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Water Use Efficiency in Pineapple Plants Fertilization Based on Water Balance Analysis

Nungki Kusuma Astuti[1], Rinaldi Nur Rahman Putra[1], Yuni Arda Br Saragih[1]
[1] PT Great Giant Pineapple, Terbanggi Besar, Central Lampung

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Correspondence:
Nungki Kusuma Astuti
PT Great Giant Pineapple, Terbanggi Besar, Central Lapmpung, Indonesia
Email:
nungki.kusumaastuti@gg-foods.com

ABSTRACT
Most fertilization in pineapple cultivation occurs through foliar application, which involves dissolving fertilizers in water and spraying them on the pineapple plants. The provision of irrigated water to plants refers to water balance analysis, which corresponds to the available water supply. The research aims to determine the effect of various foliar volumes on the growth and production of pineapple plants. The research was carried out in April 2022 - July 2023 at PT. Great Giant Pineapple Lampung using a Completely Randomized Block Design (CRBD). We applied four treatments of foliar water, which comprised of 1500 l/ha, 2000 l/ha, 3000 l/ha (as control), and based on water balance analysis. The treatment has three replication each. The results showed there was not significant different of growth and yield between treatments of water balance approach and the 3000 l/ha foliar water volume (control), in which both have reduced water usage by 22% for one cycle of pineapple cultivation. The findings provide a more efficient water management strategy for foliar fertilization, reducing water usage without affecting plant performance, and supporting sustainable agricultural practices in pineapple cultivation. Further, the findings can serve as a reference for optimizing irrigation scheduling and input costs in large-scale plantations.

KEYWORDS
efficiency plant growth, foliar, irrigation, water volume effect

1. INTRODUCTION

Water availability is a key factor influencing plant growth and development, regulating essential physiological processes such as photosynthesis, nutrient transport, and water use efficiency (Aslyng, 2020; Jacobs et al., 2022; Saputra et al., 2023). In agricultural systems, maintaining water balance, the relationship between water input, storage, and output is crucial for determining optimal irrigation strategies and ensuring adequate water supply across different crop growth stages (Jacobs et al., 2022; Yi et al., 2022). An efficient water balance not only optimizes water use efficiency but also minimizes the risks associated with drought or excessive water application (Zhang et al., 2022).

Recent studies highlight that water use is influenced by irrigation and plant specific adaptive responses to environmental stress, such as heat and water scarcity (Marchin et al., 2023). This emphasizes the need to evaluate how water management strategies affect both water balance and plant physiological performance in field conditions. In this context, understanding the response of pineapple (*Ananas comosus*), a tropical CAM plant with inherently high water use efficiency (Males and Griffiths, 2017), to different foliar water volumes becomes essential for improving resource use efficiency and maintaining crop productivity.

Pineapple (*Ananas comosus*) is a tropical plant native to South America and widely cultivated in tropical and subtropical regions. As a member of the *Bromeliaceae* family, it demonstrates strong adaptability to high humidity and dry soils. Its Crassulacean Acid Metabolism (CAM) photosynthetic pathway allows the plant to open stomata at night to absorb CO_2 and close them during the day, minimizing water loss and making pineapple one of the most water-efficient crops (Carr, 2012).

One important agronomic practice to support pineapple productivity is foliar fertilization, which involves applying nutrient solutions directly onto leaves. This technique takes advantage of the leaf's capacity to absorb essential elements such as nitrogen, potassium, iron, zinc, and boron, provided the fertilizers are highly water soluble (Darnaudery et al., 2018; Spironello et al., 2004). High spray volumes are often recommended to ensure even nutrient coverage, particularly on main leaves responsible for photosynthesis. Foliar fertilization is especially valuable when root nutrient uptake is constrained due to suboptimal soil conditions such as salinity, acidity, or nutrient fixation, which are common in tropical cultivation systems (Alshaal and El-Ramady, 2017).

Given these considerations, this study aims to evaluate the water use efficiency of the GP3 pineapple cultivar using updated actual water balance data from 2021. Specifically, the research assesses the physiological, vegetative, and productivity responses of GP3 pineapple under different foliar water volumes, with the objective of optimizing water use while sustaining high crop performance.

