Sativa : Journal of Agricultural Sciences
Volume. 1 Issue 2 June 2025
Page No: 54-67

Biomass Production of *Phyllanthus niruri* L. Under Varying Drip Irrigation Frequency and Organic Fertilization

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Received : February 20, 2025
Accepted : March 25, 2025
Published : June 27, 2025

Citation: Meiliyana, I., Budiman., Miska, M, E, E., & Sugeru, H. (2025). Biomass Production of Phyllanthus niruri L. Under Varying Drip Irrigation Frequency and Organic Fertilization. Sativa : Journal of Agricultural Sciences, 1(2), 54-67.

ABSTRACT: Green chance piedra (*Phyllanthus niruri* L.), a wild plant traditionally used for medicinal purposes, faces cultivation challenges related to water availability and organic fertilisation. This study aimed to analyse the effects of irrigation frequency and organic fertilisation on the growth and biomass production of green chance piedra, as well as the interaction between these two factors. The research was conducted in a greenhouse at Gunadarma University Campus F7 (April–June 2022) using a split-plot randomised complete block design (RCBD). The main plot consisted of drip irrigation frequency with four treatments: watering every 6, 8, 12, and 24 hours. The subplot involves organic fertilisation with three treatments: control (no fertilisation), organic fertiliser without banana corm MOL (local microorganism solution), and organic fertiliser supplemented with banana corm MOL. Results indicated that irrigation frequency and organic fertilisation significantly influenced growth and biomass production in green chanca piedra. The optimal treatments were 6-hour irrigation intervals and organic fertilisation without banana corm MOL. Furthermore, a significant interaction was observed between irrigation frequency and organic fertilisation, highlighting their combined impact on plant performance. These findings provide critical insights for optimising cultivation protocols to enhance biomass yield in green chanca piedra.

Keywords: Biomass; Irrigation Frequency; Drip Irrigation; Phyllanthus Niruri; Banana Corm MOL

INTRODUCTION

Green chance piedra (*Phyllanthus niruri* L.), a medicinal plant traditionally used to treat various ailments, derives its therapeutic potential from bioactive compounds such as flavonoids, phyllanthin, and hypophyllanthin. These compounds exhibit antiviral, antibacterial, and inhibitory effects on enzymes and proteins critical to the Human Immunodeficiency Virus (HIV) lifecycle (Cos et al., n.d.). Phyllanthus comprises approximately 750–800 species distributed across tropical and subtropical regions, many of which hold significant medicinal value (Alegantina et al., 2015). According to Yuliarti (2019), chance piedra (referred to locally as meniran) is a wild plant

commonly found in rocky, humid environments such as riverbanks, coastal areas, shrublands, abandoned rice fields, forests, and agricultural lands(Yuliarti, 2019).

Despite its pharmacological importance, cultivating green chance piedra faces challenges, particularly in water management and organic fertilisation, as it remains predominantly wild with limited domestication. Drought conditions frequently induce wilting and plant mortality, highlighting the need for balanced soil moisture and nutrient-rich organic substrates. Optimal growth requires adequate soil water and a cultivation medium enriched with organic matter, macro and micronutrients. Organic amendments like manure enhance soil quality by improving its physical, chemical, and biological properties. For instance, organic matter promotes soil aggregation and increases water retention capacity, both critical for maintaining soil structure and moisture. (Stevenson, n.d.). Furthermore, organic supplementation can elevate soil water content by up to 43.2%, directly enhancing plant growth efficiency (Murniyanto, 2017). Efficient water management is also crucial to modern agricultural practices, enhancing plant growth and optimising resource utilization. One effective method is automatic drip irrigation, which supplies water directly to the plant's root zone through a regulated and continuous release of water droplets on the soil surface or below it. This approach ensures precise water application, minimises water loss through evaporation, and maintains optimal soil moisture conditions essential for plant development. (Rahmadhan et al., 2022).

