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Post-Ratooning Water Spinach Growth and Production in Water Spinach Catfish Aquaponic Farming

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ABSTRACT

Water spinach is a plant species that can be utilized for food diversification in Indonesia. Water spinach is among the plants that can be grown using an aquaponic system. Aquaponics is a method of cultivation that integrates fish and vegetable farming in a single location. Ratoon is a pruning technique that stimulates the growth of new shoots and is a supportive method for aquaponic cultivation. The use of foliar fertilizer is an approach to enhance the growth of water spinach in aquaponic systems. The objective of this research is to assess the impact of foliar fertilizer and stocking density on the growth of water spinach ratoon in aquaponics. The study employed a factorial Randomized Block Design (RAK) approach, with foliar fertilizer as the first factor and stocking density as the second factor. The findings indicated that foliar fertilizer application had a significant effect on nearly all variables, except for the number of leaves in the third ratoon, wet and dry weight of roots in the third ratoon, root volume in the third ratoon, and plant biomass. The most effective type of foliar fertilizer was found to be Growmore. The stocking density of catfish also had a notable impact on most variables, except for the plant height in the third ratoon, number of leaves in the third ratoon, stem diameter in the second ratoon, stem diameter in the third ratoon, and dry weight in the third ratoon. The optimal catfish stocking density was determined to be 15 catfish. The combined treatment of foliar fertilizer and catfish stocking density only showed a significant effect on certain variables, such as stem diameter in the second ratoon, root wet weight in the third ratoon, root volume in the third ratoon, and plant biomass. The highest average value was observed in the treatment combination of 15 catfish with Growmore fertilizer.

Keywords: *Aquaponics, Catfish Stocking Density, Foliar Fertilizer, Kale, Ratoon*

1. INTRODUCTION

Aquaponics presents itself as a viable alternative cultivation method aimed at enhancing vegetable production and quality through the integration of soil and fish cultivation practices (Rahmadhani et al., 2020). The key distinction between hydroponic and aquaponic systems lies in the fact that hydroponics relies on chemical nutrients, whereas aquaponics operates without the need for such additives. Instead of liquid chemical nutrients, aquaponics leverages nutrients present in pond water, which is sourced from fish waste and leftover fish food. This unique approach results in improved pond water quality and enhanced vegetable productivity when compared to hydroponic systems (Halim & Pratamaningtyas, 2020). Among the various aquaponic systems available, Budikdamber, which involves cultivating catfish and water spinach in buckets, stands out as a popular choice. The Budikdamber system operates on the principle of fish and vegetable polyculture within a single bucket, thereby eliminating the need for electricity to oxygenate or circulate water within the pool (Febri et al. 2019). Notably, the utilization of catfish waste plays a crucial role in the success of the Budikdamber system. Research by Andriyeni et al. (2017) highlights the macronutrient content present in catfish waste, including total nitrogen at 1.32%, total phosphorus at 2.64%, and total potassium at 0.35%. This technology, characterized by its simplicity and cost-effectiveness, underscores the use of buckets as a practical alternative to traditional pools, particularly in settings with limited space. However, a notable drawback of this approach is its reliance solely on nutrient content from wastewater and catfish feed, potentially leading to growth limitations due to inadequate nutrition.

Efforts to promote the growth of aquaponic kale plants involve the practice of ratooning. Ratooning refers to the process of pruning certain parts of the stem after harvesting in order to stimulate the growth of new shoots or saplings (Triani & Syahrullah, 2020). Stem pruning is typically carried out during the main crop's harvest. According to Mareza et al. (2017), the height at which the stem is pruned has an impact on the number of shoots that will emerge later on. Herlinda et al. (2015) also conducted previous research on this topic. In a study conducted by Khodijah et al. (2022), it was found that there was no significant interaction between foliar fertilizer treatment and catfish stocking density in relation to the growth of aquaponic water spinach in the Budikdamber system. The results indicated that foliar fertilizer treatment with a higher nitrogen (N) composition (32% N, 10% phosphorus (P), 10% potassium (K), and 0.1% magnesium (Mg)) was more effective in supporting canopy growth compared to a foliar fertilizer with a lower N composition. Additionally, the foliar fertilizer with higher N composition had higher levels of P, K, and Mg (20% N, 15% P, 15% K, and 1% Mg), but this did not result in improved root growth. Furthermore, the catfish stocking density treatment (10, 15, and 20 fish per 50 liters of water) did not show any significant differences in terms of the growth and production of water spinach. This finding contradicts previous research, which utilized a smaller density range for the kale plants. Based on these findings, the present study aims to investigate the effects of ratooned water spinach with a higher catfish density range.