2. MATERIAL AND METHODS

2.1 Study Area and Material

The field experiment was carried out from April 2022 to July 2023 at the Research and Development experimental site of PT Great Giant Pineapple, located in Terbanggi Besar District, Central Lampung Regency, Lampung Province, Indonesia.

We used macronutrient fertilizers such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), which are essential for optimal pineapple growth. Micronutrients including iron (Fe) and zinc (Zn) were also applied to prevent nutrient deficiencies and ensure balanced plant nutrition. Water served as a critical component for both irrigation and foliar application.

In addition, we used a Cameco boom sprayer, CropWat 8.0 software, personal protective equipment (masks, gloves, rubber boots), measuring tools (measuring cups, scales, tape measures), plastic buckets, water storage drums, stationery, bamboo stakes, and raffia strings for field activities.

2.2 Water Balance Analysis

Water balance analysis provides a climatic context and serves as the basis for determining the tentative water volume treatment. Monthly rainfall data were obtained from an on-site automatic weather station at the experimental site. Reference evapotranspiration (ETo) was calculated using CropWat 8.0 software, applying standard climatic parameters including temperature, relative humidity, wind speed, and solar radiation (Clarke et al., 2001).

The monthly water balance was determined by calculating the difference between rainfall and evapotranspiration (ETo). Then, we categorized it into three groups that reflect field conditions: (1) water deficit, where rainfall was lower than ETo by more than 3 BST (Basis Standard Terbanggi); (2) moderate water surplus, where rainfall exceeded ETo by 4–10 BST; and (3) high water surplus, where rainfall exceeded ETo by more than 10 BST. These categories were used to guide the adjustment of spray volumes in the tentative water volume treatment.

2.3 Data Analysis

2.1.1 Experimental Design and Statistical Analysis

The field experiment was designed to follow a Randomized Complete Block Design (RCBD) with four treatments and three replications, and totally we had 12 experimental units. The treatments are described in Table 1.

Table 1. Description of Treatments

Treatment	Description
VT	Tentative based on actual water balance in 2021 • Water deficit = spray volume 3000 L/ha • Water surplus <100 mm = spray volume 2000 L/ha • Water surplus >100mm = spray volume 1500 L/ha
V1	Spray volume 1500 L/ha
V2	Spray volume 2000 L/ha
V3/control	Spray volume 3000 L/ha

2.1.2 Observation Parameters

Two types of observations were conducted to evaluate plant's growth and productivity:

- **Destructive observations** were conducted at 3-, 6-, and 9- months after planting (MAP), as well as during forcing and harvest. Observed parameters included D-leaf characteristics (length, width, index, and weight), leaf colour, plant weight, stem weight, number of leaves, leaf nutrient uptake, root health, fruit weight, shape, quality, yield, and both fruit and crown distribution.
- **Non-destructive observations** were conducted from 3- MAP until the forcing stage. Parameters included D-leaf length, D-leaf width, D-leaf index, and leaf color were collected.

Additional yield quality indicators observed in this study included fruit size distribution and crown distribution. Fruit size distribution was based on fruit diameter and categorized into POM, <1 T, 1 T, 1 3/8 T, 2 T, and 2.5 T classes. Small-sized fruits were classified as POM to 1 3/8 T, while large-sized fruits included 2 T and 2.5 T categories, with a higher proportion of large-sized fruits being desirable for market quality. Crown distribution was assessed based on crown length, categorized into six classes: Class 1 (>38 cm), Class 2 (34–38 cm), Class 3 (25–33 cm), Class 4 (18–24 cm), Class 5 (15–17 cm), and Class 6 (12–14 cm). These crown classifications provide insights into planting material uniformity, which is essential for the consistency and quality of subsequent cultivation cycles.

Data were analyzed using analysis of variance (ANOVA) at the 5% significance level. When significant differences were observed, Tukey's Honest Significant Difference (HSD) test was performed at the 5% level to determine statistically different treatment groups.

