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"A Comparison of the Effectiveness of *Cocos nucifera* (Coconut) Water as a Rooting Hormone in a Hydroponic and Conventional Set-up in Growing *Ocimum basilicum* (Basil)"

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ABSTRACT: Food shortage is still a problem in the Philippines since millions of people may be classified as undernourished. Efforts to augment the insufficiency include developing an efficient planting method as a source of food. This experimental study tested the effectiveness of coconut water as a rooting hormone on hydroponically and conventionally grown basil plants by measuring the height, fresh weight, leaf length, and root length for three weeks, which also served as the dependent variables. Consequently, two (2) hydroponic set-ups and two (2) conventional set-ups utilize a randomized block design. The set-ups containing coconut water served as the independent variables, while the ones without served as the control. Before the data gathering procedures, the containers were sterilized, the tap water was exposed to sunlight, and the basil seeds were soaked in coconut water. Six hours later, the seeds were planted. After three weeks, the leaf length and root length were measured using a digital caliper, while the height and weight were measured using a standard ruler and digital scale. The nutrient solution and pH level were also monitored. Data was analyzed using two-way ANOVA for leaf length and plant weight, while one-way ANOVA was used for plant height and root length. In addition, a post-hoc test was used for variables that had a significant effect. Descriptive statistics was used to analyze the mean. The hydroponic setup was effective on producing a higher yield for root length (M=112), while the conventional setup was effective on plant height (M=99.7) and leaf length (M=44.1). While the intervention had no significant contribution ($p>0.05$), hydroponics as an alternative planting technique still has potential in the agricultural sector.

KEYWORDS: hydroponics; coconut water; basil; rooting hormone; agriculture

INTRODUCTION

In their annual study, the United Nations (2020) found that more people are going hungry, with tens of millions joining the ranks of the chronically undernourished over the past five years.

Previous researchers have studied hydroponics as a method for producing more food in a short period of time (French & Roth, 2019; Treftz & Omaye, 2015). It is defined as growing plants in mineral nutrient solution without soil, but in the presence of artificial supporting mediums (Singh et al., 2019). In addition, rooting hormones have been tested to improve the growth and development of plants.

A conventional set-up is a method in which plants are grown in soil, and it is significant in farming due to its common usage in growing crops (Barbosa et al., 2015). Previous studies have found that healthy soil sustains water quality and plant productivity (Tahat et al., 2020). However, weather conditions and disparities between pH levels in conventional set-ups can stunt plant growth (Barbosa et al., 2015; Chow et al., 2017). On the other hand, a hydroponic set-up, which is a method of growing plants under soil-less conditions, is known to be the fastest growing and second generation of crop production in the agricultural industry (Aires, 2018; Chow et al., 2017). It offers a significant contribution to agriculture since it demonstrates new methods which can help farmers learn new skills and eventually increase production level (Blok et al., 2017; Khan et al., 2019). Barbosa et al. (2015) supporting this statement found that the hydroponic production of lettuce in Arizona was 11 $\pm$ 1.7 times greater than its conventional equivalent.

In addition, phytohormones are substances that can control a plant's growth and development (Baiyin et al., 2021; Dunsin et al., 2016). It significantly contributes to farming, as it is a widespread technique applied in plant set-ups in order to enhance the growth of roots (Topacoglu et al., 2016). Auxin is a type of hormone that has been proven to increase adventitious rooting and the rate of appearance of roots (Pacurar et al., 2014; Topacoglu et al., 2016). Coconut (*Cocos nucifera*) water contains auxin, along with gibberellins and cytokines (Akhiriana & Samanhudi, 2019; Trisnaningsih & Wahyuni, 2020). Similarly, Dunsin et al. (2016), this rooting hormone demonstrated the highest number of rooted cuttings over other interventions that include pure honey and moringa leaf extract.

