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Growth and Yield Performance of Pechay (*Brassica napus L.*) var. Black Behi Using the CHRRO Hydroponic System

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ABSTRACT

Hydroponic cultivation offers sustainable agricultural solutions, but the efficiency of water sources in hydroponic systems is underexplored. Understanding these sources is crucial for optimizing resource use, mitigating environmental impact, and ensuring long-term sustainability in hydroponic agriculture. This study aimed to assess the growth and yield performance of pechay (Brassica napus L.) var. Black Behi using hydroponic systems with different water sources: tap water (T1), unfiltered wastewater (T2), and filtered wastewater (T3). The research evaluated the sustainability of the CHRRO hydroponic system, which exclusively uses filtered wastewater (T3) for hydroponic cultivation. Using a Completely Randomized Design, 15 plants per treatment (T1, T2, and T3) were studied. The study measured growth parameters, including plant height, number of leaves, leaf width, and weight, and assessed the acceptability of the CHRRO hydroponic system in Bacsil, San Juan, Ilocos Sur, using standardized rating forms from experts in agriculture, science, electronics, and farming. Pechay plants in filtered wastewater (T3) exhibited superior growth and yield compared to those in tap water (T1) and unfiltered wastewater (T2). ANOVA confirmed significant differences ($p < 0.05$), with T3 being the most effective water source. The CHRRO system, utilizing filtered wastewater exclusively, received high acceptability ratings (mean rating: 4.56). However, Kendall's W indicated low agreement among experts ($W = 0.133$, $p = 0.257$), suggesting variability in evaluations due to differing expertise. The CHRRO system, which uses filtered wastewater, is ideal for hydroponic cultivation, and future research should include microbial analysis, nutrient profiling, economic and environmental assessments, continuous monitoring of water parameters, and expert feedback.

Keywords: *Hydroponic, CHRRO hydroponic system, tap water, unfiltered wastewater, filtered wastewater*

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INTRODUCTION

Urban expansion reduces farmland as cities convert rural areas into residential, commercial, and industrial spaces. to maintain food supply, innovative agricultural methods adaptable to urban and rural settings are essential.

According to Atilano (2018), the Philippines, with its vast land area of 30 million hectares, plays a significant role as an agricultural country. Approximately 47% of the land is dedicated to agricultural purposes, supporting the nation's economy. Agriculture, covering 47% of the land, is vital to the Philippine economy, employing 40% of the workforce and contributing 20% to the Gross National Product. The sector thrives on fertile land, natural resources, hardworking farmers, and strong research institutions.

Urban expansion reduces agricultural land, creating a global need for innovative farming methods. This research explores hydroponic farming using wastewater as a sustainable solution for urban and rural food production.

The Philippines, rich in agricultural heritage, faces challenges from traditional farming's environmental impact due to chemical use. This highlights the need for sustainable practices to protect the environment while ensuring food security.

The Ilocos Region is not endowed with large tracts of land for farming compared to other regions. To survive, Ilocanos have maximized the use of the small space available to them by planting diligently. Their geographic disadvantage has made Ilocanos innately cautious, very resourceful, practical, and frugal (Bañez, 2019).

Chausali and Saxena (2021) emphasized that traditional agriculture involves high inputs of pesticides, herbicides, fertilizers, and chemical drugs, which pollute the soil and cause severe risks to human health and the environment.

Mustafa et al. (2023) defined "overfertilization" as the excessive use of chemical fertilizers, which leads to various environmental, health, and economic problems. High fertilizer use harms soil by disrupting essential microbes and contributes to broader environmental issues such as global warming, ozone depletion, and eutrophication, which negatively affect aquatic ecosystems (Tian et al., 2012). Overfertilization can also lead to water contamination with nitrates, posing significant health risks. Effective fertilizer management and sustainable agricultural practices are essential to mitigate these impacts, protect soil health, and ensure long-term agricultural sustainability.

Egbuikwem et al. (2020) found that the growing demand for water in the agricultural and industrial sectors is contributing to a worldwide water scarcity crisis. Sathaiah and Chandrasekaran (2020) validated that in the future, water availability for agriculture will be threatened by growing domestic and industrial demand, and water use for irrigation in 45 countries, accounting for 83% of the world’s population, will have increased 22% from 1995 by 2025.

