The Increase in Production Efficiency of Hydroponic Salad (A Case Study Of Green Oakleaf Lettuce)

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Abstract. The trend of growing hydroponic salad has been increasingly popular because consumers are more concerned about health nowadays. However, green Oakleaf lettuce was studied in this research because the smart farm in Mae On, Chiang Mai which was the farm in this case study grew green Oakleaf lettuce on 70 percent of its land. The problems found on the farm were: 1. there was no criterion of quality level of green Oakleaf lettuce production, 2. there was no efficient system of controlling factors which caused poor quality of green Oakleaf lettuce production. The solutions to the problems mentioned above were: 1. the criteria of quality level of green Oakleaf lettuce were set by taking green Oakleaf lettuce randomly from Nong Hoi Royal Project Foundation to measure its weight, diameter, height, the number of its leaves, and leaf area. All physical characteristics of green Oakleaf lettuce were analyzed to find the relations among them and the hypothesis was tested. The finding revealed that the weight was significantly associated with all other characteristics at the level of 0.05. Therefore, the weight was used to set up criteria and they were as follows: A grade level for lettuce weighed more than 200 grams, B grade level was between 150 and 200 grams, and C grade level weighed from 50 to 150 grams. After that, these criteria were utilized to divide the quality level of green Oakleaf lettuce on the smart farm in Mae On, Chiang Mai. The result was that 72.1 percent of green Oakleaf lettuce was A grade level, 27.9 percent was B grade level, and 4.65 percent was C grade level. 2. factors affecting the growth of lettuce were studied by using the quality control principles. The finding showed that the solution with greater than 25C had an effect on the growth of lettuce of 17.79 percent, water had an effect of 16.11 percent, nutrients had an effect of 13.56 percent, temperature higher than 25C in a greenhouse had an effect of 11.01%, diseases and bugs had an effect of 10.17%, air had an effect of 10.17 percent, seeds had an effect of 9.32%, light had an effect of 8.47%, and others had an effect of 3.39%.

1. Introduction

Trend for growing soilless or hydroponic has increase due to consumer interest in maintaining their health. While there is a variety of lettuce strains, this research will focus on the green Oakleaf lettuce which is grown at the Amphur Mae On Smart Farm, Chiang Mai, Thailand [1]. This farm grows green Oakleaf lettuce on 70% of its land. The problems found in this research include 1. The lack of criterion in ranking the quality of green Oakleaf lettuce and 2. The lack of a systemized process for controlling developmental factors of green Oakleaf lettuce means the output of green Oakleaf lettuce production does not meet the expectations. This researcher will therefore analyze the problems and make a case report for possible rectifying solutions. The study aimed to apply engineering knowledge to the agricultural production of hydroponic green Oakleaf lettuce; identify ranking criterion for the quality
of hydroponic green Oakleaf lettuce so that the produce has a clearly defined ranking system; and to research and identify more effective methods of growing hydroponic green Oakleaf lettuce.

2. Materials and Methods

Following extensive research on growing Green Oak Leaf lettuce, examples of lettuces were collected from the Nong Hoi Royal Project Development Centre, Chiang Mai, Thailand, (Figure 1) using the Taro Yamane formula to find a sample with a reliability of 95% which was then measured for weight, diameter, leaf area, leaf count, and height. Following this, correlations were calculated using the Pearson Correlation Co-Efficient in order to test the hypothesis and establish standardized criteria to determine in which standard the produce would be ranked. Fish Bone and Pareto diagrams were used to determine possible improvements to the cultivation methods and to suggest solutions to the problems.

![Figure 1](https://i.imgur.com/3Q5Q5Q5.png)

**Figure 1.** Case study Farm: Learning Centre Smart farm at Amphur Mae, Chiang Mai, Thailand

3. Results and Discussions

Research of the methods of growing hydroponic green Oakleaf lettuce consists of the following areas [2]:

1) Seed throwing procedure
2) Leaf development thriving procedure
3) Curating procedure
4) Full development procedure

Examples of green Oakleaf lettuce were randomly collected a study population of 155 plants from The Nong Hoi Royal Project Development Centre, Chiang Mai, Thailand from a total population of 250 plants, with a reliability of 95% according to the Yamane formula (1), and a distance between the plants of 2 plants and pick 1 plant and measure these values and examine the relationship by using the weight as the representative [3].

\[
n = \frac{N}{1 + N(e)^2}
\]  \hspace{1cm} (1)

3.1. Statistical analysis of the relationship

as shown in Figure 2 Data gathered included weight, diameter, number of leaves, area of leaves, and height of the study population of green Oakleaf lettuce, and the relationship between correlations were found by drawing a graph, as shown in Figure 2.
From the results, this researcher used Pearson’s correlation coefficient (2) to make comparisons and determine the relationships and test whether the hypothesis is acceptable or otherwise in equation (3) [3].

