J. Trop. Plant Pests Dis.
Vol. 25, No. 2, September 2025
Pages: 298–308

ISSN: 1411-7525
E-ISSN: 2461-0399
DOI : 10.23960/j.hptt.225298-308

RESEARCH PAPER

Epidemiology of banana bunchy top disease in South Sumatra, Indonesia

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Manuscript received: 29 November 2024. Revision accepted: 27 February 2025. Available online: 28 July 2025.

ABSTRACT

Banana bunchy top disease has become increasingly important in South Sumatra. The disease, caused by *Banana bunchy top virus* (BBTV), leads to severe losses as infected plants fail to produce fruit. The virus is transmitted in a persistent manner by banana aphid, *Pentalonia nigronervosa*. Both nymphs and adults of the aphid can transmit the virus, with adults being more efficient vectors than nymphs. The threat of the disease in the province has been escalating, as indicated by the significant rise in the number of infected banana plants in the recent years. However, no epidemiological study had been conducted prior to this research. This study aimed to identify and evaluate the contributing factors to the epidemic of banana bunchy top disease in South Sumatra. A survey was conducted to assess the banana cropping system and all aspects contributing to the disease's epidemiology in the province. Thirteen regencies were surveyed using a purposive sampling method, covering 11 regencies and 3 cities selected based on the accessibility of banana plantations by transportation routes. In each site, banana plants within an imaginary 50-meter diameter circle centered on an infected plant were sampled. The result showed that the BBTV epidemic was influenced by several factors: (1) banana genome, with diploid AA and triploid AAA cultivars being more resistant than those containing the B genome; (2) cropping system, with higher disease prevalence in mixed-cropping systems than in monoculture; (3) botanical environment, where the presence of alternative hosts of *P. nigronervosa* correlated with higher disease incidence; (4) farmer behavior, with lack of concern or action against the disease contributing to its spread; and (5) transportation access, with higher incidence observed in areas closer to roads.

Key words: banana bunchy top, epidemiology, *Pentalonia nigronerosa*

INTRODUCTION

Banana is a highly demanded fruit worldwide, consumed as both dessert and a cooking banana. Most banana cultivars originated from two subspecies: *Musa acuminata* and *M. balbisiana*. The currently well-known cultivars are hybrids of *M. acuminata* or between *M. acuminata* and *M. balbisiana*. A lettering system is used to indicate cultivar genomes, where hybrid diploids of *M. accuminata* are denoted as genome AA, hybrid diploids of *M. balbisiana* as BB, and hybrids between *M. acuminata* and *M. balbisiana* as AB. Hybrid triploids are designated as AAA, AAB, ABB, or BBB (Ploetz et al., 2007).

Although bananas are very popular and consumed globally, they are a tropical crops grown in over 130 countries and are considered among the most highly demanded food crops in the world, alongside wheat, rice, and maize (Stainton et al., 2015). There are many dessert and cooking banana cultivars available (Hapsari et al., 2022), but farmers tend to cultivate the most common and marketable ones. Marketable cultivars are those with a preferred flavor, good taste, high juice quality, and strong market price (Ploetz et al., 2007).

Banana production has been threatened by Banana Bunchy Top Disease (BBTD), one of the most devastating banana diseases, causing severe crop losses in many banana-growing countries, as infected plants produce no or unmarketable fruits (Rybicki, 2015). The disease is caused by *Banana bunchy top virus* (BBTV), a member of the *Nanoviridae* family. The virus is transmitted by the banana aphid, *Pentalonia nigronervosa* Coq., in a persistent and circulative manner (Poorani et al., 2023). It is termed "circulative" because it is retained in the vector even after molting. The viral particles first localize to the anterior midgut, where they accumulate at higher concentrations than in either the hemolymph or the principal salivary glands (Di Mattia et al., 2020). The virus can be acquired within a minimum acquisition period of 4 hours and transmitted within an inoculation period of 15 min (Watanabe et al., 2013).