Foliar fertilizers are a specific type of fertilizers that are administered to plants, particularly to the leaves, through direct spraying. Commonly referred to as foliar feed, the application of foliar fertilizers has been shown to have a positive impact on plant growth. Suryani et al. (2021) found that regular use of foliar fertilizers at a high concentration can lead to an increase in plant height. Two commonly used types of foliar fertilizers in aquaponics systems are

Gandasil D and Growmore. Anam (2017) discovered that a combination treatment of Gandasil D 10 ml fertilizer with EM4 3 g/l resulted in the most favorable outcomes for the growth of water spinach. Additionally, Muksalmina et al. (2020) observed a significant increase in the number of leaves in coffee plantation crops when treated with Growmore fertilizer at a dosage of 3g/liter of water. Furthermore, the application of Gandasil D and Growmore fertilizers, along with the NAA hormone, has been found to positively impact the growth of ornamental plants like orchids (Sumiati & Astutik 2019). In a separate study focusing on kale vegetable plants, a lower dosage of 2g/liter of water was utilized for the application of foliar fertilizers.

Fish stocking density plays a crucial role in the cultivation of plants using Budikdamber aquaponics. As stated by Zalukhu et al. (2016), there is an inverse relationship between fish stocking density and fish growth. Higher stocking densities lead to reduced fish growth due to the accumulation of fish faeces, which increases the ammonia levels in the water. Ammonia, a byproduct of protein metabolism, is toxic to fish (Prayogo, 2019). However, Wahyuningsih and Gitarama (2020) suggest that ammonia can be beneficial for fish at normal levels as it aids in protein synthesis and provides energy, owing to its nitrogen content. Based on the information provided, further research is required to investigate the impact of different types of foliar fertilizers and catfish stocking densities in the Budikdamber system on the growth and yield of water spinach in the aquaponic system. This research aims to identify the optimal foliar fertilizer and catfish stocking density that can enhance the growth of aquaponic water spinach plants using the Budikdamber system.

2. MATERIAL AND METHODS

The equipment used in this research includes a 60-liter bucket, plastic cup, TDS meter, sprayer wire, thermohygrometer, lux meter, pliers, and soldering iron. The materials used are catfish seeds measuring 10-12 cm, water spinach seeds, fish pellets, rice husk charcoal, EM 4, AB Mix, Gandasil D, and Growmore.

Research Method

This research employed an experimental approach utilizing a group randomized design (RAK) factorial split plot with two factors. The first factor pertains to the type of foliar fertilizer (P), which encompasses three treatment levels: P0, representing the absence of foliar fertilizer (Control); P1, involving Gandasil D; and P2, involving Growmore (32-10-10). The second factor focuses on the stocking density of catfish (L), which encompasses three treatment levels: L1, consisting of 20 tails; L2, consisting of 40 tails; and L3, consisting of 60 tails.

Consequently, there are a total of nine combinations for each treatment factor, with each combination being repeated three times, resulting in 27 experimental units. Each experimental unit comprises five kale plants, leading to a total of 135 plant populations. Notably, the sample size for each experimental unit consists of five kale plants.

How it works

Making Green House

The greenhouse used is of the tunnel type, measuring 15 meters in length, 3 meters in width, and 3 meters in height. It is constructed with lightweight steel channel-sized 75/75, and pipes sized ¾ cm, with the roof covered by plastic. The curved shape of the Greenhouse roof is designed to prevent rainwater from accumulating.

Catfish Budikdamber Media Preparation

The experimental setup involved the utilization of Catfish Budikdamber media. A 60 L bucket was employed as the primary container, while plastic cups were used as individual pots to accommodate kale plants. To ensure proper drainage, the bottom of each plastic cup was punctured using solder, and a wire was subsequently wrapped around it to securely attach it to the bucket. Prior to commencing the experiment, the bucket was emptied and subsequently filled with 50 L of water. Additionally, EM4 (probiotics) was added to the water, and the entire setup was left undisturbed for 4 days.

