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Inhibitory Effect of Aqueous Garlic (*Allium sativum*) Bulb Extract on Growth and Physiological Response Dynamics of Two Palm Species

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Abstract. The Merrill palm (*Adonidia merrillii*) and the Yellow palm (*Dypsis lutescens*) are hosts of various pests. Garlic (*Allium sativum*) phytochemicals are applied as a phytopesticide and affect the plant host as well. On the other hand, studies related to garlic phytochemicals' effect on these palms are limited. The present study was conducted to explore the effect of aqueous garlic bulb extract (AGBE) on the Merrill palm and the Yellow palm on those physiological dynamics and growth responses to apply the best concentration as a phytopesticide and observe the palm performance. AGBE is conducted by maceration and application by spraying. Variation AGBE concentrations were 12.5 g/100 mL, 25 g/100 mL, and 50 g/100 mL. The results revealed the profiles of the two palms were different, causing significant differences in growth, in which the Merrill palm was taller while Yellow palm greater leaf number increase; physiological response of two palms was not differing significantly on carbon dioxide concentration but differ significantly on stomatal opening percentage in 28 DAS (day after spraying) and chlorophyll content in 56 DAS; AGBE 25 g/100 mL suppress height increase significantly but leaf number increase not affected; AGBE did not influenced significantly on carbon dioxide, AGBE 50 g/100 mL significantly influenced on stomatal opening in 42 and 56 DAS but chlorophyll not significantly different, overall AGBE tend to inhibit all physiological response. This study concludes that AGBE concentrations in the current study are not recommended as a phytopesticide on both palms due to all concentrations generally inhibiting the growth and physiological response of these palms.

Keywords: aqueous garlic bulb extract; growth; inhibitor; palms; physiology

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INTRODUCTION

Pests are organisms that cause plant damage (van Huis, 2020). Pests harm ornamental plants because they reduce the aesthetic value of ornamental plants and their photosynthetic ability (Mani & Shivaraju, 2016), which are both essential functions of ornamental plants in aesthetic and biological aspects. Nietupski et al. (2022) stated pests disturb the photosynthetic process of plants in three mechanisms, i.e., morphological (decreasing leaf surface caused by deformation), mechanical (honeydew affects stomatal role), and metabolic or physiological (decreasing photosynthetic pigments, chlorophyll).

Plants produce chemical compounds known as phytochemicals, which have effects on other organisms. Phytochemicals released into the environment then affect other organisms' growth, development, reproduction, and survival (Cheng & Cheng, 2015). Phytochemical groups that are able to influence other organisms are benzoic acid, amino acids, flavonoids, steroids, and tannins (Cheng & Cheng, 2015). Several phytochemical applications in agriculture are enhancing the growth and yield of crops, managing weeds, and combating insect pests and diseases (Hayat et al., 2022; Farooq et al., 2011). Additionally, based on the utilization of phytochemicals as phytopesticides, it is defined as substances derived from plants that function as insect repellents (Ayilara et al., 2023).

Garlic (*Allium sativum*) is a plant that contains phytochemicals capable of affecting other organisms. Garlic acts as an antifungal and stimulates the performance of infected crops by decreasing the disease severity of fungal infection, also increasing growth and physiological response of crops such as eggplant (*Solanum melongena*) infected by *Verticillium dahliae* (Ali et al., 2021), pepper inoculated with *Phytophthora capsici* (Hayat et al., 2016), and cucumber (*Cucumis sativus*) infected with *Fusarium oxysporum* (Ali et al., 2020). Additionally, garlic has been employed as a phytopesticide on Date palm (*Phoenix dactylifera*) (family Arecaceae) to control several insect pests, i.e., *Rhynchophorus ferrugineus* (Al-Shuraym et al., 2020), *Cerataphis orchidearum* (Al-Shuraym, 2022), and *Parlatoria blanchardi* (Al-Hussainawy et al., 2021). Garlic is capable of influencing other organisms' performance because it contains the chemical compound allicin and its derivatives, such as diallyl sulfide, diallyl disulfide, and diallyl trisulfide (Hayat et al., 2022).

Merrill palm (*Adonidia merrillii*) and Yellow palm (*Dypsis lutescens*) are ornamental plants from Arecaceae with different morphological characteristics. Merrill palm is a solitary plant (National Parks Flora & Fauna Web, 2025a), while the Yellow palm is a clustered plant (National Parks Flora & Fauna Web, 2025b). Merrill palm has characteristics stem of light-gray in color and smooth, ringed by leaf scars, crown shaft light green; leaves pinnate arranged, short petiole, light green in color, arched upward but leaflets droop downwards; fruits ovoid shaped, appear in inflorescences with flowers, green in color during immature while red during mature; flowers light green to white in color, composed of three petals, unisexual (National Parks Flora & Fauna Web, 2025a). Yellow palms have characteristics of stems of multiple, dark gray in color, smooth texture, ringed by leaf scars; leaves dark green in color, V-shaped; fruits oblong shaped, asymmetric, appear in inflorescences with flower, green in color during immature while purple and black during mature; flowers yellow in color (National Parks Flora & Fauna Web, 2025b). These palms become host plants for various pests. Several pests that attack palms are *Raoiella indica*, *Nipaecoccus nipae*, *Aleurodicus rugioperculatus*, *Rhynchophorus ferrugineus*, and *Metisa plana* (Faleiro et al., 2016).

The use of phytochemicals in agriculture is a good way for environmental sustainability due to their eco-friendliness and fewer side effects. It's an appropriate substitution for synthetic compounds such as synthetic pesticides, which are harmful to humans and the environment. Through this study, we hope to explore more comprehensively the effects of phytochemicals on palms that host pests and have never been studied in these species.