This study aimed to analyse the effects of automated drip irrigation frequency and organic fertilisation on green chance piedra's growth and biomass production and evaluate the interaction between these factors in modulating these parameters. By addressing these objectives, the research provides foundational insights into optimising cultivation protocols for this medicinally significant species under controlled conditions.

METHOD

The study was conducted in a greenhouse at Gunadarma University Campus F7, Kelapa Dua Wetan, East Jakarta, Indonesia, from April to June 2022, utilising tools such as drip irrigation systems, digital timers, Erlenmeyer flasks, calipers, analytical balances, and ovens, while materials included green chance piedra (Phyllanthus niruri L.) seedlings, soil, organic fertilisers, and polybags (35 × 35 cm). A split-plot randomised complete block design (RCBD) was employed, with irrigation frequency as the main plot factor (6, 8, 12, and 24-hour intervals labeled F1–F4) and organic fertilisation as the subplot factor (no fertiliser P0, organic fertiliser P1, and organic fertiliser with banana corm MOL P2), replicated three times across 36 experimental units. The experiment involved preparing seedlings, formulating the soil medium, installing an automated drip irrigation system, applying fertilisers, and transplanting seedlings into polybags under controlled conditions while monitoring growth parameters such as plant height, leaf count, branch number, and stem diameter, along with production parameters including biomass and leaf weight. Data analysis involved descriptive statistics and ANOVA at a 5% significance level, with significant differences further examined using Duncan's Multiple Range Test (DMRT) in SAS software version 9.4.

RESULT AND DISCUSSION

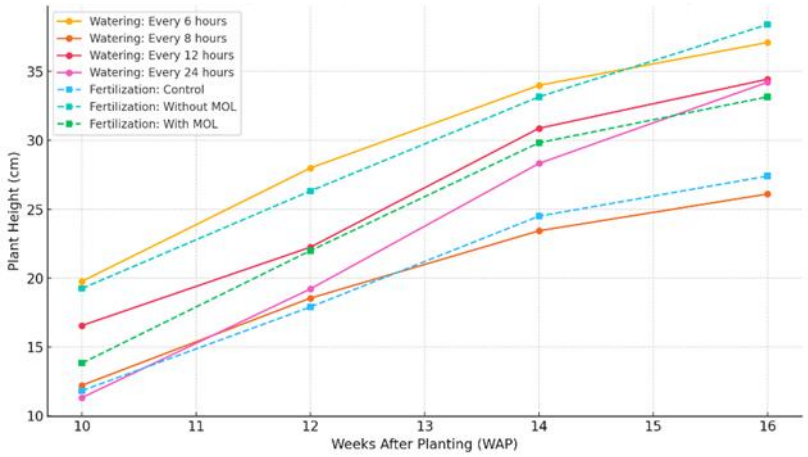
A. Growth Components

Plant Height

Plant height was significantly influenced by irrigation frequency and organic fertilisation treatments 10–16 weeks after planting (WAP). A significant interaction between irrigation frequency and fertilisation was observed at 10, 12, and 14 WAP (Table 1). Irrigation applied every 6 hours increased average plant height by 53.15% across all growth phases. This improvement is attributed to sustained water availability, facilitating optimal growth and development in green chanca piedra (*Phyllanthus niruri* L.). Oktavidiati et al. (2013) reported that maintaining adequate soil moisture significantly enhances plant height, whereas reduced irrigation frequency results in stunted growth (Jumawati et al., 2014). Similarly, Mahdya et al. (2020) demonstrated that daily irrigation markedly improves plant height compared to extended watering intervals (Mahdya et al., 2020).

Organic fertilisation without banana corm MOL application increased average plant height by 34.84% during growth. This outcome is associated with the capacity of organic fertilisers to supply essential nutrients and improve rhizosphere conditions, thereby promoting optimal growth responses in green chanca piedra. This aligns with findings by (Augustien & Suhardjono, 2016), who observed that growth media enriched with organic materials exhibit superior plant development compared to non-organic substrates, as the combination of soil and organic matter enhances nutrient availability for plant growth. Susanti (2006) corroborated these results, noting that organic manure improves plant vigor and yield components(Susanti, 2008). Further, manure application increases soil potassium availability, enhancing potassium uptake and elevating plant height (Kaya, 2014). These findings are consistent with (Sulastri, 2007), who reported superior growth metrics in organically fertilised plants relative to other treatments.

