VIF) test. The VIF threshold to detect problematic collinearity is < 10 (Vittinghoff et al., 2006). Prior to analysis, predictor variables were scaled to ensure they contribute equally to the analysis, while severity data were arcsine transformed to stabilize the variance and improve the overall model fit. Type-III analysis-of-variance table was generated using the package car in R to determine the significance of the predictor variables.

Results of the study showed a significant influence of elevation on gall rust disease severity in Falcata plantations in Mindanao consistent to earlier reports (e.g., Lacandula et al., 2017; Rahayu et al., 2018). Plantations located at altitudes more than 400 m above sea level exhibited a generally high to critical severity levels of the gall rust compared to those at lower elevations (cf. low percent severity) (Figure 2), resulting in potential yield losses estimated at approximately 23% to 52% of the total log volume per hectare (Figure 3). Independent of elevation, factors contributing to increased gall rust severity include low stand density (< 1000 trees per hectare), extended distances from natural forests or vegetation (over 1000 m), low species diversity of understorey vegetation, and low average temperatures (< 24°C). These factors interact significantly with elevation (Figure 3); however, at elevations over 600 m asl, higher severity was observed in plantations with greater understorey vegetation diversity (Figure 4a) and elevated temperatures (> 24°C) (Figure 4b). While lower temperatures are more conducive to the Falcataria gall rust fungus (*Uromycladium falcatarium*) (Rahayu et al., 2018), warmer temperatures can also stimulate germination or enhance the concentration and spread of rust fungus spores (Rahayu et al., 2020; Vuorinen & Helander, 1995). Contrary to widely held notion that vegetation diversity mitigates disease impact in an ecosystem (Ratnadass et al., 2012), our observations indicate a nuanced scenario. Higher gall rust severity was noted in plantations at elevations exceeding 600 m above sea level, despite the presence of a more diverse understorey vegetation. It is possible that at higher elevations, diverse understorey vegetation in plantations may contribute to microclimate modifications (e.g., a wetter environment) favorable for disease development (Avelino et al., 2023). Conversely, the presence and proximity of natural vegetation to plantations can disrupt the spatial cycle of the disease (Ratnadass et al., 2012) or act as a protective buffer zone, where fungal spores can prematurely settle, removing them from their normal infection cycle and preventing further spread (Avelino et al., 2023). Thus, plantations situated far from or without natural vegetation buffers are more vulnerable to gall rust disease outbreak, especially at higher elevations, where stronger wind speed may contribute to increased disease spread (Rahayu et al., 2018). This vulnerability also extends to low-density plantations at higher elevations due to increased air circulation, which may facilitate better dispersal or spread of fungal spores, although greater stand density is also likely to facilitate tree-to-tree dispersal through physical contact between trees (Avelino et al., 2023).

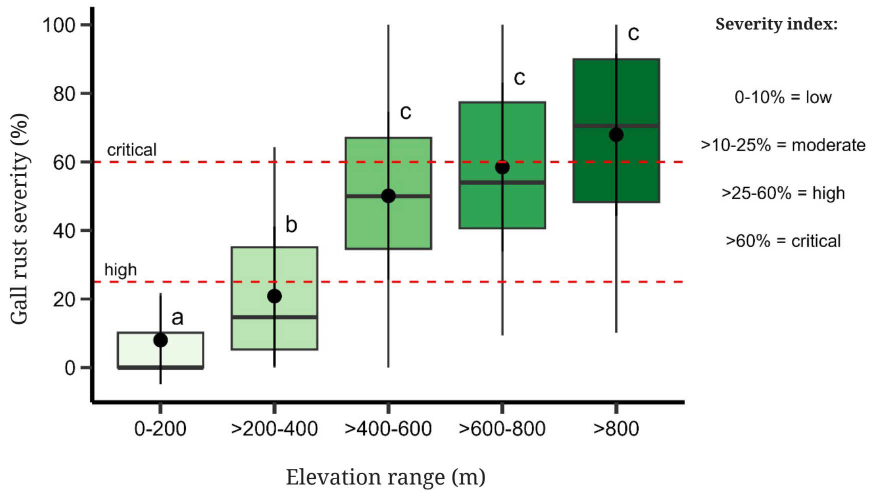

Figure 2. Relationship between gall rust severity (%) and elevation range of Falcata plantations in Mindanao, Philippines. Different letters on the boxplots indicate significant difference at $P < 0.05$.

