



Dynamics of Fusarium Wilt Severity in Banana as Affected by Different Nitrogen Fertilizer Rates

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Abstract

Fusarium wilt disease caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) is a major constraint in banana cultivation, and its development in the field is frequently associated with improper nitrogen fertilization. However, information on how different nitrogen fertilizer rates influence Fusarium wilt severity remains limited. This study aimed to evaluate the effect of varying nitrogen doses on Fusarium wilt and growth of banana. The experiment was conducted under laboratory and field conditions at the Horticulture Research Center of BRIN, Solok, Indonesia, using a randomized block design with nine treatments and four replications. The treatments were nitrogen with different rates (control, 100, 250, 400, and 550 kg ha⁻¹ year⁻¹), applied with and without Foc inoculation. The results demonstrated that nitrogen fertilization enhanced vegetative growth of banana plants under pathogen-free conditions. However, in Foc-infected plants, increasing nitrogen rates—particularly at high levels—exacerbated disease development. High nitrogen rates (400–550 kg ha⁻¹ year⁻¹) accelerated symptom appearance, indicated by shorter incubation periods, and increased disease severity. In contrast, a moderate nitrogen rate (250 kg ha⁻¹ year⁻¹) delayed symptom development and reduced disease severity, although it did not prevent infection. These findings suggest that excessive nitrogen fertilization increases Fusarium wilt severity, while moderate nitrogen application may help suppress disease progression. Therefore, nitrogen management in Fusarium wilt–endemic banana production areas should prioritize moderate nitrogen rates and avoid excessive fertilization as part of an integrated and sustainable disease management strategy.

Keywords: Attack intensity, *Fusarium oxysporum* f. sp. *Cubense*, infection, growth, nitrogen dosage

Introduction

Banana (*Musa* sp.) is one of the most essential horticultural commodities in Indonesia, playing a significant role in national food security in terms of production volume,

cultivated area, and geographical distribution. This crop is widely cultivated throughout the country and exhibits a high diversity of types and varieties (Kusumah et al., 2023; Sutriana, 2025). Globally, Indonesia ranks as the third-

largest banana-producing country after India and China (FAOSTAT, 2023). In addition to its economic value, the banana is a vital staple food commodity, alongside rice, due to its relatively complete nutritional content (Hardini et al., 2022).

One of the significant constraints in banana cultivation is Fusarium wilt disease caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) (Sulyanti et al., 2018; Dita et al., 2018; Siamak and Zheng, 2018; Rocha et al., 2020; Yan et al., 2023; Chen et al., 2024). This soil-borne pathogen is highly destructive and can cause severe damage to banana plants within a relatively short period, resulting in significant yield losses (Handayani et al., 2018; Ishak and Jumjunidang, 2024). Fusarium wilt has been reported for over five decades in Asia, Africa, Australia, and the tropical regions of the Americas (Hwang and Ko, 2004). It is currently widespread across all major banana-producing areas in Indonesia (Maryani et al., 2019).

Based on pathogenicity to specific banana genotypes, Foc is classified into four races, among which race 4 is considered the most virulent because it is capable of infecting nearly all cultivars susceptible to races 1 and 2 (Nasir and Jumjunidang, 2003; Jumjunidang and Riska, 2011; Ploetz, 2015). In addition to race classification, Foc populations are also categorized according to vegetative compatibility groups (VCGs). To date, 24 VCGs have been identified worldwide, with 15 VCGs reported in Asia (Mostert et al., 2017) and 10 VCGs documented in Indonesia (Hermanto et al., 2011). This high genetic and pathogenic diversity contributes to the difficulty of managing Fusarium wilt, explaining the limited effectiveness of current control strategies.

Various approaches to manage Fusarium wilt have been explored, including improving plant health and vigor through appropriate

nutrient management. Plants require at least 13 essential nutrients for growth and development, consisting of primary macronutrients (N, P, and K), secondary macronutrients (Ca, Mg, and S), and micronutrients (Fe, Mn, Zn, Cu, B, Mo, and Cl). As a primary macronutrient, nitrogen plays a critical role in chlorophyll formation and the synthesis of amino acids and proteins, thereby strongly influencing vegetative growth (Pandiangan et al., 2017). Nitrogen requirements vary depending on plant species and growth stages; nitrogen deficiency leads to stunted growth and pale green leaves, whereas excessive nitrogen application may inhibit flowering and yield formation (Anwar, 2014; Tando, 2019).