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Qureshi (2017) emphasized that hydroponic systems offer artificial environments that can be customized to meet specific plant needs, resulting in fresher, greener, and tastier produce. Treftz et al. (2015) highlighted that hydroponics is also water-efficient, with recirculation reducing water waste. This efficient use of water and the potential for vertical gardening enables hydroponics to produce higher yields in smaller spaces, making it ideal for urban or resource-limited environments. Resh (2013) and Hochmuth (2011) discuss automated hydroponic systems, which adjust water, nutrient, and lighting levels based on plant variety needs. This enhances growth conditions and reduces manual labor, promoting resource efficiency in modern agriculture. These systems enable year-round production, sustainable practices, and high-quality crops in various settings.

Li (2019) found that wastewater containing essential nutrients like nitrogen and phosphorus is a potential resource for agriculture, originating from sources like human waste, food, and certain soaps and detergents. Theregowda et al. (2019) explored the production of struvite fertilizer from wastewater, emphasizing its energy efficiency compared to traditional commercial fertilizers.

Contreras et al. (2017) and Becerra-Castro et al. (2015) highlighted the importance of reusing treated wastewater in protecting aquatic environments by reducing untreated discharge into rivers and oceans. This practice aligns with the UN's Sustainable Development Goals, aiming to enhance global sustainability by 2030.

Hydroponic farming emerges as a promising solution to address these challenges. Also, the effects of chemically-based fertilizer must be addressed by informing farmers of its negative effects (Rabena & Rabena, 2011). Hydroponic systems, using nutrient-rich water instead of soil, offer efficiency and sustainability but face challenges with the cost and availability of nutrients. This research explores wastewater as a cost-effective, eco-friendly solution for hydroponic farming.

Objectives of the Study

The study aimed to propose the CHRRO hydroponic system as a sustainable solution for hydroponic cultivation. The growth and yield performance of pechay (*Brassica napus L.*) var. Black Behi was then evaluated using three hydroponic systems: a system utilizing tap water (T1), a system using unfiltered wastewater (T2), and the CHRRO hydroponic system (T3). Finally, the study assessed the level of acceptability of the CHRRO hydroponic system among users.

METHODOLOGY

This section outlines the research design, data collection instruments, experimental procedures, and data analysis employed in the study.

Research Design

The study used a Completely Randomized Design (CRD) with treatment groups of tap water, unfiltered wastewater, and filtered wastewater in hydroponic systems, each with 15 replicates, to assess water type effects on plant growth and yield. Ten experts from agriculture, science, electronics, and farming evaluated the CHRRO system using purposive sampling.

Data Collection Instruments

Data collection instruments included observation forms, tally sheets, and evaluation forms to assess pechay growth and yield. Experts were provided with evaluation sheets to assess the system's acceptability based on specific criteria.

Experimental Procedure

Pechay seeds from the Department of Agriculture in Bangued, Abra were planted in coconut peat and then transplanted into hydroponic systems. Water sources included a reservoir and pump system for filtered wastewater and a commercial filtration system for tap and unfiltered wastewater. Weekly checks monitored plant health, and once mature, the plants were harvested and measured.

Data Analysis

The study followed a systematic approach for accuracy, inspired by Nguyen, McInturf, and Cozatl's (2016) work on hydroponics. Statistical methods included mean calculation, ANOVA, Tukey's Test, Welch ANOVA for plant weight comparison, and Kendall's W for expert consensus on the system's functionality.

RESULTS AND DISCUSSIONS

CHRRO hydroponic system

Figure 1 illustrates the CHRRO hydroponics model, which uses filtered wastewater in a run-to-waste system. The system features filtration techniques to eliminate contaminants, algae, fungi, and debris, ensuring clean water for hydroponic cultivation. Unfiltered wastewater is pumped into the filter, where it first passes through a coarse screen to remove large debris and sediment. It then moves through a fine screen to remove smaller particles. The filtered wastewater flows through a compressor hose and into PVC pipes, which house both the water and pechay plants.

