SALAGA Journal
Vol. 02, No. 1, June 2024, pp. 10 ~ 21
ISSN: 3032-2677
DOI: 10.70124/salaga.v2i1.1364

Cultivation of Caisim Mustard (*Brassica juncea* L.) in The NFT (Nutrient Film Technique) Hydroponic System

Hilda Agustina*[1], Muhammad Priyatama Haibir[2], and Fidel Harmanda Prima[1]
[1]Prodi Teknik Pertanian, Jurusan Teknologi Pertanian, Fakultas Pertanian, Universitas Sriwijaya, Indralaya, Sumatera Selatan
[2]Alumni prodi Teknik Pertanian, Jurusan Teknologi Pertanian, Fakultas Pertanian, Universitas Sriwijaya, Indralaya, Sumatera Selatan

Article Info

Keywords:

AB Mix Nutrient
Concentration of AB Mix
System performance
Hidroponics NFT
Productivity of plant

ABSTRACT

Plant cultivation using the NFT (Nutrient Film Technique) hydroponic system is quite widely used by people in urban areas in plant houses. Suboptimal provision of nutrients causes unsatisfactory plant production. Less than optimal provision of nutrients for plants will affect plant production. Cultivation of caisim mustard plants in hydroponic systems will also be beneficial in urban areas where land is very limited. The design of the NFT hydroponic system also affects the provision of nutrients for Caisim mustard plants. This study aims to determine the performance of the NFT hydroponic system (gutter discharge) and the concentration of AB Mix in the cultivation of caisim (*Brassica juncea* L.). The method used in this study was a Randomized Group Factorial Design (RAKF) with two treatment factors, namely water flow discharge (Q) and concentration of nutrient solution (N) consisting of three treatments and three replications. The research parameters were plant height, number of leaves, plant fresh weight, plant dry weight and plant productivity. It was concluded that the water flow discharge and concentration of nutrient solution had a significant effect on plant growth, number of leaves and fresh weight of plants.

Corresponding Author(s):

Hilda Agustina
Faculty of Agriculture, Sriwijaya University
Sriwijaya University, Palembang-Prabumulih, KM 32 Inderalaya, Ogan Ilir District, South Sumatera Province (30662)
Email: hildaagustina@fp.unsri.ac.id

1. INTRODUCTION

NFT or Nutrient Film Technique is an example of hydroponic cultivation by placing plant roots in a layer of circulating water. The circulating water will contain nutrients to meet the needs of the plants. Tests show that the NFT system provides optimal efficiency compared to the DWT hydroponic system [1]. Plants cultivated with NFT, the roots will develop in a solution containing nutrients, so that plants can grow well [2]. In the NFT hydroponic system, the depth of the water layer is one of the factors that need to be considered. If there is excess water, the amount of available oxygen decreases. The maximum depth of the water layer in the NFT hydroponic system is 3 mm so that the needs of nutrients and oxygen are met [3]. In hydroponics, a closed system, water lost due to evapotranspiration is provided by nutrient solution (a mixture of water and dissolved nutrients) [4]. In addition, the concentration of nutrients in the solution is regulated based on the optimal concentration of nutrients in plants and Water Usage Efficiency (WUE) [4].

Caisim mustard plant is a profitable crop because it is faster to harvest and generally favored. The public's preference for this crop gives it high potential to be developed by horticultural crop producers. The ease of application and supporting materials for NFT hydroponic installations in the community in plant cultivation activities on narrow land has led to increased public adoption of this system in urban areas [5].

WUE and nutrient requirements vary during plant growth [4] especially in Caisim mustard greens. The depth of the water layer and the slope of the gutter affect the absorption of water and nutrients by plants [6]. To support the need for hydroponic application technology, it is necessary to determine the combination of nutrient requirements during the growth of Caisim mustard plants with NFT Hydroponics.

The principle of mass balance is the basis of efficient fertilizer use to optimize plant nutrition without wastage. In a controlled hydroponic system, water lost due to transpiration is replaced with nutrient solution. The concentration of nutrients in the solution is regulated based on the optimal concentration of nutrients in plants and Water Usage Efficiency (WUE).

Increased CO_2 increases photosynthesis and nutrient demand but reduces transpiration, thus increasing WUE. The solution concentration should be adjusted, from 3 g/L at low CO2 to 6 g/L at high CO2. WUE and nutrient requirements are variable during the plant growth stage, so adjustment of the solution during the plant life cycle is beneficial. Electrical conductivity (EC) measurements help monitor plant health; low EC indicates active nutrient uptake. Ammonium to nitrate ratio is important for pH management.