Numerous studies on different crops have demonstrated that nitrogen fertilization affects not only plant growth but also disease development. Rolanda et al. (2021) reported that appropriate nitrogen rates promoted optimal growth in mustard plants, whereas excessive nitrogen fertilization in maize increased damage caused by pests and diseases, leading to lodging due to excessive vegetative growth (Nainggolan et al., 2016). In rice, high nitrogen application has been shown to increase the severity of blast disease (Ariyani et al., 2020; Huang et al., 2017). Conversely, in wheat, increased nitrogen fertilization has been found to exacerbate the severity of rust disease (Devadas et al., 2014). These findings suggest that nitrogen availability plays a crucial role in modulating disease dynamics, particularly in terms of disease development rate and severity.

According to fertilizer recommendations issued by the Indonesian Soil Research Institute (Balai Penelitian Tanah, 2021), optimal banana growth requires approximately 525 kg ha⁻¹ yr⁻¹ of urea, 300–500 kg ha⁻¹ yr⁻¹ of SP-36, and 375–500 kg ha⁻¹ yr⁻¹ of KCl. In other banana-producing

countries such as Australia, the recommended nitrogen fertilizer rate is approximately 250 kg ha⁻¹ yr⁻¹ (Orr et al., 2022). These fertilizer recommendations are generally applied to maximize productivity, leading farmers to use relatively high nitrogen rates. However, accumulating evidence indicates that excessive nitrogen fertilization may increase plant susceptibility to diseases.

Although the relationship between nitrogen fertilization and plant diseases has been widely documented in various crops, information regarding the effects of different nitrogen fertilizer rates on the dynamics of Fusarium wilt severity in banana remains limited, particularly in relation to disease incubation period and disease severity. Therefore, this study aimed to evaluate the dynamics of Fusarium wilt severity in banana plants as affected by different nitrogen fertilizer rates, with the expectation of providing a scientific basis for optimizing nitrogen management in areas endemic to Fusarium wilt.

Methods

The study was conducted from August to December 2024 at the shared laboratory and experimental field of the Horticulture Research Center, National Research and Innovation Agency (BRIN), Lubuk Sikarah Subdistrict, Solok City, West Sumatra, Indonesia.

Research Design

The study used a randomized complete block design (RCBD) consisting of nine treatments with four replications. Each experimental unit comprised five banana plants, resulting in 20 plants per treatment. Treatments consisted of different nitrogen fertilizer rates (Nitrogen was applied as urea with 46% N), with and without inoculation of Foc: A = 100 kg N ha⁻¹ yr⁻¹ (365.20 mg plant⁻¹

per 2 weeks), B = 250 kg N ha⁻¹ yr⁻¹ (913 mg plant⁻¹ per 2 weeks), C = 400 kg N ha⁻¹ yr⁻¹ (1,460.8 mg plant⁻¹ per 2 weeks), D = 550 kg N ha⁻¹ yr⁻¹ (2,008.6 mg plant⁻¹ per 2 weeks), E = A + Foc, F = B + Foc, G = C + Foc, H = D + Foc, and I = 0 kg N + Foc (inoculated control). Phosphorus and Potassium fertilizers were applied routinely at recommended rates; P = 55 kg ha⁻¹ yr⁻¹ and K = 650 kg ha⁻¹ yr⁻¹.

Plant and Growth Media Provision

Two-month-old tissue-cultured Barangan Merah banana plantlets (4–5 fully expanded leaves) were used after acclimatization. The growth medium consisted of garden soil and cattle manure mixed at a ratio of 3:1 (w/w). The mixture was homogenized and filled into polybags (4 kg per polybag). Plantlets were transplanted into the prepared medium and maintained for two weeks prior to the first nitrogen application.

Foc isolate and inoculum preparation

The Foc isolate used in this study was a BRIN Horticulture Research Center collection, i.e., tropical race 4 (TR4) with VCG 01213/16, maintained on sterile filter paper. Inoculum was mass-produced using millet (*Setaria italica*) medium following the method of Warman and Aitken (2018) with minor operational adjustments. The isolate was first regenerated on potato dextrose agar (PDA) and incubated at 25 ± 1 °C for 7 days to obtain an actively growing colony. Millet grains were soaked overnight, drained, and sterilized by autoclaving at 121 °C for 20 min on two consecutive cycles. After cooling, sterile millet was inoculated aseptically with a ~5 mm mycelial plug taken from the colony margin of the 7-day-old PDA culture, using one plug per 100 g millet. The inoculated millet was incubated at 25 ± 1 °C for approximately 14 days until the fungus uniformly colonized the substrate. The colonized millet was then

aseptically crumbled and used as Foc inoculum for soil application.