Based on the explanation above, garlic has been applied as a phytopesticide on date palm, corroborated by its ability to inhibit fungal pathogens on various crops but there is no research related to the application of garlic phytochemicals on Merrill palm and Yellow palm, similarly classified in Arecaceae family as Date palm, that are commonly used as ornamental plants and attacked by pests, Merrill palm and Yellow palm. Therefore, this research determines the effect of aqueous garlic bulb extract (AGBE) on physiological dynamics and growth responses in Merrill palm and Yellow palm. Here, our focus is not on the pests; thus, this study was a screening experiment conducted in healthy plant conditions without pest infection. This research can give suggestions for AGBE treatment against pests, which induces the growth and physiological performance of the two palms.

METHODS

Study Locations

This study was conducted in Sawojajar, Malang, East Java, Indonesia, from August to November 2024. The location was in the home garden, covered by a white tarpaulin on the roof to prevent plants from being exposed to rain while still allowing sunlight to reach the plants.

Research Design

The research design used in this research is a factorial completely randomized series with two factors. The first factor was two species of palms, Merrill palm (*Adonidia merrillii*) and Yellow palm (*Dypsis lutescens*), while the second factor was AGBE concentrations. There were four levels of AGBE as follows: 0 g/100 mL (control), 12.5 g/100 mL, 25 g/100 mL, and 50 g/100 mL (Bryan-Thomas et al., 2023). Every treatment used three individuals as replications; thus, there were a total of 24 individuals.

Plant Preparation and Maintenance

Plants were obtained from a local florist in Sawojajar, Malang, East Java, Indonesia, with a similar age of 6 months and height of ± 50 cm. All plants were replanted in similar medium soil: rice husk in a ratio of 1:1 (v/v) in identical polybags (20 cm in diameter, 18 cm in height). The distance between individuals was ±25 cm. The acclimatization period was carried out for two months. For the uniformity of leaf number, leaves were reduced by pruning one stem, which was done one week before the application of AGBE. The total leaf number after uniformity was 6 leaves for the Merrill palm and 65 leaves for the Yellow palm.

Microclimates in observation locations had a temperature of 29 ± 2ºC, humidity of 17 ± 2%, and light intensity of 27,411.61 ± 18,215 lux. Watering was done when the planting medium was dry with tap water ± 1,500 mL, and weeding was done regularly to remove weeds. Microclimates were ignored as an influencing factor of plant growth and physiological responses.

Garlic Extraction and Bioassays

Garlic was purchased from a local market and peeled to remove the outer skin. After that, the bulb was grounded. 562.5 g, 1,125 g, and 2,250 g bulbs mixed with 4,500 mL distilled water to obtain 12.5 g/100 mL, 25 g/100 mL, and 50 g/100 mL. Sample extraction used maceration by soaking for 48 hours at room temperature in dark conditions. The AGBE solution was then filtered with a sieve to separate the residue (Widiyastuti et al., 2022).

AGBE solution or distilled water was put into a 1000 mL spray bottle. Spraying was given as ± 10 mL on the abaxial part of the leaf. All expanded leaves on every plant were sprayed with AGBE or distilled water for the control group. The distance between the spray bottle and the leaves was ± 10 cm. Spraying was carried out from 09.00 AM to 02.00 PM.

Plant Growth Indices

The growth parameters observed were plant height increase and leaf number increase. Plant height was measured from base to tip using a measuring tape in centimeter units (Zeb et al., 2017) (Figure 1A). The leaf number counted was the fully expanded leaves (Zeb et al., 2017). Observations of growth parameters were made at 0 and 56 days after spraying (DAS) of AGBE, and the increase of those parameters was determined on 56 DAS.

Carbon Dioxide Concentration Measurements

Carbon dioxide was evaluated at 0, 14, 28, 42, and 56 DAS of AGBE. Carbon dioxide levels were detected in the lower area of the leaves. Measurement using a carbon dioxide meter brand SNDWAY SW723 (made in China). The device was placed ± 5 cm in the lower area of the leaves (Figure 1B). Carbon dioxide levels were recorded when the device was stable (Siswanto & Batoro, 2019).

Stomatal Opening Percentage Observations

Stomatal sampling was observed at 0, 14, 28, 42, and 56 DAS of AGBE. Clear nail varnish was applied on the abaxial leaf part and left to dry for 5 - 10 minutes. The dried nail varnish was taken off with clear tape. The clear tape was placed on the slide glass. The stomata pattern was observed with a Sinher XSZ-107 binocular light microscope (made in China) in three fields of view at 400x magnification (40x objective magnification, 10x ocular magnification). The percentage of opened stomata was calculated by the formula:

$$\textit{Stomatal opening percentage} = \frac{\textit{Number of opened stomata}}{\textit{Total number of stomata in a field of view}} \, x\, 100\%$$