3. RESULTS AND DISCUSSION

3.1 Water Balance Analysis

The water balance analysis of PT GGP in 2021 highlights distinct seasonal fluctuations in water availability. During the first four months (January–April) and towards the end of the year (November–December), the area experienced a water surplus, as indicated by positive water balance values across all BST categories. This surplus period coincides with relatively high rainfall exceeding evapotranspiration demands, providing favourable conditions for crop growth (Figure 1).

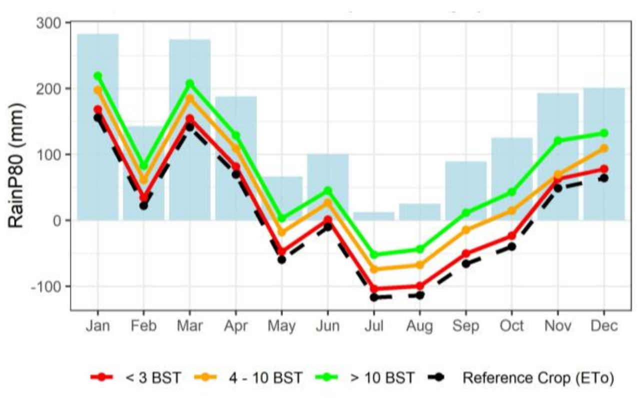

Figure 1. Water balance of PT GGP in 2021, showing monthly rainfall (P80) and water balance dynamics across BST categories and reference crop evapotranspiration (ETo).

In contrast, a prolonged water deficit occurred from May to October, and hit the peak at August. This period aligns with low rainfall and high evapotranspiration rates, resulting in negative water balance values, particularly severe for plantations with less than 3 BST (red line). The >10 BST category (green line) consistently shows a relatively better water balance, suggesting higher resilience or improved water retention capacity in more mature plantations.

The peak water deficit in August poses a critical risk for water stress, potentially affecting crop development and yield. The results emphasize the importance of strategic water management, particularly during the dry season, by optimizing irrigation schedules and considering crop stage differences (BST) to enhance water use efficiency and minimize drought impacts.

3.2 Leaf Nutrients

The leaf nutrient analysis under different water volume treatments at various growth stages is summarized in Figure 2, focusing on nitrogen (N), calcium (Ca), and magnesium (Mg), which showed significant variation at the forcing stage. At 3 MAP and 6 MAP, no clear pattern was observed in N, Ca, and Mg uptake across treatments, with values remaining relatively uniform. However, at the forcing stage, noticeable differences were evident. Nitrogen uptake was significantly higher under the 1500 L/ha treatment (1.84%), while calcium and magnesium uptake peaked under the 3000 L/ha (control) treatment, reaching 0.186% and 0.255%, respectively. These results suggest that water volume has a greater influence on nutrient accumulation during the generative phase compared to the early vegetative stages.

The complete nutrient analysis, including other elements such as phosphorus (P), potassium (K), iron (Fe), and zinc (Zn), is presented in Table A1 (Annex). In general, across all growth stages, no significant differences were observed for the additional nutrients between treatments. For instance, phosphorus and potassium uptake remained relatively stable at 3 MAP, 6 MAP, and forcing, regardless of the applied water volume. Similarly, iron and zinc levels showed no clear trend, with concentrations fluctuating slightly between treatments but without statistical significance. These results confirm that water volume variation during the early stages has limited impact on overall nutrient uptake, except for specific nutrients during critical developmental periods.

The results highlight the importance of adjusting water management strategies based on crop development stage. During the forcing stage, sufficient water availability enhances the uptake of essential nutrients such as calcium and magnesium, which are vital for fruit quality and structural development.