Catfish Seed Preparation and Stocking

The size of the catfish seeds utilized is 10-12 cm. The catfish seeds used must be in optimal health to minimize mortality rates upon being introduced into Budikdamber. Prior to stocking, the catfish seeds undergo an acclimation process to adapt to the water conditions within the bucket. The stocking of catfish seeds is carried out based on the prescribed density treatments in the bucket, and they are left undisturbed for 2 days before the kale pot is positioned at the rim of the bucket.

Preparing Kale plant

Water spinach seeds utilized for experimentation should be devoid of any pests and diseases. These seeds are planted in pots containing AB mix nutrient media at a concentration of 800 ppm. The seedling process for kale lasts for 14 days before being transferred to Budikdamber media.

Transplanting Kale Plants

After being planted for two weeks, the water spinach plants are moved to plastic containers filled with granular husk charcoal. Prior to planting, the husk charcoal is sifted to ensure only granules are used. The water spinach seedlings are then carefully placed within the charcoal media to support their growth. Additionally, wire wrapped around a plastic cup is utilized to secure the kale plants along the rim of the container.

Catfish Care

Maintenance of catfish is carried out by providing regular feeding twice a day, in the morning and afternoon, using fish pellets. Water refilling is done when the water in the bucket decreases by 20% or equivalent to 10 liters.

Ratoon treatment 2

After undergoing a 30-day maintenance period, the ratooning procedure was implemented by trimming the kale plants at a distance of 7 cm from the root collar. Additionally, the plants were nurtured until they reached the age of 44 days.

Figure 1. Kangkung post-harvest ratoon

1st foliar fertilizer spraying

Spraying treatment 1 is carried out after the plants are 37 days old following treatment 2. The spraying treatment is administered in accordance with the prescribed dosage of foliar fertilizer.

Ratooning 3 treatment

Ratoon 3 treatment is carried out after the water spinach is 44 days old. The plants are cut at the height of 7 cm from the root neck boundary, and then they are maintained until they reach 58 days for harvesting as the yield of the 3rd ratoon, which marks the end of the study.

2nd foliar fertilizer spraying

Spraying of foliar fertilizer on water spinach is carried out after the plants reach 51 days after ratoon 3. The spraying treatment is applied in accordance with the prescribed dosage of foliar fertilizer.

Observed parameter

1. Microclimate Observations

Microclimate observations consist of temperature and humidity measurements. Environmental temperature and humidity are measured using a thermohygrometer. These microclimate observations are conducted daily.

2. Plant height (cm)

Measurement of plant height starts from the base of the stem to the tip of the growing point using a ruler. Measurement of plant height is done every 1 week until harvest.

3. Number of Leaves (Strands)

The number of leaves is observed by counting the fully opened ones. This observation is carried out weekly until the harvest.

4. Header Wet Weight (g)

To measure the wet weight of the canopy, the whole plant is placed on a digital scale. This measurement is taken when the plant is 44 days old in water spinach ratoon 2 and 58 days old in water spinach ratoon 3.

5. Root Wet Weight (g)

To measure the wet weight of the roots, the entire plant is placed on a digital scale. This measurement is taken when the plant is 58 days old.

6. Header Dry Weight (g)

The dry weight of the canopy was measured using a digital scale. Before being weighed, the kale crowns go through a drying process first by relying on sunlight, also known as the wind drying method. The shoot dry weight was measured when the plants were 44 days old in Water spinach Ratoon 2 and 58 days in Water spinach Ratoon 3.

7. Dry Root Weight (g)

The dry weight of the roots is measured using a digital scale. Before weighing, the water spinach roots are dried using sunlight. The measurement of the dry weight of the canopy is done when the water spinach plants are 58 days old.

8. Root Volume

Measuring root volume is done by comparing the final amount of water with the initial amount. A 500 ml volume of water is poured into a container, and then the roots are placed in it, causing an increase in volume. This measurement is taken at 58 days old. The volume of the roots can be calculated using the following formula:

Root volume = Initial water volume - Final water volume

9. Leaf Area

The leaf area of water spinach plants was measured using a ruler by measuring the length and width of the leaves and then multiplying the values by a constant specific to water spinach leaves. The measurement was taken from the fourth leaf from the top of the plant. Leaf area measurements were conducted when the plants were 44 days old in water spinach ratoon 2 and 58 days old in water spinach ratoon 3.

10. Leaf Color

Leaf color can be observed using the Munsell Color Chartbook. The observation focuses on the fifth leaf from the top of the plant. These observations are conducted when the plants are 44 days old for Water spinach ratoon 2 and 58 days old for Water spinach ratoon 3.