Figure 1. Effect of Different Irrigation Frequencies and Fertilization on Plant Height.



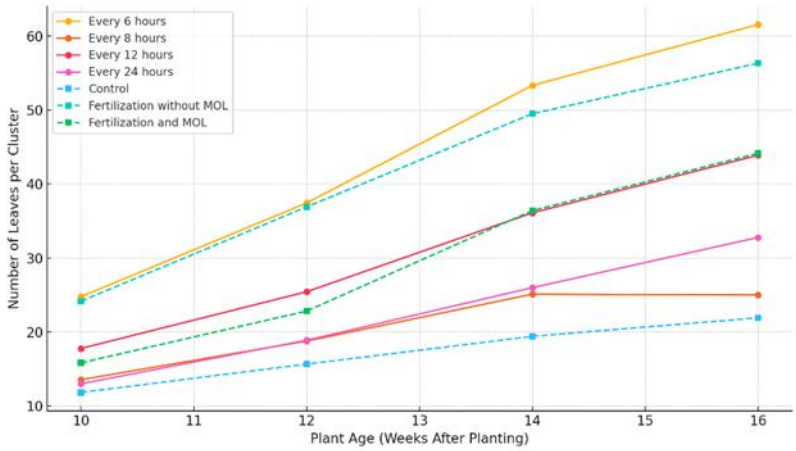
Number of Leaves per Cluster

The number of leaves per cluster was significantly influenced by irrigation frequency and fertilisation treatments at 10 and 12 weeks after planting (WAP) (Table 2). Irrigation applied every 6 hours increased the average number of leaves per cluster by 112.15% across all growth phases.

This increase is attributed to the critical role of water availability in mitigating abiotic stress and supporting leaf development in green chanca piedra (*Phyllanthus niruri* L.). Pangaribuan (2001) emphasized that water availability directly affects leaf production in green chanca piedra, with optimal irrigation reducing nutrient leaching and enhancing nutrient retention for sustained plant growth(Pangaribuan, n.d.). Further demonstrated that daily irrigation significantly increases leaf count compared to less frequent intervals . Felania (2017) corroborated this, noting that water constitutes 85–90% of plant tissue mass, underscoring its importance in driving leaf expansion and cluster formation under adequate irrigation regimes (Felania, 2017).

Organic fertilisation without banana corm MOL application increased the average number of leaves per cluster by 137.97% throughout the growth phases. This enhancement is linked to the timely availability of macronutrients (N, P, K) by 10 WAP, essential for leaf proliferation. Green chance piedra (Phyllanthus niruri L.) requires sufficient macronutrients and micronutrients, particularly nitrogen for chlorophyll synthesis, phosphorus for energy transfer, and potassium for enzymatic activation to optimise leaf development. Maryam et al. (2015) reported that chicken manure application significantly boosts leaf count, a finding consistent with (Agustine, 2017), who observed higher leaf numbers in green chanca piedra compared to other varieties (Maryam et al., 2015). Pamungkas et al. (2022) identified chicken manure as the most effective organic fertiliser for maximising leaf production, likely due to its balanced nutrient profile and slow-release properties. (Pamungkas et al., 2022). These results highlight the synergistic role of organic fertilisation in improving soil fertility and nutrient availability, thereby promoting vigorous leaf growth in green chanca piedra.