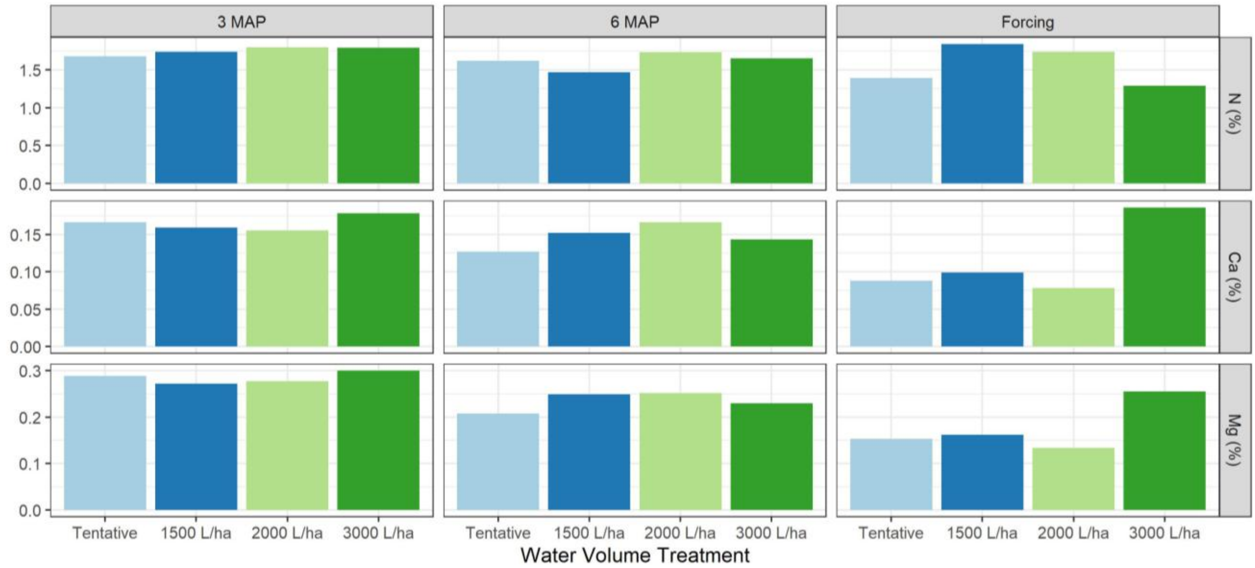

Figure 2. Essential leaf nutrient uptake (N, Ca, Mg) of pineapple plants across different water volume treatments at 3 MAP, 6 MAP, and forcing stage. The 3000 L/ha treatment generally showed higher Ca and Mg uptake at the forcing stage, suggesting improved nutrient absorption under sufficient water volume.

Moderate water application may also optimize nitrogen uptake without necessarily requiring excessive water use. This emphasized the role of efficient water application during reproductive stages in improving nutrient absorption and translocation, ultimately supporting crop productivity (Zhao et al., 2011).

3.3 Destructive and Non-Destructive Plants

The results of destructive observations at harvest time are presented in Table 2, focusing on parameters relevant to plant structure and yield. The results indicate that there were no significant differences across treatments for most parameters, including D-leaf length, leaf width, D-leaf weight, plant weight, stem weight, fruit weight, and number of leaves. However, for the crown weight parameter, the 3000 L/ha (control) treatment showed significantly higher values compared to the tentative water volume and 1500 L/ha treatments. We found that sufficient water application improved crown development, contributing to better fruit uniformity and overall plant quality. Although most growth and yield parameters showed no significant differences, crown weight consistently increased with higher water volume.

The destructive observation results at 3 MAP, 6 MAP, and at the forcing stage are provided in Table A2 (Annex). These results showed that the 3000 L/ha treatment tended to support better vegetative growth, as indicated by significantly higher D-leaf length at 3 MAP, as well as higher D-leaf weight and number of leaves at 6 MAP. At the forcing stage, plants under the 3000 L/ha treatment recorded significantly higher values for D-leaf weight, plant weight, and stem weight compared to lower water volume treatments.

Non-destructive observations of D-leaf length and width, recorded periodically from 3 MAP to 7 MAP, are presented in Table A3 (Annex). These results showed no significant differences across treatments at any growth stage, indicating that early vegetative development based on non-destructive measurements is less sensitive to water volume variation. Destructive measurements at later stages provided clearer evidence of water volume influence.

