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EFFECTIVENESS OF CITRONELLA (CYMBOPOGON NARDUS) EXTRACT IN CONTROLLING PESTS AND DISEASES ON SURI 4 SORGHUM IN THE DRYLANDS OF NORTH CENTRAL TIMOR

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Sorghum variety Suri 4 is an alternative food crop known for its adaptability to dryland conditions. However, its productivity is often constrained by pest and disease infestations. Lemongrass (Cymbopogon nardus) contains natural active compounds with potential as an environmentally friendly botanical pesticide. This study aims to examine the effects of various concentrations and application frequencies of lemongrass leaf extract on the growth, yield, and levels of pest and disease incidence in Suri 4 sorghum. The research was conducted in Lapeom Village, Insana Barat Subdistrict, North Central Timor Regency, using a two-factor Randomized Block Design (RBD). The first factor was extract concentration (0, 50, 75, and 100 g/l), and the second was spraying frequency (3, 5, and 7 times), resulting in 36 experimental units. Data were analyzed using analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. The results indicated that the application of 100 g/l lemongrass extract combined with seven sprayings yielded the best performance in enhancing plant growth and sorghum yield, while effectively reducing aphid infestation and leaf spot disease incidence. Thus, lemongrass extract is recommended as a biological control strategy in sorghum cultivation under dryland conditions.

Keywords: Botanical Pesticide, Cymbopogon Nardus, Pest Control, Suri 4 Sorghum

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is one of the cereal commodities that has been gaining attention due to its ability to grow in unfavorable environments such as dry areas with poor soil fertility (Putri, 2022). As a member of the Gramineae family, sorghum holds great potential for supporting food diversification in tropical and subtropical regions, especially as an alternative to rice in the face of climate change and food crises (Wahida et al., 2011). Its physiological advantages, such as efficient water use, drought tolerance, and adaptability to marginal lands, make sorghum suitable for development in areas like North Central Timor (TTU) Regency, East Nusa Tenggara (BPS TTU, 2014). Despite its many advantages, sorghum productivity in TTU remains low, averaging around 1 ton per hectare per planting season, far below its maximum potential yield of 5–7 tons/ha (Nurhayati, 2011). This low productivity is caused by various factors, one of which is pest and disease attacks, including soil-borne diseases and major pests that damage the vegetative and generative phases of the crop (Suswanto et al., 2018).

One of the most detrimental diseases is root rot caused by the fungal pathogen *Rhizoctonia solani*, which can survive in the soil as sclerotia or dormant mycelia and infect the plant from the seedling to the generative stage (Endang, 2017). Infection by this fungus leads to root tissue damage, characterized by wilting, stunted growth, chlorosis, and even death (Nurhayati, 2011). This pathogen is difficult to control due to its complex life cycle and long survival in the soil without a host (Suswanto et al., 2018). In addition to diseases, *Spodoptera frugiperda* (fall armyworm) poses a serious threat due to its ability to attack more than 100 plant species, including sorghum, maize, and rice

(Sharanabasappa et al., 2018). This polyphagous pest has a short life cycle, and a single female can lay 1,500–2,000 eggs during her lifetime, enabling rapid population explosions (Deshmukh et al., 2021). Symptoms of attack include perforated leaves, damaged growing points, and ear damage, which directly reduce yields (Ganiger et al., 2018; Hruska, 2019). In addition, aphids (Aphididae) are also significant vectors of plant viruses. These pests damage plants by piercing and sucking plant sap, disrupting growth and spreading viruses such as mosaic and yellowing viruses (Millatinassilmi, 2014; Pabbage et al., 2007). The combined attacks of pests and pathogens can accelerate crop damage and significantly reduce harvests (Saragih, 1994).

Synthetic pesticides such as Abamectin, Deltamethrin, and Beta-cyfluthrin remain the primary method of pest and disease control among farmers due to their practicality and immediate visible effects (Purwanto et al., 2009). However, long-term use of these pesticides can lead to pest resistance, population resurgence, soil and water contamination, and negative effects on human health and natural enemies (Ismail & Tenrirawe, 2011). Therefore, more sustainable and environmentally friendly pest control approaches are being developed, including the use of botanical pesticides derived from local plants (Orr & Suh, 2000). One promising plant for botanical pesticide production is citronella (*Cymbopogon nardus*). This plant is known for its essential oil content rich in active compounds such as citronellal, geraniol, and citronellol, which function as natural insecticides, repellents, and contact poisons against various pests (Susetyo et al., 2008; Bassolé & Juliani, 2011). These compounds disrupt insect nervous systems, inhibit feeding, or damage pest cell membranes (Anugrah, 2021). Research by Nopriansyah & Rustam (2023) demonstrated that citronella extract effectively reduced *Spodoptera exigua* populations in shallots, with a mortality rate of 77.5% at 100 g/L concentration. Anugrah (2021) also reported a repellency rate of up to 82% against *Tribolium castaneum*, a common postharvest pest. Moreover, Kotambunan et al. (2020) found that at a 40% concentration, citronella extract caused 93.3% larval mortality in *Crocidolomia pavonana*, a major cabbage pest.