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Legend:
1. Water pump
2. Unfiltered wastewater
3. Reservoir
4. Inlet
5. Filtration system
6. Outlet
7. Pechay plant
8. Cocopeat
9. Styro
10. PVC pipe (orange)
11. Stand (steel bar)
12. Ball Valves (3/4)

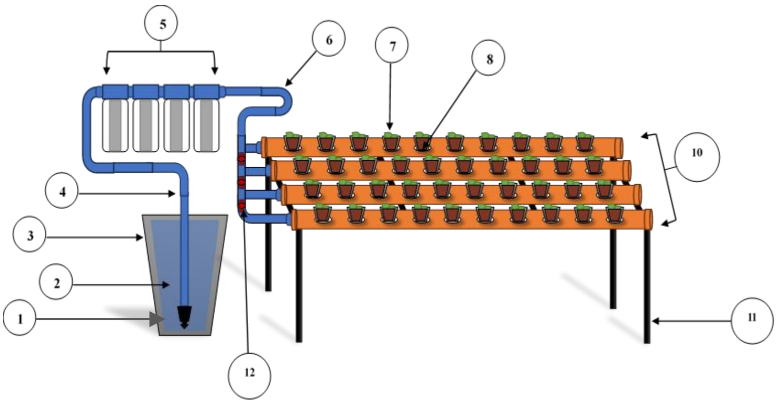

Figure 1

CHRRO Hydroponics System

Legend:
1. Water pump
2. Tap water
3. Unfiltered wastewater
4. Reservoir
5. Inlet
6. Pechay plant
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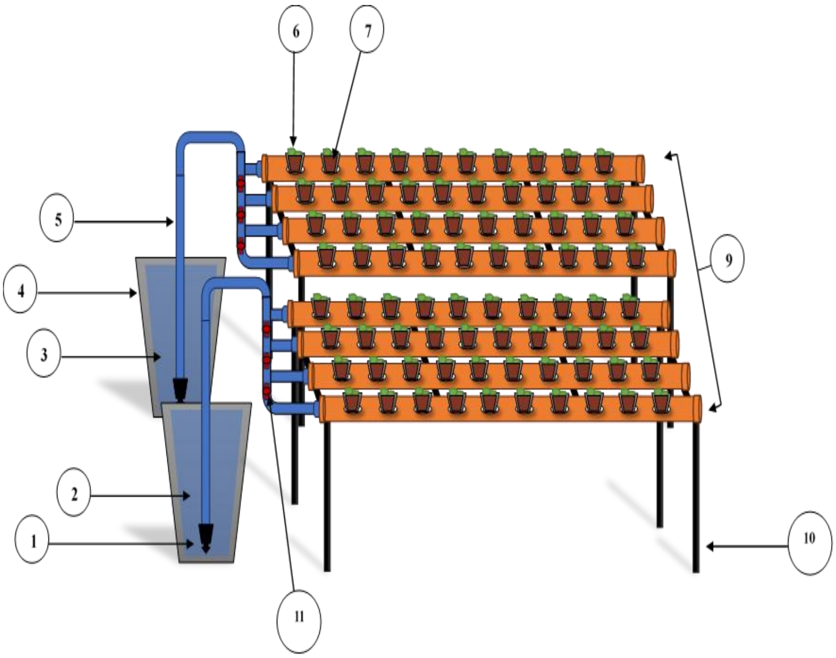

Figure 2

Hydroponic System

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Figure 2 depicts a hydroponic model that uses unfiltered wastewater and tap water separately in a run-to-waste system. The system includes a water pump that propels water to a compressor hose, with each water type flowing through distinct pathways. Unfiltered wastewater and tap water are directed into separate channels within the compressor hose. Each type of water then flows independently into PVC pipes, which serve as containers for both the water and pechay plants. This design allows for the cultivation of pechay plants using both unfiltered wastewater and tap water in separate channels, supporting efficient water management in the system.

Growth and Yield Performance of Pechay (Brassica napus L.) var. Black Behi

Table 1 shows that pechay plants irrigated with filtered water grew significantly better than those with tap or unfiltered water. After two weeks, filtered water plants reached 20.70 cm, while those with tap and unfiltered water grew to 11.30 cm and 11.60 cm, respectively. This suggests that filtered wastewater enhances growth by providing optimal nutrients with fewer impurities.

These results support Hossain et al. (2020) and Xu et al., (2023), who found that treated wastewater boosts crop growth and resource efficiency.

Table 2 shows that pechay growth rates were highest with filtered water at 0.85 cm per day, likely due to fewer impurities and more nutrients. Unfiltered water supported moderate growth at 0.43 cm per day, while tap water had the slowest growth at 0.33 cm per day. This suggests that filtered wastewater can enhance growth in hydroponic systems due to its nutrient composition. Makhadmeh et al. (2021) found that treated wastewater provides essential nutrients for plant growth and reduces reliance on commercial fertilizers.

