# Temporal Dynamics of *Ganoderma* Basal Stem Rot (BSR) Disease Progress in Oil Palm: Effects of Planting Generation, Topography, and Previous Crop

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**DOI: https://dx.doi.org/10.47772/IJRISS.2025.907000383**

**Received: 15 July 2025; Accepted: 29 July 2025; Published: 19 August 2025**

## ABSTRACT

Ganoderma basal stem rot (BSR) disease poses a major threat to oil palm plantations in Southeast Asia. This study examined how BSR disease progress, quantified using the area under the disease progress (AUDPC), varies with planting generation, topography, and previous crop. Data from 1,184 palms in Sabah, Malaysia were analysed using non-parametric statistical tests due to non-normal distribution. Results showed significantly higher AUDPC in second-generation palms, replantings after oil palm, and flat to undulating terrain. These findings highlight the importance of considering replanting history and site conditions when managing BSR in oil palm plantations.

**Keywords:** Ganoderma, BSR, AUDPC, disease progress, planting generation, topography, palm oil

## INTRODUCTION

*Ganoderma* basal stem rot (BSR), primarily caused by the pathogen *Ganoderma boninense*, poses significant challenges to oil palm production, particularly in Southeast Asian nations such as Malaysia and Indonesia. This devastating disease leads to the progressive decay of the basal stem and roots of the oil palms, and in severe cases, can result in palm collapse, with economic losses estimated between 50% to 80% in badly affected plantations [1],[2]. Managing BSR effectively requires a thorough understanding of the disease's progression over time, integrating factors such as planting generation, site topography, and previous agricultural practices.

A fundamental aspect of assessing the severity and progression of BSR is the utilization of the Area Under the Disease Progress Curve (AUDPC), which quantifies cumulative disease incidence over time. Research indicates that disease dynamics are influenced not only by the pathogen's biological characteristics, such as its genetic diversity and virulence, but also by environmental and management-related factors [3],[4]. For instance, the work of Midot *et al*. highlights the genetic diversity of *G. boninense* in Malaysian plantations, suggesting that variations in the pathogen may impact disease severity depending on the specific genetic strains present [3].

The role of planting generation in disease progression is particularly noteworthy. Suwandi *et al.* [2] underscored that the prevalence and intensity of BSR increase significantly with successive planting generations. Their findings indicate an annual growth rate of affected areas reaching up to 10.3% from 1994 to 2009, with more recent estimates suggesting even higher rates of infestation [2]. This information signals the necessity for strategic replanting decisions, which should consider the historical experiences of oil palm cultivation at specific sites. Furthermore, site-specific factors, such as topography and soil *health*, can profoundly influence the pathogen's inoculum potential and the microclimatic conditions conducive to disease development [5],[6].

Empirical studies examining the interaction between previous cropping regimes and current BSR incidence remain limited but are crucial for informed decision-making regarding crop management. For example, the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

introduction of intercropping strategies with resistant herbaceous plants, as demonstrated by Suwandi et al., has shown promising results in suppressing the severity of BSR through ecological competition and enhanced soil health [1],[7]. Such findings reinforce the importance of integrating ecological principles into agricultural practices to mitigate disease risks and promote long-term sustainability.

Moreover, the significance of ongoing research into innovative detection methods, such as remote sensing and machine learning, cannot be overstated. Technologies like autonomous unmanned aerial vehicles (UAVs) equipped with multispectral cameras offer unprecedented opportunities for early detection and monitoring of BSR across expansive oil palm plantations, allowing for timely intervention to manage and control outbreaks effectively [7]. In summary, a multifaceted approach that combines understanding the dynamics of *Ganoderma boninense*, employing integrated disease management strategies, and leveraging advanced technological tools is critical to - effectively address the challenges --posed by basal stem rot in oil palm cultivation. Continued research is essential to further elucidate the interactions between the various factors influencing disease severity, which will ultimately inform better management practices and promote the sustainability of this vital agricultural sector.

# METHODOLOGY

## A. Study Site and Sampling

This study was conducted using field data collected from three selected estates in Sabah, Malaysia. It covers a total of 1,184 palms assessed for *Ganoderma* BSR disease severity across multiple census periods. The sample included palms from different planting generations (first vs second generation), topographic zones (level 0-4%, undulating 4-12%, and flat and undulating), and sites with varied cropping histories (previous oil palm vs previous rubber).