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Nymphs of *P. nigronervosa* go through four instars to become adults in 11 to 13 days. Both nymphs and adults are capable of transmitting the virus, although adults transmit the virus more efficiently (Balqis et al., 2023). After a pre-nymphiposition period of 3.0 to 6.0 days, a female banana aphid can produce 20 to 35 nymphs over a lifespan of 35 to 48 days (Basak et al., 2015). *P. nigronervosa* prefers to colonize banana (*Musa* spp.) and is thus called the banana aphid. However, it also colonized various plants species in the Musaceae, Zingiberaceae, and Araceae families (Foottit et al., 2010). The presence of alternative or minor hosts plants for *P. nigronervosa* increases the efficiency of disease spread and complicates control efforts. These minor hosts include ginger lily (*Alpinia purpurata*), taro (*Colocasia esculenta*), dumbcanes (*Dieffenbachia*), cardamom (*Elettaria cardamomum*), cocoyam (*Xanthosoma*), ornamental banana (*Heliconia*), and ginger (*Zingiber officinale*) (Cheraghian, 2013).

When infesting banana mats, *P. nigronervosa* prefers young suckers over mother plant, forming colonies around the base of the pseudostems. These colonies attract ants that build nests nearby and feed on the large quantities of honeydew excreted by the aphids. The presence of ants around aphid colonies significantly reduces the density of indigenous predators by protecting the aphids within their nests. Ants also facilitate the spread of aphids from plant to plant, leading to new infestations (Stechmann et al., 1996; Wellings et al., 1994). Herwina et al. (2013) reported that many ant species associate with banana aphids in a mutualistic relationship, with both parties benefiting. Biale et al. (2017) found that ant nests at the base of banana mats reduced the presence of 17 species of natural enemies of banana aphids, belonging to the Syrphidae, Cecidomyiidae, and Coccinellidae families. Therefore, farmers are advised to dismantle ant nests as part of integrated aphid control.

P. nigronervosa has been managed using various methods, including insecticide. However, due to the negative impacts of chemical pesticides, researchers and farmers are moving toward reducing insecticide use and enhancing biological control through natural enemies (Ahmad et al., 2024). Several natural enemies of banana aphids have been identified, including the parasitoids *Aphidius colemani* and *Endaphis maculans*, which were reported to attack *P. nigronervosa* in Hawaii. However, the level of parasitism in banana plantations was low, and there is little evidence that these parasitoids can effectively control *P. nigronervosa* in the field (Van Elsen et al., 2003). Wellings et al. (1994) and Tricahyati et al. (2022) speculated that ant colonies might prevent parasitoid access to aphid colonies, or that these parasitoids may prefer other aphid species. Another parasitoid, *A. transcaspicus,* has also been reported to attack *P. nigronervosa* (Wang & Messing, 2006), and may have potential as a biological control agent, although further field release studies are needed.

The incidence of BBTD in South Sumatra has been increasing, posing a serious threat to the local banana industry. The threat is compounded by the fact that many farmers are unaware of the disease's severity (Abiola et al., 2020). Infected banana plants are common in the field, yet *P. nigronerosa* is often absent from these mats, while the aphid is frequently found infesting healthy banana plants (Suparman et al., 2011). Similarly, Niyongere et al. (2012) found no significant correlation between the incidence of BBTD and the presence of the banana aphid in the field. They suggested that the fluctuations in the population of winged adults may explain the weak correlation between disease incidence and its vector.

This research was conducted to investigate the factors affecting the development and spread of BBTD in South Sumatra and to use the resulting epidemiological data to formulate locally specific disease control measures.

MATERIALS AND METHODS

Research Site. The study on BBTD epidemiology was conducted in South Sumatra, Indonesia, in 2024. The research covered 11 regencies—Ogan Ilir, Ogan Komering Ilir, OKU Timur, OKU Sekatan, OKU Induk, Muara Enim, PALI, Lahat, Banyuasin, Musi Rawas, and Musi Banyuasin—and three cities: Palembang, Prabumulih, and Pagar Alam. The selection of the sampled regencies and cities was based on the intensity of banana cultivation in each area.

