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THE IMPACT OF PLANTING SPACING ON THE GROWTH AND YIELD OF GREEN BUTTERHEAD LETTUCE (*Lectuca sativa var. capitata L.*) IN SWU 02 SMART WATERING HYDROPONIC SYSTEM.

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ABSTRACT

The growth of the human population has resulted in the conversion of agricultural land into residential areas, and one potential solution to this issue is utilizing hydroponic technology for agriculture. The Smart Watering SWU02 hydroponic system is one type of hydroponic technology that can be employed for this purpose. Proper spacing plays a crucial role in hydroponics because it can impact plant growth and development. Therefore, the objective of this study was to examine the impact of spacing on the growth and yield of green butterhead lettuce (Lectuca sativa var. capitata L.). A completely randomized design (CRD) with three treatments, consisting of 12.5 x 12.5 cm, 20x20cm, and 25 x 25 cm spacing, each replicated three times, was used in this study. The results demonstrated that plant spacing significantly affected plant growth and yield. Planting lettuce with a spacing of 25 x 25 cm resulted in the best outcomes and had a significant impact on plant growth and yield compared to other spacing options, with a plant height growth of 18.33 cm, a plant width of 31.17 cm, a yield of plant weight of 122.78 grams, and a distance between leaves of 0.03 cm. Optimal plant growth and avoiding etiolation symptoms can be achieved by spacing plants apart, which minimizes competition for nutrients.

Keywords: Green Butterhead Lettuce., Hydroponics, Planting Spacing, Plant Yield

INTRODUCTION

The conversion of agricultural land to non-agricultural land has a negative impact on food production. To combat this issue, one solution is to utilize narrow land for cultivating crops using hydroponic technology. Hydroponics is an agricultural method that does not rely on the soil as a planting medium but instead uses water to distribute nutrients to each plant. This approach was defined by Roidah (2014). The hydroponic planting system offers several advantages over conventional planting systems, such as a cultivation process that is not influenced by climate, a continuous yield, and easier maintenance, as stated by (1).

Careful consideration must be given to the spacing between plants, as it is a factor that significantly affects both the quality and quantity of lettuce plants. The growth of plant height is greatly influenced by spacing, with closer spacing resulting in higher plant growth (2). By adjusting the plant density to a specific limit, plants can efficiently utilize their environment for growth (2). In the cultivation of green butterhead lettuce with the Smart Watering 02 system, spacing was selected as a means of optimizing growth and preventing etiolation. Several important parameters must be taken into account when cultivating plants with this system, including plant height, the number of leaves per plant, the distance between plant stems, and wet plant weight. Therefore, it is necessary to research the effects of different plant spacing on the growth and yield of green butterhead lettuce based on the aforementioned explanation.

This study aims to investigate how varying spacing in the SWU 02 hydroponic smart watering system affects green butterhead lettuce plants' growth and yield and identify the optimal spacing for supporting their growth and yield. This research will contribute to the

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development of knowledge about the impact of different planting spacings on the growth and yield of green butterhead lettuce in the SWU 02 Smart Watering Hydroponic System. The findings of this study are expected to provide valuable information and insights into the effects of planting spacing on the growth and yield of green butterhead lettuce plants in the Smart Watering SWU 02 hydroponic system.

MATERIALS AND METHODS

Time and Place

The study was conducted at the Greenhouse Hydroponic Learning Center in Pedca Utara, which is part of the Faculty of Agricultural Industry Technology at Padjadjaran University. The research was carried out during a single planting season of green butterhead lettuce from September 2022 to November 2022.

Materials

The materials required for this study include water, green butterhead lettuce seeds, pH down solution (sulfuric acid), vegetable ab mix nutrition, and rock wool.

Tools

The equipment needed for this study includes stationery items, DO meters, EC and TDS meters, measuring cups, hacksaws, hygrometers, cameras, harvest baskets, trays, stirrers, rulers, pH meters, smart watering hydroponic system installation kits (SWU 02), digital scales, toothpicks, and nutrient solution containers.