## B. Measurement of Disease Progress

(i) Disease Severity Rating

BSR disease severity for each palm was assessed visually on a zero to four scale during multiple census periods (from year 2017 to 2021). Table 1.0 shows the rating for disease severity and their symptoms.

Table I. Disease Severity Ratings

| Disease Ratings | Symptoms |
|---|---|
| 1 | Healthy |
| 2 | Mild |
| 3 | Moderate |
| 4 | Severe |

(ii) AUDPC Calculation

The AUDPC was computed for each palm based on its severity ratings across observation dates using the general formula:

$$\text{AUDPC} = \sum_{i=1}^{n} \frac{(y_i + y_{i+1})}{2}(t_{i+1} - t_i)$$

where:

| | | |
|---|---|---|
| $Y_i$ | = | Disease assessment on the *i*th date ($i = 1,2,\ldots,n$) |
| $n$ | = | The number of disease assessment; and |
| $(t_{i+1} - t_i)$ | = | The interval between two consecutive assessments. |

AUDPC served as the continuous outcome variable to quantify temporal disease dynamics.

### C. Statistical Analysis

(i) Normality Test

Normality test should be done to identify which test is suitable to be used. The Kolmogorov-Smirnov test in Table II revealed that the data for area under the disease progress curve (AUDPC), disease severity, generation, previous crop, and topography are not normally distributed (all p-values < 0.05). Hence, the Mann-Whitney U test should be used to check for the changes or variations in the *Ganoderma* BSR disease progress.

| Variables | | Kolmogorov-Smirnov | | |
|---|---|---|---|---|
| | | Statistic | df | Significance |
| Disease severity rating | R1 | 0.330 | 990 | <0.001 |
| | R2 | 0.369 | 43 | <0.001 |
| | R3 | 0.240 | 101 | <0.001 |
| | R4 | 0.138 | 50 | 0.019 |
| Topography: Level (0-4%) VS Undulating (4-12%) | Level 0-4% | 0.450 | 839 | <0.001 |
| | Undulating (4-12%) | 0.419 | 345 | <0.001 |
| Topography: Level (0-4%) VS Flat and Undulating | Level 0-4% | 0.444 | 748 | <0.001 |
| | Flat and Undulating | 0.514 | 436 | <0.001 |
| Generation | 1st generation | 0.491 | 403 | <0.001 |
| | 2nd generation | 0.409 | 781 | <0.001 |
| Previous crop | Oil palm | 0.409 | 781 | <0.001 |
| | Rubber | 0.491 | 403 | <0.001 |

Table II. Normality Tests with Selected Variable Against Audpc

(ii) Hypothesis Testing

Due to the non-normality, non-parametric tests were used which are the Mann-Whitney U test for comparisons between two groups (generation, previous crop) and Kruskal-Wallis H test for comparisons across three topography categories.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

(iii) Software

All analyses were conducted using SPSS Version 26.

# RESULTS

### A. Effect of Planting Generation

The Mann-Whitney U test indicated a statistically significant difference in AUDPC between first and second generation plantings (U=128,391.5; Z=-5.394; p<0.05).

Table III. Mann Whitney U Test for Generation Against Audpc

| | Total AUDPC |
|---|---|
| Mann-Whitney U | 128391.500 |
| Wilcoxon W | 209797.500 |
| Z | -5.394 |
| Asymp. Sig. (2-tailed) | <0.001 |

Median for AUDPC shows first generation with value of 25 and second generation with value of 29. This suggests that second generation palms experienced higher cumulative disease severity over the period.

### B. Effect of Topography

The Kruskal-Wallis H test revealed significant differences in AUDPC across topographic categories (H=369.879; df=2; p<0.05).

Table IV. Kruskal Wallis H Test for Topography Against Audpc

| | Total AUDPC |
|---|---|
| Kruskal-Wallis H | 369.879 |
| df | 2 |
| Asymp. Sig. | <0.001 |

Median for AUDPC shows level (0-4%) with value of 25, undulating (4-12%) with value of 24, and flat and undulating with value of 29. Pairwise comparisons (Mann-Whitney U, Bonferroni-adjusted) showed all topographic pairs differed significantly with p-value of less than 0.05. Palms on flat and undulating terrain had significantly higher AUDPC, suggesting more severe or prolonged disease progress.

### C. Effect of Previous Crop

The Mann-Whitney U test showed a statistically significant difference between palms replanted after oil palm and those replanted after rubber (U=128,391.5; Z=-5.394; p<0.05).