Sampling Method. Banana plants were sampled using a purposive sampling method. A 50-m radius imaginary circle was established, with a banana plant showing typical BBTD symptoms as the center point (Figure 1). GPS was used to record the location and altitude of both banana healthy and infected banana plants. Additional sampling circles were created with a minimum distance of 100 m between the center points of two consecutive sampling sites.

To examine the effect of proximity to transportation routes on disease spread, the observed areas were divided into two categories: Near= up to 100 m from a transportation route, while distant= more than 100 m from a transportation route. Transportation routes considered in this study were those accessible by vehicles with four or more wheels.

Epidemiological Survey and Farmer Interviews. An epidemiological survey was conducted to gather data on banana cropping system, crop management practices, cultivars selection, pests and disease management, and other factors influencing BBTD development and spread. Within each imaginary circle, all banana cultivars were examined to collect data on: cultivar name, genome type, presence of BBTD symptoms, and presence of *P. nigronervosa* colonies.

Structured interviews were conducted with farmers responsible for each sampled field. Information collected included: origin of planting materials, reasons for cultivar selection, crop management practices, response to infected plants, farmer awareness and perceptions of BBTD.

Interviews were conducted using a standardized questionnaire. A total of 214 banana fields were surveyed, and the same number of farmers were interviewed. Only landowners were interviewed. In addition to interviews, visual observations were made to assess the cropping system, field conditions, and surrounding vegetation.

Disease Diagnosis and Incidence Measurement. BBTD diagnosis was conducted through visual inspection based on typical symptoms, including: 1) Morse code-like streaks on leaf lamina, midrib, and petiole; 2) Bunchy top appearance of the banana plant. Disease incidence (DI) in each sampling unit was calculated using the following formula (Rahayuniati et al., 2021):

$$DI = \frac{n}{N} \times 100\%$$

DI = Disease incidence;
n = Number of banana plant infected by BBTV in the sampled area;
N = Total number of banana plants in the sampled area.

Disease severity was not measured, as infected banana plants, regardless of severity, eventually showed similar symptoms and failed to recover.

Cultivar Susceptibility Assessment. To determine the level of susceptibility of different banana cultivars to BBTV infection, disease frequency (DF) was calculated:

$$DF = \frac{m}{M} \times 100\%$$

DF = Disease frequency of BBTD on certain banana cultivar;
m = Number of BBTV-infected banana plants of a given cultivar;
M = Total number of banana plants of that cultivar in the sampled area.

Based on the frequency, cultivar susceptibility was categorized (modified from Sanap et al., 2020) as follows Table 1.

Identification of Alternative Hosts and Natural Enemies. Field observation focused on identifying: 1) Plants species potentially acting alternative host for *P. nigronervosa*, 2) Natural enemies associated with the banana aphid. Samples of Zingiberaceae and Araceae plants found near banana mats were collected for laboratory testing.

Laboratory Experiment on Host Suitability. A laboratory experiment was conducted to evaluate the suitability of collected Zingiberaceae and Araceae species as alternative hosts for *P. nigronervosa*. The

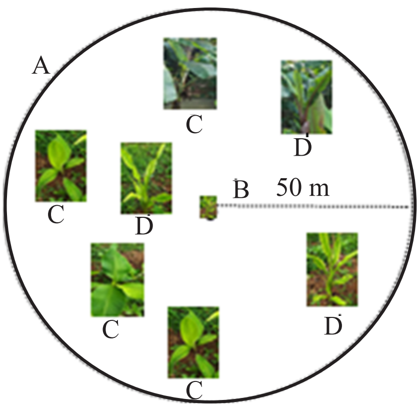

Figure 1. Illustration of the sampling method. A. Imaginary circle; B. Radius of the imaginary circle; C. Healty banana plant; D. Infected banana plant.

steps were as follows: 1) Infestation: Five wingless adults aphids were introduced to each plant species inside an aphid-proof cage (a wooden box covered with cheesecloth on all sides except the bottom), 2) Transfer: Aphids were carefully transferred using a moistened paintbrush, 3) Conditions: All cages were maintained in an air-conditioned insectarium at 25 ^{o}C ± 5 ^{o}C, 4) Assessment: After 7 weeks, the number of surviving aphids was counted to assess plant suitability.