Leaf length is one of the most commonly measured variables by researchers to assess plant growth, since it helps measure the effect of various environmental factors including light intensity and nutrient and water availability (Jones, 1995; Wang et al., 2019). Saha et al. (2016), the leaves of a basil plant were measured and averaged in the condition of sunlight. A separate study by Nazarideljou (2019) found that the increase in K^{+}:Ca^{++} in growing strawberry plants in a hydroponic culture directly influenced the leaf area, causing its length to increase. Plant height is another important variable to use as comparison since it signifies the characteristics of plants including vigor, stage of growth, site classification and range of readiness (Heady, 1957). A study by Trisnaningsih and Wahyuni (2020) found that the treatment of coconut water and planting media affected plant height during all stages of observation. Another study used plant height to compare the growth responses of the plant to organic and inorganic fertilizers (Purbajanti et al., 2019). Alongside the other two variables, plant weight is used as an indicator for plant growth evaluation since it also affects leaf size (Chen et al., 2016; Huang et al., 2019). Previous studies have weighed plants using a digital scale immediately upon harvest or after being dried in an oven, then compared the values with one another (Alvarado-Camarillo et al., 2018; Saha et al. 2016). Root length has also been considered important as it has an implied positive correlation with plant height, as well as a significant association with soil recovery from drought (Ekanayake et al., 1985). In a study by Dunsin et al. (2016), this variable was taken to determine the effectiveness of using alternative hormones on the rooting capability of *Parkia biglobosa*. Coconut water was used in the study, which yielded the second longest root length, indicating positive results.

As such, this research aimed to test the impacts of coconut water as a rooting hormone on the growth of basil plants in a Deep Water Culture Hydroponic Setup. The hydroponic set-up was then compared to a conventional (soil-based) set-up with the same rooting hormone to test its effectiveness, with both serving as the independent variables. Control set-ups were added for further comparison (a hydroponic and conventional set-up without coconut water). The following dependent variables were measured to determine the efficiency of plant development: (i) leaf length, (ii) plant height, (iii) plant weight, (iv) root length. Currently, studies on using coconut water as a rooting hormone have only been done on crops grown in soil (Dunsin et al., 2016; Hebbar et al., 2021; Topacoglu et al., 2016), which is the gap this research addressed. A conventional set-up was still included in the experiment to enable the researchers to fully address the differences between a conventional and hydroponic one. The researchers wanted to ascertain the effectiveness of coconut water as a rooting hormone under each set-up to determine their differences.

METHODOLOGY

Research Design

The study utilized a Randomized block design (RBD) which involves the assignment of subjects to blocks that are then randomly given treatments (King & Eckersley, 2019). In this study, the subjects included basil plants, rooting hormones, and the type of setup employed. The variables used were the farming setups, which were categorized into two types: the hydroponic and the conventional setups. The second independent variable was the coconut water which acted as the rooting hormone of the study. Additionally, there were four dependent variables which are the following: root length, plant height, plant weight, and leaf length. In total, the study used the following setups: (i) hydroponic set-up with coconut water, (ii) hydroponic set-up without coconut water, (iii) conventional set-up with coconut water, and (iv) conventional set-up without coconut water.

Data Gathering Procedures

The researchers conducted the data gathering procedures by constructing (2) Deep water culture hydroponics setups (DWC) and (2) Conventional setups. The experimental group of seeds soaked in coconut water was then planted in the first hydroponics setup and the first conventional setup, while the control group was planted in the remaining setups.

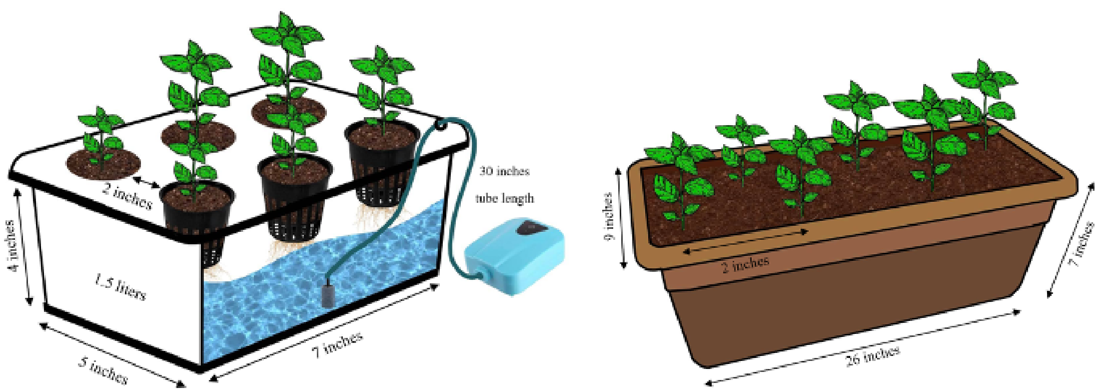
Preparation of Materials

Before the construction of the setups the researchers sterilized all the containers to be used for the study with 10% hydrogen peroxide to remove any foreign substances that may interfere with plant growth (Gu & Neethling, 2008). Additionally, all of the tap water used in the study was exposed to sunlight for a period of 24 hours to remove chlorine which is harmful to plants (McDonnell, 2014). The researchers then opened a bag of basil seeds and directly transferred 36 of them to 300 ml of coconut water, where they were soaked for six hours (Trisnaningsih & Wahyuni, 2020). The other half for the control set-ups remained untouched. The seeds were manufactured by Yates in Auckland, New Zealand.