Data Analysis

Data analysis involves using statistical tests such as analysis of variance or F test (ANOVA) at a confidence level of 95%. This analysis is performed when the collected data follows a normal distribution. The F test is used to assess the impact of the treatment on the observed variable. If there is a significant relationship between the treatment and the observed variable, a follow-up DMRT (Duncan Multiple Range Test) is conducted. The data analysis is conducted using the SAS application.

3. RESULT AND DISCUSSION

3.1 Environmental Microclimatic Conditions

The environmental microclimate in this study reveals that the temperature and humidity levels inside the Green House fluctuate throughout the day. On average, the highest temperature inside the greenhouse occurs during the daytime, reaching 43.5^0 C, while the lowest temperature is recorded in the afternoon at 29.5^0 C. The highest average air humidity inside the greenhouse is observed in the afternoon, reaching 90%, whereas the lowest humidity is during the daytime, at 44.5%.

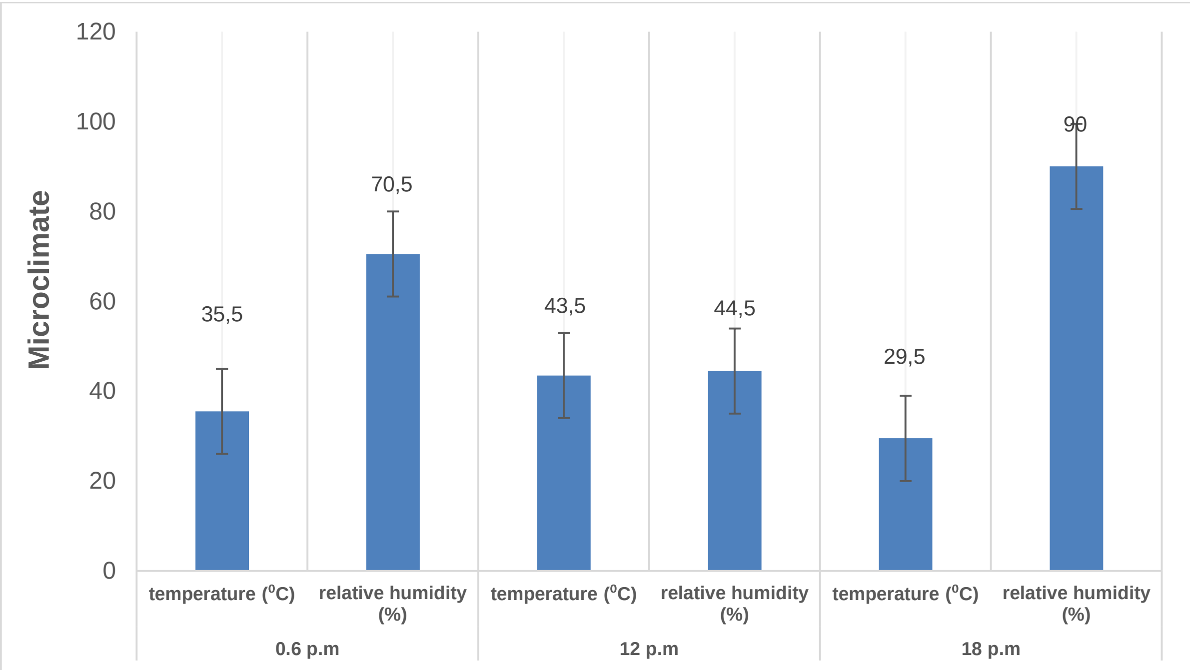


Figure 2. Microclimate condition of the growing environment

3.2 Visual of Leaf Color

The observation of water spinach leaves in the second planting cycle at 44 days after planting and the third planting cycle at 58 days after planting indicates that applying all the catfish stocking density treatments combined with foliar fertilizers Gandasil D, Growmore, and without foliar fertilizer results in relatively similar leaf colors, which are a shade of greenish-yellow, differing only in their intensity.

The findings reveal that the color of Water spinach leaves in ratoons 2 and 3 tends to be similar, mostly 5GY (Green Yellow) across all treatments, with variations in brightness and color intensity. The value represents how light or dark the color is, while chroma indicates the smoothness and intensity of the color on the leaves. According to (Sumenda, 2011), differences in leaf color suggest varying pigment levels, whereas darker leaves imply higher chlorophyll content. The leaf color of a plant is affected by its chlorophyll content, which, in turn, is influenced by the nitrogen levels in the plant's nutrient solution (Gunawan & Daningsih, 2019).