Data Analysis. Quantitative data such as disease incidence and frequency were analyzed descriptively to compare patterns of BBTD distribution across locations and cultivars. Disease frequency values were used to classify the level of susceptibility of each banana cultivar.

RESULTS AND DISCUSSION

Banana Cultivars in South Sumatra. Most bananas cultivated in South Sumatra were local cultivars. Farmers had limited cultivars options due to the lack of a formal market for banana planting materials. Planting materials were typically obtained from older mats on their own farms or were freely shared by neighboring farmers, leaving little room for cultivar selection. As a result, the expansion of banana cultivation did not reflect farmer preferences but rather mirrored the dominant cultivar in each area. This situation led to limited changes in cultivar composition over time. This contrasts with the findings of Ploetz et al. (2007), who noted that people generally tend to cultivate the most common and marketable cultivars.

In South Sumatra, eight dessert banana cultivars and six cooking banana cultivars were frequently encountered. The dessert cultivars, from most to least frequent, were: *Pisang Putri* (Lady Finger, AA), *Pisang Mas* (Sucrier, AA), *Pisang Ambon Hijau* (Cavendish Williams, AAA), *Pisang Ambon Lumut* (False Lacatan, AAA), *Pisang Barangan* (Lacatan, AAA), *Pisang Badak* (Dwarf Cavendish, AAA), *Pisang Udang* (Red, AAA), and *Pisang Raja* (Custard Apple, AAB). The six cooking banana cultivars, ranked by frequency, were: *Pisang Lilin* (Lilin Jambi, AAB), *Pisang Raja Sereh* (Silk, AAB), *Pisang Nangka* (Ducasse, AAB), *Pisang Kepok* (Cardaba, BBB), and *Pisang Tanduk* (True Horn, AAB). Although *Pisang Raja* contains genome B, it is categorized as a dessert banana (Hapsari et al., 2022).

Banana Bunchy Top Incidence. BBTD was found in all surveyed regencies and cities across different cropping system. The disease affected all dessert banana cultivars with varying levels of frequency, while infections were rare among cooking banana cultivars.

The overall incidence of BBTV infection was low, with the highest frequency observed in *Pisang Putri* (3.72%), followed by *Pisang Mas* (2.19%). This low incidence was likely due to the widespread cultivation of BBTV-tolerant cultivars in many sampled plots. However, the presence of susceptible cultivars created epidemiological hotspots, especially where those cultivars were cultivated intensively.

For example, *Pisang Putri* was predominantly grown in Ogan Ilir Regency, where BBTV infections appeared in clusters. Similarly, *Pisang Mas*, preferred by farmers in Ogan Komering Ilir, had the second-highest disease incidence.

Based on susceptibility categories defined in this study, the results were as follows: Highly susceptible: *Pisang Putri* (34.18%), Susceptible: *Pisang Mas* (20.45%), Moderately susceptible: *Pisang Uli* (15.50%) and *Pisang Udang* (10.38%), Less susceptible: *Pisang Badak* (8.45%), *Ambon Hijau* (4.30%), *Ambon Lumut* (3.70%), *Barangan* (3.20%), *Kepok* (2.40%), and *Tanduk* (0.90%), Resistant (0% infection): *Pisang Raja, Raja Sereh* and *Nangka* (Table 2).

Diagnosis of BBTD was based on typical symptoms, including Morse-code-like streaks on veins, midribs, and petioles; upright and bunched leaves at the plant apex; yellowing of leaf margins; and dwarfing (Hooks et al., 2008). No differences in symptom development were noted among cultivars

Table 1. Classification of banana cultivar susceptibility to Banana Bunchy Top Virus (BBTV) based on disease frequency.