Figure 2. Effect of Different Irrigation Frequencies and Fertilization on the Number of Leaves per Cluster



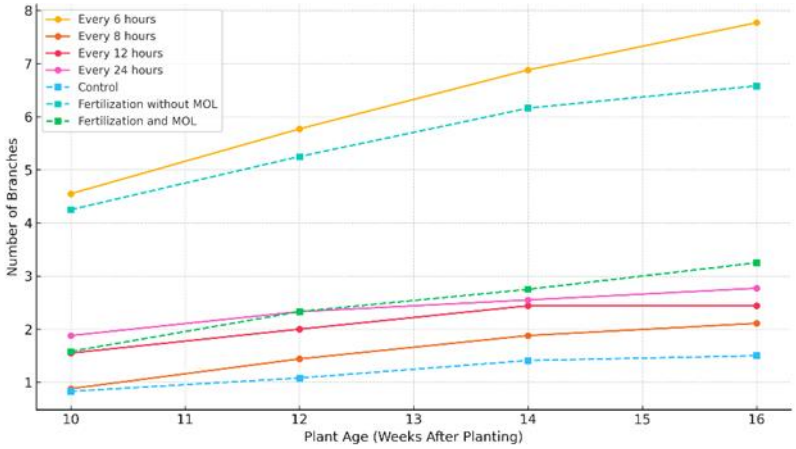
Number of Branches

The number of branches was significantly influenced by irrigation frequency and fertilisation treatments at 10–16 weeks after planting (WAP) (Table 3). Irrigation applied every 6 hours increased the average number of branches by 312.98% across all growth phases. This enhancement is attributed to sufficient water availability, which promotes vegetative growth and productive branching in green chanca piedra (*Phyllanthus niruri* L.). Gardner et al. (2008) emphasized that plant branching is governed by water availability, mineral uptake, and organic matter absorption from

the soil (Gardner et al., n.d.). Reduced branching under water-deficient conditions aligns with findings by Desmarina et al. (2009), who linked limited branch development to inadequate water supply. As water is critical for metabolic processes, restricted irrigation directly compromises growth outcomes (Desmarina, 2019).

Organic fertilisation without banana corm MOL supplementation increased the average number of branches by 368.42% throughout the growth phases. This result is associated with the ability of organic amendments to improve soil water retention and nutrient-holding capacity, thereby fostering robust vegetative growth. Haridjaja et al. (2013) corroborated that organic fertilisers optimize water-nutrient synergy, enhancing plant performance. (Haridjaja et al. 2013.). Setyanti (2013) further noted that adequate nutrient availability from organic fertilisation stimulates branching by supporting meristematic activity. Additionally, organic fertilisation enhances soil water-holding capacity, ensuring sustained moisture availability for plant uptake, which is critical for vegetative expansion (Sarief, 2014). The use of appropriate growth media also influences the rate of plant growth and development while facilitating seedling transportation (Imanda & Suketi, 2018; Yulianingtyas et al., 2015). These mechanisms collectively explain the superior branching observed in organically fertilized green chanca piedra under optimal irrigation regimes.

Figure 3. Effect of Different Irrigation Frequencies and Fertilization on the Number of Branches