In rice cultivation, botanical pesticides from citronella have also proven effective in reducing brown planthopper and grasshopper populations and improving vegetative growth (Telaumbanua et al., 2021). Additionally, Ningsih & Wahyuni (2016) found that citronella extract significantly killed black ants (*Dolichoderus thoracicus*), which are known as secondary pests in horticulture. The advantages of citronella-based botanical pesticides lie not only in their biological effectiveness but also in their eco-friendly nature, safety for humans, biodegradability, and affordability, as they can be locally produced (Bassolé et al., 2011). However, their effectiveness can be influenced by factors such as extract concentration, application timing, plant age, and microclimatic conditions in the field (Rahmawati, 2018). Therefore, further research is needed to determine the optimal dosage, stable formulation methods, and potential combinations with biocontrol agents such as *Trichoderma* spp. to synergistically control soil-borne pathogens like *Rhizoctonia solani* (Suswanto et al., 2018). If developed and widely applied, citronella-based botanical pesticides have the potential to become part of an integrated pest management (IPM) strategy aligned with the principles of sustainable agriculture in dryland areas like TTU and similar regions.

RESEARCH METHOD

This study aimed to evaluate the effectiveness of plant-based extract from citronella (*Cymbopogon nardus*) in controlling pests and diseases in Suri 4 sorghum variety. To support the implementation of the experiment, several primary materials were used, including Suri 4 sorghum seeds as the test crop, citronella extract as the active botanical pesticide, and manure as an organic soil amendment. The research was conducted from December 2023 to April 2024 in Lapeom Village, Insana Subdistrict, North Central Timor Regency, East Nusa Tenggara Province. This location was selected as it represents a typical dry tropical area and has historically been a site of sorghum cultivation by local communities. The climate and soil characteristics at the site are well-suited to testing the adaptability of sorghum and the effectiveness of biological control treatments. This study employed an experimental method using a Randomized Complete Block Design (RCBD) with two treatment factors, each consisting of multiple levels:

- The first factor was citronella extract concentration, with four levels:
  - V0: No treatment (control, 0 grams of citronella extract per liter of water),
  - V1: 50 grams per liter of water,
  - V2: 75 grams per liter of water,
  - V3: 100 grams per liter of water.
- The second factor was the frequency of extract application, also with three levels:
  - K1: Spraying three times during the growth period,
  - K2: Spraying five times,
  - K3: Spraying seven times.

The combination of these two factors resulted in 12 treatment combinations (e.g., V0K1, V0K2, V0K3, ... up to V3K3). Each combination was replicated three times, and each block consisted of 12 experimental plots, resulting in a total of 36 plots.

Observed Parameters

- The study measured both morphological and physiological variables, including:
- Plant height (cm)
- Number of leaves per plant
- Panicle length (cm)
- Fresh and dry weight of panicles (grams)
- Number of grains per panicle
- Dry weight of grains per panicle (grams)

Two primary indicators were used to assess treatment effectiveness:

1. Pest attack intensity
2. Disease incidence on sorghum plants

Pest attack intensity was measured by calculating the percentage of plant parts infested compared to the total observed, as formulated by Syahrawati et al. (2009).

All collected data were analyzed using Analysis of Variance (ANOVA) to determine the significance of treatment effects on each variable. If significant differences were found, the results were further analyzed using Duncan's Multiple Range Test (DMRT) at a 5% confidence level. This statistical approach follows the methodology described by Gomes & Gomes (2010), which is commonly used in agronomic research to ensure the validity and reliability of experimental results.

RESULTS AND DISCUSSION

Plant Height (cm)

There was a significant interaction between citronella extract concentration and spraying frequency on the height of Suri 4 sorghum plants, particularly during the early growth phase observed at 14, 28, and 42 Days After Planting (DAP). This finding indicates that the effectiveness of treatment depends not only on the amount of extract applied but also on how frequently the solution is sprayed onto the plants. The treatment combination of 100 grams of citronella extract per liter of water with seven spray applications proved to be the most optimal in increasing plant height at all three observation intervals. It is presumed that the high concentration and more frequent application effectively suppressed pest populations (plant-disturbing organisms), allowing the plants to undergo faster and more stable vegetative growth.