Table 1. Observation of leaf color using Munsell Color Charts For Plant Tissues

Combination of treatments	Leaf color Ratun 2	Leaf color 3	Picture
P1J0	5GY 5/6	5GY 4/8	
P1J1	5GY 5/8	5GY 4/8	
P1J2	5GY 5/6	5GY 5/6	
P2J0	5GY 5/6	5GY 5/6	
P2J1	5GY 5/6	5GY 4/6	
P2J2	5GY 5/6	5GY 5/8	
P3J0	5GY 5/6	5GY 5/8	
P3J1	5GY 5/6	5GY 5/8	
P3J2	5GY 5/6	5GY 4/8	

Keterangan: P1J0: Kontrol + padat tebar 5
P1J1: Gandasil D + padat tebar 5
P1J2: Growmore + padat tebar 5
P2J0: Kontrol + padat tebar 10
P2J1: Gandasil D + padat tebar 10
P2J2: Growmore + padat tebar 10
P3J0: Kontrol + padat tebar 15
P3J1: Gandasil D + padat tebar 15
P3J2: Growmore + padat tebar 15

3.3 Analysis of Variance

The analysis of variance results in Table 2 reveals that the application of different foliar fertilizers on water spinach ratoon 2 has a significant impact on plant height, leaf count, canopy's wet and dry weight, stem diameter, and leaf area. On the other hand, the stocking density treatment significantly influences leaf count, canopy's wet and dry weight, and leaf area. In the analysis of the third water spinach ratoon, the use of foliar fertilizers significantly affects plant height, canopy's wet and dry weight, leaf area, and stem diameter. Similarly, the stocking density treatment significantly impacts plant height, canopy's wet and dry weight, leaf area, stem diameter, root volume, root's wet weight, and overall plant biomass.

The analysis results indicate that using foliar fertilizer significantly impacts the height of water spinach plants R2 and R3, the number of water spinach leaves R2, the fresh weight of water spinach canopy R2 and R3, the dry weight of water spinach canopy R2 and R3, the leaf area R2 and R3, and the stem diameter R2 and R3. Providing external nutrient input through foliar fertilizer assists in plant growth. As per (Manurung et al., 2020), applying foliar fertilizer to plants can enhance the absorption of nutrients essential for direct chlorophyll synthesis in leaves. Foliar fertilizers generally contain a mix of macro and micronutrients.

3.4 Foliar fertilizer type

The results of the DMRT test indicate that the J2 foliar fertilizer treatment (Growmore) produced the highest yields for the height of water spinach plants R2 and R3, the number of R2 water spinach leaves, the fresh weight of R2 and R3 canopies, the dry weight of R2 and R3 canopies, the leaf area of R2 and R3, and the stem diameter of R2 and R3. The J2 foliar fertilizer treatment (Growmore) showed significantly different results compared to the J1 foliar fertilizer (Gandasil D) treatment and the treatment without foliar fertilizer. Further DMRT test results can be found in Table 3.

Table 2. Analysis of variance of the second and third ratoon kale foliar fertilizer applications and different catfish stocking densities on ratoon kale Budikdamber aquaponic system.

Variable	Types of Foliar Fertilizer	Dense Catfish Stocking	Interaction	CV (%)
	Pr>F	Pr>F	Pr>F	
Plant height R2	0,01*	0,14^{tn}	0,08^{tn}	8,94
Plant height R3	0,008*	0,02*	0,09^{tn}	5,61
Number of leaves R2	0,006*	0,001*	0,10^{tn}	4,53
Number of leaves R3	0,45^{tn}	0,21^{tn}	0,09^{tn}	2,80
Fresh weight of shoots R2	0,02*	0,007*	0,82^{tn}	5,92
Fresh weight of shoots R3	0,02*	0,003*	0,65^{tn}	6,33
Shoot dry weight R2	0,01*	0,03*	0,81^{tn}	15,24
Shoot dry weight R3	0,01*	0,001*	0,13^{tn}	7,38
Leaf area R2	0,0007*	0,004*	0,06^{tn}	8,86
Leaf area R3	0,01*	0,0007*	0,04^{tn}	4,34
Stem diameter R2	0,0004*	0,12^{tn}	0,04*	12,89
Stem diameter R3	0,02*	0,08^{n}	0,11^{tn}	20,91
Fresh weight of root R3	0,75^{tn}	0,03*	0,003*	7,81
Root dry weight R3	0,05^{tn}	0,11^{tn}	0,05^{tn}	9,29
Root Volume R3	0,32^{tn}	0,006*	0,003*	6,76
Plant Biomass R2 + R3	0,46^{tn}	0,01*	0,004*	5,43