Fertilizer Application

The first nitrogen application was conducted two weeks after transplanting. Subsequent applications were performed at two-week intervals for four months. Nitrogen was applied by dissolving the fertilizer together with the routine P and K fertilizers in water and pouring the solution into a shallow circular furrow made around the plant base (approximately 5 cm from the pseudostem).

Pathogen Inoculation

Foc inoculation was carried out four weeks after the first nitrogen application. Inoculum was placed at three points around each plant by making three holes (4–5 cm depth) using a small spoon. Approximately 15 mL of Foc propagules mixed with colonized millet medium was applied per plant (distributed across the three holes), and the holes were covered again with soil. Plant maintenance was performed optimally, including watering, weeding, soil loosening, and adding medium if necessary; pests were controlled when observed.

Variables Observed

Plant height (cm)

Plant height was measured from 1 cm above the soil surface to the highest point of the pseudostem (up to the junction of the two youngest leaves) using a ruler/tape measure. A stake was used as a measurement reference. The variable analyzed was plant height increment (final minus initial height).

Number of leaves (leaves)

The number of leaves counted included all functional, fully expanded leaves. The variable analyzed was leaf number increment (final minus initial number).

Pseudostem circumference (cm)

Circumference was measured at 1 cm above the soil surface (aligned with the reference stake) using a measuring tape. The variable analyzed was circumference increment (final minus initial circumference).

Incubation period (days)

The incubation period was defined as the time from inoculation to the first appearance of Fusarium wilt symptoms. Symptoms were characterized by yellowing at the margins of older leaves followed by progression to younger leaves. Observations were recorded daily until initial symptoms were detected.

Disease incidence (%)

Disease incidence was recorded weekly and calculated as:

$$P = \frac{T_1}{T_2} \times 100 \dots\dots\dots (1)$$

where P = disease incidence (%), T1 = the number of infected plants, and T2 = the total number of observed plants.

Disease severity (%)

Disease severity was assessed weekly based on the proportion of leaves showing wilting/yellowing symptoms and calculated as:

$$I = \frac{D_1}{D_2} \times 100 \dots\dots\dots (2)$$

where I = disease severity (%), D1 = the number of symptomatic leaves, and D2 = is the total number of observed leaves.

Plant growth variables (height, leaf number, and pseudostem circumference) were measured every two weeks, starting one day after the first nitrogen application, and continued until the end of the observation period.

Data Analysis

All variables were subjected to analysis of variance (ANOVA). When significant effects

were detected, means were separated using a Tukey test at the 5% significance level.

Results

Vegetative Growth

Based on Table 1, nitrogen application significantly affected the vegetative growth of banana plants, as indicated by variations in plant height, pseudostem circumference, and leaf number. In banana plants not inoculated with Foc, increasing nitrogen rates enhanced vegetative growth, with the highest values generally observed at nitrogen levels of 250–550 kg ha⁻¹ yr⁻¹. In contrast, growth parameters were consistently reduced in Foc-inoculated plants across all nitrogen

treatments. At equivalent nitrogen rates, Foc-infected plants exhibited lower plant height, smaller pseudostem circumference, and fewer leaves than non-inoculated plants.

Increasing nitrogen supply did not compensate for growth suppression in Foc-infected plants. High nitrogen applications (400–550 kg ha⁻¹ yr⁻¹) failed to improve vegetative growth and were associated with the lowest growth performance. Conversely, Foc-inoculated plants receiving a moderate nitrogen rate (250 kg ha⁻¹ yr⁻¹) exhibited relatively better vegetative growth compared with plants receiving lower or higher nitrogen rates.

Tabel 1. Vegetative growth of Barangan Merah banana plants under different nitrogen fertilizer rates at three months after Foc (*Fusarium oxysporum* f. sp. *cubense*) inoculation.