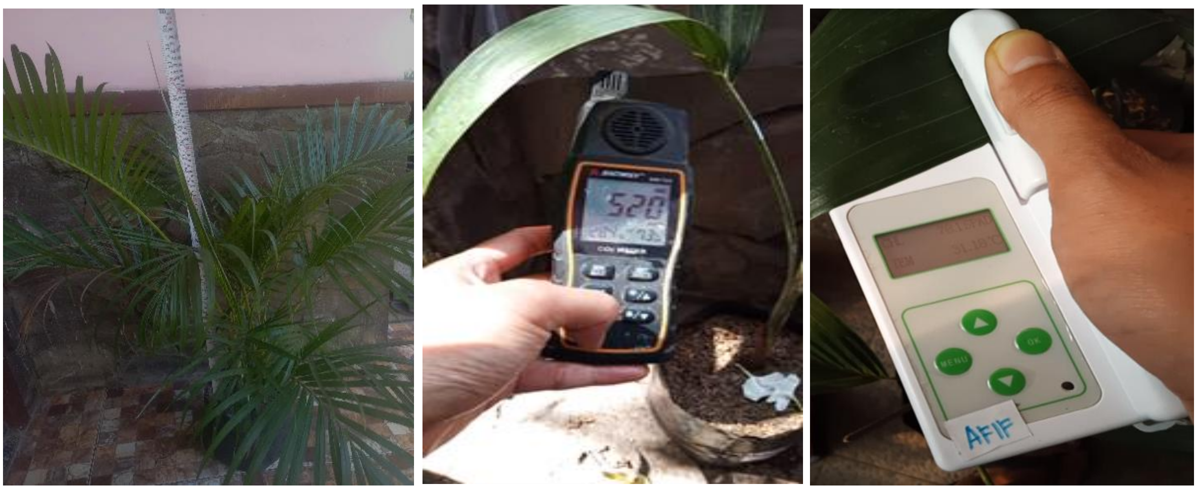
(Purwidyasari et al., 2020)

Chlorophyll Content

Chlorophyll content was investigated at 0, 14, 28, 42, and 56 DAS of AGBE. Chlorophyll content determination was measured using a SPAD TYS-A chlorophyll meter (made in China). The adaxial part of the leaf was placed in the emitting window, and the main venation was not measured (Figure 1C). Measurements were taken at three points in the leaf tip area, middle, and basal area (Sari et al., 2016). Chlorophyll was determined on one leaf of every individual.

Data Analysis

The obtained data were analyzed for normality with the Shapiro-Wilk test and homogeneity with the Levene test. The interaction test was analyzed as well. Data was analyzed by the Kruskal-Wallis test with post hoc Mann-Whitney test if data distribution was not normal at a 95% confidence level. Data was analyzed by the Brown-Forsythe test with post hoc Games-Howell test if data distribution was normal but not homogenous at a 95% confidence level. Data was analyzed by a one-way analysis of variance (ANOVA) with post hoc Duncan multiple range test (DMRT) if data distribution was normal and homogenous at a 95% confidence level. A correlation test was done with the Spearman test at a 95% confidence level, considering that the data distribution was not normal after a normality test was done to determine the relationship between (1) carbon dioxide concentration and chlorophyll content, and (2) carbon dioxide concentration and stomatal opening percentage. Statistical analysis was done in IBM SPSS Statistics 23 for Windows.



A B C

Figure 1. Observation process (A) height measurement, (B) carbon dioxide measurement, (C) chlorophyll measurement

RESULTS AND DISCUSSION

Profile of Growth Attribute of Two Palms on Control and AGBE Treatments

The interaction test revealed that the interaction between AGBE and palm species was not significant in all growth parameters. AGBE treatments caused growth inhibition. Height increase on AGBE treatments was lower than control (0 g/100 mL) despite a 50 g/100 mL difference, but the differences were not significant; however, others were significantly lower. A 25 g/100 mL treatment was the most inhibiting concentration on height increase (Table 1). The present study showed AGBE caused growth inhibition despite low concentration, as proven by a significant reduction in height increase. Garlic has been reported to suppress pea (*Pisum sativum*) growth completely both at low and high temperatures that germinated on premoistened seed extract solution 10, 30, or 60%, which are equivalent to 10 g/100 mL, 30 g/100 mL, and 60 g/100 mL, respectively (Hanan, 2016). Different species induced different results on height increase as well, whereas Merrill palm was significantly higher than Yellow palm. Differences in growth response to garlic phytochemicals are influenced by internal factors, i.e., genes and hormones (Cheng et al., 2016). It explains the different heights of these two palms due to their different responses to AGBE.

Height increase parameters in the current study may be related to auxin and ABA phytohormones. Auxin is responsible for height increase or apical dominance (Kochhar & Gujral, 2020). Cheng et al. (2016) reported that the application of diallyl disulfide solution, a commercial product of garlic substance, caused an increase in IAA (indole acetic acid) auxin levels in the roots of tomatoes. However, Hanan (2016) reported that auxin levels decreased in pea, causing growth inhibition due to IAA auxin decreased while ABA (abscisic acid) increased. ABA has the opposite role to auxin. ABA represses apical dominance and leaf growth (Brookbank et al., 2021). From these explanations, it was retrieved that hormones (auxin and ABA) alteration response to AGBE on height increase is auxin decrease and ABA increase in these two palms, causing significantly lower height increase.

The leaf number on all plants treated by AGBE and the control was statistically not significant. However, 25 g/100 mL concentration tends to induce higher leaf number increase (Table 1). This phenomenon can be explained by palm phenology (development stage), which requires a long time. Forero et al. (2011) reported that African oil palm (*Elais guineensis*) development stages from seed germination to fruit and bunch ripening occur over a long time, 18 months of observation. In leaf development stages, palms have three stages based on the leaf anatomy. The first is a simple lanceolate leaf, the second is a bifurcated leaf, and the third is completely pinnate.

The transition time from lanceolate to bifurcated took several months. Therefore, the duration of observation in this study was inadequate due to its limited scope of 56 days (2 months), whereas the development process of the palm is known to span multiple months. It may explain why the AGBE treatments do not significantly affect the increase in leaf number on both palms.

The Yellow palm leaves were greater than the Merrill palm (Table 1). These palms have different growth characteristics. Based on present observation, the Yellow palm produces more stems than the Merrill palm. Besides that, leaf numbers in a rachis are different between these species. Yellow palm contains 6 – 23 leaflets, while Merrill palm contains 11 – 15 leaflets.