Table 3 shows the growth and yield of pechay based on the number of leaves at harvest. The filtered water group had the highest mean at 7.33 leaves per plant, indicating better yield. Tap water plants had an average of 5.60 leaves, slightly higher than the unfiltered water group, which had the lowest mean of 5.47 leaves per plant.

Damasceno et al., (2010) found that treated wastewater, combined with chemical fertilizers, improved plant growth and leaf development, emphasizing the importance of proper wastewater treatment for sustainable agriculture.

Table 4 shows the leaf width of pechay at harvest, with filtered water resulting in the largest mean width of 14.53 cm, indicating broader leaves and potentially higher overall yield. Tap water plants had a mean leaf width of 6.40 cm, while unfiltered water plants had the smallest mean at 5.13 cm, suggesting that impurities in unfiltered water may limit leaf development.

These findings align with Alghobar et al., (2016), who reported that both treated and untreated wastewater irrigation resulted in significantly better plant growth and yield in crops like Napier grass and sugarcane compared to groundwater irrigation.

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Table 1
Plant Height (cm) of Pechay (Brassica napus L.) var. Black Behi in Three Treatments

Replication	Tap Water			Unfiltered wastewater			Filtered wastewater		
	Day 0	Week 1	Week 2	Day 0	Week 1	Week 2	Day 0	Week 1	Week 2
1	4.90	9.00	17.00	4.50	10.00	16.00	8.00	17.00	30.10
2	5.00	5.20	9.00	9.00	11.00	12.00	8.00	12.50	21.20
3	7.20	8.00	8.00	9.00	9.00	11.00	11.00	11.70	19.30
4	12.00	12.50	13.00	2.50	7.50	15.00	6.00	10.20	13.00
5	8.00	13.00	12.00	6.00	9.00	10.00	11.00	11.00	17.00
6	8.50	14.00	10.00	6.50	10.00	13.00	9.00	11.00	19.00
7	7.50	11.00	17.00	14.00	4.00	10.50	8.50	10.50	23.00
8	13.00	10.00	10.00	6.30	5.00	6.00	11.00	13.00	21.00
9	8.50	7.00	7.00	8.00	8.00	11.00	8.00	11.80	16.00
10	4.80	5.00	14.00	10.00	7.00	9.00	10.00	12.00	16.00
11	8.00	6.00	10.00	9.50	10.00	10.00	9.00	15.00	26.00
12	10.00	10.00	12.00	6.00	8.60	11.00	7.50	9.00	26.00
13	3.50	7.00	10.50	4.00	12.00	12.00	7.00	12.00	24.00
14	7.70	11.00	10.50	8.00	5.00	7.50	8.50	10.00	18.00
15	6.50	6.00	10.00	10.00	10.00	20.00	10.00	16.00	21.00
Mean height	7.70	9.00	11.30	7.60	8.40	11.60	8.80	12.20	20.70

Table 2
Growth Rate of Pechay (Brassica napus L.) var. Black Behi in terms of Plant Height (cm)

Water Used	N	Mean	Std. Deviation
Tap water	13	0.33	0.26
Unfiltered wastewater	11	0.43	0.29
Filtered wastewater	15	0.85	0.35
Total	39	0.56	0.38

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Table 3
Growth and Yield Performance of Pechay (Brassica napus L.) var. Black Behi in terms of Number of Leaves

	Water Used	N	Mean	Std. Deviation
Number of Leaves at Harvest Time	Tap Water	15	5.60	1.64
	Unfiltered wastewater	15	5.47	1.55
	Filtered wastewater	15	7.33	1.05
	Total	45	6.13	1.65

Table 4
Growth and Yield Performance of Pechay (Brassica napus L.) var. Black Behi in terms of Leaf Width

	Water Used	N	Mean	Std. Deviation
Plant Weight at Harvest Time	Tap Water	15	6.40	5.29
	Unfiltered wastewater	15	5.13	3.72
	Filtered wastewater	15	14.53	7.29
	Total	45	8.69	6.92

Table 5
Growth and Yield Performance of Pechay (Brassica napus L.) var. Black Behi in terms of Weight (g)

	Water Used	N	Mean	Std. Deviation
Plant Weight at Harvest Time	Tap Water	15	5.59	2.24
	Unfiltered wastewater	15	5.47	1.18
	Filtered wastewater	15	8.37	1.81
	Total	45	6.48	2.22

The filtered water group had the highest mean plant weight at 8.37 g, indicating higher biomass and greater yield potential. The tap water group had a mean weight of 5.59 g, while the unfiltered water group had the lowest at 5.47 g, with moderate variability (SD = 1.18), suggesting that unfiltered water may contain impurities that hinder growth.