Nitrogen rate	Plant height (cm)	circumference (cm)	Leaf number (leaves)
100 kg N ha ⁻¹ yr ⁻¹	36.44b	14.91abc	12.87ab
250 kg N ha ⁻¹ yr ⁻¹	42.74a	16.95a	13.37a
400 kg N ha ⁻¹ yr ⁻¹	43.12a	15.93ab	13.25a
550 kg N ha ⁻¹ yr ⁻¹	44.05a	15.58abc	13.25a
100 kg N ha ⁻¹ yr ⁻¹ + Foc	25.66c	13.21cd	12.25bc
250 kg N ha ⁻¹ yr ⁻¹ + Foc	29.25c	14.64abc	13.31a
400 kg N ha ⁻¹ yr ⁻¹ + Foc	26.21c	14.29bcd	12.75ab
550 kg N ha ⁻¹ yr ⁻¹ + Foc	24.11c	12.21d	11.62c
Foc (control)	25.66c	13.21cd	12.25bc

Notes: Numbers in the same column sharing the same lowercase letter indicate no significant difference according to Tukey's test at $\alpha = 0.05$

Incubation Period

Based on Table 2, the incubation period of Fusarium wilt was not observed in non-inoculated banana plants across all nitrogen treatments, indicating that symptom development was exclusively associated with Foc infection. In contrast, nitrogen application had a significant effect on the incubation period in Foc-inoculated plants. High nitrogen application (550 kg N ha⁻¹ yr⁻¹) resulted in the shortest incubation period, with initial symptoms appearing at 34.0 days after inoculation, and this value differed

significantly from that observed under moderate nitrogen application (250 kg N ha⁻¹ yr⁻¹), which exhibited the longest incubation period (50.8 days).

Plants receiving low to intermediate nitrogen rates (0–400 kg N ha⁻¹ yr⁻¹) showed intermediate incubation periods that were not significantly different from one another. These results indicate that nitrogen availability influences the rate of disease development rather than the occurrence of infection, with excessive nitrogen accelerating symptom expression, whereas moderate

nitrogen application delays the onset of Fusarium wilt symptoms.

Table 2. Incubation period of Fusarium wilt in Barangan Merah banana plants under different nitrogen fertilizer rates at three months after Foc (*Fusarium oxysporum* f. sp. *cubense*) inoculation

Nitrogen rate	Incubation period (day)
100 kg N ha ⁻¹ yr ⁻¹	~
250 kg N ha ⁻¹ yr ⁻¹	~
400 kg N ha ⁻¹ yr ⁻¹	~
550 kg N ha ⁻¹ yr ⁻¹	~
100 kg N ha ⁻¹ yr ⁻¹ + Foc	44.75 ab
250 kg N ha ⁻¹ yr ⁻¹ + Foc	50.80 a
400 kg N ha ⁻¹ yr ⁻¹ + Foc	42.44 b
550 kg N ha ⁻¹ yr ⁻¹ + Foc	34.00 c
Foc (control)	43.38 b

Notes: Numbers in the same column sharing the same lowercase letter indicate no significant difference according to Tukey's test at $\alpha = 0.05$. (~) = not tested

Disease Incidence and Severity

Based on Table 3, all banana plants inoculated with Foc exhibited 100% disease

incidence regardless of nitrogen fertilizer rate, indicating that nitrogen application did not influence the occurrence of infection (Table 2, Figure 1). In contrast, disease severity differed significantly among nitrogen treatments. The highest disease severity was observed in plants receiving the highest nitrogen rate (550 kg N ha⁻¹ yr⁻¹ + Foc), reaching 83.83%, whereas the lowest severity was recorded at the moderate nitrogen rate of 250 kg N ha⁻¹ yr⁻¹ + Foc (69.41%). Plants receiving low to intermediate nitrogen rates (0–400 kg N ha⁻¹ yr⁻¹ + Foc) exhibited intermediate severity levels that were not significantly different from one another.

These results showed that nitrogen availability modulated the progression and severity of Fusarium wilt rather than the incidence of infection. Excessive nitrogen application intensified disease severity, whereas moderate nitrogen application was associated with reduced disease severity, suggesting that appropriate nitrogen management may mitigate disease damage without preventing pathogen infection.

Table 3. Disease incidence and severity of Fusarium wilt in Barangan Merah banana plants under different nitrogen fertilizer rates at three months after Foc inoculation

Perlakuan	Disease incidence (%)	Disease severity (%)
100 kg N ha ⁻¹ yr ⁻¹	0	0
250 kg N ha ⁻¹ yr ⁻¹	0	0
400 kg N ha ⁻¹ yr ⁻¹	0	0
550 kg N ha ⁻¹ yr ⁻¹	0	0
100 kg N ha ⁻¹ yr ⁻¹ + Foc	100	73.45ab
250 kg N ha ⁻¹ yr ⁻¹ + Foc	100	69.41b
400 kg N ha ⁻¹ yr ⁻¹ + Foc	100	74.09ab
550 kg N ha ⁻¹ yr ⁻¹ + Foc	100 ^{ns}	83.83a
Foc (control)	100	74.67ab

Notes: Numbers in the same column sharing the same lowercase letter indicate no significant difference according to Tukey's test at $\alpha = 0.05$.