Table 1. Profile of growth parameters of two palm species after AGBE treatments on growth attributes. Different letters indicate significant differences at $\alpha \leq 0.05$ using the DMRT test or the Mann-Whitney test within columns and factors.

Treatment	Growth Parameters	
	Height Increase	**Leaf Number Increase**
Concentrations		
0 g/100 mL	16.83 ± 1.45^{b}	47.50 ± 16.56^{a}
12.5 g/100 mL	9.58 ± 1.96^{ab}	41.83 ± 12.14^{a}
25 g/100 mL	6.92 ± 0.86^{a}	49.67 ± 14.55^{a}
50 g/100 mL	12.00 ± 1.72^{b}	29.33 ± 7.72^{a}
Species		
Merrill palm	13.75 ± 1.37^{b}	17.33 ± 1.72^{a}
Yellow palm	8.92 ± 1.30^{a}	66.83 ± 7.38^{b}

Effect of AGBE on Physiological Responses

The interaction test revealed interaction between AGBE and palm species was not significant in all physiological parameters. Carbon dioxide concentration was influenced by AGBE treatments (Table 2). Carbon dioxide concentration fluctuates during observation. In 0 DAS, carbon dioxide concentration did not differ significantly. However, carbon dioxide concentrations at 14, 28, and 56 DAS differed significantly, while 42 DAS did not differ significantly. AGBE treatments that induced lower carbon dioxide concentration were 50 g/100 mL at 14 and 28 DAS while 25 g/100 mL at 56 DAS compared with the control. However, it is underscored that these concentrations and controls were unsignificantly differ. Different species do not differ significantly. However, from the trend, it was revealed that Yellow palm tends to lower carbon dioxide concentration than Merrill palm. The carbon dioxide parameter in the current study is attributed to the photosynthesis process, whereas it is assumed that the rest of the carbon dioxide concentration in the lower area of leaves is not absorbed by the leaf. Higher carbon dioxide is considered to be the result of a low photosynthetic rate, and vice versa. Phytochemicals' mechanism in affecting photosynthetic rate is by controlling stomata, electron transport in thylakoid (light reaction), and the cycle of carbon reduction (dark or carbon reaction) (Zhou & Yu, 2006).

The stomatal opening percentage was affected by different species and AGBE treatments (Table 2). Different species influenced stomatal opening percentage significantly at 28 DAS only, while AGBE treatments significantly affected it at 42 and 56 DAS. Merrill palm induced a higher stomatal opening percentage in all DAS than Yellow palm, but the difference was statistically not significant in 0, 14, and 42 DAS. Except in 56 DAS, Merrill palm was unsignificantly different than the Yellow palm. AGBE treatments mostly induced lower stomatal opening, with 50 g/100 mL consistently being the lowest. 12.5 g/100 mL and 25 g/100 mL concentrations were unsignificantly different than the control at 14, 28, and 42 DAS. Stomata are pores responsible for gas exchange, such as carbon dioxide and oxygen, as well as water transpiration (Kochhar & Gujral, 2020). A previous study by Hussain & Regosa (2011) reported similar results to the current study; application of benzoxazolin-2(3H)-one (BOA) and cinnamic acid induced stomatal closure on *Dactylis glomerata*, *Lolium perenne*, and *Rumex acetosa*, followed by a decrease in water content. Additionally, according to the different significance between the two palms on 28 DAS and Merrill palm induces higher stomatal opening than the Yellow palm trend, these two palms have differences in stomatal density and size. Merrill palm has a larger size with low density, while Yellow palm has a smaller size but high density. This is consistent with Xiong et al. (2022), who reported stomatal size and stomatal density on various rice genotypes. It was found that the relationship between stomatal size and stomatal density was negative; higher stomatal density was followed by lower stomatal size and vice versa. Additionally, plants with smaller and denser stomata induced faster stomatal opening. However, in the present study, the Yellow palm has denser and smaller stomata and lower stomatal openings than the Merrill palm (Figure 2). Elliott-Kingston et al. (2016) found that the opening and closing rates of stomata are not correlated with stomatal morphology. Atmospheric carbon dioxide may influence stomatal closing. Based on the phenomenon, it is inferred that the Merrill palm and the Yellow palm have different responses in the stomatal opening on AGBE.

Chlorophyll content has a similar trend to carbon dioxide concentration, which fluctuates during observation (Table 2). AGBE treatments generally tend to lower chlorophyll content. Furthermore, different species induce significantly different chlorophylls investigated at 56 DAS. The Yellow palm detected contains more chlorophyll than the Merrill palm. The photosynthesis process occurred due to the presence of photosynthetic pigments chlorophyll (Kochhar & Gujral, 2020). Phytochemicals impact chlorophyll and thus influence the photosynthesis rate. A previous study by Hanan (2016) reported that the total chlorophyll content of pea (*Pisum sativum*) seedlings decreased after being treated with garlic seed extract solution 10, 30, or 60% (10 g/100 mL, 30 g/100 mL, and 60 g/100 mL). It indicates that low and high concentrations of garlic extract reduce chlorophyll content, similar to all AGBE concentrations in the present study. The reduction of chlorophyll due to phytochemicals initiates chlorophyll degradation and inhibits the synthesis (Alqarawi et al., 2018). Related to photosynthesis, reducing the photosynthesis rate is caused by a reduction in photosystem II (PSII) fluorescence and chlorophyll fluorescence (Ding et al., 2019). Another mechanism is blocking the chloroplasts from oxygen release (Kostina-Bednarz et al., 2023). Merrill palm and Yellow palm have different chlorophyll content, causing these palms to have different leaf colors. The green color of the Merrill palm is light, while the Yellow palm is dark. Darker green indicates higher chlorophyll content in the leaf (Sari et al., 2016).