2. MATERIALS AND METHODS

This research was conducted at the Plant House of the Faculty of Agriculture, Sriwijaya University, Palembang (latitude -2.990141º and longitude 104.731412º) from October 2022 to December 2022. The tools used in this research are 1) NFT hydroponic installation, 2) Aquarium pump, 3) Bucket / nutrient reservoir, 4) 30 cm and 100 cm ruler, 5) 500 ml and 25 ml measuring cups, 6) pH meter, 7) TDS and EC meter, 8) Hose, 9) Water meter, 10) Netpot 8 cm, 9) Tray, 10) Thermohygrometer, 11) Digital scales, 12) Stationery, 13) Camera, 13) Stopwatch, 14) Oven, 15) Scales, 16) Hallway. The materials used in this study are 1) Water, 2) Caisim seedlings, 3) AB mix nutrition, 4) Rockwool, 5) Paper envelope.

This research used the Randomized Group Factorial Design method. The test consisted of two treatment factors, namely water flow discharge and concentration of nutrient solution consisting of three treatments and three replications. The treatment of the two factors is as follows:

Table 1. Treatment factor of installation flow rate and gutter flow rate

No	Water flow Discharge of installation (Q)	Water flow discharge of gutter (T)
1	0.27 m^3/h	0.069 – 0.076 m^3/h
2	0.43 m^3/h	0.092 – 0.098 m^3/h
3	0.34 m^3/h	0.117 – 0.135 m^3/h

Table 2. Three Nutrient Treatments according to plant age (Days After Planting)

Nutrient (N)	0-6 DAP (ppm)	7-13 DAP (ppm)	14-20 DAP (ppm)	21-26 DAP (ppm)
1	506 – 567	646 – 688	833 – 878	1138 – 1173
2	509 – 577	731 – 773	961 – 983	1243 – 1277
3	515 – 576	821 – 875	1021 – 1066	1314 – 1370

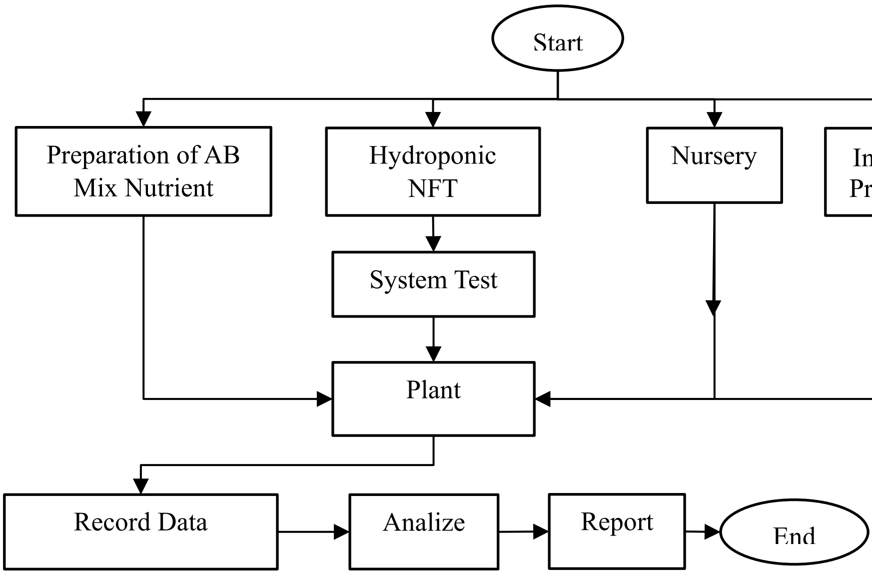


Figure 1. Flow chart General Research Method

A. The process in the Nursery is as follows:
   a. Preparation of 10 cm x 20 cm x 5 cm nursery tubs
   b. Cutting rockwool as a medium for planting seeds at the time of nursery, and perforating it
   c. Preparation of rockwool that has been cut in the nursery tubs
   d. Fill the prepared nursery tub with water to moisturize the rockwool
   e. Insert the mustard seeds in the rockwool with the help of tweezers
   f. Place the caisim mustard seedling tubs in a place where there is no light for 1 day (24 hours) (until the seeds sprout)
   g. Move to a place where there is solar radiation for 7 days (until 3 leaves grow)
   h. Move the rockwool with the mustard seedlings into the net pots that have been prepared while keeping the rockwool moist.