Preparation of the Conventional and Hydroponic Setups

Figure 1

Hydroponic and Conventional Set-ups



The researchers then began the construction of the setups which included two (2) Deep water culture hydroponic setup (7x5x4 inches) and two (2) conventional setups which were made using a rectangular pot (26x9x7 inches) with loam soil. After six hours, 18 seeds were then planted into each of the four set-ups to ensure germination (Trisnaningsih & Wahyuni, 2020). The nutrient solution for the hydroponic setups was changed every two weeks to ensure a rich supply of nutrients (Rufi-Salis et al., 2020). It was manufactured by the Institute of Plant Breeding in the University of the Philippines, Los Baños (IPB, UPLB). Its components are the following: calcium, nitrogen, potassium, phosphorus, sulfur, magnesium, iron, manganese, boron, zinc, copper, chlorine, and molybdenum (Santos & Ocampo, 2005). Furthermore, the pH levels of the hydroponic setups were also monitored every week (Dunn & Singh, 2016). After three weeks the researchers collected the data by selecting the six biggest plants in each of the setups, after which the researchers measured the three longest leaves per plant (Echavarría-Heras et al., 2013), the ten longest roots per setup, measured plant fresh weight, and plant height. The leaf and root lengths were measured with a digital caliper, while the plant height was measured with a standard ruler and the plant weight was recorded using a digital scale (Pérez-Harguindeguy et al., 2013; Yeboah et al., 2009).

Data Analysis

The data gathered by the researchers was inputted in JAMOVI and analyzed with the application of Analysis of Variance (ANOVA). Under leaf length and plant weight, a Two-Way Analysis of Variance was implemented to measure the effects of coconut water as an intervention and the type of set-up employed on its growth. A one-way analysis of variance (non-parametric Kruskal-Wallis H test) was used to measure the same effects but on plant height and root length. For those that had a significant effect, a post-hoc test was used to determine where the differences lie. Additionally, descriptive statistics was used to analyze the mean of all four variables.

RESULTS AND DISCUSSION

Effects of Coconut Water on the Growth of Basil

Table 1

Descriptive Statistics for Leaf Length, Plant Height, Plant Weight, and Root Length

	Setup	Intervention	Leaf Length (mm)	Plant Height (mm)	Plant Weight (mm)	Root Length (mm)
Mean	Hydroponic	with intervention	31.6	66.9	2.60	112
		without intervention	31.6	68.0	2.88	110
	Conventional	with intervention	44.1	99.7	2.57	25.5
		without intervention	44.1	102	2.32	26.2

The mean of the leaf length of plants grown in a hydroponic set-up with and without intervention was equal to (M = 31.6), as was the two set-ups grown conventionally (M = 44.1). In addition, the plant height in both hydroponic and conventional set-ups with the intervention had a smaller mean than those without the intervention (M = 66.9 < M = 68; M = 99.7 < M = 102). Furthermore, plant weight with the intervention had a smaller mean between the two hydroponic set-ups (M = 2.6 < 2.88), but had a greater mean in the conventional set-up with coconut water compared to the one without it (M = 2.57 > M = 2.32). Finally, the root length of plants in the hydroponic set-up subjected to the rooting hormone had more growth compared to the one without (M = 112 > M = 110), but had less growth in the conventional set-up following the same conventions (M = 25.5 < M = 26.2).

These results imply that overall, the plants subjected to the hydroponics set-up with the intervention produced more notable effects in terms of plant weight and root length in comparison to the hydroponics set-up without the intervention, and both of the conventional set-ups. However, the effects of the different set-ups and interventions for the leaf length and plant height were not as evident. Thus, only certain variables were affected by the set-ups and interventions.

A hydroponic set-up may be used to investigate the relationship between roots and liquids, and how they react with each other (Torabi et al., 2012). The growth conditions of plants in soil and plants in a hydroponics set-up greatly differ, which may affect the interactions between the plant, its interventions, and its growing medium (Zabłudowska et al., 2009), which may explain the differences observed in the computation of means of the four variables measured in this study.