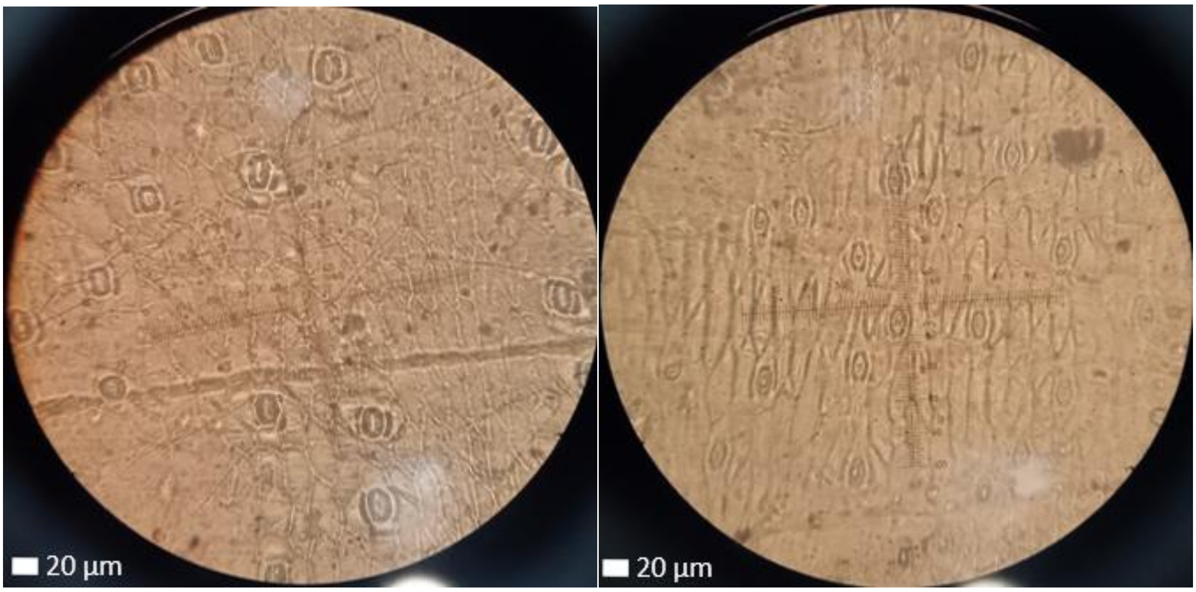


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Figure 2. Stomatal micrograph (A) Merrill palm, (B) Yellow palm

Table 2. Effect of AGBE on physiological responses of two palm species on carbon dioxide concentration, stomatal opening percentage, and SPAD chlorophyll content. Different letters indicate significant differences at $\alpha \leq 0.05$ using the DMRT test, the Mann-Whitney test, or the Games-Howell test among treatments within the same columns and factors.

Treatments	The day after spraying				
	0	14	28	42	56
Carbon dioxide concentration (ppm)					
AGBE Concentrations					
0 g/100 mL	459.33 ± 6.81^{a}	465.39 ± 14.90^{ab}	538.50 ± 27.37^{ab}	496.28 ± 9.44^{a}	489.95 ± 7.33^{ab}
12.5 g/100 mL	443.00 ± 7.74^{a}	502.00 ± 17.64^{b}	570.67 ± 7.37^{b}	483.00 ± 11.21^{a}	537.00 ± 23.86^{b}
25 g/100 mL	473.83 ± 7.07^{a}	500.00 ± 22.35^{b}	585.33 ± 8.06^{b}	547.33 ± 14.99^{a}	473.67 ± 4.92^{a}
50 g/100 mL	476.50 ± 18.95^{a}	437.83 ± 1.97^{a}	452.17 ± 5.53^{a}	507.83 ± 22.75^{a}	524.17 ± 28.18^{ab}
Species					
Merrill palm	461.92 ± 6.84^{a}	481.14 ± 15.10^{a}	538.25 ± 20.89^{a}	522.42 ± 13.57^{a}	525.00 ± 14.84^{a}
Yellow palm	464.42 ± 10.12^{a}	471.47 ± 11.46^{a}	535.08 ± 15.88^{a}	494.81 ± 10.18^{a}	487.39 ± 12.69^{a}
Stomatal percentage opening (%)					
AGBE Concentrations					
0 g/100 mL	66.81 ± 4.02^{b}	65.99 ± 2.75^{a}	64.45 ± 1.93^{a}	61.84 ± 3.28^{b}	62.47 ± 2.39^{b}
12.5 g/100 mL	69.89 ± 4.21^{b}	64.08 ± 2.59^{a}	57.53 ± 3.26^{a}	61.28 ± 4.43^{b}	63.89 ± 2.40^{b}
25 g/100 mL	61.75 ± 3.46^{b}	59.52 ± 4.75^{a}	63.19 ± 5.96^{a}	57.55 ± 2.17^{b}	56.06 ± 2.40^{b}
50 g/100 mL	50.13 ± 2.43^{a}	50.08 ± 6.46^{a}	53.70 ± 3.97^{a}	43.35 ± 3.53^{a}	43.83 ± 3.24^{a}
Species					
Merrill palm	64.80 ± 3.01^{a}	63.35 ± 3.02^{a}	64.73 ± 2.99^{b}	57.92 ± 3.63^{a}	55.91 ± 2.95^{a}
Yellow palm	59.49 ± 3.07^{a}	56.49 ± 3.68^{a}	54.72 ± 2.20^{a}	54.10 ± 2.67^{a}	57.21 ± 2.99^{a}
SPAD chlorophyll content (%)					
AGBE Concentrations					
0 g/100 mL	64.58 ± 1.56^{a}	66.60 ± 1.94^{a}	64.65 ± 0.77^{a}	64.92 ± 1.86^{a}	65.95 ± 1.81^{a}
12.5 g/100 mL	66.86 ± 1.48^{a}	62.58 ± 1.42^{a}	63.72 ± 2.73^{a}	64.74 ± 1.47^{a}	66.07 ± 2.86^{a}
25 g/100 mL	60.89 ± 1.71^{a}	68.11 ± 3.09^{a}	60.74 ± 0.97^{a}	61.52 ± 1.97^{a}	62.47 ± 1.83^{a}
50 g/100 mL	65.42 ± 2.70^{a}	63.04 ± 0.33^{a}	61.06 ± 1.96^{a}	60.13 ± 4.11^{a}	63.72 ± 3.77^{a}
Species					
Merrill palm	62.55 ± 1.25^{a}	66.04 ± 1.57^{a}	61.68 ± 1.11^{a}	60.84 ± 1.50^{a}	59.64 ± 1.01^{a}
Yellow palm	66.33 ± 1.42^{a}	64.12 ± 1.38^{a}	63.40 ± 1.44^{a}	64.82 ± 1.95^{a}	69.46 ± 1.27^{b}

