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Bottom Nutrient Solution Application In Kale (*Brassica oleracea* var. Tuscan) Microgreens Produces the Best Productivity Metrics and Sensory Attributes

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Abstract. As arable lands decrease, the shift to crop production in small spaces elevates. Microgreens is an emerging commodity aligned with this goal to produce more food in vertical spaces. However, crop production and management practices could affect the quality of microgreens based on its agronomic and sensory attributes. Thus, this study evaluated the agronomic productivity and sensory acceptability of kale microgreens as affected by different methods of nutrient solution application. Two trials of a completely randomized design experiment were laid out with the following treatments: control (T1), top and bottom (T2), top (T3), and bottom (T4) nutrient solution application. Initial germination rate for the kale microgreens seedlot averaged 87%. Results revealed the bottom nutrient solution application significantly ($p<0.05$) produced the best productivity metrics, which included stem length (10.94 cm), and fresh weight (91.35 g). In the consumer acceptability test among 80 randomly-selected respondents, the questionnaire was divided into two groups, namely, overall liking using nine-point hedonic scale and assessing the appropriate level of sensory attributes of the samples using the just-about right (JAR) scale. Hedonic scores revealed the best consumer acceptability towards fresh microgreens with bottom nutrient application method with a score of 7.35 (like moderately). It also gained the highest ratings in specific attributes such as color, glossiness, smoothness, thickness, crispiness, and sweetness with a score of 7.28 (like moderately) for the Hedonic scale. JAR scale also revealed an acceptability score of 3.24 based on color, aroma, taste, bitterness, sweetness, and crispiness. This reflects the nascent nature of microgreens for Filipinos, thus, necessitates microgreens consumer education. Since bottom watering also uses less water compared to conventional agriculture, this study can also contribute to attaining sustainable development goals such as responsible consumption and production, while also achieving zero hunger.

Keywords: Kale Microgreens; Nutrient Application; Productivity Metrics; Sensory Attributes

INTRODUCTION

Agriculture plays an important role in the economy of a country. The agricultural sector allows the self-sufficiency of a country that regards food supplies and other agricultural products. Considering the threat of food insecurity, we need to search for viable sources of food. Microgreens have that potential. Microgreens are a relatively new category of leafy vegetables, consisting of young seedlings from various edible herbaceous plants. They are typically harvested 7 to 21 days post-germination, depending on the specific species, once the cotyledon leaves have fully matured and the first true leaves have started to appear (Xiao *et al.,* 2012).

Hydroponic system is a method of production wherein nutrient solutions are used for growing plants rather than in a soil, which can be used in the case of microgreens (Di Gioia

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et al., 2015). The system needs less water than any conventional method of farming. It allows the plant roots to come in direct contact with the nutrients while having oxygen access which is essential for better and proper growth of crops and offers a highly efficient way of providing the necessary nutrients and water needed by the plants (Carruthers, 1988).

Kale is a cool-season crop that is part of the cabbage family. It is packed with essential nutrients, including β-carotene, vitamin K, and vitamin C, and is a good source of calcium. It's commonly used in salads and soups. Like other vegetables in the mustard family, kale contains indole-3-carbinol, a compound that helps repair DNA in cells and may inhibit the growth of cancer cells. Kale features non-heading, curled, and tender leaves. Although it is a biennial plant, it is typically grown as an annual for vegetable production. (Rana & Mamatha, 2017).

The watering methods of microgreen crops involve top and bottom. Top watering methods is essential in the germination phase of seeds to keep it moist, but the negative effect is it can encourage the growth of fungus and diseases to the growing stage of the plant because microgreen is prone to mold growth. Bottom watering keeps the moist uniform to all plants, but the downside is the salt build up over time (Misra & Gibson, 2021; Green 2021).

The existing potential of microgreens that can be harvested in a short period of time are a good alternative and great solution in the food scarcity we are facing. Identifying suited watering methods that can affect the production of kale microgreen under hydroponic systems is being proposed.