Table 1. Plant Height (cm)

Observation Time	Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
		3 times	5 times	7 times	
14 DAP	Control	18.44b	21.34ab	20.57ab	20.12
	50 grams	19.22ab	19.44ab	18.33b	19.00
	75 grams	19.56ab	19.78ab	20.11ab	19.82
	100 grams	20.89ab	21.89a	22.22a	21.67
	Average	19.53	20.61	20.31	(+)
28 DAP	Control	29.78b	32.89ab	35.22ab	32.63
	50 grams	32.89ab	28.78b	31.44ab	31.04
	75 grams	30.55ab	32.11ab	33.00ab	31.89
	100 grams	38.55a	35.55ab	36.67ab	36.92
	Average	32.94	32.33	34.08	(+)
42 DAP	Control	47.89bc	52.44abc	55.33abc	51.89
	50 grams	56.44abc	47.11c	49.88abc	51.14
	75 grams	51.22abc	54.00abc	52.67abc	52.63
	100 grams	60.33abc	61.45ab	62.44a	61.41
	Average	53.97	53.75	55.08	(+)
56 DAP	Control	85.11	91.45	99.00	91.85a
	50 grams	91.78	82.22	84.00	86.00a
	75 grams	77.99	77.22	101.78	85.66a
	100 grams	94.67	98.55	98.00	97.07a
	Average	87.39a	87.36a	95.70a	(-)
70 DAP	Control	132.33	134.11	141.45	135.96ab
	50 grams	139.56	148.89	136.22	141.56ab
	75 grams	135.66	127.56	133.78	132.33b
	100 grams	153.67	141.44	148.56	147.89a
	Average	140.31a	138.00a	140.00a	(-)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level ($\alpha = 0.05$) according to DMRT; (+) Indicates interaction between factors.

Observation Results

These findings align with the concept that plant pests and diseases (organisms harmful to plants/OPT), whether attacking plant tissues directly or indirectly, can inhibit the physiological activities of plants, such as photosynthesis and nutrient absorption. By reducing biotic stress from the early growth stages, plants are provided with a more stable environment to adapt and carry out optimal meristematic growth. From a physicochemical perspective, lemongrass (*Cymbopogon nardus*) is known to produce secondary metabolite compounds, particularly citronellal, citronellol, and geraniol, which possess natural insecticidal and repellent properties. Lemongrass essential oil contains active components that act as antibiosis agents—disrupting the nervous system of insect pests and inhibiting pathogenic microbial activity (Bassolé & Juliani, 2011; Susetyo et al., 2008). Therefore, the use of lemongrass extract as a botanical pesticide provides biological protection to plants from the early growth stages, which in turn promotes increased plant height. Interestingly, on the 56th and 70th days after planting, no significant interaction was observed between the two treatment factors. However, individually, the high concentration treatment (100 g/L) still resulted in the tallest plant growth compared to other treatments. This suggests that even though the interaction effect between frequency and concentration does not persist continuously, the cumulative effect of early treatments still provides growth benefits during the late vegetative phase.

More frequent spraying (7 times) also had a positive effect on plant height, although the effect tended to diminish once the plant entered the reproductive phase. This highlights that the timing of botanical pesticide application is crucial, especially during the early stages, which are critical for determining plant height and structural formation. These results are consistent with the study by Tahir et al. (2019), which stated that intensive application of botanical pesticides during the early growth phase of tomato plants could accelerate growth and increase plant height due to reduced thrips attacks. Another study by Sari et al. (2021) also supports that botanical pesticides effectively enhance the vegetative growth of long beans by significantly reducing armyworm infestation. Thus, it can be concluded that the application of lemongrass extract-based botanical pesticides has great potential in promoting plant height growth in sorghum, especially when applied at high concentrations and with sufficiently intensive spraying frequency. The application of botanical pesticides is not only environmentally friendly but also presents an efficient alternative approach for farmers to reduce reliance on synthetic chemical inputs.

Number of Leaves (Blades)

There was a significant interaction between lemongrass extract (*Cymbopogon nardus*) concentration and spraying frequency on the number of sorghum leaves, particularly on the 14th and 28th days after planting (DAP). The treatment combination of 100 grams per liter of water and a spraying frequency of 7 times resulted in the highest number of leaves during the early growth phase. This indicates that intensive and repeated application of lemongrass extract can create more optimal vegetative growth conditions. The increase in leaf number can be attributed to the reduced pressure from plant-disturbing organisms (OPT). Lemongrass extract, which contains active compounds such as citronellal and geraniol, is known to have insecticidal, antifungal, and antibacterial activities, thereby acting as a natural protector against insect and pathogen disturbances (Bassolé & Juliani, 2011; Susetyo et al., 2008). In a biotic stress-free environment, plants can undergo more optimal cell division and elongation, particularly in the meristematic tissues of the leaves.