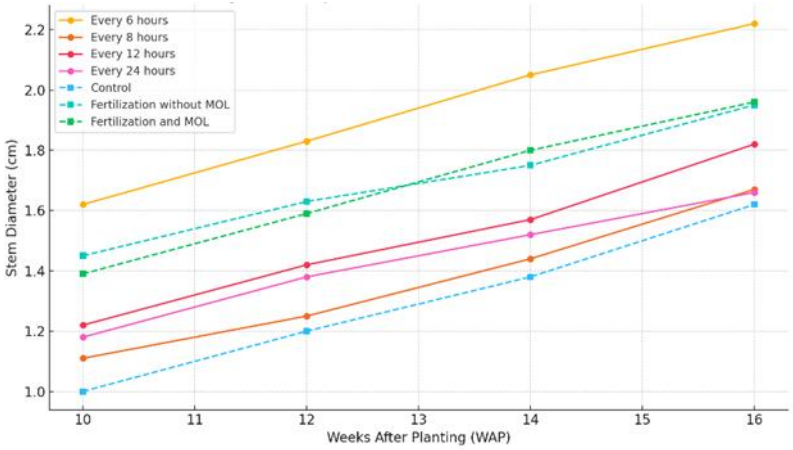
Stem Diameter

Stem diameter was significantly influenced by irrigation frequency at 16 weeks after planting (WAP) and fertilization treatments at 10 and 12 WAP (Table 4). Irrigation applied every 6 hours increased the average stem diameter by 42.10% across all growth phases. This improvement is linked to water availability, a critical environmental factor affecting cell turgor and vascular development in green chanca piedra (*Phyllanthus niruri* L.). Highlighted that adequate soil moisture significantly enhances stem diameter in green chanca Piedra (Oktavidiati, 2012). Conversely, reduced irrigation frequency compromises turgor pressure, limiting cell expansion and elongation (Manurung et al., 2019). Optimal vegetative growth, including stem thickening, depends on water availability to maintain cellular hydration and structural integrity.

Organic fertilisation without banana corm MOL supplementation increased average stem diameter by 33.06% at 10–12 WAP. This outcome is attributed to the role of organic fertilisers in supplying

essential macronutrients (N, P, K), which drive vegetative growth and biochemical processes. Dewi (2017) noted that nitrogen (N) facilitates protein synthesis and vegetative development, while phosphorus (P) accelerates carbohydrate formation, directly influencing cell enlargement and stem thickening (Setiono & Azwarta, 2020). Potassium (K), vital for enzymatic activation and osmotic regulation, further supports structural expansion. The synergistic effects of these nutrients enhance the plant's ability to assimilate resources, promoting robust stem development. These findings underscore the importance of organic fertilisation in optimising nutrient availability and soil water retention, both critical for maximizing stem diameter in green chanca piedra cultivation. This finding aligns with the research conducted by Amaliyah (2020), which reported that the application of banana corm-based local microorganisms (MOL) resulted in the optimal increase of plant stem diameter(Amaliyah, 2020).

Figure 4. Effect of Different Irrigation Frequencies and Fertilization on Stem Diameter



B. Biomass Production Components

Total Wet and Dry Weight

Total wet weight was significantly influenced by irrigation frequency and fertilisation treatments at 16 weeks after planting (WAP), with a significant interaction between these factors (Table 1). The highest total wet weight (8.09 g) was observed under 6-hour irrigation intervals, while the lowest (1.86 g) occurred with 8-hour intervals. This variation is attributed to superior water availability under frequent irrigation (every 6 hours), which enhances biomass accumulation in green chanca piedra (*Phyllanthus niruri* L.). Rahardjo et al. (1999) reported that water stress reduces biomass accumulation, as limited moisture availability restricts metabolic activity and cellular expansion. Consistent with this, Budiati (2016) demonstrated that higher vegetative growth parameters—including leaf count, branch number, and stem diameter—correlate with increased biomass production (Budiati, 2016). Optimal irrigation sustains water-dependent physiological processes, thereby maximizing biomass yield.

Organic fertilisation without banana corm MOL application yielded the highest average total wet weight (5.65 g), whereas the control treatment (no fertilisation) produced the lowest (2.06 g). This result underscores the role of organic fertilisers in enhancing canopy biomass by improving nutrient availability and soil structure. This finding is supported by research conducted by

Chaniago et al. (2017), which demonstrated that the application of liquid organic fertiliser (LOF) derived from banana corms at various concentrations had a positive effect on plant height, production per plot, yield per plant, and the number of pods per mung bean plant (Chaniago et al., 2017). Sanjutha et al. (2008) emphasised that fertilisation directly influences herb yield and medicinal quality in plants(Sanjutha et al., 2008). Specifically, macronutrients (N, P, K) supplied through organic amendments drive biomass synthesis by supporting photosynthesis, energy transfer, and enzymatic processes (Rahardjo & Setiawan, 2015). Optimal fertilisation promotes root and shoot development, leading to greater biomass partitioning. These findings align with agronomic principles in which nutrient-rich substrates enhance plant growth efficiency and resource allocation, ultimately increasing biomass production in green chanca piedra.