METHOD

Collection of Materials and Equipment

The materials and equipment needed like the kale seeds, coco coir, lights, growing trays, growing chamber, thermometer and pH meter (was first calibrated for accurate measurements), are bought from online shops, and the digital weighing scale was borrowed from the Department of Crop Science. For the nutrient solution, it was bought in the nearest agricultural store.

Establishment of Growing Chamber

Small indoor growing chamber was constructed using metal and wood (Figure 3), in the Department of Crop Science to control the environment of the experiment. The size of the growing chamber was 198cm tall and 39cm wide and 118cm long.

Experimental Design and Treatments

The experiment was laid out in a Single Factor Experiment, Completely Randomized Design (CRD). Twelve (12) trays were used and each tray has a size of 13x10.5x6cm that represented the treatment replicate. There are four (4) treatments and replicated three times and conducted twice for better results. The treatments used are as follows: T1-Control; T2- top and bottom nutrient solution application; T3- top nutrient solution application; and T4-bottom nutrient solution application.

Cultural Management Practices Seed Sowing and Seed Establishment

The seeds were soaked for 8 hours and sown 2 grams of microgreen kale seeds on the growing media using the growing trays and placed inside the greenhouse. The medium was kept moist and the seeds were covered for a few days to let the seeds germinate then removed when seeds already show germination after 2-4 days after sowing. Then, the trays

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were exposed in the fluorescent lights with 15 watts for 16-20 hours per day and continued to water the plants and monitor its growth until harvest time.

Nutrient Solution Application

This study utilized the nutrient solution from the nearest agricultural store then mixed to the recommended amount of water and used in the hydroponic system for microgreen kale. The recommended ratio is 30 ml of solution A & B in every 6 liters of water, then watered 150 ml of it to each tray except on controlled treatment.

Potential Hydrogen and Temperature Monitoring

The pH and temperature are closely monitored and observed at 7:00 am and 2:00 pm daily until the end of the experiment.

Harvesting

Microgreen Kale are harvested after 8-12 days after sowing. Kale was harvested after the first true leaves developed and reached the preferred size of leaves and length of stem, by using a pair of scissors the kale was simply cut starting from the stems. Then freshly harvested microgreen kale was weighed using the digital weighing scale.

Parameters Gathered

The following growth parameters was evaluated:
1***. Germination rate.*** It was calculated by dividing the number of healthy seedlings by the total number of seeds tested and multiply it by 100 to get the percentage.
2. ***Stem Length (cm).*** It was measured using a ruler from above the ground stem up to the tip of the fully developed cotyledon leaves or the partially developed true leaves on harvest time. In each tray five (5) sample plants were used for measuring the stem length, and a total of 60 sample plants were used for this experiment.
3. ***Fresh Weight (kg).*** The total fresh weight of the plants was based on the added fresh weight of all the replicates per treatment and weighed using the digital weighing scale. All of the harvest in twelve (12) trays were the sample plants and weighed at harvest.
4. ***Water Quality Parameters (pH and temperature).*** The relationship of water quality parameters specifically the potential hydrogen and temperature of the water with nutrient solution was determined in this study. Monitoring was done every day at 7:00 in the morning and 2:00 in the afternoon using the pH and temperature meter.
5. ***Sensory Evaluation.*** The harvested microgreen kale was evaluated based on the crafted Sensory Evaluation of Kale (Consumer Acceptability) by the Food Science and Technology Department, in the College of Home Science and Industry, Central Luzon State University. The study used the consumer acceptability test, to assess the liking of a product based on its sensory appeal (Fiorentini et al., 2020). The degree of liking scale by Lawless and Heymann (2010) was administered as a 9- point hedonic scale that ranges from "like extremely" to "dislike extremely". The target respondents of this study were forty (40) students that are randomly recruited at CLSU and forty (40) residents in San Quintin Pangasinan. The respondents are informed about the study and asked if they are willing to participate, to avoid any conflicts between the respondents and the researcher. The measurements, analysis, and interpretations of data gathered from sensory evaluation was conducted using the Consumer Acceptability Test. Questionnaire is divided into two groups; overall liking as the first part using nine-point hedonic scale and part two is assessing the appropriate level of sensory attributes of the samples using the just-about- right (JAR) scale.