These findings highlight the importance of sufficient water application, particularly during critical phases such as the forcing stage, to optimize vegetative growth, crown development, and overall plant performance. Adequate spray volume enhances nutrient dissolution and absorption, supporting better plant structure and potentially improving fruit quality, in line with the findings of Tomar and Kalra (2018) and Hotegni et al. (2012).

3.4 Leaf Color

Leaf colour monitoring further reflected the plant's physiological response to different water volume treatments. At 3 and 4 MAP, all treatments, exhibited yellowish-green (C) leaf colour, indicating suboptimal nutrient status during early growth. However, by 5 and 6 MAP, the leaf colour improved towards green (B), suggesting a recovery in nutrient status as plants developed (Figure 3).

The gradual shift to greener leaves aligns with the nature of pineapple as a CAM plant, which is known for its high-water use efficiency under dry conditions (Males & Griffiths, 2017). The improvement in leaf colour at later stages also reflects the role of sufficient water volume, particularly the 3000 L/ha treatment, in

Table 2. Variation of plant parameters based on destructive sampling at harvest time

Treatment	D-Leaf			Weight (g)		Number of	Fruit	Crown
	Length (cm)	Width (cm)	Weight (g)	Plants	Stem	Leaves (blade)	Weight (g)	Weight (g)
VT = Tentative	99,75[a]	5,6 [a]	74,2 [a]	2717,3 [a]	608,0 [a]	37,3 [a]	1396,0 [a]	161,3 [b]
V1 = 1500 L/ha	98,51[a]	5,5 [a]	70,8 [a]	2608,0 [a]	633,3 [a]	36,5 [a]	1325,3 [a]	158,3 [b]
V2 = 2000 L/ha	99,89[a]	5,5 [a]	71,9 [a]	2634,7 [a]	636,0 [a]	39,1 [a]	1390,7 [a]	187,3 [ab]
V3 = 3000 L/ha	100,45[a]	5,6 [a]	75,9 [a]	2634,7 [a]	594,6 [a]	37,4 [a]	1382,7 [a]	214,7 [a]
p-value	0,191	0,259	0,111	0,319	0,58	0,205	0,336	0,003

supporting nutrient uptake, as discussed in Section 3.2. Therefore, leaf colour serves as a simple but reliable indicator of plant health and nutrient sufficiency throughout the growth period.

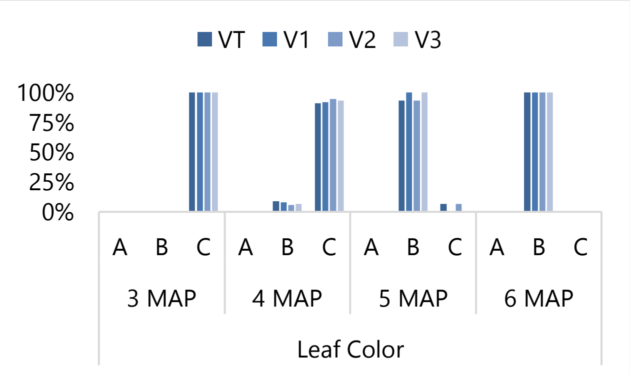

Figure 3. Leaf colour on pineapple plant at 3 MAP – 6 MAP

3.5 Root Health

The improvement in leaf colour and vegetative growth was also supported by root health observations. At 3MAP, plants treated with 1500 L/ha, 2000 L/ha, and 3000 L/ha water volumes exhibited healthy root conditions (score 3.7), while tentative water volume treatment showed slightly lower root health (score 3.4). By 6MAP, all treatments showed uniform and healthy root conditions (score 3.7).

This consistent root health under sufficient water volumes complements earlier findings on improved nutrient uptake and vegetative growth, particularly under the 3000 L/ha treatment. Healthy roots are essential for nutrient and water absorption, ensuring that the positive effects observed at the leaf level are also supported belowground (Taiz and Zeiger, 2010). This underlines the interconnectedness between foliar application, root development, and overall plant health.