This supports Urbano et al. (2017), who found that using treated domestic effluent for irrigation increased lettuce weight and highlighted the benefits of wastewater reuse in reducing potable water demand, recycling nutrients, and ensuring sustainable agricultural practices.

A one-way ANOVA was conducted to compare the growth rates (cm/day) of pechay plants grown with tap water (n = 13), unfiltered wastewater (n = 11), and filtered wastewater (n = 15). Filtered wastewater plants showed the highest growth rate (M = 0.85 cm/day, SD = 0.35), followed by unfiltered wastewater (M = 0.43 cm/day, SD = 0.29), and tap water plants had the lowest growth rate (M = 0.33 cm/day, SD = 0.26). The differences were statistically significant, $F(2, 36) = 11.32$, $p < 0.001$, indicating that water type significantly affects plant growth in hydroponic systems.

Abidi et al., (2023) found that treated wastewater, while meeting irrigation standards, requires continuous monitoring for heavy metal buildup. Their study supports using treated wastewater to enhance soil fertility and nutrient efficiency in agriculture.

Table 6

ANOVA on the Mean Height (cm) of Pechay (Brassica napus L.) var. Black Behi

Source of Variations	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2.14	2	1.07	11.32	0.00*
Within Groups	3.40	36	0.09		
Total	5.54	38			

*The mean difference is significant at the 0.05 level

Table 7

Tukey's HSD Multiple Comparisons for Growth and Yield of Pechay (Brassica napus L.) var. Black Behi in terms of Plant Height (cm)

Mean Comparisons		Mean Difference (I-J)	Std. Error	Sig.
(I)	(J)			
Tap water	Unfiltered wastewater	0.10	0.13	0.71
	Filtered wastewater	-0.52*	0.12	0.00
Unfiltered wastewater	Filtered wastewater	-0.42*	0.12	0.00

* The mean difference is significant at the 0.05 level

The Tukey's HSD test assessed the impact of different water types on pechay growth, focusing on plant height. Comparison between tap water and unfiltered water showed a mean difference of 0.10 cm (SE = 0.13) with a significance level of 0.71, indicating no significant

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difference in plant height. In contrast, the comparison between tap water and filtered water showed a mean difference of -0.52 cm (SE = 0.12) with a p-value of 0.00, indicating that filtered water significantly increases plant height. Similarly, the comparison between unfiltered water and filtered water showed a mean difference of -0.42 cm (SE = 0.12), also with a p-value of 0.00, highlighting that filtered water promotes significantly better growth than both tap and unfiltered water. Filtered water positively impacts pechay plant height compared to the other water types.

A one-way ANOVA revealed a statistically significant difference in the number of leaves between pechay plants grown with different water types, $F(2, 42) = 7.88$, $p = 0.00$. This suggests that the water type significantly influences leaf development from transplanting to harvest.

A 2023 study by Petrík et al., highlighted how leaf traits, such as stomatal size and density, affect water-use efficiency (WUE) in C3 plants. This suggests that the water type may impact these traits, potentially influencing leaf quantity.

Table 8
ANOVA on the Plant's Growth and Yield of Pechay (Brassica napus L.) var. Black Behi in terms of Number of Leaves

Sources of Variations	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.53	2	16.27	7.88	0.00*
Within Groups	86.67	42	2.06		
Total	119.20	44			

* The mean difference is significant at the 0.05 level

Table 9
Tukey's HSD Multiple Comparisons for Growth and Yield of Pechay (Brassica napus L.) var. Black Behi in terms of Number of Leaves (cm)

Comparisons		Mean Difference (I-J)	Std. Error	Sig.
(I)	(J)			
Tap Water	Unfiltered wastewater	0.13	0.53	0.97
	Filtered wastewater	-1.73*	0.53	0.00
Unfiltered wastewater	Filtered wastewater	-1.87*	0.53	0.00

*The mean difference is significant at the 0.05 level

The Tukey's HSD test evaluated the impact of different water types on the number of leaves of pechay. The comparison between tap water and unfiltered wastewater showed a

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mean difference of 0.13 (SE = 0.53) with a significance level of 0.97, indicating no significant difference in leaf count. In contrast, the comparison between tap water and filtered wastewater showed a mean difference of -1.73 (SE = 0.53) with a p-value of 0.00, indicating a significant increase in leaf count with filtered water. Similarly, the comparison between unfiltered wastewater and filtered wastewater showed a mean difference of -1.87 (SE = 0.53) with a p-value of 0.00, confirming that filtered water leads to a significantly higher number of leaves compared to both tap and unfiltered water. Filtered water has a significantly positive impact on leaf development in pechay.