Figure 1. Barangan Merah banana plants under the same nitrogen rate at three months after inoculation; A. Without Foc (*Fusarium oxysporum* f. sp. *cubense*) inoculation, B. with Foc inoculation

Discussion

The results indicated that increasing nitrogen application generally enhanced vegetative growth under non-infected conditions, with optimal growth observed at nitrogen rates of 250–550 kg N ha⁻¹ yr⁻¹. However, all growth parameters declined markedly at the same nitrogen rates when plants were infected with *Fusarium oxysporum* f. sp. *cubense* (Foc). Even increasing nitrogen supply to high levels (400–550 kg N ha⁻¹ yr⁻¹) failed to compensate for growth suppression in infected plants and instead resulted in reduced growth performance (Table 1). This finding suggests that nitrogen promotes vegetative growth only in the absence of pathogen stress, whereas under Foc infection, excessive nitrogen aggravates physiological impairment rather than alleviating it.

This response is likely attributable to the fact that excessive nitrogen promotes the formation of succulent and nitrogen-rich tissues, which are more susceptible to colonization by vascular pathogens such as Foc. Infection of the vascular system disrupts xylem function, thereby impairing the transport of water, gases, and nutrients within the plant. Similar patterns have been reported

in several crops, where high nitrogen fertilization increased vegetative growth under healthy conditions but enhanced disease susceptibility when pathogens were present (Nainggolan et al., 2016; Ariyani et al., 2020; Li et al., 2021; Huang et al., 2024). In banana, Zakaria et al. (2024) reported that Foc infection significantly reduces plant height, pseudostem diameter, total biomass production, and physiological performance, and may ultimately lead to plant death.

At the cellular level, excessive nitrogen availability has been shown to reduce cellulose and lignin content in plant cell walls (Zhang et al., 2017), thereby weakening structural defenses against pathogen invasion. Rapid cell division and elongation induced by high nitrogen supply can result in thinner and mechanically weaker cell walls, facilitating pathogen penetration. Lignin plays a crucial defensive role as a physical barrier restricting pathogen entry, as emphasized by Lee et al. (2019). These mechanisms likely contribute to the reduced growth performance observed in Foc-infected plants under high nitrogen input.

Nitrogen availability also influenced the temporal development of Fusarium wilt. In Foc-inoculated plants, the incubation period was significantly affected by nitrogen

fertilization, with excessive nitrogen input ($550 \text{ kg N ha}^{-1} \text{ yr}^{-1}$) accelerating disease development, whereas moderate nitrogen application ($250 \text{ kg N ha}^{-1} \text{ yr}^{-1}$) delayed the appearance of early symptoms (Table 2). From a physiological perspective, high nitrogen levels may create conditions favorable for pathogen growth and systemic spread within vascular tissues, leading to more rapid symptom expression. Although information on the effect of nitrogen on the incubation period of Fusarium wilt in banana is still limited, similar trends have been reported in other crop–pathogen systems, where increased nitrogen supply shortened incubation periods and accelerated disease progression (Sharma et al., 2020; Sun et al., 2020).

Despite clear effects on disease progression, nitrogen application did not influence disease incidence, as all inoculated plants exhibited 100% infection regardless of nitrogen rate. In contrast, disease severity differed markedly among nitrogen treatments. The highest disease severity was recorded under high nitrogen application ($550 \text{ kg N ha}^{-1} \text{ yr}^{-1} + \text{Foc}$), whereas the lowest severity occurred at the moderate nitrogen rate ($250 \text{ kg N ha}^{-1} \text{ yr}^{-1} + \text{Foc}$) (Table 3). This pattern confirms that nitrogen does not determine whether infection occurs, but rather modulates the extent of disease development.

These findings are consistent with previous reports, which indicate that nitrogen fertilization has a minimal effect on disease incidence but a significant influence on disease severity (Mur et al., 2017; Sharma et al., 2020; Sun et al., 2020). In addition to weakening cell wall structure, excessive nitrogen application can alter soil chemical properties, including an increase in soil pH, which may reduce the abundance and diversity of antagonistic soil microorganisms that contribute to disease suppression (Yang et al., 2018; Orr et al., 2022). Such changes can

promote pathogen accumulation and increase disease pressure, ultimately disrupting the regulation and maintenance of plant growth and defense systems (Orr et al., 2022).