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Table 2. Number of Leaves (Blades)

Observation Time	Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
		3 times	5 times	7 times	
14 DAP	Control	3.00b	3.11b	3.11b	3.07
	50 grams	3.44ab	3.00b	3.11b	3.18
	75 grams	3.33ab	3.22b	3.22b	3.26
	100 grams	3.22b	3.33ab	3.78a	3.44
	Average	3.25	3.17	3.31	(+)
28 DAP	Control	3.22ab	3.44ab	3.33ab	3.33
	50 grams	3.77a	3.33ab	3.11b	3.40
	75 grams	3.33ab	3.33ab	3.33ab	3.33
	100 grams	3.22ab	3.33ab	3.78a	3.44
	Average	3.39	3.36	3.39	(+)
42 DAP	Control	4.11	4.33	4.56	4.33a
	50 grams	4.22	4.11	4.00	4.22a
	75 grams	4.11	4.11	4.44	4.22a
	100 grams	4.56	4.33	4.56	4.37a
	Average	4.25a	4.22a	4.39a	(-)
56 DAP	Control	6.56	6.00	6.78	6.45a
	50 grams	6.44	6.33	6.11	6.29a
	75 grams	6.67	6.33	6.11	6.37a
	100 grams	6.44	6.67	6.89	6.67a
	Average	6.53a	6.33a	6.47a	(-)
70 DAP	Control	7.00	6.56	7.22	6.93a
	50 grams	7.00	6.67	6.78	6.82a
	75 grams	7.22	6.88	6.45	6.85a
	100 grams	6.78	6.78	7.55	7.04a
	Average	7.00a	6.72a	7.00a	(-)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level ($\alpha = 0.05$) according to DMRT; (+) Indicates interaction between factors.

Based on the research results, in addition to its direct effects on pests (OPT), the metabolite compounds in lemongrass also play a role in strengthening plant physiology. According to Wijayakusuma (2000), the essential oil compounds in lemongrass have bioactive effects that can inhibit the development of pest larvae and adult insects, including aphids and leaf caterpillars. As the intensity of pest attacks decreases, plants are able to use nutrients more efficiently and allocate them to the formation of vegetative organs such as leaves. It is important to note that in subsequent observations (at 42, 56, and 70 days after planting), the interaction between concentration and spraying frequency no longer showed significant differences, but the treatment with 100 g/L concentration still resulted in the highest individual number of leaves. This reinforces the assumption that the early growth

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phase is a critical period for plants in determining their vegetative capacity, and pest control during this phase is essential to support the development of plant structure in the following stages (Taiz & Zeiger, 2010).

These findings are consistent with research by Rahni (2012), who reported that an increase in leaf number in horticultural plants is closely related to the availability of beneficial microbes in the rhizosphere that support root exudate production and enhance physiological activity in plants. Meanwhile, research by Nik (2023) demonstrated that high concentrations of biobased insecticides can suppress aphid development on bitter melon plants, which in turn increases both the number and size of leaves. Therefore, the use of lemongrass extract as a botanical pesticide not only functions as a pest control agent but also indirectly enhances the vegetative growth performance of sorghum. Applying high concentrations and maintaining consistent application during the early growth phase is an effective strategy for environmentally friendly pest management that supports increased productivity.

Fresh Panicle Weight (g)

There was a significant interaction between the lemongrass extract (*Cymbopogon nardus*) concentration and the spraying frequency on the fresh panicle weight of sorghum plants. The best combination was achieved with the treatment of 100 g/L concentration and 7 sprayings, which produced the highest fresh panicle weight, amounting to 44.85 grams. This increase in fresh panicle weight is believed to be closely related to the decreased intensity of pest attacks, particularly aphids (Aphididae), which are one of the main pests of sorghum. The application of lemongrass extract at high concentrations with frequent and consistent spraying can function as a natural bioinsecticide, reducing pest populations from the early vegetative stage. With minimal pest pressure, the plants are able to perform photosynthesis more efficiently because the leaf surface remains undamaged and the stomata function properly (Bassolé & Juliani, 2011; Wijayakusuma, 2000).