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$  \hspace{1cm} (2)$$

$$z = \frac{R - \mu_R}{\sigma_R}$$  \hspace{1cm} (3)$$

Weight had a positive correlation with diameter, height, number of leaves, and leaf area [4], with a weight to diameter correlation of 0.81, a weight to height correlation of 0.81, a weight to leaf number
correlation of 0.881, and a weight to leaf area correlation of 0.887. As the total Z value was outside the critical area (significance?) $H_1$ is accepted and $H_2$ is rejected, meaning the correlation value is equal to 0.9 with a statistical significance of 0.5 proving that when weight increases, diameter, height, leaf number, and leaf area will increase also.

3.2. **Criterion in ranking the quality of green Oakleaf lettuce**

When compared with diameter, height, number of leaves, and leaf area, weight was found to have a statistical significance of 0.05, meaning it is an important factor which is the easiest to use for measurement. As such, this researcher used weight as the factor to set the criteria for ranking quality and established 3 grades – namely Grade A, B, and C – using the following method. The weight distribution gave a mean weight of 192.47 grams and a standard deviation of 75.489 grams. From this, Grade A was defined as between $\bar{x}$ and $\bar{x}+SD$, or 192.945 to 269.431 grams, Grade B as between $\bar{x}$ and $\bar{x}-SD$, or 117.45 grams to 192.942 grams, and Grade C as between $\bar{x}$ and $\bar{x}-2SD$, or 41.964 to 117.453 grams [3]. After obtaining the aforementioned data, the researcher used the Delphi method [5] to determine the information for accurately establishing the criteria for ranking quality, as shown in Table 1.

| Grade | Products | Standards |
|-------|----------|-----------|
| A     |          | - The weight is more than 200 g. |
| B     |          | - Agricultural pests mark in leaves less than 5% |
| C     |          | - The weight is in 150-200 g. |

3.3. **Random Sampling of green Oakleaf lettuce in Farm case study**

Using the Taro Yamane formula on a total of 300 plants, a study sample of 172 plants with a 95% reliability score was established. This distance between plants was 2 plants for every 1 plant picked. When the variables were identified as correlating, only the weight was measured and compared with products from the case study farm and industry standards.

3.4. **A comparison of the products from the farm case study with standards**

The farm case study products consisted of 4.65% Grade A products, 27.9% Grade B products, and 72.1% Grade C products. Analysis of the problems reducing the quality and weight of hydroponic green Oakleaf lettuce. The problems negatively affecting the quality and weight of hydroponic green Oakleaf lettuce were analysed using a Fish Bone diagram, as shown in Figure 3.
Figure 3. Causes negatively affecting the quality of green Oakleaf lettuce.

The problems affecting weight and quality as identified in the Fish Bone diagram were assigned a score according to impact, with Most Impactful scored at 5 points, Impactful 4, Medium Impact 3, Little Impact 2, and Least Impactful 1. This information was then graphed into a Pareto diagram in order to determine which factor was the most impactful, as shown in Figure 4.

![Pareto Diagram](image)

Figure 4. Factors affecting the quality of green Oakleaf lettuce

Figure 4 shows the main reasons for negative effects on the quality of green Oakleaf lettuce, 70% of which results from 5 main reasons, namely temperature in solutions being higher than 25 degrees Celsius (17.79%), water (16.10%), fertilizer (13.56%), temperature inside the house being higher than...
25 degrees Celsius (11.01%), and climate (10.17%). This means the researcher can use the established reasons for negative effects on the quality of green Oakleaf lettuce to find the solutions.