3.6 Crop Production Potential

Despite improvements in vegetative growth, leaf color, and root health, these did not translate into significant yield differences. Fruit weight, 100-fruit weight distribution, and production potential were similar across treatments (Table 4), indicating that increasing water volume beyond 3000 L/ha does not guarantee higher yield. This suggests that beyond ensuring adequate water for nutrient uptake, factors like nutrient formulation, environmental conditions, and the physiological limits of CAM plants play a greater role in determining yield (Carr, 2012; Marchin et al., 2023; Spironello et al., 2004).

Table 4. Observation of fruit weight, weight distribution of 100 fruit, and production potential at harvest

Treatment (L/ha)	Fruit Weight (kg)	Weight distribution of 100 fruit (kg)	Potential Production (ton/ha)
VT = Tentative	1,3[a]	129,37[a]	94,08[a]
V1 = 1500	1,3[a]	129,47[a]	94,16[a]
V2 = 2000	1,2[a]	124,80[a]	90,76[a]
V3 = 3000	1,3[a]	131,27[a]	95,47[a]
p-value	0,816	0,816	0,816

3.7 Fruit and Crown Distribution

The fruit and crown distribution results further support the previous production findings. At harvest, all treatments did not show significant differences in the proportion of small and large fruits. Despite improvements in vegetative parameters and root health under higher water volume, these differences did not translate into changes in fruit size distribution. This suggests that fruit development in pineapple is influenced by factors beyond just foliar water volume, such as nutrient status, leaf efficiency, or plant genetics.

Meanwhile, crown distribution showed clearer differences among treatments, as presented in Table 5. For Class 3 crowns (smaller crowns), the 1500 L/ha and 2000 L/ha treatments resulted in significantly higher proportions compared to the control. In contrast, for Class 6 crowns (larger crowns), the 3000 L/ha control treatment produced a significantly higher proportion than the tentative water volume treatment. No significant differences were observed for crowns in Class 4 and 5.

These findings align with the overall vegetative growth trends, where sufficient foliar water application (3000 L/ha) supports more vigorous plant development. The higher proportion of larger crowns in the control treatment reflects better vegetative growth, potentially enhancing the plant's resilience and marketable appearance. However, the increased proportion of smaller crowns under reduced water volumes indicates possible limitations in growth, further confirming the benefits of optimal water application for crown development.

Table 5. Crown distribution of pineapple at harvest across different crown size classes.

Treatment (L/ha)	Class (%) 3	4	5	6
VT = Tentative	4,3[ab]	55,4[a]	19,2 [a]	21,1[b]
V1 = 1500	8,0[a]	44,9[a]	15,9 [a]	31,2[ab]
V2 = 2000	7,9[a]	45,0 [a]	17,6 [a]	29,4[ab]
V3 = 3000	3,0[b]	23,8 [a]	25,1 [a]	48,0[a]
p-value	0,013	0,08	0,38	0,06

3.8 Fruit Analysis

The analysis of fruit quality parameters such as brix, acidity, and number of fruit eyes, showed no significant differences across all treatments (Table 6). These results demonstrated that increased spray volume beyond 3000 L/ha does not significantly affect pineapple fruit quality.

This implies that moderate reductions in foliar spray volume can be implemented without compromising key fruit quality attributes. Efficient water use through volume adjustment remains a viable strategy to maintain fruit quality while optimizing resource use, provided other critical factors such as nutrient and environmental management are well controlled (Darnaudery et al., 2018; Yi et al., 2022).

Table 6. Observation results of fruit quality parameters at harvest.

Treatment	Brix (⁰)	Acidity (%)	Number of Fruit Eye
VT = Tentative	9,72[a]	0,47[a]	9,6[a]
V1 = 1500	10,07 [a]	0,47[a]	9,8[a]
V2 = 2000	10,31[a]	0,48[a]	10,3[a]
V3 = 3000	10,32[a]	0,50[a]	9,7[a]
p-value	0,679	0,789	0,201

4. CONCLUSIONS

Based on the results of the experiment, it can be concluded that foliar spray application using water volumes based on the water balance—3,000 L/ha during the dry season, 1,500 L/ha during the rainy season, and 2,000 L/ha during the transitional season—can be used as an alternative to optimize water use, with pineapple growth and crop yield not significantly different from the 3,000 L/ha volume. The benefits of this research include promoting more efficient water management, reducing resource use without compromising plant performance, and contributing to the sustainability of large-scale pineapple farming by adapting to seasonal water availability. This strategy offers an important step toward more sustainable agricultural practices and better resource conservation in tropical crop cultivation.