Table 3. Fresh Panicle Weight (g)

Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
	3 times	5 times	7 times	
Control	30.41abc	32.65abc	29.27abc	30.78
50 grams	19.20c	31.38abc	40.08ab	30.22
75 grams	26.56bc	32.78abc	33.90abc	31.08
100 grams	27.63bc	28.87abc	44.85a	33.78
Average	25.95	31.42	37.03	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

According to the research results, an efficient photosynthesis process produces assimilates (photosynthetic products) that are then translocated to the reproductive organs, in this case, the panicle. The accumulation of these photosynthates influences seed formation and filling, thus directly contributing to the increase in fresh panicle weight (Taiz & Zeiger, 2010). Therefore, panicle weight can serve as one of the indicators of sorghum plant productivity, as explained by Kurniasari et al. (2023), who emphasized that panicle biomass is positively correlated with harvest yield and seed recovery. A study by Susetyo et al. (2008) also supports the notion that lemongrass extract has the potential to reduce leaf pest populations and improve plant health, allowing

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generative organs such as panicles to develop more optimally. Low concentration treatments and infrequent spraying still have some effect, but they are not as effective as the combination of high concentration and more frequent applications. In the results table, the control treatment without lemongrass extract only produced average panicle weights of 29–32 grams. In contrast, the 100 g/L concentration with seven applications significantly increased fresh panicle weight to more than 44 grams, demonstrating the effectiveness of this treatment in improving the physiological performance of the plant.

Dry Panicle Weight (g)

There was a significant interaction between the concentration of lemongrass extract and spraying frequency on the dry panicle weight of sorghum. The best treatment combination was found at a concentration of 100 grams per liter of water with a spraying frequency of 7 times, resulting in the highest dry panicle weight of 20.56 grams among all treatment combinations. Dry panicle weight is an important parameter in evaluating productivity because it reflects the accumulation of dry biomass in the plant's generative parts. This weight increase indicates that the allocation of photosynthetic products (assimilates) from the leaves to the reproductive organs was effective, supported by healthy plants experiencing minimal biotic stress. In this context, lemongrass extract acts as a biocontrol agent that reduces pressure from pests such as aphids and armyworms (Susetyo et al., 2008; Bassolé & Juliani, 2011).

In line with these findings, Kurniasari et al. (2023) stated that dry panicle weight positively correlates with sorghum seed yield potential. The successful transfer of photosynthates to the panicle is not only influenced by internal physiological factors but is also highly dependent on external environmental conditions, such as the presence of plant-disturbing organisms (OPT). Under pest-free conditions, photosynthesis runs more efficiently, and the products are effectively mobilized to the seeds. The essential oils contained in lemongrass include active compounds such as citronellal and geraniol, which possess insecticidal, antifungal, and repellent properties, capable of repelling or killing plant pests without leaving chemical residues (Wijayakusuma, 2000; Taiz & Zeiger, 2010). With spraying carried out seven times during both the vegetative and generative phases, plants receive continuous protection, especially during the critical phases of panicle formation and grain filling.

Table 4. Dry Panicle Weight (g)

Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
	3 times	5 times	7 times	
Control	13.62abc	17.51abc	12.98abc	14.70
50 grams	10.73c	11.81bc	20.41a	14.32
75 grams	9.93c	19.50ab	18.33abc	15.92
100 grams	13.70abc	12.58abc	20.56a	15.61
Average	12.00	15.35	18.07	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

The data in the table show that the combination of 50 g/L concentration with seven sprayings also resulted in a relatively high outcome (20.41 g), although it was not as effective as the 100 g/L treatment. This confirms that increasing the concentration of the extract plays an important role in maximizing the potential of plant-based bioinsecticides, especially when combined with the appropriate application frequency. Research by Sharma et al. (2022) also found that the use of botanical pesticides based on essential oils significantly improved the dry biomass yield of legume crops by reducing leaf pest infestations and enhancing photosynthetic efficiency during critical periods. Thus, the combination of high extract concentration and optimal spraying frequency of lemongrass extract has been proven to positively contribute to the increase in dry panicle weight, ultimately impacting sorghum yield potential and farming efficiency in dryland areas.

Panicle Length (cm)

There was a significant interaction between the concentration of lemongrass extract (*Cymbopogon nardus*) and spraying frequency on the panicle length growth of sorghum variety Suri 4. The most effective treatment combination was found at a concentration of 100 g/L of water with seven sprayings, resulting in the longest panicle length of 21.78 cm. This value was significantly higher than other treatments and indicates the positive impact of optimal use of plant-based bioinsecticides. Panicle length is an important indicator in determining yield potential, as it influences the number of seeds that can form per panicle. The development of good panicle length greatly depends on the physiological health of the plant during the generative phase. In this context, treatment with lemongrass extract provides effective protection against pest attacks, especially aphids and leaf caterpillars, which can damage plant tissues and interfere with the processes of flower and seed formation.