Difference in Plant Height and Root Length Between Basil Plants Grown with and without Coconut Water

Table 2

Kruskal-Wallis H Test of Plant Height with and without Intervention

	X^2	df	p	ε^2
Plant Height	0.00750	1	0.931	3.26e-4

The data for the effects of the coconut water on plant height violate the assumption checks of Levene's Homogeneity of Variances ($p = 0.008$) and Shapiro-Wilk's Normality Test ($p = 0.017$). As such, the non-parametric Kruskal-Wallis H test is used instead of two-way ANOVA. As a result, the Kruskal-Wallis H test showed that the effect of coconut water on the plant height was not significant, $X^2(1) = 0.0075$, $p = 0.931$.

Based on the results, plant height was most likely unaffected due to the type of rooting hormone used regardless of the set-up. Singh et al. (2019) noted that plants grown in Hoagland solution grew faster than those subjected to just water. Hoagland solution is different from coconut water, meaning its effects on plant height could differ too. However, the results contradicted a study by Trisnaningsih and Wahyuni (2020), which noted that coconut water did in fact affect growth significantly. One possible explanation for the results differing in this study is the way in which the coconut water was applied to the basil plants.

Table 3

Kruskal-Wallis H Test of Root Length with and without Intervention

	X^2	df	p	ε^2
Root Length	0.0834	1	0.773	0.00363

** p < 0.05 is significant. p > 0.05 is not significant.*

The data for the effects of the coconut water on root length violate the assumption checks of Levene's homogeneity of variances ($p = 0.029$) and Shapiro-Wilk's normality test ($p < 0.001$). As such, the non-parametric Kruskal-Wallis H test was used instead of two-way ANOVA. The Kruskal-Wallis H test showed that there was no statistically significant difference in root length between the two set-ups, $X^2(1) = 0.0834$, $p = 0.773$.

These results imply that the intervention had no notable effects on the root length regardless of the set-up. This can be attributed to the usage of alternative rooting hormones, which may be less effective than synthetic rooting hormones in promoting the rooting of the plant. Al-Amad and Qrunfleh (2014) investigated the effects of willow water extract on promoting the rooting of stem cuttings of olive. Their results showed that the olive cuttings that were not soaked in K-IBA solution, a synthetic rooting hormone, were insignificant. Furthermore, the cuttings soaked in willow water extract showed insignificant results, regardless of whether or not the cuttings were soaked in K-IBA beforehand. In comparison, these results are in line with this study, which used coconut water as an alternative rooting hormone. Moreover, coconut water is known to have an abundance of cytokinins (Akhiriana, Samanhudi, & Yunus, 2019; Dunsin et al., 2016), which may suppress growth in the root apical meristem (Albrecht & Argueso, 2017), thus affecting the significance of the results.

A longer duration of data gathering is needed to produce more significant effects. Onanuga et al. (2012) examined the effects of using different phytohormones (IAA, GA_3, and Z) on cotton plants grown in a hydroponic nutrient solution. Any notable effects in the roots were not observed in the plants applied with the phytohormones until 80 to 90 days after transplanting. On the contrary, the researchers only observed the growth of basil plants in both set-ups for 21 days.

Difference in Plant Height and Root Length Between a Hydroponic and Conventional Set-up

Table 4

Kruskal-Wallis H Test of Plant Height in a Conventional and Hydroponic Set-up

	X^2	df	p	ε^2
Plant Height	8.01	1	0.005	0.348

** $p < 0.05$ is significant. $p > 0.05$ is not significant.*

The data for the effects of the set-up on plant height violate the assumption checks of Levene's homogeneity of variances ($p = 0.008$) and Shapiro-Wilk's normality test ($p = 0.017$). As such, the non-parametric Kruskal-Wallis H test was used instead of two-way ANOVA. The Kruskal-Wallis H test (seen in Table 4) showed that there was a statistically significant difference in plant height between the two set-ups, $X^2(1) = 8.01$, $p = 0.005$.

Table 5

Dwass-Steel-Critchlow-Fligner Pairwise Comparisons for Plant Height in a Hydroponic and Conventional Setup

		W	p
Hydroponic	Conventional	4.00	0.005

** $p < 0.05$ is significant. $p > 0.05$ is not significant.*

Since the Kruskal-Wallis table shows that there is a significant difference in the plant height among the two types of set-ups, the post-hoc test using Dwass-Steel-Critchlow-Fligner Pairwise Comparisons was performed to examine where these differences lie. Table 5 shows that the p-value for the hydroponic and conventional set-ups is less than 0.05 ($p = 0.005$). After performing the said procedure, it is inferred that plant height is significantly different among the hydroponic and conventional set-ups.