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ANNEX

Table A1. Nutrient uptake of pineapple leaves at 3 MAP, 6 MAP, and at forcing

Age	Treatment	N	P	K	Ca	Mg	Fe	Zn
		%	%	%	%	%	ppm	ppm
3 MAP	VT = Tentative	$1,68^{a}$	$0,19^{a}$	$2,62^{a}$	$0,166^{a}$	$0,289^{a}$	$322,85^{a}$	$47,31^{a}$
	V1 = 1500 L/ha	$1,74^{a}$	$0,18^{a}$	$2,76^{a}$	$0,159^{a}$	$0,272^{a}$	$386,66^{a}$	$40,00^{a}$
	V2 = 2000 L/ha	$1,80^{a}$	$0,20^{a}$	$2,62^{a}$	$0,155^{a}$	$0,277^{a}$	$370,53^{a}$	$42,08^{a}$
	V3 = 3000 L/ha	$1,79^{a}$	$0,20^{a}$	$2,74^{a}$	$0,178^{a}$	$0,300^{a}$	$457,99^{a}$	$57,96^{a}$
	p-value	0,45	0,7	0,378	0,522	0,741	0,282	0,142
6 MAP	VT = Tentative	$1,62^{a}$	$0,24^{a}$	$2,33^{a}$	$0,127^{a}$	$0,208^{a}$	$110,81^{a}$	$33,50^{a}$
	V1 = 1500 L/ha	$1,47^{a}$	$0,23^{a}$	$3,01^{a}$	$0,152^{a}$	$0,249^{a}$	$179,40^{a}$	$32,94^{a}$
	V2 = 2000 L/ha	$1,73^{a}$	$0,22^{a}$	$2,69^{a}$	$0,166^{a}$	$0,252^{a}$	$149,21^{a}$	$33,51^{a}$
	V3 = 3000 L/ha	$1,65^{a}$	$0,22^{a}$	$2,44^{a}$	$0,143^{a}$	$0,230^{a}$	$209,81^{a}$	$32,04^{a}$
	p-value	0,384	0,705	0,252	0,299	0,173	0,115	0,960
At Forcing	VT = Tentative	$1,39^{ab}$	$0,22^{a}$	$2,48^{a}$	$0,088^{b}$	$0,153^{b}$	$250,57^{a}$	$54,85^{a}$
	V1 = 1500 L/ha	$1,84^{a}$	$0,22^{a}$	$2,10^{a}$	$0,099^{a}$	$0,162^{ab}$	$145,99^{a}$	$39,01^{a}$
	V2 = 2000 L/ha	$1,74^{a}$	$0,21^{a}$	$2,21^{a}$	$0,078^{b}$	$0,134^{b}$	$196,49^{a}$	$34,91^{a}$
	V3 = 3000 L/ha	$1,29^{b}$	$0,23^{a}$	$1,95^{a}$	$0,186^{a}$	$0,255^{a}$	$276,23^{a}$	$20,17^{a}$
	p-value	0,015	0,324	0,487	0,002	0,020	0,300	0,242

Table A2. Destructive observations on pineapple plants at 3 MAP, 6 MAP, and forcing stage