A one-way ANOVA was conducted to compare leaf widths of pechay plants grown with tap water (n = 15), unfiltered wastewater (n = 15), and filtered wastewater (n = 15). Plants grown with filtered wastewater had the greatest leaf width (M = 14.53 cm, SD = 7.29), followed by tap water (M = 6.40 cm, SD = 5.29), and unfiltered wastewater (M = 5.13 cm, SD = 3.72). The differences were statistically significant, F(2, 42) = 12.50, p = 0.00, indicating that water type significantly affects leaf width in hydroponic pechay growth.

Studies by Petrík et al., (2023) and Ding and Johnson (2020) emphasized the relationship between leaf morphology and water status, noting that factors like stomatal size and density impact water-use efficiency (WUE). This suggests that water type influences traits such as leaf width.

Table 10

ANOVA on the Plant's Growth and Yield of Pechay (Brassica napus L.) var. Black Behi in terms of Leaf Width

Sources of Variations	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	80.94	2	40.47	12.50	0.00*
Within Groups	135.98	42	3.24		
Total	216.91	44			

*The mean difference is significant at the 0.05 level

Table 11

Tukey's HSD Multiple Comparisons for Plant Width

Comparisons (I)	Comparisons (J)	Mean Difference (I-J)	Std. Error	Sig.
Tap Water	Unfiltered wastewater	0.11	0.66	0.98
	Filtered wastewater	-2.79*	0.66	0.00
Unfiltered wastewater	Filtered wastewater	-2.90*	0.66	0.00

* The mean difference is significant at the 0.05 level

Table 12
Welch ANOVA Results on the Plant's Growth and Yield of Pechay (Brassica napus L.) var. Black Behi in terms of Plant Weight

Welch Statistics	Df1	Df2	Sig.
9.74	2	26.18	0.00*

* The mean difference is significant at the 0.05 level

The Tukey's HSD (Honestly Significant Difference) test evaluated the impact of water types on the growth and yield of pechay, specifically focusing on plant width. The results showed no significant difference between tap water and unfiltered water (mean difference = 0.11, p = 0.98), suggesting that plant width is not affected by this comparison. However, when comparing tap water to filtered water, the mean difference was -2.79 (p = 0.00), indicating that plants watered with filtered water are significantly wider than those watered with tap water. Similarly, the comparison between unfiltered water and filtered water showed a mean difference of -2.90 (p = 0.00), also indicating that filtered water results in significantly wider plants. Therefore, filtered water has a significantly positive impact on plant width compared to both tap and unfiltered water.

A one-way Welch ANOVA was conducted to examine if plant weight differed across groups using tap water (n = 15), unfiltered wastewater (n = 15), and filtered wastewater (n = 15). The results showed that plants grown with filtered water had the highest weight (M = 8.37 g, SD = 1.81), while plants grown with tap water (M = 5.59 g, SD = 2.24) and unfiltered wastewater (M = 5.47 g, SD = 1.18) had almost the same weight. The differences in plant weight were statistically significant, Welch F (2, 26.18) = 9.74, p < 0.00.

These findings suggest that the type of water used significantly impacts plant weight in hydroponic systems. Studies by Gatta (2020) and Riaz (2022) support the use of filtered wastewater, noting its positive effects on plant growth and yield, especially for pechay, by providing a sustainable water source and essential nutrients.

Table 13
Games-Howell Multiple Comparisons for Plant Weight

Comparisons		Mean Difference (I-J)	Std. Error	Sig.
(I)	(J)			
Tap water	Unfiltered wastewater	1.27	1.67	0.73
	Filtered wastewater	-8.13*	2.33	0.00
Unfiltered wastewater	Filtered wastewater	-9.40*	2.11	0.00

* The mean difference is significant at the 0.05 level

Table 13 summarizes the results from the Games-Howell multiple comparisons test, comparing plant weight among three groups: tap water, unfiltered wastewater, and filtered wastewater.