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Statistical Analysis

Analysis of variance (ANOVA) for the Complete Randomized Design (CRD) was used in this study to evaluate the relationship of different nutrient solution application on the treatments. Comparison among means was calculated using Least Significant Difference (LSD) at 5% level of significance ($p < 0.05$). Data collected was analyzed using the Statistical Tool for Agricultural Research (STAR) version 2.0.1.

RESULTS AND DISCUSSION

Germination rate

Results revealed that in 1g of kale seeds with a total number of 321 seeds sown, the healthy seedlings that grown in two (2) growing trays are 276 and 284 at day 3. It was calculated and the results are 85% to 89% germination rate. The results of this study were increased for about 15%-19% compared to the claimed germination rate of Lemonique Farm where the seeds were bought that is only 70%-80%. Soaking the seeds for 8- 24 hours, triggers the germination and removes germination inhibitors that break down natural defenses so that the germination of seeds speed-up.

Stem Length

Figure 1 illustrates the stem length of kale at harvest, showing that Treatment 4 (bottom nutrient solution application) resulted in the longest stem length, with an average of 10.95 cm in the first setup and 10.93 cm in the second. On the other hand, the shortest stem length in the first setup was observed in Treatment 1 (control) with a mean of 7.47 cm, while in the second setup, Treatment 2 (top and bottom nutrient solution application) had the shortest stem length at 7.37 cm.

In the first setup, Treatment 1 (control) had the lowest stem length mean at 7.47 cm. Meanwhile, Treatments 4, 3, and 2 had comparable stem lengths of 10.95 cm, 10.40 cm, and 10.09 cm, respectively. All treatments that received the recommended nutrient solution showed similar stem lengths. In the second setup, the stem lengths of Treatments 4 and 3 were again comparable, with means of 10.93 cm and 9.37 cm, respectively. However, Treatments 1, 2, and 3 had similar means of 8.33 cm, 7.37 cm, and 9.37 cm. Treatment 2, which had the lowest mean, exhibited signs of lodging—likely due to the top and bottom nutrient solution application.

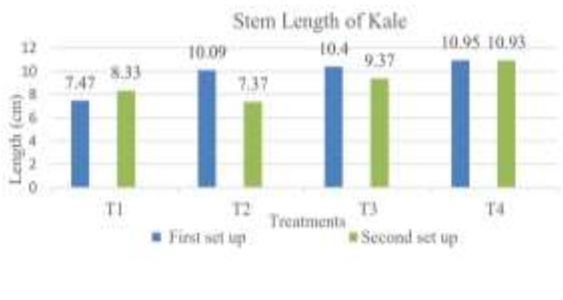

Figure 1. Analysis of variance on stem length (cm) of kale at harvest as affected by different methods of nutrient solution application (first and second set-up)

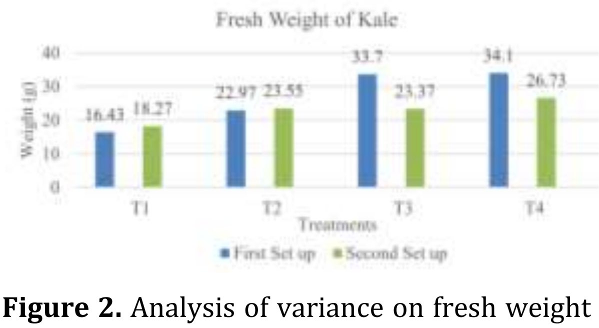

Figure 2. Analysis of variance on fresh weight (g) of kale at harvest as affected by different methods of nutrient solution application (first and second set-up)

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Fresh Weight

Figure 2 shows that in the first setup, Treatment 4 (bottom nutrient solution application) produced the highest fresh weight, with an average of 34.1 g, while in the second setup, it resulted in 26.73 g. In contrast, the microgreen kale in Treatment 1 (control) had the lowest fresh weight, recording 16.43 g in the first setup and 18.27 g in the second.