Table 3. Speaman's correlation coefficient and the significance (2-tailed) score at α ≤ 0.05 between physiological response parameters

Parameters	Merrill palm		Yellow palm	
	Spearman correlation	Significance	Spearman correlation	Significance
Carbon dioxide concentration and Chlorophyll content	−0.161	0.218	−0.099	0.453
Carbon dioxide concentration and Stomatal opening percentage	−0.097	0.462	0.099	0.452

Relationship Between Carbon Dioxide Concentration to Chlorophyll Content and Stomatal Opening Percentage

The relationship between carbon dioxide and chlorophyll content demonstrated a negative correlation. However, the correlation score was very weak on the two palm species and not significant (Table 3). It proved that higher chlorophyll content caused lower carbon dioxide, which is the photosynthesis effect. Photosynthesis produces carbohydrates and oxygen emissions from the carbon synthesis process, whereas carbon dioxide is retrieved from the air (Kochhar & Gujral, 2020). The higher the chlorophyll content, the higher the photosynthetic rate (Santoso & Zakariyya, 2019), resulting in lower carbon dioxide concentration in the lower leaf area due to absorption by the leaf. The very weak and insignificant relationship expected due to AGBE treatments inhibits the photosynthetic rate by decreasing the carbon dioxide assimilation rate. Zhou & Yu (2006) mentioned that phytochemicals reduce the carbon dioxide assimilation rate through several pathways. i.e., reducing chlorophyll content, altering stomatal response, abnormal PSII and electron transportation function, and carbohydrate metabolism. From the present study, chlorophyll content is assumed not to affect the carbon dioxide assimilation rate due to AGBE not being influenced significantly (Table 2). The assumption is that AGBE may affect factors other than chlorophyll content.

The relationship between carbon dioxide and stomatal opening percentage demonstrated different correlations, negative in Merrill palm and positive in Yellow palm. However, the relationship was very weak and not significant; thus, the stomatal opening percentage does not look like it affects carbon dioxide (Table 3).

This was an expected negative correlation in Merrill palm, proving that a higher stomatal opening percentage caused less carbon dioxide due to higher absorption by the leaf for photosynthesis. The present result is similar to that of Ali et al. (2021), who reported that higher stomatal conductance is followed by a higher photosynthetic rate. Nevertheless, a positive correlation in Yellow palms might be caused by respiration. Respiration is the catabolism of glucose with oxygen as the result of carbon dioxide and water (Kochhar & Gujral, 2020). The higher percentage of open stomata leads to an increase in carbon dioxide levels retrieved due to a lower photosynthesis rate compared to respiration, a consequence of AGBE administration. It was expected that stomatal morphology would be more influential than stomatal percentage opening due to the two palms having different stomatal morphology, such as stomatal density and size, causing a very weak and insignificant relationship between stomatal opening percentage and carbon dioxide concentration. Xiong et al. (2022) mentioned that stomatal conductance is influenced by stomatal morphology, including stomatal spacing, density, and size.

CONCLUSION

AGBE mostly acts as an inhibitor in all concentrations. Height increase on 25 g/100 mL was inhibited significantly, but AGBE did not significantly affect the leaf number increase. AGBE did not significantly affect carbon dioxide concentration at all DAS, but AGBE 50 g/100 mL significantly influenced on stomatal opening at 42 and 56 DAS, while all AGBE concentrations mostly caused higher carbon dioxide concentration and lower stomatal opening. Chlorophyll content was not influenced by AGBE but tended to be lower than the control. Two palms also showed significantly different results due to different morphology, such as height increase, leaf number increase, stomatal opening at 28 DAS, and chlorophyll content at 56 DAS. From these findings, AGBE concentrations in our study are not recommended for phytopesticide application on Merrill palm and Yellow palm due to their suppressing these two palms' performance. Future investigations may be conducted with longer time observations, considering that palms are plants with a long development process and more growth and physiological parameters to obtain more comprehensive results.

AUTHOR CONTRIBUTION STATEMENT

AERS was responsible for conceiving and designing the study, conducting the data collection and analysis, and writing the manuscript. AMN & T were responsible for providing substantial feedback during the manuscript drafting process. DS was responsible for providing substantial feedback during the manuscript drafting process and proofreading the manuscript. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this paper.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript.