Disease frequency (%)	Susceptibility Category
> 30	Highly susceptible
21–30	Susceptible
11–20	Moderately susceptible
1–10	Less susceptible
0	Resistant

with different genome compositions.

As shown in Table 2, cultivars with only genome A (AA or AAA) were generally more susceptible, while those with genome B (AAB or BBB) were more tolerant. Notably, *Pisang Kepok* (BBB) and *Pisang Tanduk* (AAB) were among the few genome cultivars showing minor infection.

Symptoms of the disease varied among cultivars; the severity of symptoms appeared to indicate the level of host susceptibility. Not all cultivars exhibited advanced symptoms such as acute chlorosis and necrosis along the leaf margins. Cultivars showing advanced disease symptoms were typically those with a high incidence of bunchy top in the field, whereas cultivars with mild symptoms were less frequently infected. Infection of banana bunchy top virus in cultivars containing genome B generally resulted in mild symptoms, including a bunchy appearance with wider leaves and no visible chlorosis or necrosis on the infected leaves (Figure 2).

Role of Transportation and Spatial Distribution. BBTD was frequently observed in backyard gardens and areas near transportation routes. This suggests that human activities play a crucial role in BBTV spread —either directly (through the planting of infected suckers) or indirectly (by transporting viruliferous aphids via vehicles). This role was clearly reflected in the higher disease frequency observed in areas near (<100 m) versus far (>100 m) from roads (Table 3).

Table 3 shows a typical pattern of disease distribution, clearly indicating that banana bunchy top disease develops more frequently in areas close to transportation routes. The role of transportation in the long-distance spread of BBTV infection is supported by the difference in the number of imaginary-circle sample plots, which were based on symptomatic plants used as the center points. The total number of sample plots near transportation routes was 445, which was significantly higher than the 181 plots located farther from transportation (Table 2). The spread of BBTV via transportation may occur either through the movement of infected banana suckers or planting materials (Niyongere et al., 2012), or incidentally through the transfer of viruliferous aphid vectors from infested to non-infested areas.

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Farmers' Perception of Banana Bunchy Top Disease. Interviews with 214 farmers revealed that most cultivated bananas not for commercial purposes, but for personal or family use. Farmers preferred certain cultivars, but due to limited availability, they often planted whatever suckers were accessible, typically from their own fields or neighbors.

Table 2. Distribution of banana bunchy top disease among banana cultivars in South Sumatra

No.	Banana cultivar and its genome	Number of symptomatic banana plants	Disease incidence (%)	Number of banana sampled	Disease frequency (%)	Presence of banana aphid
1	*Pisang Putri* (Lady Finger, AA)	214	3.72	626	34.18	7/214
2	*Pisang Mas* (Sucrier, AA)	126	2.19	616	20.45	5/126
3	*Pisang Ambon Hijau* (Cavendish Williams, AAA)	27	0.47	628	4.30	0
4	*Pisang Ambon Lumut* (False Lacatan, AAA)	18	0.31	486	3.70	0
5	*Pisang Barangan* (Lacatan, AAA)	11	0.19	458	2.40	0
6	*Pisang Badak* (Dwarf Cavendish, AAA)	53	0.92	627	8.45	3/53
7	*Pisang Udang* (Red, AAA)	65	1.13	626	10.38	2/65
8	*Pisang Raja* (Custard Apple, AAB)	0	0	316	0.00	0
9	*Pisang Uli,* (Muli, AA)	97	1.69	626	15.50	0
10	*Pisang Raja Sereh* (Silk, AAB)	0	0	342	0.00	0
11	*Pisang Nangka* (Ducasse, AAB)	0	0	167	0.00	0
12	*Pisang Kepok* (Saba, ABB)	4	0.07	125	3.20	0
13	*Pisang Tanduk* (True Horn, AAB)	1	0.02	111	0.90	0
Total		626		5754		

Figure 2. Infection of banana bunchy top virus in. A. *Pisang Tanduk*; B. *Pisang Mas*.