Table 1. Interaction of Different Irrigation Frequencies and Fertilization on Total Wet Weight at 16 Weeks After Planting (WAP)

Watering Frequency	Fertilisation			
	Control	Fertilisation without MOL	Fertilisation and MOL	Average
	g/Plant			
Every 6 hours	3.07 cd	12.24 a	8.96 ab	8.09
Every 8 hours	1.28 d	2.60 cd	1.71 cd	1.86
Every 12 hours	1.68 cd	5.79 bc	2.32 cd	3.26
Every 24 hours	2.19 cd	1.96 cd	4.23 cd	2.79
Average	2.05	5.64	4.30	

Values within the same column followed by the same letter are not significantly different at the 5% significance level (Duncan's Multiple Range Test, DMRT). MOL = local microorganisms.

The interaction between irrigation frequency and fertilisation at 16 weeks after planting (WAP) significantly influenced biomass production, particularly total wet weight. Combining 6-hour irrigation intervals and organic fertilisation without banana corm, MOL yielded the highest total wet weight, outperforming all other treatments. This aligns with findings by Yuliana (2002), who demonstrated synergistic interactions between irrigation and fertilisation in modulating biomass output. (Yuliana, 2002.). Optimal fertilisation rates enhance water-use efficiency, as plants under balanced nutrient regimes exhibit improved water uptake and metabolic activity. Fazriyati (2008) noted that adequate soil moisture amplifies plant responsiveness to fertilisation, creating a feedback loop that maximises biomass accumulation (Fazriyati, n.d.). These results underscore that biomass production in green chanca piedra (*Phyllanthus niruri* L.) can be significantly enhanced through integrated management of irrigation frequency and organic fertilisation, ensuring concurrent water and nutrient availability optimisation.

Table 2. Effect of Different Irrigation Frequencies and Fertilization on Total Wet and Dry Weight at 16 Weeks After Planting (WAP)

Treatment	Total Wet Weight		Total Dry Weight
	----------	g/Plant	----------
Watering Frequency			
Every 6 hours	8.09 a		2.17 a
Every 8 hours	1.86 b		0.52 b
Every 12 hours	3.27 b		0.75 b
Every 24 hours	2.79 b		0.81 b
Fertilisation			
Control	2.06 b		0.69 b
Fertilisation without MOL	5.65 a		1.38 a
Fertilisation and MOL	4.31 a		1.12 ab
Interaction	*		ns

Values within the same column followed by the same letter are not significantly different at the 5% significance level (Duncan's Multiple Range Test, DMRT). WAP = Weeks After Planting; MOL = Local Microorganisms; ns = insignificant at the 5% F-test.

Irrigation frequency and fertilisation treatments significantly influenced total dry weight 16 weeks after planting (WAP). The highest dry weight (2.17 g) was observed under 6-hour irrigation intervals, while the lowest (0.52 g) occurred with 8-hour intervals. This correlation arises from the direct relationship between wet and dry biomass, as the higher moisture content in fresh biomass typically corresponds to greater dry matter accumulation post-desiccation. Biomass production is directly modulated by vegetative parameters such as leaf count, branch number, stem diameter, and total wet weight. (Oktavidiati et al., 2013). In addition, Muhammad (2013) demonstrated that increased plant height, enhanced leaf production, branching, and stem thickening elevate dry biomass yield.(Muhammad, 2013). Rahardjo and Setiawan (2015) further corroborated that dry herb accumulation is driven by plant height and branch proliferation, hallmarks of vigorous growth.

Organic fertilisation without banana corm MOL application yielded the highest average total dry weight (1.38 g), whereas the control treatment (no fertilisation) produced the lowest (0.69 g). This disparity underscores the role of macronutrients (N, P, K) in dry biomass synthesis, as optimal nutrient availability enhances metabolic processes and structural development in green chanca piedra (*Phyllanthus niruri* L.). Leigh and Jones (1984) highlighted that potassium (K) alone constitutes approximately 10% of plant dry weight, emphasising its critical role in osmotic regulation and enzymatic activation (Leigh & Jones, n.d.). Mulyana (2015) attributed elevated dry biomass under organic fertilisation to improved nutrient availability and rhizosphere conditions, synergistically enhancing resource partitioning. Rahardjo and Setiawan (2015) reiterated that balanced fertilisation optimises growth efficiency, maximising dry biomass production in green chance piedra. These findings collectively emphasise that organic fertilisation, by supplying essential macronutrients, significantly boosts dry matter accumulation provided irrigation regimes sustain adequate water availability for nutrient uptake and assimilation.