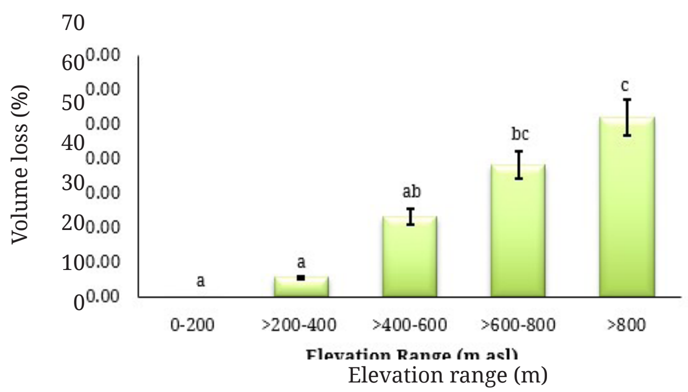

Figure 3. Percentage losses of total log volume per hectare across different elevation ranges. Different letters on the error bars in each bar indicate significant difference at $P < 0.05$. Error bars represent ± SE.

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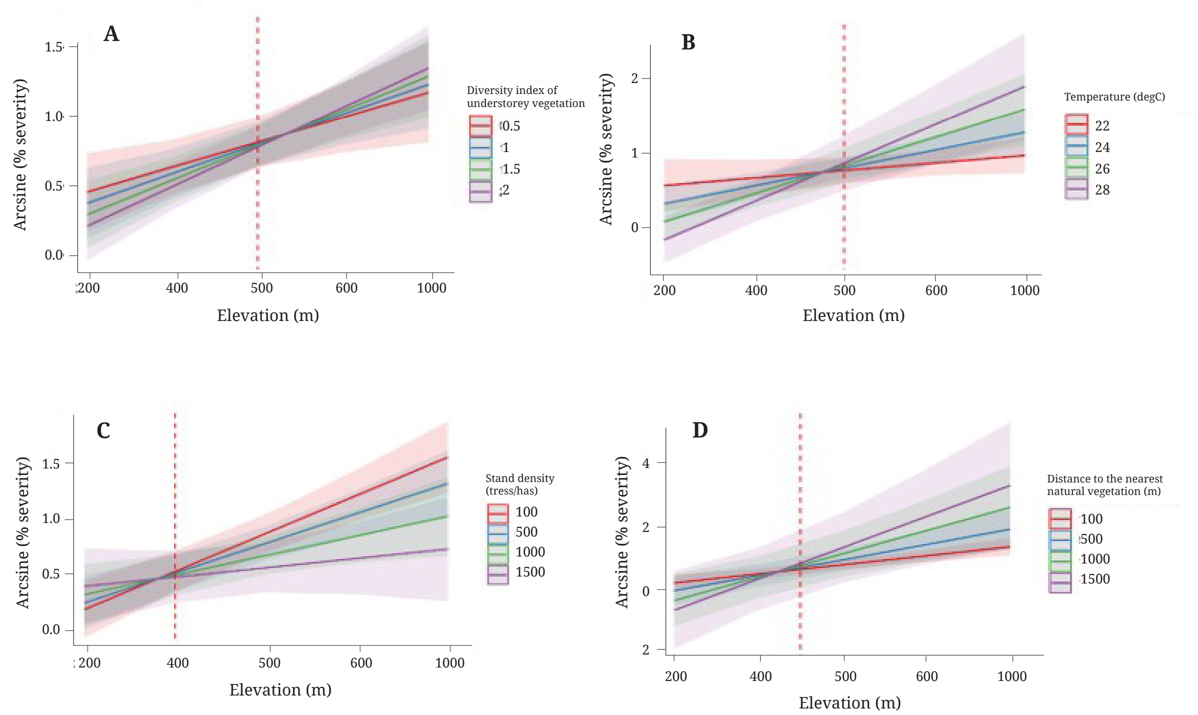

Figure 4. Relationship between gall rust severity (%) and site factors across different elevations (meters above sea level) in Falcata plantations in Mindanao, Philippines: (A) understory diversity; (B) temperature (°C); (C) stand density (trees/ha); (D) distance (m) to the nearest natural vegetation. Note that only variables with significant effects are presented.