Design

In this experiment, a completely randomized design (CRD) was employed with one treatment factor having three levels and three repetitions, resulting in a total of 9 experimental units. The spacing was the observed factor, and the data collected were analyzed using ANOVA. Duncan's Multiple Range Test (DMRT) was performed at a 95% confidence level if a significant treatment effect was observed.

Research Procedures

Initial Phase

The initial phase of the experiment involves cleaning the SWU 02 smart watering hydroponic installation to ensure it is free from any contaminants. Following this, three Styrofoam pieces are prepared by punching holes in them. Each Styrofoam piece has a different spacing of 20 x 20 cm, and each contains 15 planting holes.

Nursery Phase

The nursery phase begins by sowing green butterhead lettuce seeds in rock wool planting media measuring 24 x 14 cm. Subsequently, the rock wool is cut into 2 x 2 cm sizes and a hole is made in the center, where a single green butterhead lettuce seed is inserted. The rock wool with the seed is then placed on a tray, which is adequately filled with water to maintain seed moisture. The seeding process continues until the plants have grown 2-3 true leaves or until 2 weeks have elapsed.

Transplanting phase

The transplanting phase involves relocating the green butterhead lettuce plants that have attained 2-3 leaves to the SWU 02 smart watering hydroponic installation. These plants are then placed on Styrofoam pieces that contain rock wool growing media with the appropriate spacing. As this study incorporated 3 treatments with 3 repetitions, it necessitated the use of 9 Styrofoam pieces with 3 distinct spacing dimensions.

Fertilization Phase

After the green butterhead lettuce seeds have been planted, they are provided with AB mix nutrition as it is necessary to fulfill their nutrient requirements.

Maintenance Phase

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The maintenance carried out in this study was measuring nutrition and controlling pests and diseases. Nutrition measurements used a Total Dissolved Solid (TDS) meter and a Potential of Hydrogen (pH) meter, which was carried out three times a day at 07.00, 12.00, and 17.00 WIB. The purpose of checking nutrition is to maintain sufficient nutrient availability in plants.

Harvesting Phase

Harvesting is initiated once the green butterhead lettuce plants exhibit physical attributes indicating readiness for harvesting and reach the appropriate age for harvesting, which is between 38 to 41 days after transplanting. In this study, harvesting was performed at a 41-day-old plant.

Research methods

The research employed an experimental approach and a completely randomized design (CRD). The variables under observation included: a) the height of the plant, b) the width of the plant, c) the number of leaves, d) the distance between leaves, e) the weight of the plant without roots, and f) the weight of the plant with roots.

Data analysis

The analysis of data in this study commenced with the Kolmogorov Smirnov Normality Test to determine the normality of the data collected. The results of this test indicated that the data were normally distributed, and the testing process could proceed with the One-way ANOVA test. The One-way ANOVA test was chosen since the data in this study was both normal and homogenous. The completely randomized design employed in this study utilized analysis of variance (ANOVA). When the analysis of variance indicated a significant effect, further testing was carried out to determine differences between treatments using the Duncan multiple range test (DMRT).

RESULTS AND DISCUSSION

Plant Height

Plant height was measured using a ruler for 41 days after planting and the results are shown in Table 1. The plant height parameters were observed to differ significantly based on variations in plant spacing.

Table 1. Average Height of Green Butterhead Lettuce Plants

Treatment	Plant Height (cm)
	41 HST
Spacing 25 cm x 25 cm	18.33a
Spacing 20 cm x 20 cm	18.48a
Spacing 12,5 cm x 12,5 cm	21.05b