The fresh weight results indicate that Treatments 4 and 3 were similar in the first setup, with means of 34.1 g and 33.70 g, respectively. Treatments 1, 2, and 3 were comparable, with averages of 16.43 g, 22.97 g, and 33.70 g, respectively. Treatments using only one method of nutrient application tended to yield higher fresh weights, while Treatment 1 (control), which did not receive any nutrient solution, had the lowest yield. In the second setup, Treatments 4, 3, and 2 were comparable, with fresh weight means of 26.73 g, 23.37 g, and 23.55 g, respectively. Treatment 1 (control) had a significantly lower mean compared to the other treatments.

Overall, treatments that received the recommended nutrient solution achieved the highest yields. While microgreens generally require low fertilizer inputs and make excellent salad crops, Bulgari et al. (2017) suggest that applying the recommended amount of nutrient solution in hydroponic production can improve yields further. Growing in coco coir without added nutrients can still enhance their growth, resulting in faster development, larger leaves, and richer colors.

Water Quality Parameters

Temperature of Nutrient Solution

The temperature of the nutrient solution plays a crucial role in a crop's ability to absorb water and nutrients, making temperature monitoring essential. The daily average temperature of the nutrient solution was recorded. According to Nxawe *et al.* (2009), the optimal temperature range for nutrient solutions is 18–28°C, a range that was successfully maintained throughout this study.

All treatments exhibited an afternoon temperature increase, with Treatment 3 (top nutrient solution application) experiencing the most significant rise, nearly reaching the upper limit of the optimal range (28°C). In contrast, Treatment 2 (top and bottom nutrient solution application) showed a noticeable temperature decrease between days 9 and 10, although temperatures gradually rose from day 11 until harvest on day 12 in the second setup. The results for the second setup indicated more stable temperature trends compared to the first setup, with fewer afternoon temperature decreases. Across all treatments, temperatures gradually increased from day 8 to day 9, eventually peaking on the harvest day (day 10).

Overall, the temperature of the nutrient solution remained within the acceptable range for hydroponically growing kale, even with occasional spikes of up to 3°C above the desired temperature. Trejo and Gomez (2012) reported that temperature fluctuations of up to 6°C above or below the optimal range do not significantly impact a crop's water and nutrient uptake.

pH of the Nutrient Solution

The pH level, which measures the acidity or alkalinity of a nutrient solution, ranges from 0 to 14. In hydroponic systems, regulating the pH of the nutrient solution is crucial, as

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it directly impacts nutrient uptake and, ultimately, plant productivity. Monitoring and adjusting the pH were key steps in this study to ensure it remained within the ideal range for kale growth. The acceptable pH range for nutrient solutions in hydroponics is between 5.8 and 6.8, where plant roots can efficiently absorb the essential nutrients needed for normal growth (Catigday *et al.,* 2023). Weak acids and water were added when necessary to adjust the pH to optimal levels, ensuring nutrient uptake was not hindered.

At times, there were slight drops in the pH of the nutrient solution, especially in the afternoon. Most of the time, the pH stayed within the acceptable range, with occasional deviations. For instance, Treatment 4 (bottom nutrient solution application) showed pH values slightly below the acceptable range at certain points, but these deviations were minor.

In some cases, the pH of the nutrient solution exceeded the preferred range, particularly on the first day of Treatment 1 (control) and Treatment 2 (top and bottom nutrient solution application). Treatment 3 (top nutrient solution application) consistently maintained pH levels within the acceptable range. The pH fluctuations had an observable effect on plant growth, particularly reducing the fresh weight yield at harvest.