REFERENCES

Al-Hussainawy, K. J., Hasan, S. M., & Chebaani, H. (2021). Study of The Effect of Hot Water Extract of Garlic and Pepper Plants, With Different Concentrations Saline Solution on The Mortality on *Parlatoria blanchardi* (Targioni-Tozzetti) on Date Palms. *IOP Conf. Ser.: Earth Environ. Sci.*, *923*, 012021. https://doi.org/10.1088/1755-1315/923/1/012021

Ali, A., Ghani, M. I., Haiyan, D., Iqbal, M., Cheng, Z., & Cai, Z. (2020). Garlic Substrate Induces Cucumber Growth Development and Decreases Fusarium Wilt through Regulation of Soil Microbial Community Structure and Diversity in Replanted Disturbed Soil. *International Journal of Molecular Sciences*, *21*(17), 6008. https://doi.org/10.3390/ijms21176008

Ali, M., Ahmad, H., Hayat, S., Ghani, M. I., Amin, B., Atif, M. J., Wali, K., & Cheng, Z. (2021). Application of garlic allelochemicals improves growth and induces defense responses in eggplant (*Solanum melongena*) against *Verticillium dahliae*. *Ecotoxicology and Environmental Safety*, *215*, 112132. https://doi.org/10.1016/j.ecoenv.2021.112132

Alqarawi, A. A., Hashem, A., Kumar, A., Al-Arjani, A. B. F., Abd_Allah, E. F., Dar, B. A., Wirth, S., Davranov, K., & Egamberdieva, D. (2018). Allelopathic effects of the aqueous extract of *Rhazya stricta* on growth and metabolism of *Salsola villosa*. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology*, *152*(6), 1263 – 1273. https://doi.org/10.1080/11263504.2018.1439117

Al-Shuraym, L. A. (2022). The impact of the onion-garlic extracts to control date palm aphids in Saudi Arabia. *Journal of the Saudi Society of Agricultural Sciences, 21*, 546–551. https://doi.org/10.1016/j.jssas.2022.03.004

Al-Shuraym, L. A., Al-Keridis, L. A., Al-Dakhil, A. A., & Al-Qahtani, W. S. (2020). The impact of onion-garlic mixture to control of *Rhynchophorus ferrugineus* in Saudi Arabia. *Journal of the Saudi Society of Agricultural Sciences, 19*(8), 521–527. http://dx.doi.org/10.1016/j.jssas.2020.09.005

Ayilara, M. S., Adeleke, B. S., Akinola, S. A., Fayose, C. A., Adeyemi, U. T., Gbadegesin, L. A., Omole, R. K., Johnson, R. M., Uthman, Q. O., & Babalola, O. O. (2023). Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. *Frontiers in Microbiology, 14*, 1040901. https://doi.org/10.3389/fmicb.2023.1040901

Brookbank, B. P., Patel, J., Gazzarrini, S., & Nambara, E. (2021). Role of Basal ABA in Plant Growth and Development. *Genes*, *12*, 1936. https://doi.org/10.3390/genes12121936

Bryan-Thomas, J., McClear, T., & Omoregie, S. (2023). Antimicrobial potential of unstressed and heat stressed *Allium sativum*. *Saudi Journal of Biological Sciences*, *30*(9), 103749. https://doi.org/10.1016/j.sjbs.2023.103749

Cheng, F. & Cheng, Z. (2015). Research Progress on the use of Plant Allelopathy in Agriculture and the Physiological and Ecological Mechanisms of Allelopathy. *Front. Plant Sci*., *6*, 1020. https://doi.org/10.3389/fpls.2015.01020

Cheng, F., Cheng, Z., Meng, H., & Tang, X. (2016). The Garlic Allelochemical Diallyl Disulfide Affects Tomato Root Growth by Influencing Cell Division, Phytohormone Balance and Expansin Gene Expression. *Front. Plant Sci*., *7*, 1199. https://doi.org/10.3389/fpls.2016.01199

Ding, H., Ali, A., & Cheng, Z. (2019). An Allelopathic Role for Garlic Root Exudates in the Regulation of Carbohydrate Metabolism in

Cucumber in a Hydroponic Co-Culture System. *Plants*, *9*(1), 45. https://doi.org/10.3390/plants9010045

Elliott-Kingston, C., Haworth, M., Yearsley, J. M., Batke, S. P., Lawson, T., & McElwain, J. C. (2016). Does size matter? Atmospheric CO_2 may be a stronger driver of stomatal closing rate than stomatal size in taxa that diversified under low CO_2. *Front. Plant Sci.*, *i*, 1253. https://doi.org/10.3389/fpls.2016.01253

Faleiro, J. R., Jaques, J. A., Carrillo, D., Giblin-Davis, R., Mannion, C. M., Peña-Rojas, E., & Peña, J. E. (2016). Integrated Pest Management (IPM) of Palm Pests. In: D. P. Abrol (Ed.), *Integrated Pest Management in The Tropics* (pp.439 – 497). New India Publishing Agency.

Farooq, M., Jabran, K., Cheema, Z. A., Wahid, A., & Siddique, K. H. M. (2011). The role of allelopathy in agricultural pest management. *Pest Manag Sci*, *67*(5), 493–506. https://doi.org/10.1002/ps.2091

Forero, D. C., Hormaza, P., & Romero, H. M. (2011). Phenological growth stages of African oil palm (*Elaeis guineensis*). *Annals of Applied Biology*, *160*(1), 56–65. https://doi.org/10.1111/j.1744-7348.2011.00520.x

Hanan, M. A. E. G. (2016). Physiological Allelopathic Effect of Aqueous Extracts of Cucumber, Carrot, Onion, and Garlic Seeds on Germination and Growth of Pea. *Journal of Pharmaceutical, Chemical and Biological Sciences*, *4*(1), 13–19.