CONCLUSION

The results underscore the significant impact of elevation on gall rust disease severity in Falcata plantations consistent to earlier reports, with higher elevations exceeding 400 m above sea level showing higher severity and potential yield losses. The significant interaction between elevation and other site factors such as stand density, distance from natural vegetation, understorey vegetation diversity, and temperatures also provide insights for targeted management of Falcata plantations to reduce gall rust disease severity. While diverse understorey vegetation at higher elevations was observed, it unexpectedly correlated with increased disease severity, possibly due to the enhanced microclimate conditions favorable for the pathogen. The close proximity of natural vegetation to plantations can serve as a protective buffer, disrupting the spatial cycle of the disease. Plantations without this protective zone, especially at higher elevations, face heightened vulnerability to gall rust outbreak.

Implications and recommendations

Effectively managing gall rust disease in Falcata plantations in Mindanao requires a comprehensive, site-specific approach. Falcata farmers must carefully consider factors such as elevation, understorey and surrounding vegetation, and microenvironment to counteract conditions conducive to gall rust. Considering the results of the study, the following recommendations aim to reduce gall rust severity:

1. Avoid planting Falcata in areas with elevation exceeding 400 m above sea level.
2. Establish and maintain natural vegetation within 1000 m around plantations as a protective buffer zone to prevent or control disease spread.
3. Maintain a more diverse understorey vegetation for plantations at lower elevations (below 400 m above sea level). However, at elevations above 600 m, it is recommended to control

understorey vegetation growth (e.g., regular brushing or trimming) to minimize conditions (e.g., a wetter environment) that favor gall rust development and spread.

4. If establishing plantations at higher elevations is unavoidable, ensure adequate tree spacing (about 3 m x 3 m or 3 m x 4 m spacing) to maintain a moderate stand density of around 1000 - 1500 trees per hectare. This moderate stand density will help control air circulation within the plantation and reduce the risk of pathogen spread between trees. Consequently, it helps in controlling understorey vegetation growth at higher elevations and minimizes conditions favorable for gall rust, including elevated temperatures.

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REFERENCES

Avelino, J., Gagliardi, S., Perfecto, I., Isaac, M. E., Liebig, T., Vandermeer, J., Merle, I., Hajian-Forooshani, Z., and Motisi, N. (2023). Tree effects on coffee leaf rust at field and landscape scales. *Plant Disease*, 107(2), 247-261.

FMB-DENR. (2022). Philippine Forestry Statistics. Forest Management Bureau-Department of Environment and Natural Resources (FMB-DENR), Philippines.

Lacandula, L., Rojo, M. J., Casas, J., and Puno, G. R. (2017). Geospatial analysis on the influence of biophysical factors on the gall rust prevalence in falcata (Paraserianthes falcataria L. Nielsen) plantation in Gingoog city, Philippines.

Paler, D. A., Shinohara, T., Del Castillo, R. A., and Nomura, I. (1998). Development of industrial tree plantation in the administrative region No. 10, in mindanao island, philippines: With two case studies. *Journal of Forest Research*, 3(4), 193-197.

PCAARRD. (2010). Challenges and Recommendations in the Industrial Tree Plantations. Policy Brief.

R Core Team. (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing.

Rahayu, S., See, L., Shukor, N., and Saleh, G. (2018). Environmental factors related to gall rust disease development on *falcataria moluccana* (miq.) barneby and jw grimes at brumas estate, Tawau, Sabah, Malaysia. *Applied Ecology and Environmental Research*, 16(6), 7485-7499.

Rahayu, S., Widiyatno, W., and Adriyanti, D. T. (2020). Pathogenesis of gall-rust disease on *falcataria moluccana* in areas affected by Mount Merapi eruption in Indonesia. *Biodiversitas Journal of Biological Diversity*, 21(4).

Ratnadass, A., Fernandes, P., Avelino, J., and Habib, R. (2012). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for sustainable development*, 32, 273-303.

Tulod, A. M., Casas, J. V., Rojo, M. J. A., Aribal, L. G., Libayao, U. K. Y. F., and Monteroso, B. R. L. (2022). Gall Rust Disease Incidence and Severity in a Falcata (*Falcataria moluccana* (Miq.) Barneby and JW Grimes) Plantation Grown from Select Mother Trees in Mindanao, Philippines. *CMU Journal of Science*, 26(2).

Vittinghoff, E., Glidden, D. V., Shiboski, S. C., and McCulloch, C. E. (2006). Regression methods in biostatistics: linear, logistic, survival, and repeated measures models.

Vuorinen, P., and Helander, M. L. (1995). Variation in airborne urediniospore concentration of Melampsoridium betulinum. *Aerobiologia*, 11, 259-264.