Sensory Evaluation & Consumer Acceptability

Hedonic Scale. Table 1 shows the average score for question number 1 about the participants overall like and dislike on the sample. Based on the score value assigned the microgreen kale is like slightly on Treatment 1 but it was like moderately on Treatments 2,3 and 4 when not dip on thousand island dressing. However, the sample was like moderately by the participants on Treatments 1,2 and 3 and like very much on Treatment 4 when the samples was dip on thousand island dressing.

Without being dipped in Thousand Island dressing, participants slightly liked the microgreens in Treatments 1 and 2, while they moderately liked those in Treatments 3 and 4. The highest-rated attribute was stem color, scoring 8.3 in Treatment 4, corresponding to "like very much." Being dipped in Thousand Island dressing, in across all treatments, the participants generally liked the microgreens moderately. The flavor (including aroma and taste) in Treatment 4 received the highest score of 8.35, equating to "like very much."

JAR Scale. Table 2 reports the average scores for question number 5, assessing the attributes of microgreens without the dressing. Participants generally found the attributes to be "just right" across all treatments. The highest score was for taste, with a 3.45 in Treatment 4, corresponding to "just right." The lowest score was for aroma, which was rated as "too weak/light/soft" with a score of 2.8 in Treatment 1. Evaluating the attributes of microgreen kale when dipped in Thousand Island dressing, the participants found that the microgreens in all treatments had attributes that were "just right." The highest-rated attribute was taste in Treatment 4, with a score of 3.6, which indicates that participants felt the taste was balanced and satisfactory. However, the green color of the leaves received the lowest score, with a 2.75 in Treatment 1, signifying those participants found the color to be "too weak/light/soft." This suggests that while the dressing may enhance the flavor profile of microgreen kale, certain visual attributes like the vibrancy of leaf color may still fall short for some treatments, especially in Treatment 1. Balancing taste and visual appeal could be key to improving overall satisfaction.

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Table 1: Sensory evaluation (9-point Hedonic scale) average score results on samples of kale microgreens as affected by different methods of nutrient solution application (not dip and dip).

PRODUCT	ATTRIBUTES	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Not Dipped	Overall	6.75	7.05	7.10	**7.35**
	Color	6.70	5.40	7.05	**8.30**
	Glossiness	6.70	6.95	7.30	**7.35**
	Smoothness	6.65	6.85	7.20	**7.80**
	Thickness	6.65	6.45	7.00	**7.25**
	Crispiness	6.45	7.15	7.60	**7.65**
	Sweetness	6.60	6.25	7.00	**7.20**
Dipped in Dressing	Overall	7.80	7.85	7.80	**8.05**
	Color	7.45	7.75	7.90	**8.05**
	Glossiness	7.50	7.85	7.55	**8.10**
	Smoothness	7.65	7.55	7.75	**8.05**
	Thickness	7.70	7.60	7.50	**7.90**
	Crispiness	7.85	7.45	7.85	**8.00**
	Sweetness	7.45	7.80	**7.90**	7.85

Sensory evaluation score value equivalent (1= Dislike Extremely, 2= Dislike Very Much, 3= Dislike Moderately, 4= Dislike Slightly, 5= Neither Like or Dislike, 6= Like Slightly, 7= Like Moderately, 8= Like Very Much, 9= Like Extremely).

Table 2: Sensory evaluation (Just About Right scale) average score results on samples of kale microgreens as affected by different methods of nutrient solution application (not dip and dip).