Note: *: Significantly affected α 5%, tn: Not significantly affected, F hit: F count, pr>F: Probability value, KK: Coefficient of variation. R2 : Second ratoon, R3 : Third ratoon.

Table 3. The DMRT test results on how different types of water spinach ratoon foliar fertilizers affect the plant height R2 and R3, number of leaves R3, wet weight R2, leaf area R2, stem diameter R2 and R3, as well as plant biomass.

Variable	Treatment		
	J0 (Kontrol)	J1 (Gandasil D)	J2 (Growmore)
Plant height R2	13,42c	18,26b	19,35a
Plant height R3	13,54c	19,73b	21,25a
Number of leaves R2	8,60c	12,30b	13,33a
Fresh weight of shoots R2	8,74c	12,25b	13,34a
Fresh weight of shoots R3	8,62c	11,93b	13,34a
Shoot dry weight R2	0,39c	1,01b	1,14a
Shoot dry weight R3	0,59c	1,16b	1,39a
Leaf area R2	10,18c	13,11b	14,58a
Leaf area R3	8,97c	11,63b	13,65a
Stem diameter R2	0,47c	0,68b	0,86a
Stem diameter R3	0,37b	0,44b	0,54a

Note: Numbers followed by the same letters in the same column indicate no significant difference in the DMRT follow-up test at a 95% confidence level. R2: Second treatment, R3: Third treatment.

3.4 Stocking Density

The results of the DMRT test indicate that the P3 stocking density treatment (15 catfish) resulted in the highest values for the Water spinach plant height in R3, leaf count in R2, fresh weight of canopy in R2 and R3, dry weight of canopy in R2 and R3, leaf area in R2 and R3, fresh weight of roots in R3, root volume in R3, and plant biomass. The P3 stocking density treatment (15 catfish) yielded significantly different results compared to the P1 (5 catfish) and P2 (10 catfish) stocking density treatments. More detailed DMRT test results can be found in Table 4.

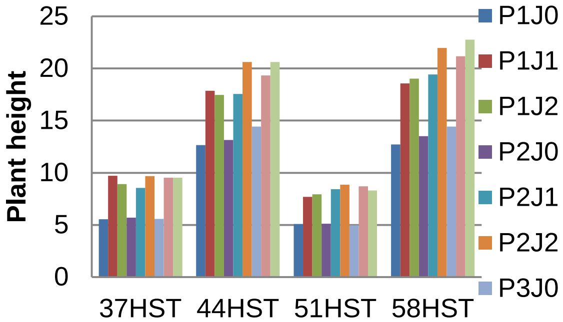
Table 4. DMRT test results of the effect of stocking density of ratoon kale on the variables of plant height R2, root wet weight R3 and root volume R3.

Variable	Treatment		
	P1 (5 Catfish tail)	P2 (10 Catfish tail)	P3 (15 Catfish tail)
Plant height R3	16,76c	18,30b	19,45a
Number of leaves R2	10,70c	11,43b	12,10a
Fresh weight of shoots R2	9,98c	11,40b	12,94a
Fresh weight of shoots R3	9,62c	11,33b	12,94a
Shoot dry weight R2	0,56c	0,89b	1,08a
Shoot dry weight R3	0,79c	1,08b	1,27a
Leaf area R2	9,68c	12,69b	15,50a
Leaf area R3	10,05c	11,39b	12,81a
Shoot dry weight R3	35,28c	38,59b	40,51a
Root Volume R3	38,36c	42,69b	43,42a
Plant Biomass R2 + R3	54,21c	60,13b	64,65a

Note: Numbers followed by the same letters in the same column indicate no significant difference in the DMRT follow-up test at a 95% confidence level. R2: Second treatment, R3: Third treatment.

3.5 Treatment Interaction

Applying foliar fertilizer to water spinach plants during the 2nd and 3rd planting seasons has shown a significant increase in plant height and leaf quantity. Research results demonstrate that this application leads to a notable growth in both plant height and leaf quantity. These improvements undoubtedly impact the overall wet and dry weight increase of the plants.