Table 3. Distribution of banana bunchy top disease among regencies in South Sumatra, grouped by proximity to transportation routes

No	Regency	Number of BBTV symptomatic plant (plant)			Number of plots sampled (plots)	Number of banana plant (plants)
		Near transportation means*	Distant to transportation means**	Total		
1	Palembang	27	12	39	15	578
2	Ogan Ilir	63	14	77	23	514
3	Ogan Komering Ilir	35	15	50	19	403
4	OKU Timur	27	11	38	13	351
5	OKU Selatan	23	9)	32	13	347
6	OKU Induk	36	12)	48	21	527
7	Muara Enim	43	14)	57	22	579
8	PALI	24	7	31	12	325
9	Lahat	67	33	100	28	623
10	Pagar Alam	0	0	0	0	0
11	Prabu Mulih	32	18	50	14	397
12	Banyu Asin	36	15	51	16	674
13	Musi Banyuasin	32	21	53	18	436
Total	Total	445	181	626	214	5754

* = up to 100 m rom the transportation means; ** = 100 m from the transportation means and beyond.

Banana were typically in mixed cropping systems with minimal maintenance. Most farmers were unaware of BBTD and its effects, even when the disease caused dwarfing and fruitlessness. Despite yield losses, few took action to manage the disease. Infected plants were sometimes cut and left on-site as mulch, unaware that infected pseudostems could harbor BBTV-carrying aphids for extended periods (Suparman et al., 2023).

The presence of many infected banana plants in household yards (Figure 3) is also a strong indication of farmers' misperception about banana bunchy top disease. Interview results surprisingly revealed that many farmers deliberately planted diseased suckers for their visual appeal, without realizing that these plants eventually became sources of inoculum for nearby banana mats. The use of suckers from older mats or from other farmers is another risky practice, as these suckers may have already been infected with the bunchy top virus, even if symptoms had not yet appeared. This situation represents a case of an "enforced mistake," where farmers, faced with limited options and a lack of plant disease knowledge, unknowingly contribute to the spread of the disease. Under such conditions, the epidemic of banana bunchy top disease progresses unchecked, except by natural limiting factors.

Figure 3. Many BBTV infection symptomatic banana were found in the house yard.

Use of tissue-cultured, virus-fee planting material should be promoted. As Kakati & Nath (2019) emphasized, the use of uncertified local cultivars contributes significantly to BBTV spread.

Fertilization was also rare. Only a small number of commercial banana farmers (less than 5%)applied fertilizers. Most relied on banana residues as organic fertilizer, with no use of inorganic fertilizers. This nutrient deficiency likely weakened the plants and increased their susceptibility to BBTV (Mukwa et al., 2014). Yayla (2022) noted that traditional cultivation systems without proper inputs lead to pest outbreaks and reduced plant vigor.

Ecological Factors. Ecological factors influencing BBTV spread were closely tied to poor crop management. Infected plants were often ignored, enabling vector populations to grow and infections to cluster. Although P. nigronervosa is the sole known BBTV vector, it was only found in 17 out of 626 infected plants (Table 2). This suggests that the aphid prefers to colonize healthy banana suckers rather than diseased plants.

The aphids likely make brief visits to infected plants, responding to volatile organic compounds (Murhububa et al., 2024), before moving to healthier hosts. Even short feeding periods (15 mi) are sufficient for virus transmission (Suparman et al., 2023). Transmission efficiency can reach up to 70% (Pertiwi et al., 2022). While BBTV passes through the aphid body, it does not reproduce inside, though it may affect the aphid's physiology (Murhububa et al., 2023), including shortening of hind tibiae.