Table 5. Panicle Length (cm)

Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
	3 times	5 times	7 times	
Control	17.44bc	17.45bc	17.78bc	17.56
50 grams	17.44bc	17.33bc	17.89bc	17.55
75 grams	17.45bc	19.77ab	20.67a	19.30
100 grams	16.67c	21.55a	21.78a	20.00
Average	17.25	19.03	19.53	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

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ased on the research results, lemongrass extract contains active compounds such as citronellal and geraniol, which have been proven to possess natural insecticidal and antimicrobial properties. These compounds are capable of repelling or inhibiting the development of plant-disturbing organisms (Bassolé & Juliani, 2011). Through this mechanism, plants remain healthy and are able to optimize the photosynthesis process and the allocation of assimilates to reproductive parts such as the panicle (Taiz & Zeiger, 2010). Moreover, the longer panicle length observed in treatments using lemongrass extract with higher spraying frequency indicates that application intensity also plays an important role. More frequent spraying provides continuous protection to the plant during the critical period of panicle formation. This aligns with the findings of Susetyo et al. (2008), which stated that routine application of botanical pesticides increases pest control effectiveness and supports generative organ development. Treatments with moderate concentrations (75 g/L) also showed positive results, especially with 5–7 sprayings. However, the highest values were still achieved at the maximum concentration and frequency, indicating that optimal use of botanical pesticides must consider both dosage and application schedule.

Number of Seeds per Panicle

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There was a significant interaction between the two treatment factors, lemongrass extract concentration (*Cymbopogon nardus*) and bioinsecticide spraying frequency, on the number of seeds per panicle in sorghum variety Suri 4. The treatment combination with a high concentration, namely 100 grams per liter of water, and seven sprayings consistently produced the highest number of seeds, reaching 323.78 seeds per panicle. This reflects the effectiveness of the treatment in quantitatively increasing yield. This increase can be explained through plant physiological mechanisms related to tissue health during the generative phase. When pest attacks are successfully suppressed through regular application of botanical pesticides, the plant can undergo the processes of seed formation and filling without mechanical or metabolic disruption (Bassolé & Juliani, 2011). Active compounds such as citronellal, geraniol, and citronellol found in lemongrass essential oil possess antibacterial and insecticidal properties, which play a crucial role in protecting the plant's reproductive organs from damage and pathogen infection (Susetyo et al., 2008).

Table 6. Number of Seeds per Panicle

Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
	3 times	5 times	7 times	
Control	223.22b	242.67ab	216.78b	227.56
50 grams	208.55b	253.33ab	249.78ab	237.22
75 grams	190.55b	231.78b	259.89ab	227.41
100 grams	220.45b	222.89b	323.78a	255.71
Average	210.69	237.67	262.56	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level ($\alpha = 0.05$) according to DMRT; (+) Indicates interaction between factors.

In the context of plant physiology, the number of seeds per panicle strongly depends on the success of flowering, pollination, and seed filling processes, all of which are highly sensitive to biotic stress. When plants are optimally protected, metabolic energy and assimilates can be efficiently allocated toward the development of spikelets and seeds, ultimately increasing yield quantity (Taiz & Zeiger, 2010; Kurniasari et al., 2023). Spraying conducted seven times also provides continuous protection during critical periods, ensuring that pest attacks do not interfere with key stages of plant reproduction. This is consistent with research by Rahmawati et al. (2022), which stated that the intensity and timing of botanical pesticide application significantly affect the success of yield formation in cereal crops. Beyond protective effects, several studies have shown that essential oils also contain phenolic and flavonoid compounds that can act as stimulants for generative growth, including flower and seed formation. According to Sembiring et al. (2019), these compounds can stimulate plant physiological processes, thereby contributing to improved yield parameters such as the number of seeds per panicle. Thus, it can be concluded that lemongrass extract treatment at high concentrations and sufficient spraying frequency has a positive impact on crop productivity, not only through pest control mechanisms but also by enhancing plant metabolic efficiency.

Dry Seed Weight per Panicle

The results of the analysis of variance (ANOVA) showed no significant interaction between the lemongrass extract concentration treatment (*Cymbopogon nardus*) and the spraying frequency of the bioinsecticide on the dry seed weight per panicle in sorghum plants. However, individually, the 100 g/L water concentration treatment yielded the highest average dry seed weight of 68.41 grams, while the treatment with seven sprayings showed the best result at 73.80 grams. Dry seed weight is a key indicator of the plant's success in seed filling, which is directly related to photosynthetic capacity, efficiency of assimilate transport, and minimal biotic interference during the generative phase. Lemongrass extract, which contains active compounds such as citronellal and geraniol, has natural insecticidal and antifungal effects that are effective in suppressing pests such as *Spodoptera frugiperda* and aphids (*Aphididae*), which commonly attack leaves and panicles (Bassolé & Juliani, 2011; Susetyo et al., 2008).