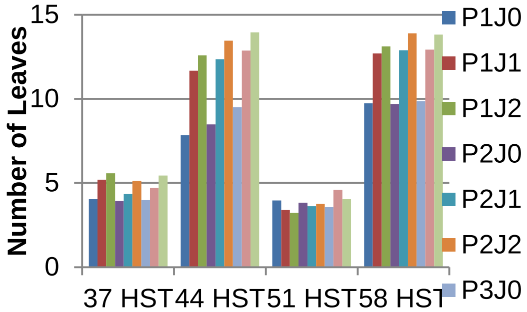


Figure 3. Increase in height and number of leaves at 37, 44, 51 and 58 days after planting

According to Wahyuningsih & Fajriani (2016), the fresh weight and dry weight of the plant indicate that it not only absorbs water optimally but also can absorb nutrients and store them as an energy source. The wet and dry weights of water spinach in treatments 2 and 3 show the best results with the use of Growmore fertilizer. In their book, Lingga and Marsono (2013) explained that the primary function of nitrogen (N) nutrients is to stimulate overall growth, especially in the stem, leaves, and branches. Growmore fertilizer, with its higher nitrogen content compared to Gandasil D, leads to better growth when applied.

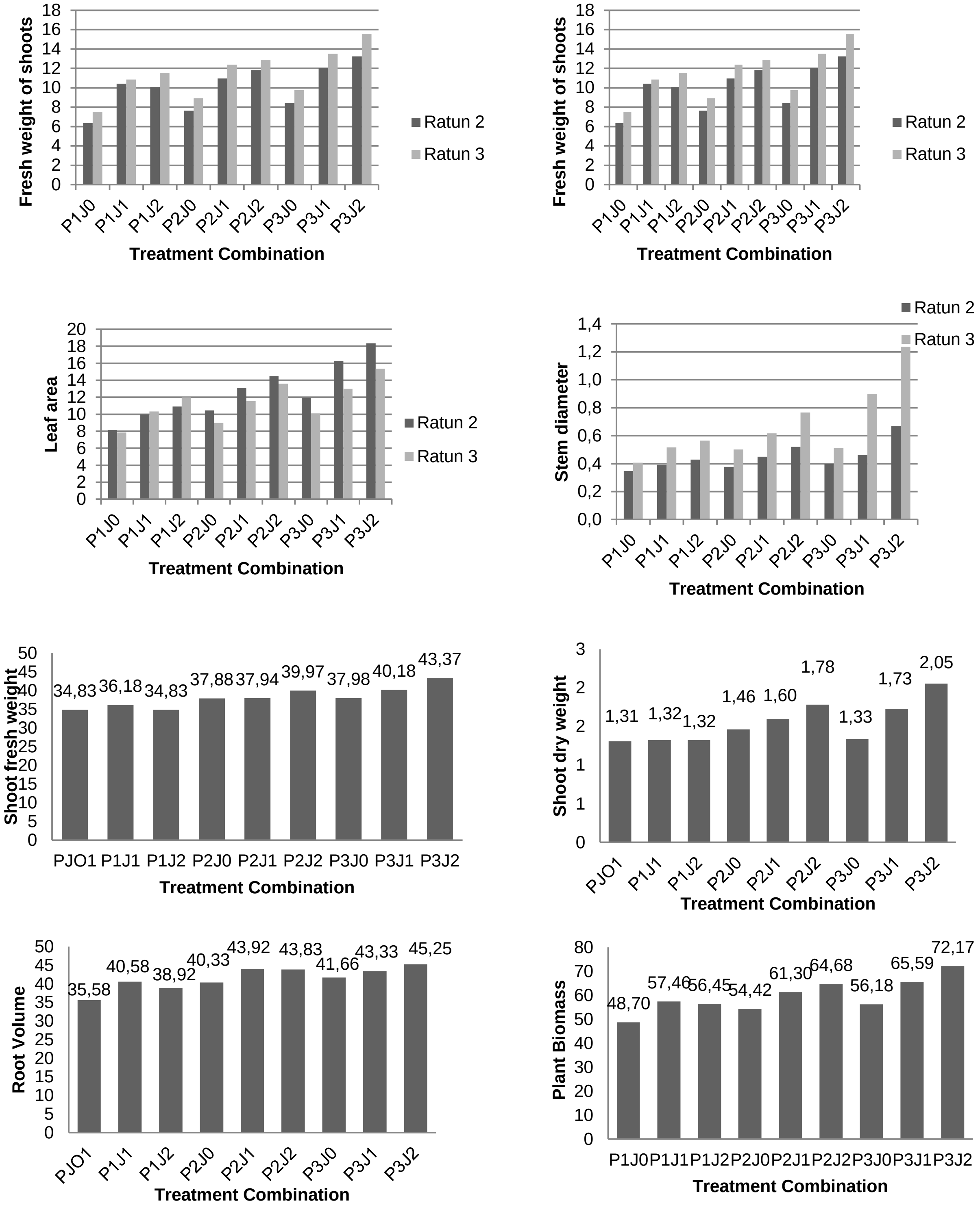


Figure 4. Post-ratoon kale growth and production in catfish kale aquaponic culture

The findings of the study indicated that the utilization of foliar fertilizer on water spinach ratoons 2 and 3 had a significant impact on leaf area variables. The leaf area of ratoon 2 and ratoon 3 water spinach exhibited the most favorable outcomes under the Growmore treatment. The provision of macronutrients such as N, P, and K in Growmore is essential for leaf development (Bernatha et al., 2017). The observation of the leaf area variable reflects the number of photosynthesis products accumulated and generated by the plant. According to Hartatik and Asmawan (2022), a broader leaf area leads to increased assimilation results, thereby enhancing the rate of photosynthesis. The type of foliar fertilizer administered to kale leaves post-ratoon plays a significant role in the stem diameter of ratoons 2 and 3. Qibtiyah (2015) asserts that an increase in stem diameter signifies a growth process characterized by an enlargement in size and volume due to an augmentation in substance and cell count. Conversely, the study revealed that the application of foliar fertilizer on ratoon 3 water spinach did not have a notable impact on root wet weight, root dry weight, and root volume variables of ratoon 3. This could be attributed to the direct application of foliar fertilizer on the leaves, resulting in suboptimal absorption from the roots. Roots typically exhibit rapid growth and development when functioning as an absorption organ; hence, diminished nutrient absorption may impede root growth (Khodijah et al., 2022). Additionally, Manurung et al. (2020) suggested that the application of foliar fertilizer to plants may hinder root growth.