Leaf Wet and Dry Weight

With a significant interaction between these factors, irrigation frequency and fertilisation treatments significantly influenced leaf wet weight 16 weeks after planting (WAP). The highest leaf

wet weight (3.37 g) was observed under 6-hour irrigation intervals, while the lowest (0.57 g) occurred with 8-hour intervals. This result highlights the critical role of water availability in supporting the growth and production of green chanca piedra (*Phyllanthus niruri* L.). Adequate irrigation facilitates nutrient solubilisation in the growth medium, enhancing root absorption and sustaining ecophysiological processes such as photosynthesis. Conversely, water scarcity disrupts these processes, impairing biomass accumulation (Aminudin, n.d.). Manan and Machfudz (2015) corroborated that leaf wet weight directly correlates with water availability, as optimal hydration sustains cellular turgor and metabolic activity (Manan & Al Machfudz, 2015).

Organic fertilisation without banana corm MOL application yielded the highest average leaf wet weight (2.18 g), whereas the control treatment (no fertilisation) produced the lowest (0.61 g). This enhancement is attributed to the ability of organic fertilizers to improve soil water retention, nutrient availability, and root absorption efficiency. Nitrogen (N), a key component of chlorophyll and proteins, stimulates vegetative growth in leaves, stems, and branches (Hanafiah, n.d.). Phosphorus (P) drives photosynthetic energy transfer and leaf expansion, with optimal P availability increasing light-use efficiency. (Musyarofah et al., n.d.). Potassium (K) regulates osmotic pressure, stomatal function, and photosynthetic efficiency, further amplifying biomass production (Sanyal & Dhar, n.d.). Collectively, these nutrients synergize under organic fertilisation to optimize leaf development, demonstrating that integrated water and nutrient management is pivotal for maximizing leaf biomass in green chanca piedra under controlled cultivation systems.

Table 3. Interaction of Different Irrigation Frequencies and Fertilization on Total Leaf Wet Weight at 16 WAP

Watering Frequency	Fertilisation			
	Control	Fertilisation without MOL	Fertilisation and MOL	Average
	----------	g/Plant	----------	
Every 6 hours	0.98 b	5.06 a	4.08 a	3.37
Every 8 hours	0.45 b	0.84 b	0.42 b	0.57
Every 12 hours	0.54 b	2.31 b	0.96 b	1.27
Every 24 hours	0.49 b	0.53 b	1.45 b	0.82
Average	0.61	2.18	1.72	

Values within the same column followed by the same letter are not significantly different at the 5% significance level (Duncan's Multiple Range Test, DMRT). MOL = local microorganisms.

The interaction between irrigation frequency and fertilisation at 16 weeks after planting (WAP) significantly enhanced leaf wet biomass production. Combining 6-hour irrigation intervals and organic fertilisation without banana corm MOL yielded the highest leaf wet weight, outperforming all other treatments. Rozari and Mar'ah (1995) emphasized that limited water availability reduces nutrient absorption efficiency compared to well-irrigated conditions, highlighting the interdependence of water and fertilisation in plant growth and development (Rozari & Mar'ah, n.d.). Fazriyati (2008) further noted that maintaining soil moisture at 20% of its potential water-holding capacity maximises biomass yield with appropriate fertilisation. Studies by Ekawati (2013) and Mulyana (2015) demonstrated that organic fertilisation increases leaf production by improving soil water retention and nutrient solubility(Ekawati, 2013; Mulyana et al., 2015)Organic

amendments enhance the soil's capacity to retain moisture, enabling water to act as a nutrient solvent and facilitating root uptake and metabolic processes. These findings underscore synchronised irrigation and organic fertilisation optimize water-nutrient synergy, driving superior leaf biomass accumulation in green chance piedra (*Phyllanthus niruri* L.).