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

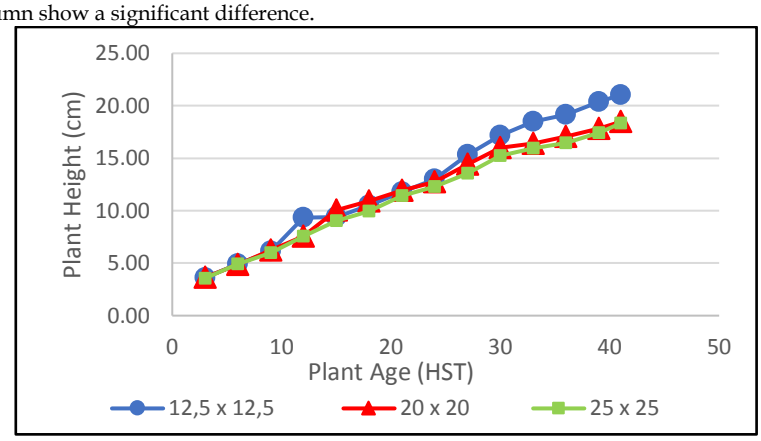

Figure 1: Diagram of Average Plant Height

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According to (3), the height of green butterhead lettuce plants on day 41 has an average of 18 to 20 cm. The height of the green butterhead lettuce obtained in this study is expected to continue to increase if the harvest is carried out at a longer plant age because the growth chart for plant height is still increasing.

The study found that the average yield of plant height at a spacing of 12.5 cm x 12.5 cm was 21.05 cm, which was the highest among all the plant heights observed. The increase in plant height at tighter spacing was attributed to the decreased quality of light received by plants, as reported by (4). The plant height at a spacing of 20 cm x 20 cm showed an average yield of 18.48 cm, while the yield at 25 cm x 25 cm was the lowest at 18.33 cm. Based on the yield data, a spacing of 25 cm x 25 cm was deemed the best for green butterhead lettuce growth as it helps minimize competition for resources in a relatively smaller environment compared to tight spacing, where intra-plant competition is high. This conclusion was drawn by (5).

Plant Width

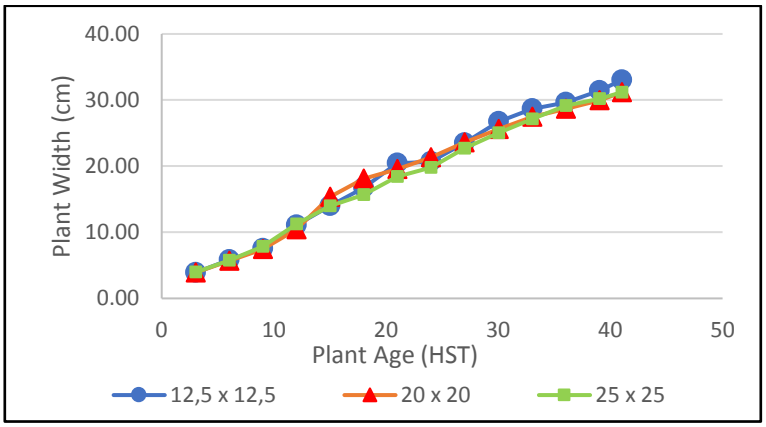

Figure 2: Diagram of Average Plant Width

According to Table 2, the average width of green butterhead lettuce plants was measured for different spacing treatments. The spacing treatment of 20 cm x 20 cm resulted in the lowest plant width of 31.16 cm, while the spacing treatment of 25 cm x 25 cm showed an average plant width of 31.17 cm. However, the difference between the two treatments was insignificant because they were both sufficiently spaced to receive optimal sunlight and nutrients and reduce competition between plants for growth in plant width. On the other hand, the treatment of 12.5 cm x 12.5 cm resulted in significantly different plant width parameters compared to other spacing treatments.

Table 2. Average Width of Green Butterhead Lettuce Plants

Treatment	Plant Width (cm)
	41 HST
Spacing 25 cm x 25 cm	31.17a
Spacing 20 cm x 20 cm	31.16a
Spacing 12,5 cm x 12,5 cm	33.03b

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

The average values presented in Table 2 indicate that a spacing of 12.5 cm x 12.5 cm yields the widest plants, with an average width of 33.03 cm. However, this close spacing causes the leaves of neighboring plants to overlap, resulting in irregular growth and poor crop yield. Additionally, the veins of the leaves become distorted, and the plants are more fragile and prone to breakage.