Hayat, S., Ahmad, A., Ahmad, H., Hayat, K., Khan, M. A., & Runan, T. (2022). Garlic, from medicinal herb to possible plant bioprotectant: A review. *Scientia Horticulturae*, *304*, 111296. https://doi.org/10.1016/j.scienta.2022.111296

Hayat, S., Cheng, Z., Ahmad, H., Ali, M., Chen, X., & Wang, M. (2016). Garlic, from Remedy to Stimulant: Evaluation of Antifungal Potential Reveals Diversity in Phytoalexin Allicin Content among Garlic Cultivars; Allicin Containing Aqueous Garlic Extracts Trigger Antioxidants in Cucumber. *Frontiers in Plant Science*, *7*, 1235. https://doi.org/10.3389/fpls.2016.01235

Hussain, M. I. & Reigosa, M. J. (2011). Allelochemical stress inhibits growth, leaf water relations, PSII photochemistry, non-photochemical fluorescence quenching, and heat energy dissipation in three C3 perennial species. *Journal of Experimental Botany*, 62(13), 4533–4545. https://doi.org/10.1093/jxb/err161

Kochhar, S. L. & Gujral, S. K. (2020). *Plant Physiology : Theory and Applications*, 2nd edition. Cambridge University Press. Cambridge.

Kostina-Bednarz, M., Plonka, J., & Barchanska, H. (2023). Allelopathy as a source of bioherbicides: challenges and prospects for sustainable agriculture. *Rev Environ Sci Biotechnol*, *22*, 471–504. https://doi.org/10.1007/s11157-023-09656-1

Mani, M. & Shivaraju, C. (2016). Economic Importance. In: M. Mani & C. Shivaraju (Eds.), *Mealybugs and Their Management in Agricultural and Horticultural Crops* (pp. 131 – 140). Springer. https://doi.org/10.1007/978-81-322-2677-2_11

National Parks Flora & Fauna Web. (2025a, 11 February). *Adonidia merrillii* (Becc.) Becc. https://www.nparks.gov.sg/florafaunaweb/flora/2/6/2688

National Parks Flora & Fauna Web. (2025b, 11 February). *Chrysalidocarpus lutescens* H.Wendl. https://www.nparks.gov.sg/florafaunaweb/flora/2/6/2622

Nietupski, M., Ludwiczak, E., Olszewski, J., Gabry´s, B., & Kordan, B. (2022). Effect of Aphid Foraging on the Intensity of Photosynthesis and Transpiration of Selected Crop Plants in Its Early Stages of Growing. *Agronomy*, *12*, 2370. https://doi.org/10.3390/agronomy12102370

Purwidyasari, Y.C., Munawarti, A., & Siswanto, D. (2020). Optimasi penyerapan formaldehid dari asap rokok oleh *Euphorbia milii* Des Moul. dan *Sansevieria trifasciata* Prain menggunakan Light Emitting Diode (LED) merah-biru. *Biotropika: Journal of Tropical Biology, 8*(3), 144 – 151. http://dx.doi.org/10.21776/ub.biotropika.2020.008.03.02

Santoso, T.I. & Zakariyya, F. (2019). Several Physiological Changes of Cocoa (*Theobroma cacao* L.) in Response to Vascular Streak Dieback Diseases. *Agrivita Journal of Agricultural Science*, *41*(1), 129 – 138. https://doi.org/10.17503/agrivita.v41i1.1668

Sari, L., Purwito, A., Sopandie, D., Purnamaningsih, R., & Sudarmonowati, E. (2016). Agronomic Characterization of Wheat Mutants (*Triticum aestivum*) of M3 Generation Planted in Sukabumi. *Biosaintifika Journal of Biology & Biology Education*¸ *8*(3), 352 – 360. http://dx.doi.org/10.15294/biosaintifika.v8i3.6612

Siswanto, D. & Batoro, J. (2019). The Sacred Plants and Their Support for Conservation, Poncokusumo District, Malang Regency, East

Java Indonesia. *Plant Archives*, *19*(1), 1515 – 1520.

van Huis, A. (2020). Insect pests as food and feed. *Journal of Insects as Food and Feed, 6*(4), 327–331. http://dx.doi.org/10.3920/JIFF2020.x004

Widiyastuti, Y., Matoha, H. K., & Fitriana, F. (2022). Antibacterial Activity of *Melaleuca alternifolia* Extract from Different Extraction Method. *Biosaintifika Journal of Biology & Biology Education*¸ *14*(2), 285 – 292. http://dx.doi.org/10.15294/biosaintifika.v14i2.36223

Xiong, Z., Dun, Z., Wang, Y., Yang, D., Xiong, D., Cui, K., Peng, S., & Huang, J. (2022). Effect of Stomatal Morphology on Leaf Photosynthetic Induction Under Fluctuating Light in Rice. *Front. Plant Sci*., *12*, 754790. https://doi.org/10.3389/fpls.2021.754790

Zeb, A., Ullah, F., Gul, S. L., Khan, M., Zainub, B., Khan, M. N., & ul Amin, N. (2017). Influence of Salicylic Acid on Growth and Flowering of Zinnia Cultivars. *Sci.Int.(Lahore), 29*(6), 1329–1335.

Zhou, Y. H. & Yu, J. Q. (2006). Allelochemicals and photosynthesis. In: M. J. Reigosa, N. Pedrol, L. González (Eds.), Allelopathy: a physiological process with ecological implications (pp. 127–139). Springer Publishers. https://polydora.github.io/General-ecology/Literature/Allelopaty.pdf