The results from Tables 4 and 5 imply that both types of set-ups significantly affected the height of the plant. This finding is supported by the studies of Gashgari et al. (2018) and Saha et al. (2016), which noted that the hydroponics set-up had a notable effect on the height of the plants. However, as shown in Table 1, the means of the height of the plants subjected to the hydroponics set-up are unexpectedly much lower than those subjected to the conventional set-up ($M = 66.9 < M = 99.7$; $M = 68 < M = 102$). This is supported by the results of the study of Saha et al. (2016), which stated that basil plants subjected to an aquaponics system were 14% taller than those subjected in a hydroponics set-up. According to them, these results were due to the aquaponics set-up having more nutrients. Thus, this implies that the nutrients in a hydroponics set-up may not be enough, and more may be required to produce a higher plant height. Additionally, the researchers identified the inaccessibility to a greenhouse as another cause for this unusual occurrence. Greenhouses are commonly used by other researchers for growing plants as it offers a controlled environment for optimum plant growth (Cifuentes Torres et al., 2021). Without access to a controlled environment it might have caused the plants to deviate in results when compared to other researches.

Table 6

Kruskal-Wallis H Test of Root Length in a Hydroponic and Conventional Setup

	X^2	df	p	ε^2
Root Length	17.3	1	< .001	0.752

** p < 0.05 is significant. p > 0.05 is not significant.*

The data for the effects of the set-up on root length violate the assumption checks of Levene's homogeneity of variances ($p = 0.029$) and Shapiro-Wilk's normality test ($p < 0.001$). As such, the non-parametric Kruskal-Wallis H test was used instead of two-way ANOVA. The Kruskal-Wallis H test showed that there was a statistically significant difference in root length between the two set-ups, $X^2(1) = 17.3$, $p < 0.001$.

Table 7

Dwass-Steel-Critchlow-Fligner Pairwise Comparison for Root Length in a Hydroponic and Conventional Setup

		W	p
Hydroponic	Conventional	-5.88	< .001

** $p < 0.05$ is significant. $p > 0.05$ is not significant.*

Since the Kruskal-Wallis Table shows that there is a significant difference in the root length among the two types of set-ups, the post-hoc test using Dwass-Steel-Critchlow-Fligner Pairwise Comparisons was performed to examine where these differences lie. Table 7 shows that the p-value for the hydroponic and conventional set-ups is less than 0.05 ($p < 0.001$), therefore, root length is significantly different among the hydroponic and conventional set-ups.

The results from Tables 6 and 7 imply that the hydroponics set-up produced a significantly positive effect on the root length of the plant. This can be associated with a study conducted by Li et al. (2018) regarding the growth of plants in hydroponics and substrate-based mediums which demonstrated that in terms of root length, a hydroponics setup had a higher gain when compared to the root length of a plant grown in a substrate based medium. Additionally, Girdthai et al. (2010) also found root length to be greater on a hydroponics setup. Furthermore, another study stated that a possible cause for more root growth in hydroponic setups is that nutrient availability and uptake is more efficient (Rouphael et al., 2004).

Effect of set-ups and intervention on leaf length and plant weight

Table 8

Two-Way Analysis of Variance of Leaf Length

	Sum of Squares	df	Mean Square	F	p
Setup	938.1251	1	938.1251	50.52619	< .001
Intervention	9.38e-4	1	9.38e-4	5.05e-5	0.994
Setup ✻ Intervention	0.0234	1	0.0234	0.00126	0.972
Residuals	371.3421	20	18.5671		

** p < 0.05 is significant. p > 0.05 is not significant.*

In Table 8, a two-way analysis of variance showed that the effect of coconut water on the leaf length was not significant, $F(1) = 5.05e{-5}$, $p = 0.994$. Additionally, it was shown that the type of set-up has a significant effect on leaf length, $F(1) = 50.52619$, $p < 0.001$.

One of the probable causes of the intervention having no effect on leaf length was the controlled amount of coconut water used in each setup. According to a study by Huang et al. (2019), a negative correlation between leaf area and water-loss was observed in plants. In relation to the results shown in Table 8 ($p = 0.994$), it can be implied that there was no loss in moisture since none of the leaves were significantly smaller than the others. This possibly kept the leaf length the same rather than having any positive or negative effect on its development.