Number of Leaves

According to Table 3, green butterhead lettuce plants grown with a spacing of 25 cm x 25 cm produced the highest average number of leaves, which was 41, compared to other spacings. This finding significantly differs from the results obtained with a spacing of 12.5 cm

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x 12.5 cm. This difference may be attributed to the more spacious arrangement of plants, which allows them to move more freely, as noted by (6).

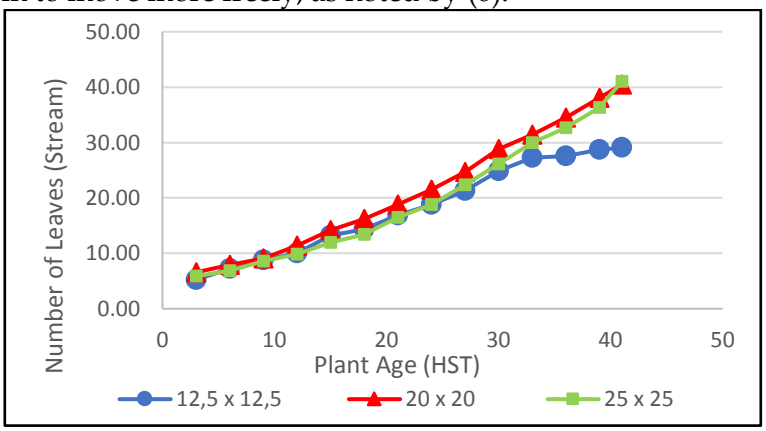

Figure 3. Diagram of the Average Number of Plant Leaves

Table 3. Average Number of Green Butterhead Lettuce Plant Leaves

Treatment	Number of Leaves (Stream)
	41 HST
Spacing 12,5 cm x 12,5 cm	29.06a
Spacing 20 cm x 20 cm	40.46b
Spacing 25 cm x 25 cm	41.00b

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

The increase in the number of leaves every day can be attributed to the presence of sufficient phosphorus and nitrogen, which facilitate the conversion of carbohydrates from photosynthesis into protein (7). Meanwhile, the significant presence of nitrogen elements in plant nutrition causes a greater number of leaves to emerge (8). However, the average number of leaves for plants grown at a spacing of 12.5 x 12.5 cm is lower, with a value of 29, due to the occurrence of leaf discoloration, wilting, and rotting caused by yellowing of the leaves (9). This is a result of the plants being too closely spaced, which leads to etiolation. Etiolation has a considerable effect on chloroplasts, where the chloroplasts not exposed to sunlight become etioplasts, causing the leaves to turn yellow and become smaller in size. In the case of seedlings, their height may increase in low light conditions, but this is not accompanied by an increase in the number of leaves, a phenomenon referred to as etiolation (9).

Wet Weight Result with Roots

The wet weight of green butterhead lettuce plants was measured by considering the weight of the roots at the harvest time, which was 41 days-old plant. Table 4 shows the average wet weight of the plants with their roots included.

Table 4. Average Wet Weight of Plants with Roots

Treatment	Wet Weight with Root (gram)
Spacing 12,5 cm x 12,5 cm	78.69a
Spacing 20 cm x 20 cm	115.93b
Spacing 25 cm x 25 cm	122.78b

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

Table 4 indicates a significant difference in plant weight between the spacing of 12.5 cm x 12.5 cm, which yielded 78.69 grams, and other spacing treatments. The relationship between root weight and wet plant weight is positively correlated, as (10) reported. The average wet weight of plant roots at a spacing of 12.5 cm x 12.5 cm was lower than the average wet weight of plants and roots at other spacings. This can be attributed to the fact that plants grown at 12.5 cm x 12.5 cm spacing had a limited number of leaves, which caused less dense roots and consequently resulted in lower plant weight with roots.