The minimum care given to banana plants and their environment had led to the uncontrolled growth of various plants species, creating a shrubby habitat. Relative humidity and temperature also can influence the development and growth of *P. nigronervosa* (Basak et al., 2015). During the dry season, from July to August in Burundi, the number of winged *P. nigronervosa* individuals was highest (Niyongere et al., 2013). Such conditions favor *P. nigronervosa* by providing suitable alternative hosts.

As reported by Foottit et al. (2010), minor or alternative hosts of *P. nigronervosa* belong to the families Musaceae, Zingiberaceae, and Araceae. During the survey, *P. nigronervosa* was difficult to located on both infected and non-infected banana plants. However, the survey also revealed that many zingiberaceous and araceous plants grow wild in the area, suggesting that the banana aphid may use them as alternative hosts. An experiment conducted to determine the suitability of these wild plants confirmed that some zingiberaceous and araceous species can serve as alternative hosts for *P. nigronervosa*, with varying levels of suitability (Table 4).

As seen in the Table 4, one zingiberaceous plant (*A. galanga*) and two species of araceous plants (*Caladium bicolour* and *T. flagelliforme*) are proved to be highly suitable alternative host of. *P. nigronervosa*. Unfortunately, the plants are among the predominant wild crops in the surveyed areas (Figure 3 and 4) , which could be responsible of the fast spreading of banana bunchy top virus in the field. Taro and cardamom also moderately suitable as alternative hosts, but cardamom less frequently cultivated in the surveyed areas. Other plant tested show low suitability as banana aphid host but the case might change under certain field conditions. The results of the experiment suggest that we have to pay more attention to the presence of *C. bicolor*, *T. flagelliforme, A. galanga, C. esculenta, A. compactum, C. domestica* and *C. zanthorrhiza* since

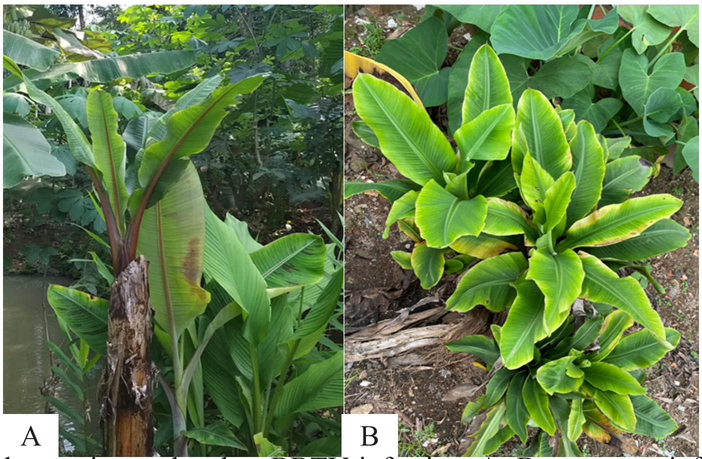

Figure 4. Typical field observations related to BBTV infection. A. Banana mat infected by BBTV, surrounded by Zingiberacerous plants (left); Araceous plant (right); B. Numerous banana plants showing BBTV infection symptoms found in a household yard.

Table 4. Suitability of zingiberaceous and araceous plants as alternative hosts of *Pentalonia nigronervosa*

No	Host name		Degree of suitability
	Scientific nama	Common name	
1	*Alpinia galanga*	Greater galangal	****
2	*Zingiber officinale*	Ginger	**
3	*Curcuma domestica*	Turmeric	***
4	*Curcuma zanthorrhiza*	Javanese ginger	***
5	*Zingiber zerumbet*	Bitter ginger	**
6	*Kaempferia galanga*	Aromatic ginger	*
7	*Canna edulis*	Edible canna	*
8	*Amomum compactum*	Round cardamom	***
9	*Etlingera elatior*	Torch ginger	**
10	*Colocasia esculenta*	Taro	***
11	*Caladium bicolor*	Angel wings	****
12	*Typhonium flagelliforme*	Rodent tuber	****

**** = Highly suitable; *** = Suitable, ** = Moderately suitable; * = Less suitable.

they are proved to be alternetive hosts of banana aphid with high and moderate suitability. The population development of *P. nigronerosa* in zingiberaceous and araceaous plants varied considerably indicating their suitability to the aphid. The aphid develop rapidly on highly suitable alternative host such as *A. galanga* and *C. bicolor* even though not as rapidly as when they develop on highly suitable banana plant (Figure 4).