PRODUCT	ATTRIBUTES	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Not Dipped	Overall	3.00	3.00	3.14	**3.24**
	Color	2.90	2.90	3.05	**3.15**
	Aroma	2.80	2.80	3.15	**3.25**
	Taste	3.25	3.25	3.25	**3.45**
	Bitterness	***3.00***	***3.00***	*3.15*	*3.10*
	Sweetness	2.95	2.95	3.05	**3.15**
	Crispiness	3.05	3.05	**3.25**	3.10
Dipped in Dressing	Overall	3.10	3.22	3.23	**3.31**
	Color	2.90	3.00	3.15	**3.20**
	Aroma	3.00	3.20	**3.45**	3.25
	Taste	3.45	3.45	3.50	**3.60**
	Bitterness	***3.05***	*3.55*	*3.15*	***3.05***
	Sweetness	3.30	3.15	3.00	**3.45**
	Crispiness	3.25	3.15	3.05	**3.40**

Sensory evaluation score value (1= Much too weak/light/soft, 2= Too weak/light/soft, 3= Just right, 4= Too strong/dark/soft, 5= Much too strong/dark/soft).

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Willingness to Buy. Table 3 displays the willingness of the respondents to buy the kale microgreens with and without dip.

Table 3: Willingness to buy (5-point Likert scale) average score results on samples of kale microgreens as affected by different methods of nutrient solution application (not dip and dip).

PRODUCT	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Not Dipped	3.85	4.05	4.05	**4.10**
Dipped in Dressing	3.95	4.05	4.10	**4.25**

Likert scale descriptive equivalents (1= Definitely will not buy, 2= Probably would not buy, 3= Neutral, 4= Probably would buy, 5= Definitely will buy)

The sensory evaluation results for consumer acceptability indicate that flavor, particularly aroma and taste, was the most influential attribute in determining the overall eating quality of kale microgreens. This finding aligns with Xiao et al. (2015), who noted in their study on microgreens that sensory attributes, especially flavor, play a crucial role in consumer satisfaction. While flavor was a key factor, visual and textural qualities—such as color, crispness, and freshness—also significantly contributed to consumer acceptance.

The study revealed that consumer preferences for kale microgreens were largely shaped by these attributes. Participants rated the overall eating experience from "good" to "excellent," with the willingness to purchase the product being notably high, suggesting strong market potential. This supports Keutgen et al. (2021), who emphasized the connection between flavor and overall eating quality in microgreens.

Interestingly, while some participants expressed initial reservations about the kale—specifically its aftertaste—this hesitation disappeared when the microgreens were dipped in dressing. One respondent even mentioned initial hesitation but recommended promoting the product to the public. This highlights the potential of microgreens to grow in popularity with proper education about their health benefits, a point reinforced by Senevirathne et al. (2019). Educating consumers could further boost their acceptance of kale microgreens and similar products.

CONCLUSION

The results of this study highlight the significant influence of nutrient solution application methods on the growth of microgreen kale, particularly in terms of stem length and fresh weight. It was observed that the performance of different nutrient application techniques directly affected kale growth and led to increased yields. Additionally, consumer acceptability of microgreen kale was notably influenced by various sensory attributes, including taste, aroma, appearance, texture, crispness, and color. The overall liking of these attributes played a critical role in the consumers' willingness to purchase the product once it becomes available in the market. Furthermore, the study assessed the relationship between water quality parameters and nutrient solution. Daily monitoring of pH levels indicated that fluctuations in pH significantly impacted the growth of microgreens, ultimately affecting the harvest weight. Conversely, the temperature of the nutrient solution did not exhibit a significant influence on water and nutrient uptake, suggesting that it did not impact the growth and yield of kale.

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Based on the findings of the study, it is recommended that microgreen kale production be optimized by focusing on the bottom nutrient solution application method, which has demonstrated superior performance in promoting growth. Additionally, further research should be conducted to improve the efficacy of nutrient solutions specifically for crops within the Brassicaceae family, as this could enhance overall yield and quality. Lastly, comprehensive studies should be undertaken to evaluate the nutrient content of microgreen kale, exploring its relationship to nutrient solution uptake and its impact on consumer acceptance. These efforts could lead to more informed practices and greater marketability of microgreen kale.

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