In the comparison between tap water and unfiltered wastewater, the mean difference is 1.27 with a standard error of 1.67, and the result is not statistically significant, suggesting similar plant weights between these groups.

However, when comparing tap water with filtered wastewater, the mean difference is -8.13 with a standard error of 2.33, which is statistically significant ($p = 0.00$), indicating that filtered wastewater significantly increases plant weight compared to tap water.

Similarly, the comparison between unfiltered wastewater and filtered wastewater shows a mean difference of -9.40 with a standard error of 2.11, which is also statistically significant ($p = 0.00$), indicating that filtered wastewater leads to significantly heavier plants than unfiltered wastewater.

These results suggest that filtered wastewater positively impacts plant weight compared to both tap water and unfiltered wastewater, likely due to the removal of impurities or contaminants in the water.

Acceptability of the CHRRO Hydroponic System

Table 14

Mean Rating on the Level of Acceptability of the CHRRO Hydroponic System

Variable	Mean	Descriptive Rating
Functionality	4.5	Excellent
Usability	4.7	Excellent
Durability	4.5	Excellent
Maintainability	4.7	Excellent
Safety	4.4	Excellent
Overall Mean	4.56	Excellent

Legend:	**Numerical Rating**	**Descriptive Interpretation**
	4.21– 5.00	Excellent
	3.41– 4.20	Very good
	2.61– 3.40	Good
	1.81– 2.60	Fair
	1.01– 1.80	Poor

Table 14 shows that the CHRRO hydroponic system received an "Excellent" rating from evaluators, with an overall mean of 4.56. The system's functionality, usability, durability, and maintainability each received mean ratings of 4.5 to 4.7, while safety scored 4.4. These

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results highlight the system's high acceptability, demonstrating its reliability and efficiency in real-world applications.

Kendall's *W* was conducted to assess the agreement among ten experts regarding their evaluations of the functionality, usability, durability, maintainability, and safety features of the filtration system. The five features were rated using a 5-point Likert scale. The results showed no significant agreement among the experts, with W = 0.13 and p = 0.26. This suggests that the experts' assessments lacked consistency and a strong consensus. The variability in their evaluations may be attributed to differences in their backgrounds, perspectives, or criteria used in the assessment, leading to differing opinions on the system's features.

Table 15

Related-Samples Kendall's Coefficient of Concordance Summary

Total N	10
Kendall's W	0.13
Test Statistic	5.31[a]
Degree Of Freedom	4
Asymptotic Sig. (2-sided test)	0.26

*The mean difference is significant at the 0.05 level

CONCLUSIONS

The study found that pechay plants grown with filtered wastewater (T3) had better growth and yield, including height, number of leaves, leaf width, and weight. ANOVA confirmed filtered wastewater as the most effective for plant growth, making it a sustainable alternative. However, Kendall's W revealed no significant agreement among experts on evaluating the CHRRO hydroponic system, indicating differing opinions. The CHRRO system is adaptable for urban farming, addressing land and water scarcity while enhancing food security. Its modular design suits rooftops, vertical farms, and community hubs, optimizing resources and reducing environmental impact. Policymakers can integrate the system into urban agriculture with public-private partnerships and training programs. Filtered wastewater in hydroponics offers a resource-efficient, sustainable solution, aligning with SDGs 2 (Zero Hunger) and 6 (Clean Water and Sanitation). Expanding adoption will require further research, guidelines for wastewater treatment, and capacity-building initiatives to support resilient food systems globally.

RECOMMENDATIONS

Future research should include microbial analysis, nutrient profiling, water testing, and metal analysis to assess the health and safety risks associated with consuming harvested crops. Additionally, testing different crops and advanced filtration systems can enhance the sustainability of the model. Economic and environmental analyses, along with continuous monitoring of water parameters, are needed to evaluate the potential of using filtered wastewater in hydroponic systems. Gathering operational data, user feedback, and consulting experts from engineering, environmental science, and agriculture will help confirm the system's benefits and provide a comprehensive evaluation. To improve agreement among experts, further analysis and discussions may be needed to provide more objective measurements and identify common evaluation criteria.

ETHICAL STATEMENT

Ethical principles were maintained by obtaining informed consent from participants, ensuring anonymity, confidentiality, and the option to decline without consequence. The study minimized risks and adhered to ethical standards, with benefits outweighing potential risks.

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