The findings indicated that the manipulation of catfish stocking density had a significant impact on various aspects of plant growth, including R3 plant height, R2 leaf number, R2 and R3 shoot wet weight, R2 and R3 shoot dry weight, R2 and R3 leaf area, R3 root wet weight, R3 root volume, and Plant Biomass. This aligns with the research conducted by Effendi et al. (2015), which demonstrated that kale exhibits a rapid growth rate, enabling it to efficiently absorb nutrients. Consequently, kale plants can effectively utilize the waste generated from fish cultivation, as suggested by Setijaningsih and Umar (2015), who emphasized the positive influence of phosphorus and nitrogen nutrients present in water on fish growth. The average histogram for each variable further revealed that the stocking density treatment involving 15 catfish exhibited the highest average compared to other stocking density treatments. It is important to note that apart from the fish species, the stocking density employed also plays a crucial role in the growth of the cultivated plants. Higher stocking density levels can lead to a decline in water quality due to the accumulation of ammonia (NH_3), as highlighted by Pratama et al. (2017).

The combination of foliar and solid fertilizer treatments for catfish stocking density resulted in the highest average yields for each variable in treatment P3J2 (15 fish + Growmore). This result is believed to be due to the higher nutrient source of having 15 catfish in the stocking density treatment because it has a greater number of fish compared to other treatments. Apart from stocking density, the type of fertilizer like Growmore also has a more significant impact compared to other types of fertilizers. According to Hasan et al. (2018), the absorption of nutrients such as nitrate and phosphate by plants in aquaponic cultivation leads to better water spinach growth as the nutrients are more readily available compared to conventional farming methods.

4. CONCLUSION

The most effective foliar fertilizer for the growth of second and third-cycle plants is found in foliar fertilizers rich in macronutrients. Optimal catfish stocking density for the growth of water spinach in the second and third cycles is achieved at 15 catfish per unit. The most successful treatment combination for water spinach growth in the aquaponic system of Budikdamber involves using foliar fertilizer with the highest macronutrient content (Growmore) alongside a stocking density of 15 catfish per bucket.

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