Table 7. Dry Seed Weight per Panicle (g)

Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
	3 times	5 times	7 times	
Control	58.63	65.30	49.42	57.78a
50 grams	39.02	69.93	84.26	64.40a
75 grams	47.38	58.88	67.23	57.83a
100 gram s	51.29	59.64	94.30	68.41a
Average	49.08a	63.44a	73.80a	(-)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

The condition of pest-free plants during the flowering and seed-filling phases allows for the accumulation of biomass in the seeds, which is reflected in the increased dry seed weight. A high spraying frequency (seven times) enhances plant protection during this critical period, thereby maintaining the effectiveness of the bioinsecticide (Rahmawati et al., 2022). Although there was no significant interaction between treatments, the combination of high concentration and maximum spraying frequency still showed the highest absolute value 94.30 grams under the combination of 100 g/L and seven sprayings. This indicates a synergistic effect in field practice, even if statistically insignificant (Taiz & Zeiger, 2010). Several studies also note that beyond its pest control function, lemongrass essential oil contains phenolic compounds that can stimulate metabolism and protein synthesis in seeds, supporting seed formation and maturation (Sembiring et al., 2019).

Aphid Pest Infestation Intensity (%)

There was a significant interaction between lemongrass extract concentration (*Cymbopogon nardus*) and spraying frequency on the aphid infestation rate in sorghum plants of the Suri 4 variety. Treatments using concentrations of 75 grams/liter and 100 grams/liter of water, combined with spraying frequencies of 5 and 7 times, significantly reduced infestation intensity to as low as 0.08%. This reduction is strongly linked to the presence of active metabolites in lemongrass, such as citronellal and geraniol, which possess toxic and antifeedant properties against insects. These compounds inhibit feeding activity, disrupt metabolism, and impair the nervous system of insects, thereby reducing their aggressiveness and the extent of damage to plant tissues (Bassolé & Juliani, 2011). Repeated application of high concentrations results in an accumulation of toxic effects, leading to a significant decrease in aphid populations. This finding is supported by a study by Nik et al. (2022), which demonstrated that extracts from soursop (*Annona muricata L.*) at high doses could inhibit the development and growth of *Sitophilus* spp. in storage, through a similar mechanism involving secondary metabolite toxicity.

Table 8. Aphid Pest Infestation Rate (%)

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Observation Time	Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
		3 times	5 times	7 times	
42 DAP	Control	0.16abc	0.18a	0.17ab	0.17
	50 grams	0.13cd	0.13cd	0.13cd	0.13
	75 grams	0.14bcd	0.11de	0.08e	0.11
	100 grams	0.13cd	0.08e	0.08e	0.10
	Average	0.14	0.13	0.12	(+)
56 DAP	Control	0.22a	0.19ab	0.20ab	0.20
	50 grams	0.16bcd	0.11de	0.14cde	0.14
	75 grams	0.17bc	0.10e	0.10e	0.12
	100 grams	0.14cde	0.10e	0.11de	0.12
	Average	0.17	0.13	0.14	(+)
70 DAP	Control	0.23a	0.22a	0.22a	0.22
	50 grams	0.17b	0.17b	0.17b	0.17
	75 grams	0.15b	0.08c	0.08c	0.10
	100 grams	0.15b	0.08c	0.08c	0.10
	Average	0.18	0.14	0.14	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

Based on the table data, observations at 42, 56, and 70 days after planting (DAP) show a declining trend in pest attacks in line with increased concentration and intensity of spraying. The control treatment without extract tended to show higher infestation rates (>0.20%), whereas treatments with 75–100 g/L and 5–7 spray applications consistently resulted in the lowest infestation rates, below 0.10%. From an agronomic perspective, effective control of aphids during the critical vegetative and generative growth phases is essential, as it helps maintain photosynthetic efficiency, prolong leaf lifespan, and maximize crop yield. Pest-free plants have better physiological capacity for seed development and filling (Taiz & Zeiger, 2010).

Leaf Spot Disease Incidence (%)

There was a significant interaction between lemongrass extract concentration (*Cymbopogon nardus*) and spraying frequency on the incidence of leaf spot disease in sorghum plants of the Suri 4 variety. Treatment combinations using 75 g/L and 100 g/L of water with seven sprayings were found to be the most effective in reducing disease incidence to as low as 0.06–0.08% during observations at 56 and 70 DAP. This effectiveness indicates that lemongrass-based botanical bioinsecticides can suppress pathogen infections due to their secondary metabolite content, such as flavonoids, saponins, essential oils, and polyphenols, which act as natural antimicrobial and antifungal agents (Bassolé & Juliani, 2011; Anggraito et al., 2018). These active compounds can inhibit protein synthesis, mycelium and spore growth, and damage pathogen protein structures through denaturation, ultimately leading to cell death (Achmad, 2007).