Conclusion

nitrogen fertilization enhanced vegetative growth of banana plants under pathogen-free conditions. However, in Foc-infected plants, increasing nitrogen rates—particularly at high levels—exacerbated disease development. High nitrogen rates ($400\text{--}550 \text{ kg ha}^{-1} \text{ year}^{-1}$) accelerated symptom appearance, indicated by shorter incubation periods, and increased disease severity. In contrast, a moderate nitrogen rate ($250 \text{ kg ha}^{-1} \text{ year}^{-1}$) delayed symptom development and reduced disease severity, although it did not prevent infection. These findings suggest that excessive nitrogen fertilization increases Fusarium wilt severity, while moderate nitrogen application may help suppress disease progression. Therefore, nitrogen management in Fusarium wilt–endemic banana production areas should prioritize moderate nitrogen rates and avoid excessive fertilization as part of an integrated and sustainable disease management strategy.

Declaration

Author contribution

Zulfahri Arifandi is the main contributor to this paper. Jumjunidang as corresponding author, Chrisnawati, Aulia Meyuliana, Riska contributed as co-authors. All authors read and approved the final manuscript.

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Competing interest

The authors declare that there are no financial or personal relationships that could have influenced the work reported in this article.

References

- Anwar K. 2014. Ameliorasi dan pemupukan untuk meningkatkan produktivitas kedelai di lahan gambut. Dalam: Prosiding Seminar Nasional Inovasi Teknologi Pertanian Spesifik Lokasi. Banjarbaru: 6–7.
- Ariyani NI. 2020. Karakter agronomi dan satuan panas padi varietas unggul pada berbagai dosis nitrogen di lahan pasang surut. *Enviro Scienceae* 16(1): 1–10. DOI: 10.20527/es.v16i1.9005
- Balai Penelitian Tanah. 2021. Rekomendasi pupuk N, P, dan K untuk tanaman hortikultura. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian.
- Buddenhagen IW. 1990. Banana breeding and fusarium wilt. In RC Ploetz (ed.). *Fusarium wilt of banana*. 107–113. APS Press. St. Paul.
- Chen A, T-Y Chou, Y Chen, SMA Fallatah, J Anderson, J Sun, H Cosgrove, S Gao, BJ Ferguson, A Soper, DM Gardiner, EAB Aitken. 2024. Histological dissection of Fusarium–banana interaction using a GFP-tagged subtropical race 4 strain of *Fusarium oxysporum* f. sp. *cubense* on banana cultivars with differing levels of resistance. *Microorganisms* 12(12): 2472. DOI: 10.3390/microorganisms12122472
- Devadas R, S Simpfendorfer, D Backhouse, DW Lamb. 2014. Effect of stripe rust on the yield response of wheat to nitrogen. *The Crop Journal* 2(4): 201–206. DOI: 10.1016/j.cj.2014.05.002
- Dita M, M Barquero M, D Heck, ESG Mizubuti, Staver CP. 2018. Fusarium wilt of banana: Current knowledge on epidemiology and research needs toward sustainable disease management. *Frontier Plant Science* 9: 1468. DOI: 10.3389/fpls.2018.01468
- Food and Agriculture Organization of the United Nations (FAOSTAT). 2023. World food and agriculture statistical yearbook 2023. Accessed in September 2025.
- Handayani T, D Martanti, YS Poerba, Witjaksono. 2018. Deteksi awal ketahanan beberapa aksesori pisang lokal dan hasil persilangan terhadap penyakit layu fusarium (Foc VCG 01213/16 TR4). *Jurnal Hortikultura Indonesia* 8(2): 88–96. DOI: 10.29244/jhi.8.2.88-96
- Hardini LP, SN Sulistyowati, R Febriyanti. 2022. Pelatihan pengolahan makanan dari buah pisang pada anggota Karangtaruna Desa Kesamben. *Selaparang: Jurnal Pengabdian Masyarakat Berkemajuan* 6(2): 883–890. DOI: 10.31764/jpmb.v6i2.8323
- Hermanto C, A Sutanto, Jumjunidang, HS Edison, JW Danniels, WT O’Neil, VGO Sinohin, AB Molina, P Taylor. 2011. Incidence and distribution of fusarium wilt disease in Indonesia. in: I Van den Bergh, M Smith, R Swennen, C Hermanto (eds.). *Proceedings international ISHS-Promusa symposium on global perspective on Asian challenges*. *Acta Horticulturae* 897: 313–322.
- Huang Y, B Gao, C Long, Y Wang, L Long, F Yang. 2024. The growth and nitrogen utilization strategies in two dominant Symbiodiniaceae species facing nitrogen deficiency and enrichment. *Algal Research* 84: 103772. DOI: 10.1016/j.algal.2024.103772
- Hwang SC, WH Ko. 2004. Cavendish banana cultivars resistant to fusarium wilt acquired through somaclonal variation in Taiwan. *Plant Disease* 88(6): 580–588. DOI: 10.1094/PDIS.2004.88.6.580
- Ishak I, Jumjunidang. 2024. Morphological characterization and fusarium wilt resistance of triploid banana mutant line (*Musa acuminata* cola). *AGRIVITA Journal of Agricultural Science* 46(1): 121–133. DOI:10.17503/agrivita.v46i1.3900
- Jumjunidang, Riska. 2011. Respon ketahanan pisang varietas Ketan 01 dan Barangan di lahan endemis Foc VCG 01213/16 (TR4). In: *Prosiding Seminar Nasional Program dan Strategi Pengembangan Buah Nusantara*. Solok: 204–211.