Table 9

Post Hoc Test for Set-ups on Leaf Length

Comparison										95% Confidence Interval	
Setup	Setup	Mean Difference	SE	df	t	p_{tukey}	$p_{scheffe}$	$p_{bonferroni}$	Cohen's d	Lower	Upper
Hydroponic - Conventional		-12.5	1.76	20.0	-7.11	< .001	< .001	< .001	-2.90	-4.18	-1.62

** Comparisons are based on estimated marginal means. p < 0.05 is significant. p > 0.05 is not significant.*

Since the ANOVA table shows that there is a significant difference in the leaf length among the two types of set-ups, the post-hoc test using Tukey's HSD, Scheffe's Method, and Bonferroni's Procedure was performed to examine where these differences lie. In Table 9, those highlighted cells show the p values that are less than 0.05. To conclude, leaf length is significantly different among the hydroponic and conventional set-ups.

Given that the leaf length had a significant difference due to the setups (mean difference = -12.5; $p < 0.05$), with more growth shown in the conventional setups, one of the probable causes could be the amount of nutrients absorbed by the plants. Healthy soil is known to maintain water quality, sustain plant productivity, and control nutrient decomposition (Tahat et al., 2020), which implies that the plants in the conventional setup had a generous intake of nutrients. However, this finding was contradicted by a previous research conducted by Nazarideljou (2019), which showed an increase in leaf area of strawberry plants grown in a hydroponic culture rather than a conventional one. One possible reason for this difference could be that not all ideal conditions were met in creating the hydroponic set-up for the basil plants in this study, which is often enclosed in a greenhouse to control temperature and artificial lighting, reduce water loss, and protect the plants against weather conditions (Barbosa et al., 2015; Chow et al., 2017; Manos & Xydis, 2019). Since a greenhouse and artificial lighting were not implemented, it is possible that the basil plants subjected to hydroponics did not receive the maximum benefits it offers.

Table 10

Two-way Analysis of Variance of Plant Weight

	Sum of Squares	df	Mean Square	F	p
Setup	0.54000	1	0.54000	0.46452	0.503
Intervention	0.00167	1	0.00167	0.00143	0.970
Setup * Intervention	0.42667	1	0.42667	0.36703	0.551
Residuals	23.25000	20	1.16250		

** p < 0.05 is significant. p > 0.05 is not significant.*

In Table 10, a two-way analysis of variance showed that the effect of coconut water on the plant weight was not significant, F (1) = 0.00143, p = 0.970. Additionally, it was determined that the type of set-up has no significant effect on plant weight, F(1) = 0.46452, p = 0.503.

As hypothesized for the opposite effect of the setups on leaf length, there may have been no effect on weight due to multiple planting factors. One probable cause of coconut water having no effect is its chemical composition. It contains auxin, gibberellins, and cytokines, which are known to increase tissue culture growth and root appearance (Akhiriana & Samanhudi, 2019; Trisnaningsih & Wahyuni, 2020). However, in a study by Saha et al. (2016), the presence of nitrogen is what yielded a greater fresh plant weight, with plants weighing up to 56% more.

On the other hand, the setups might have had no effect on plant weight due to the intensity of light present. As stated by Chen et al. (2016), cabbage plants in a hydroponic setup subjected to more light grew faster. As plants in both the hydroponic and conventional setups received the same amount of natural light, this was not taken into consideration. In addition, multiple studies contradict this result as a hydroponic setup is proven to produce a higher yield in terms of plant production and weight. A review by Sardare and Admane (2013) showed that plants grown hydroponically had a higher yield in weight with sometimes more than double of that of a conventional setup.

CONCLUSION

There were no notable differences of coconut water as a rooting hormone on both the hydroponic and conventional setups. Rather than finding differences between the independent variables, variations on the control setups were recorded. The hydroponic setup in particular was effective in producing a higher yield for root length, while the conventional setup was effective on plant height and leaf length. Even though the intervention was proven to have no significant contribution, the usage of coconut water as a rooting hormone in various setups still has potential in the agricultural sector. As a future direction for researchers to come, the enhanced application of growing factors in hydroponic systems can be studied, since they may also affect the effectiveness of coconut water in plant development. Some factors include the addition of artificial light, the usage of a greenhouse to control weather conditions, and the ensured quality and freshness of materials used. Dry weight can also be considered as a dependent variable, which has been used by previous studies alongside fresh weight in measuring plant development (Baiyin et al., 2021). Additionally, a longer time period for testing can be conducted to further observe the growth of the plants. Furthermore, alternative natural rooting hormones can be tested in place of coconut water, as well as different application techniques such as but not limited to the direct soaking of roots.

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