Age	Treatment	D-Leaf				Weight		Number of Leaves (blade)
		Length (cm)	Width (cm)	Index (cm^2)	Weight (g)	Plant (g)	Stem (g)	
3 MAP	VT = Tentative	$57,3^{a}$	$3,3^{a}$	$189,1^{a}$	$21,1^{a}$	$571,3^{a}$	$62,7^{a}$	$37,1^{a}$
	V1 = 1500 L/ha	$56,8^{ab}$	$3,3^{a}$	$187,4^{a}$	$21,1^{a}$	$598,7^{a}$	$59,3^{a}$	$37,1^{a}$
	V2 = 2000 L/ha	$55,0^{b}$	$3,3^{a}$	$181,5^{a}$	$20,8^{a}$	$596,0^{a}$	$64,7^{a}$	$38,7^{a}$
	V3 = 3000 L/ha	$59,5^{a}$	$3,3^{a}$	$196,4^{a}$	$21,7^{a}$	$566,7^{a}$	$64,0^{a}$	$36,7^{a}$
	p-value	0,020	0,775	0,487	0,520	0,488	0,805	0,144
6 MAP	VT = Tentative	$74,7^{a}$	$4,4^{a}$	$333,2^{a}$	$39,9^{b}$	$1124,0^{a}$	$118,7^{a}$	$48,3^{a}$
	V1 = 1500 L/ha	$74,2^{a}$	$4,5^{a}$	$334,9^{a}$	$41,3^{b}$	$1250,7^{a}$	$106,7^{a}$	$43,1^{b}$
	V2 = 2000 L/ha	$73,1^{a}$	$4,4^{a}$	$327,6^{a}$	$40,2^{b}$	$1094,7^{a}$	$108,0^{a}$	$45,3^{ab}$
	V3 = 3000 L/ha	$74,2^{a}$	$4,9^{a}$	$362,5^{a}$	$48,2^{a}$	$1258,0^{a}$	$114,7^{a}$	$48,5^{a}$
	p-value	0,929	0,064	0,344	0,003	0,073	0,229	0,014
At Forcing	VT = Tentative	$92,1^{a}$	$5,8^{a}$	$532,3^{a}$	$71,1^{a}$	$2173,3^{ab}$	$244,0^{ab}$	$50,0^{a}$
	V1 = 1500 L/ha	$89,5^{a}$	$5,3^{b}$	$482,5^{b}$	$60,7^{b}$	$2012,0^{b}$	$205,3^{bc}$	$50,0^{a}$
	V2 = 2000 L/ha	$90,8^{a}$	$5,6^{ab}$	$505,3^{ab}$	$64,8^{ab}$	$1993,3^{b}$	$204,0^{c}$	$50,2^{a}$
	V3 = 3000 L/ha	$92,5^{a}$	$5,6^{ab}$	$519,2^{ab}$	$68,9^{a}$	$2401,3^{a}$	$268,0^{a}$	$54,6^{a}$
	p-value	0,383	0,012	0,032	0,001	0,007	0,000	0,101

Table A3. Non-destructive observations on pineapple plants at 3 MAP, 6 MAP, and forcing stage

Treatment	3 MAP		4 MAP		5 MAP		6 MAP		7 MAP	
	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)
VT = Tentative	$60,13^{a}$	$3,59^{a}$	$63,98^{a}$	$3,78^{a}$	$68,39^{a}$	$4,67^{a}$	$74,16^{a}$	$5,42^{a}$	$81,97^{a}$	$5,65^{a}$
V1 = 1500 L/ha	$56,17^{a}$	$3,43^{a}$	$60,33^{a}$	$3,59^{a}$	$65,19^{a}$	$4,18^{a}$	$73,37^{a}$	$4,68^{a}$	$79,83^{a}$	$5,48^{a}$
V2 = 2000 L/ha	$55,75^{a}$	$3,38^{a}$	$59,74^{a}$	$3,63^{a}$	$64,75^{a}$	$4,24^{a}$	$72,58^{a}$	$4,75^{a}$	$79,82^{a}$	$5,57^{a}$
V3 = 3000 L/ha	$57,85^{a}$	$3,39^{a}$	$61,73^{a}$	$3,64^{a}$	$66,46^{a}$	$4,20^{a}$	$74,95^{a}$	$4,83^{a}$	$81,36^{a}$	$5,69^{a}$
p-value	0,180	0,210	0,470	0,350	0,270	0,190	0,837	0,424	0,570	0,640