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Wet Weight Result Without Roots

The wet weight of green butterhead lettuce was determined by assessing the weight without roots at the 41-day-old plant, which was the harvest time after cutting the plant roots. The mean wet weight without the plant roots is reported in Table 5.

Table 5. Average Wet Weight of Plants Without Roots

Treatment	Wet Weight Without Root (gram)
Spacing 12,5 cm x 12,5 cm	61.31a
Spacing 20 cm x 20 cm	103.37b
Spacing 25 cm x 25 cm	108.00b

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

Table 5 displays that the spacing of 12.5 cm x 12.5 cm resulted in a yield of 61.31 grams, which was significantly different from the other spacing treatments. As (10), the weight of the plant roots has a direct correlation with the wet weight of the plant. The average wet weight of plant roots at the spacing of 12.5 cm x 12.5 cm exhibited the lowest value compared to other spacing treatments, which could be attributed to the etiolation symptoms experienced by the plants at this spacing. The low plant weight was due to the small number of leaves, and the frail nature of leaf stems resulting from the etiolation symptoms.

Distance Between Leaves

The distance between plant leaves was measured to determine which plants were etiolated and which were not. The growing distance between the leaves was measured every three days in the morning using a ruler. The measurement was taken from the base of the first vein to the second vein and had to be carried out with care to avoid damaging the relatively soft leaves of the plants, which could result in leaf scratching or vein breakage. The spacing between the leaves in each treatment exhibited a significant difference. Details of the average plant height data are presented in Table 6 below:

Table 6: The average distance between leaves

Treatment	Distance Between Leaves (cm)
	41 HST
Spacing 25 cm x 25 cm	0.03a
Spacing 20 cm x 20 cm	0.11b
Spacing 12,5 cm x 12,5 cm	0.42c

Note: Numbers written with the same letter in the same column show no significant difference; Numbers written with different letters in the same column show a significant difference.

In the study, measuring the distance between plant leaves at a parameter of 12.5 cm x 12.5 cm resulted in a significant difference of 0.42 cm compared to other plant spacings. The green butterhead lettuce plants planted closely had fewer and more spaced leaves, while those with wider spacing had leaves that were not too far apart. The number of leaves produced decreases as the distance between leaves increases, which is one of the indications of etiolation in plants. Etiolation occurs due to the continuous production of auxin, which elongates the cells. As reported by (11), light can inhibit auxin production. Etiolation symptoms arise from a lack of sunlight, which can be caused by tight spacing, hindering plant photosynthesis and reduced leaf growth. Dense planting leads to competition for sunlight, causing etiolation issues or tall plant stems due to a lack of sunlight, as stated (4). The tight spacing of plants also results in competition for nutrients, which blocks the flow and leads to excessive root growth, as reported by (12). The development of plants experiencing etiolation is hindered due to suboptimal photosynthesis, which affects the formation of food substances, ultimately leading to improper plant development.

Based on the data presented in Table 6, the average distance between leaves for the 25 cm x 25 cm plant spacing treatment is 0.03 cm. Narrow spacing between leaves is indicative of plants that are not affected by etiolation symptoms. Lettuce plants with larger spacing

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between plants tend to reduce intra-species competition, resulting in relatively lower competition for resources in the environment compared to treatments with denser plant spacing (5). This, in turn, facilitates optimal plant growth.

CONCLUSION

The study concludes that variations in spacing within the Smart Watering SWU 02 hydroponic system significantly impact the growth and yield of green butterhead lettuce (Lectuca sativa var. capitata L.). Based on the findings, the optimal spacing treatment that produced the best growth and yield of green butterhead lettuce in this hydroponic system was 25 x 25 cm, resulting in a plant height of 18.33 cm, plant width of 31.16 cm, 41 leaves, a leaf stalk distance of 0.03 cm, and a wet weight of 122.78 grams. These results suggest the importance of evaluating spacing under various systems to determine the optimal conditions for achieving maximum growth and yield of green butterhead lettuce (Lectuca sativa var. capitata L.).

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