CONCLUSION

The epidemiology of banana bunchy top disease in South Sumatra is very complex. The banana cultivation system and the farmers' behavior tend to support the development and spread of the disease. The lack of knowledge has caused farmers to be unaware of the dangers of banana bunchy top disease and to apply cultural practices that inadvertently favor the disease's development and spread. Minimal crop management has made the environment even more favorable for the disease and its vector, making it difficult to prevent and halt the bunchy top epidemic. The presence of various wild plants that serve as potential alternative hosts for *P. nigronervosa* complicates the problem further. Transportation means play an important role in the epidemic of banana bunchy top disease, and little can be done to overcome this challenge.

ACKNOWLEDGMENTS

Thanks you to the Directorate of Research, Technology, and Community Service, Directorate General of Higher Education, Research, and Technology, in accordance with the Implementation

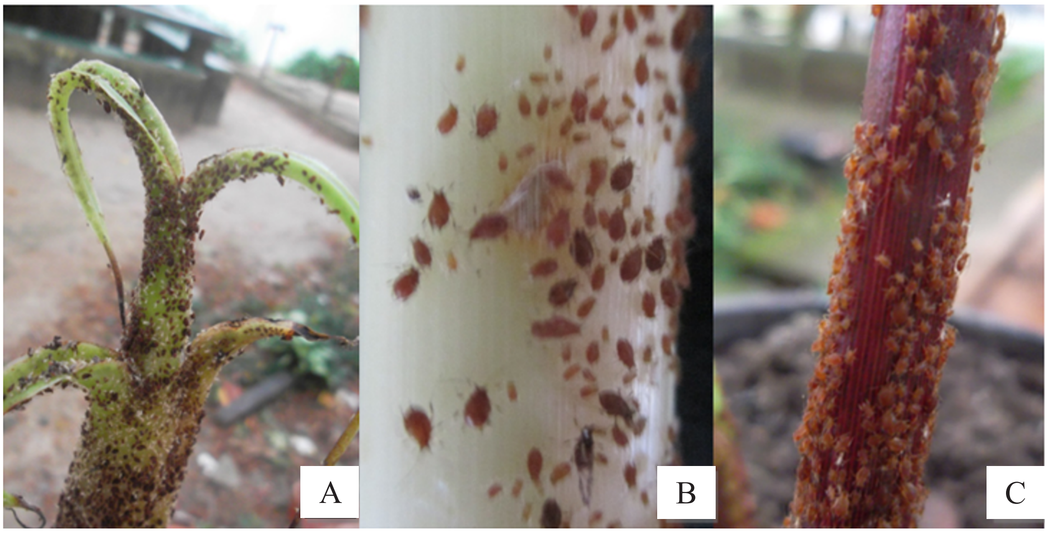

Figure 5. Population development of *Pentalonia nigronervosa.* A. True horn banana; B. *Alpinia galanga*; C. *Caladium bicolor*.

Contract for the State University Operational Assistance Program, Research Program Fiscal Year 2024, Number: 090/E5/PG.02.00.PL/2024.

FUNDING

The authors are grateful to the Ministry of Agriculture of the Republic of Indonesia for funding this studyunder contract Number: 830/Kpts/Kp.320/A/12/2020.

AUTHORS' CONTRIBUTIONS

A, as a Doctor of Agricultural Science student, conducted the research, wrote the manuscript, and managed the data. Suparman, Yulia Pujiastuti, and Chandra Irsan provided consultation, guidance, and direction. All authors have read and approved the final manuscript.

COMPETING INTEREST

This article is prepared as part of the requirements to complete the Dissertation.

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