- Kusumah FMW, A Ismail, A Karuniawan, VF Pratiwi, AD Safitria. 2023. Pola penyebaran varietas pisang roid (*Musa* spp.) lokal Jatigede di Kecamatan Jatigede Kabupaten Sumedang. *Paspalum: Jurnal Ilmiah Pertanian* 11(2): 355–360. DOI. 10.35138/paspalum.v11i2.629
- Lee MH, HS Jeon, SH Kim, JH Chung, D Roppolo, HJ Lee, HJ Cho, Y Tobimatsu, J Ralph, OK Park. 2019. Lignin-based barrier restricts pathogens to the infection site and confers resistance in plants. *The EMBO Journal* 38: e101948. DOI. 10.15252/embj.2019101948
- Li Z, B Xu, T Du, Y Ma, X Tian, F Wang, W Wang. 2021. Excessive nitrogen fertilization favors the colonization, survival, and development of *Sogatella furcifera* via bottom-up effects. *Plants* 10(5): 875. DOI. 10.3390/plants10050875
- Li Z, Y Jiao, J Yin, B Wang, K Zhang, X Zheng, Y Hong, H Zhang, C Xie, Y Li, Y Duan, Y Hu, Z Zhu, Y Liu. 2021. Productivity and quality of banana in response to chemical fertilizer reduction with bio-organic fertilizer: insight into soil properties and microbial ecology. *Agriculture Ecosystems and Environment* 322: 107659. DOI. 10.1016/j.agee.2021.107659
- Maryani N, L Lombard, YS Poerba, S Subandiyah, PW Crous, GHJ Kema. 2019. Phylogeny and genetic diversity of the banana fusarium wilt pathogen *Fusarium oxysporum* f. sp. *cubense* in the Indonesian centre of origin. *Studies in Mycology* 92: 155–194. DOI. 10.1016/j.simyco.2018.06.003
- Mostert D, AB Molina, J Daniells, G Fourie, C Hermanto, CP Chao, E Fabregar, VG Sinohin, N Masdek, R Thangavelu, C Li, G Yi, L Mostert, A Viljoen. 2017. The distribution and host range of the banana fusarium wilt fungus *Fusarium oxysporum* f. sp. *cubense* in Asia. *PLoS One* 12(7): e0181630. DOI. 10.1371/journal.pone.0181630
- Mur LA, C Simpson, A Kumari, AK Gupta, KJ Gupta. 2017. Moving nitrogen to the centre of plant defence against pathogens. *Annals of Botany* 119(5): 703–709. DOI. 10.1093/aob/mcw179
- Nainggolan EP, PB Hastuti, WDU Parwati. 2016. Pengaruh jumlah benih dan dosis pupuk N terhadap pertumbuhan dan hasil jagung manis. *Jurnal Agromast* 1(2): 1–10. DOI. -
- Nasir N, Jumjunidang. 2003. Karakterisasi ras *Fusarium oxysporum* f. sp. *cubense* dengan metode vegetative compatibility group test dan identifikasi kultivar pisang yang terserang. *Jurnal Hortikultura* 13(4): 276–284. DOI. 10.21082/jhort.v13n4.2003.p276-284
- Orr R, PG Dennis, Y Wong, DJ Browne, M Cooper, HW Birt, HRL Gaza, AB Pattison, PN Nelson. 2022. Nitrogen fertilizer rate but not form affects the severity of fusarium wilt in banana. *Frontiers in Plant Science* 13: 907819. DOI. 10.3389/fpls.2022.907819
- Pandiangan DN, A Rasyad. 2017. Komponen hasil dan mutu biji beberapa varietas tanaman kedelai (*Glycine max* (L.) Merrill) yang ditanam pada empat waktu aplikasi pupuk nitrogen. *JOM Faperta* 4(2): 1–14. DOI. -
- Ploetz RC. 2015. Fusarium wilt of banana. *Phytopathology* 105(12):1512–1521. DOI. 10.1094/PHYTO-04-15-0101-RVW
- Rocha ADJ, MDS Ferreira, LDS Rocha. 2020. Interaction between *Fusarium oxysporum* f. sp. *cubense* and *Radopholus similis* can lead to changes in the resistance of banana cultivars to fusarium wilt. *European Journal of Plant Pathology* 158:403–417. DOI. 10.1007/s10658-020-02081-y
- Rolanda IA, AZ Arifin, S Sulistyawati. 2021. Pengaruh pemberian dosis pupuk nitrogen terhadap pertumbuhan dan hasil tanaman sawi pahit (*Brassica juncea* L.). *Jurnal Agroteknologi Merdeka Pasuruan* 5(2): 1–6. DOI. -
- Sharma S. 2020. Impacts of nitrogen on plant disease severity and plant defense mechanism. *Fundamental and Applied Agriculture* 5(3): 303–314. DOI. 10.5455/faa.103334
- Siamak SB, S Zheng. 2018. Banana fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*) control and resistance, in the context of developing wilt-resistant bananas within sustainable production systems. *Horticultural Plant*