**Result of using hydroponic method for growing green Oak leaf lettuce to increase product quality.**

1) Temperature in solution higher than 25 degrees Celsius

(a) Use an Air-Cooled Chiller system under the principles of a Chilled Water Return system, which generates only some heat when pumping chilled water through the chilled water pump. Through an evaporator, water will be exchanged with the refrigerator liquid to have a lower temperature before being sent to the Air Handling unit, machine, or other heat-generating equipment via a controlling valve which controls the amount of water to conform to the requirements of creating chilled water. This will be done in conjunction with a thermostat or temperature controller. After passing the heat load, the water will be sent back to the chiller before the temperature is reduced for the water to be used again in order for the process to continue unobstructed. The characteristics of the process of the chiller [6] are shown in Figure 5, and a comparison of the benefits and drawbacks is shown in Table 2.

![Figure 5. The Air Cooled Chiller system](image)

| Advantage                      | Disadvantage                        |
|-------------------------------|-------------------------------------|
| Temperature of Solution less  | Temperature is not suitable          |
| High quality                  | High investment cost                |
|                               | High electricity cost               |

(b) A cooling system is a tool which uses water to reduce the temperature of water flow by removing heat and releasing it into the environment. The system uses evaporation, with the main result being remaining water will be much cooler. The necessary equipment, including coolant, climate entry channel, water pump, steam extractor, fan, has been included in the design as shown in Figure 6, and a comparison of the advantages and disadvantages of the cooling tower system[7] is shown in Table 3.
Figure 6. The hydroponic fertilizer cooling tower system

Table 3. A comparison of the advantages and disadvantages of the cooling tower system.

| Advantage                       | Disadvantage                                      |
|---------------------------------|---------------------------------------------------|
| Reduce temperature in Solution  | The water will turn to vapor                       |
| Save price                      | High solution concentration                        |
| The System is not complicate    | Must always fill water in tank                    |

2) Water

(a) Ground water is not pure, and water is the main factor in soilless crop cultivation. No matter how much ground water is used, it will be impossible to cultivate anything if the quality is low, especially if sodium and chloride levels are too high. The solution is to take the water to a laboratory in order to discover whether the nutrients in the water from the case study are suitable enough for the cultivation of vegetation or not [4] according to Table 4.

Table 4. Composition of water suitable for cultivation

| The substance in the water | Quantity Standard |
|----------------------------|-------------------|
| Calcium                    | 20-40 ppm         |
| Carbonate                  | < 10 ppm          |
| Magnesium                  | < 20 ppm          |
| Sodium                     | < 10 ppm          |
| Copper                     | > 20 ppm          |

(b) Water grade and PH level in process 3 and 4 were not stable. Process number 3 contained traces of fertilizers mixed in the water, and the water level needed to be stable at 8-10cm. Process 4. The water level in Process 4 needed reducing by 4-5cm in order to increase the intensity of the solution, as vegetation needs a constant supply of 10-30% water and fertilizer daily.

The solution to this would be to organize a check sheet in order to create a performance and control system for each process.
4. Conclusions
This researcher collected a random sample using the Taro Yamane technique at the Nong Hoi Royal Project Foundation in order to determine standard criteria for measuring weight, height, diameter, number of leaves, and leaf area and used the various values to calculate the relationship using Pearson’s correlation coefficient to test the hypothesis of using weight as comparative. The results which were obtained showed that weight had a positive correlation with each factor, with a significance of 0.05. The values were used to set three grades of quality – Grades A, B, and C – with Grade A weighing between 200 and 300 grams, Grade B weight between 150 and 200 grams, and Grade C weighing between 50 and 150 grams. This grading system meets industry standards and thus has a practical application. Following this, the factors which most impactful factors on the production of green Oakleaf lettuce were determined, as follows; 1. Temperature in the solution higher than 25 degrees Celsius (17.79%), 2. Water (16.11%), 3. Nutrients (13.56%), 4. Temperature in the house higher than 25 degrees Celsius (11.01%), 5. Disease and insects (10.17%), 6. Air (10.17%), 7. Enameled seeds (9.32%), 8. Light (8.47%), 9. Others (3.39%). From the Pareto diagram, it can be concluded that the first two factors accounted for 40% of the factors affecting the quality of green Oakleaf lettuce production. As a result, this researcher can propose using an air-cooled chiller system and cooling tower as solutions for the first factor, and checking the nutrient level of the water supply and organizing a water level control checklist as solutions for the second factor.

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