Table V. Mann Whitney U Test for Previous Crops Against AUDPC

| | Total AUDPC |
|---|---|
| Mann-Whitney U | 128391.500 |
| Wilcoxon W | 209797.500 |

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

| | |
|---|---|
| Z | -5.394 |
| Asymp. Sig. (2-tailed) | <0.001 |

Median for AUDPC shows oil palm as previous crop has value of 29 and rubber as previous crops has value of 25. This indicates that planting oil palm after oil palm may worsen disease progress compared to rotation with rubber. Fig. 1 shows visual summary of median AUDPC across the generation, topography, and previous crops. Categories with higher AUDPC are marked as “high risk” to help identify conditions where *Ganoderma* BSR disease progress is more severe.

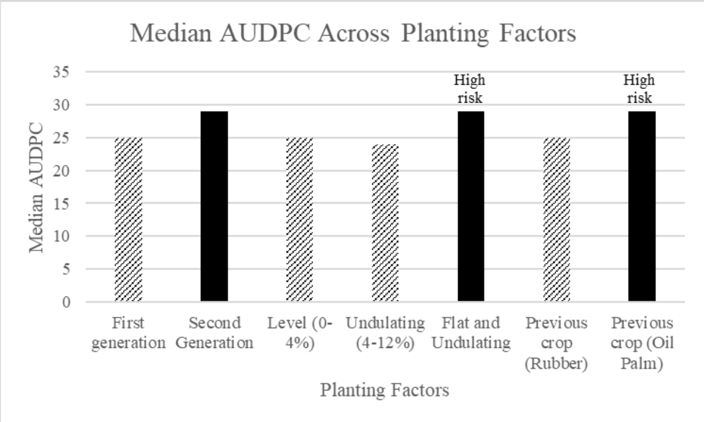


Fig. 1 Median AUDPC across selected planting factors showing high risks factors based on median value

## DISCUSSION

The analysis indicates that second-generation oil palms, those planted after similar crops, and those grown on flat and undulating terrain exhibit more progressive patterns of *Ganoderma* BSR development, as reflected in higher AUDPC values. These findings support earlier observations by Turner [8], who lined increased infection to replanting on infested sites, where symptoms typically emerge five to six years post-planting and may reach up to 50% incidence by year fifteen.

However, the findings on topography contrast with [9], who observed greater disease incidence in high-density plantations, particularly on sloped terrains. This discrepancy may arise from regional agroecological variations, such as rainfall, soil type, and management practices. Japanis *et al.*[10] also highlighted that hilly plantations often adopt stricter soil and water management, which may help suppress disease. In contrast, flatter areas may retain moisture, encouraging disease progression and limiting early detection. Variability in how topographic categories are defined, as well as microclimate and previous crop influences, further complicate comparisons. Rakib *et al*. [11] also linked cropping history to soil microbial dynamics, which can alter pathogen pressure and disease outcomes.

## CONCLUSION

This study confirms that AUDPC is a useful metric in quantifying *Ganoderma* BSR progress in oil palms, with higher values indicating more severe and sustained disease. Future research should examine site-specific conditions and refine the classification of topographic categories to better understand their influence on *Ganoderma* progression. Relevant management strategies considering generation, cropping history, and local terrain are essential for mitigating BSR impact in oil palm plantations.

Results suggest that replanting oil palm after similar crops, especially those within the coconut family, increases infection risk, likely due to residual inoculum. Therefore, it is important to do--crop rotation, especially avoiding successive oil palm planting on historically infested plots. Additionally, second-generation palms on historically infested sites appear more susceptible. While topographic effects were significant, their relationship with disease dynamics remains unclear and warrants further study. Second-generation palms and flat or poorly drained areas show greater *Ganoderma* BSR disease progress. To mitigate the risks, oil palm players should enhance drainage in flat terrains, and implementing early monitoring in replanting areas. These targeted strategies can reduce cumulative disease burden over time.

## ACKNOWLEDGEMENT

This work was financially supported by Skim Dana NIC, Universiti Malaysia Sabah (UMS) under grant number SDN0014-2019. We are grateful to the Malaysia Palm Oil Board (MPOB) for granting permission to conduct the study in their selected oil palm estates located in Sungai Kawa, Merotai Besar, and Mawao. We extend our sincere thanks to all field assistants especially -to Mr. Jumain Sinring, Mr. Mohd. Irwan Salleh, and Mr. Sustrisno Sumarno, for their invaluable assistance with data collection.

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