- Journal 4(5):208–218. DOI. 10.1016/j.hpj.2018.08.001
- Sulyanti E, T Habazar, EF Husin, N Nasir, A Dharma. 2018. Evaluation of indigenous *Pseudomonas fluorescens* isolates from healthy banana rhizospheres on endemic area of fusarium wilt for controlling fusarium wilt. Jurnal Proteksi Tanaman (Journal of Plant Protection) 2(2): 87–96. DOI. 10.25077/jpt.2.2.87-96.2018
- Sun Y, M Wang, LAJ Mur, Q Shen, S Guo. 2020. Unravelling the roles of nitrogen nutrition in plant disease defences. International Journal of Molecular Sciences 21(2): 572. DOI. 10.3390/ijms21020572
- Sutriana S. 2025. Keanekaragaman genetik tanaman pisang (*Musa* sp.) di Indonesia: pendekatan molekuler dan implikasinya untuk konservasi dan pemuliaan. Jurnal Ilmiah Multidisiplin Amsir 3(2): 139–145. DOI. 10.62861/jimat%20amsir.v3i2.625
- Tando E. 2019. Upaya efisiensi dan peningkatan ketersediaan nitrogen dalam tanah serta serapan nitrogen pada tanaman padi sawah (*Oryza sativa* L.). Buana Sains 18(2): 171–180. DOI. 10.33366/bs.v18i2.1190
- Warman NM, EAB Aitken. 2018. The movement of *Fusarium oxysporum* f.sp. *cubense* (Sub-Tropical Race 4) in susceptible cultivars of banana. Frontier Plant Science 9: 1748. DOI. 10.3389/fpls.2018.01748
- Yan X, S Guo, K Gao, S Sun, C Yin, Y Tian. 2023. The impact of the soil survival of the pathogen of fusarium wilt on soil nutrient cycling mediated by microorganisms. Microorganisms 11: 2207. DOI. 10.3390/microorganisms11092207
- Yang XD, K Ni, YZ Shi, XY Yi, QF Zhang, L Fang, LF Ma, J Ruan. 2018. Effects of long-term nitrogen application on soil acidification and solution chemistry of a tea plantation in China. Agriculture, Ecosystems & Environment 252(5):74–82. DOI. 10.1016/j.agee.2017.10.004.
- Zakaria MAK, ZS Sakimin, MR Ismail. 2024. Growth enhancement and resistance of banana plants to fusarium wilt disease as affected by silicate compounds and application frequency. Plants 13(4): 542. DOI. 10.3390/plants13040542
- Zhang W, L Wu, Y Ding, X Yao, X Wu, F Weng, G Li, Z Liu, S Tang, C Ding, S Wang. 2017. Nitrogen fertilizer application affects lodging resistance by altering secondary cell wall synthesis in japonica rice (*Oryza sativa*). Journal of Plant Research 130: 859–871. DOI. 10.1007/s10265-017-0943-3

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