Table 9. Leaf Spot Disease Incidence (%)

Observation Time	Lemongrass Extract Concentration (g/liter of water)	Spraying Frequency			Average
		3 times	5 times	7 times	
42 DAP	Control	0.17a	0.18a	0.16ab	0.17
	50 grams	0.18a	0.16ab	0.16ab	0.17
	75 grams	0.14abc	0.10cd	0.08d	0.11
	100 grams	0.11bcd	0.10cd	0.10cd	0.10
	Average	0.15	0.14	0.13	(+)
56 DAP	Control	0.19a	0.19a	0.19a	0.19
	50 grams	0.13bc	0.13bc	0.12bc	0.13
	75 grams	0.14b	0.08cd	0.06d	0.09
	100 grams	0.13bc	0.06d	0.06d	0.08
	Average	0.15	0.12	0.11	(+)
70 DAP	Control	0.22a	0.19abc	0.21ab	0.21
	50 grams	0.17bcd	0.13de	0.17bcd	0.16
	75 grams	0.16cd	0.10ef	0.08f	0.11
	100 grams	0.14d	0.10ef	0.08f	0.11
	Average	0.17	0.13	0.14	(+)

Note: Numbers in rows and columns followed by the same letter indicate no significant difference at the 5% level (α = 0.05) according to DMRT; (+) Indicates interaction between factors.

Research findings indicate that most previous studies have generally highlighted the insecticidal activity of lemongrass extract (*Cymbopogon nardus*). However, this study reveals that its mechanism of action is also effective against pathogens causing leaf spot disease, particularly pathogenic fungi. The secondary metabolites present in lemongrass, such as essential oils, flavonoids, and polyphenols, are known to have antifungal properties that can inhibit mycelial growth, disrupt pathogen cell structures, and interfere with the synthesis of essential enzymes (Bassolé & Juliani, 2011; Anggraito et al., 2018). This effectiveness is reflected in the gradual reduction of leaf spot incidence in sorghum plants treated with lemongrass extract—from 0.13% at 42 days after planting (DAP) to 0.11% at 56 DAP, and further down to 0.10% at 70 DAP. These figures are significantly lower compared to the control group, which ranged between 0.19–0.22%, indicating that plant-based treatments with high concentrations and optimal spraying frequency can provide systemic and sustainable protection against pathogen infection. From an agronomic perspective, the low level of disease infection allows the plants to maintain healthy leaf function, enhance photosynthetic activity, and ultimately contribute directly to increased crop yields. Therefore, the use of plant-based pesticides derived from lemongrass is not only a safe and environmentally friendly alternative, but also an effective strategy within the Integrated Pest Management (IPM) program, particularly in dryland areas with limited access to synthetic chemical pesticides (Wahyuni et al., 2022; Susetyo et al., 2008).

CONCLUSION AND RECOMMENDATION

This study demonstrates that the application of lemongrass leaf extract (*Cymbopogon nardus*) at a concentration of 100 grams per liter, with a spraying frequency of seven times, provides the most optimal agronomic outcomes for *Sorghum* variety Suri 4. This treatment significantly enhanced growth indicators such as plant height and number of leaves, while positively contributing to yield components including fresh and dry panicle weight, number of grains per panicle, and grain weight. Additionally, it effectively reduced aphid infestations and the prevalence of leaf spot disease to below the economic threshold (<0.10%), thereby affirming lemongrass extract's dual role as a growth enhancer and a biological control agent against plant pests and diseases.

Accordingly, it is highly recommended that farmers adopt the use of lemongrass extract at the tested dosage and frequency as part of an environmentally friendly pest and disease management strategy. This botanical pesticide can also be produced locally using simple and low-cost methods, making it an ideal solution for farmers in areas with limited access to modern agricultural inputs, such as in East Nusa Tenggara. Moreover, local governments, through relevant technical agencies, should facilitate its adoption by providing training, production tools, and policy-based incentives for farmers implementing biological control systems. To ensure sustainability, further development of lemongrass-based pesticides in ready-to-use liquid or more durable solid formulations is necessary. Follow-up research is also crucial to evaluate the long-term effectiveness and explore potential integration with other biological control agents, such as *Trichoderma spp.* and *Beauveria bassiana*, to strengthen integrated and sustainable pest and disease management systems.

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