Table 4. Effect of Different Irrigation Frequencies and Fertilization on Leaf Wet and Dry Weight at 16 Weeks After Planting (WAP)

Treatment	Leaf Wet Weight	Dry Leaf Weight
	g/Plant	
Watering Frequency		
Every 6 hours	3.37 a	1.04 a
Every 8 hours	0.57 b	0.23 b
Every 12 hours	1.27 b	0.30 b
Every 24 hours	0.82 b	0.32 b
Fertilisation		
Control	0.61 b	0.23 b
Fertilisation without MOL	2.18 a	0.63 a
Fertilisation and MOL	1.73 a	0.56 a
Interaction	*	ns

Values within the same column followed by the same letter are not significantly different at the 5% significance level (Duncan's Multiple Range Test, DMRT). WAP = Weeks After Planting; MOL = Local Microorganisms; ns = insignificant at the 5% F-test.

Irrigation frequency and fertilisation treatments significantly influenced leaf dry weight 16 weeks after planting (WAP). The highest dry weight (1.04 g) was recorded under 6-hour irrigation intervals, while the lowest (0.23 g) occurred with 8-hour intervals. As a critical herbal material, *Phyllanthus niruri* L. leaves serve as a primary source of bioactive compounds for health applications, and their dry biomass serves as an indicator of the plant's capacity to synthesize organic compounds from inorganic substrates such as water and carbohydrates. Kastono et al. (2005) highlighted that dry weight quantifies the accumulation of organic matter derived from photosynthetic processes, whereas Michael (2013) emphasized leaf dry biomass as a key indicator of plant productivity(Kastono et al., n.d.; Michael, 2013). Desmarina et al. (2009) further demonstrated that irrigation frequency modulates dry matter partitioning in medicinal plants.

Organic fertilisation without banana corm MOL application yielded the highest average leaf dry weight (0.63 g), whereas the control treatment (no fertilisation) produced the lowest (0.23 g). This disparity underscores the role of nitrogen (N) sourced from chicken manure in enhancing dry matter accumulation. Brady (1990) reported that optimal leaf N sufficiency ranges between 2.50–3.50%, with dry weight correlating to 1.50–6.00% N content in leaf tissues. Excessive phosphorus (P) levels (>1.00%) or deficiencies (<0.20%) negatively impact nutrient balance (Havlin et al., n.d.), potassium (K) content in mature leaves typically ranges from 1–5%, with sufficiency levels ranging from 1.5–3% (Jones, 1998). Tresnawati (1999) attributed accelerated leaf growth to nitrate accumulation, which stimulates meristematic activity—a finding corroborated by Susanti (2008), who identified chicken manure as a potent N source for enhancing leaf dry weight(Tresnawati, n.d.). Ressie et al. (2018) concluded that higher nutrient solubility enhances bioavailability, directly increasing dry biomass production (Ressie et al., 2018). These results demonstrate that organic

fertilisation significantly elevates leaf dry weight in green chance piedra by optimising N availability and nutrient synergy, provided that irrigation maintains an adequate water supply for nutrient assimilation.

CONCLUSION

This study demonstrates that integrating 6-hour irrigation intervals with organic fertilisation (without banana corm MOL) significantly enhances the growth and biomass production of *Phyllanthus niruri* L., underscoring the critical role of coordinated water and nutrient management. These protocols provide sustainable alternatives to synthetic inputs, improving water-use efficiency and soil health—key priorities for climate-resilient agriculture. Smallholder farmers in tropical regions could adopt these methods to reduce costs and stabilise yields in water-limited environments. Further research is recommended to explore the potential of combining banana corm-based microbial organic liquid (MOL) fertilisers with varying irrigation schedules to evaluate their synergistic effects on plant growth, soil health, and nutrient dynamics. Additionally, assessing the long-term economic viability and adaptability of these integrated practices across different agroecological conditions would be beneficial to support their broader application in sustainable and climate-resilient agriculture.

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