B. The construction design of NFT hydroponics is as follows:
   a. Installation of gutters that have been perforated according to the size of the netpot
   b. Installation of a water meter at the output end of the gutter
   c. Installation of a hose from the water pump to the water meter to the divider gutter
   d. Setting the discharge on the divider gutter
   e. Installation of nutrient basin at the end of the catchment gutter
   f. Filling nutrients with fertilizer solutions A and B and water according to treatment (check ppm levels with TDS and EC meters) in the nutrient tub.

C. Observation and data collection

In the morning at 07.00 a.m, the data taken are temperature and humidity data using a thermohygrometer and the pH, ppm and EC values of the solution in each reservoir. At noon at 00.00 pm, the data taken are temperature and humidity data using a thermohygrometer and the pH, ppm and EC values of the solution in each reservoir. In the afternoon at 04.00 p.m, the data taken are temperature and humidity data using a thermohygrometer and the pH, ppm and EC values of the solution in each water reservoir.

a. Potential Evapotranspiration.

The potential evapotranspiration measurement method is calculated using the Blaney-Criddle formula which can be seen in equation 3.1.

$$ETo = c\ [\ p\ (0,46T + 8)\ ] \quad \ldots\ldots (1)$$

Description:

Eto = Reference evaporation (mm/day)

C = Adjustment factor for minimum relative humidity, hours of sunshine and daytime wind forecast
P = Average daily percentage of total daylight hours in a year for a given month and line
T = Average daily temperature (ºC)

b. Observed Plant Growth

- Plant height (cm)

Plant height observations were made by measuring the height of the plant using a ruler. Plant height variables were observed from the base of the plant to the highest part of the plant (tip of the leaf) every 3 days.

- Number of leaves (strands)

Observation of the number of leaves is done by counting the number of leaves that have opened completely every 3 days until harvest.

c. Harvest (27 days after planting)

- Fresh weight (g)

Observations of fresh weight of caisim plants were made after harvest by weighing all parts of caisim plants (stems and leaves) using digital scales.

- Plant productivity

Plant productivity is done by calculating the amount of yield with the area of the plant.

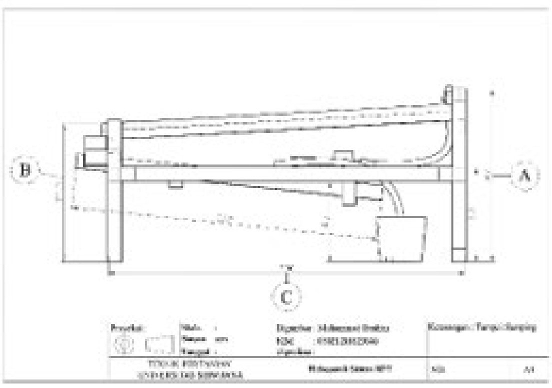
D. Research Parameters

The parameters carried out in this research are as follows:

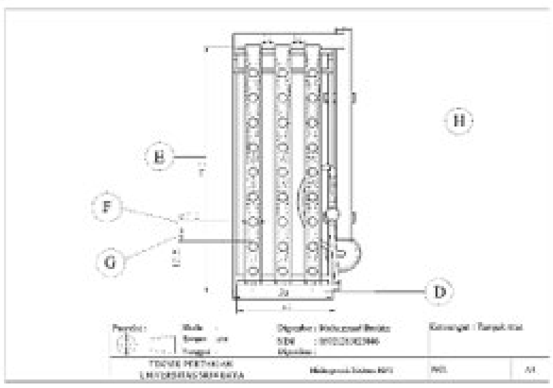
a. Plant Height (cm)
   Plant height was measured using a ruler from the base of the stem to the highest part of the plant (tip of the leaf). This measurement was carried out every 3 days until harvest.
b. Number of Leaves (strands)
   Observation of the number of leaves is to count the leaves that have opened completely. This observation is done every 3 days until harvest.
c. Plant Fresh Weight (g)
   Plant fresh weight observations were made after harvest by weighing all parts of the caisim plant (stems and leaves) using digital scales.
d. Plant Dry Weight (g)
   Observations of plant dry weight were obtained by weighing the roots, stems and leaves of caisim plants that had been in the oven for 3 x 24 hours at a temperature of 40ºC in a closed room.
e. Plant Productivity (kg/m2)
   Observation of plant productivity was done after harvest. Plant productivity is the result of the ability of a place to produce plants. Observations of plant productivity can be calculated by calculating the amount of plant yield divided by the area of land.

3. RESULTS AND DISCUSSION

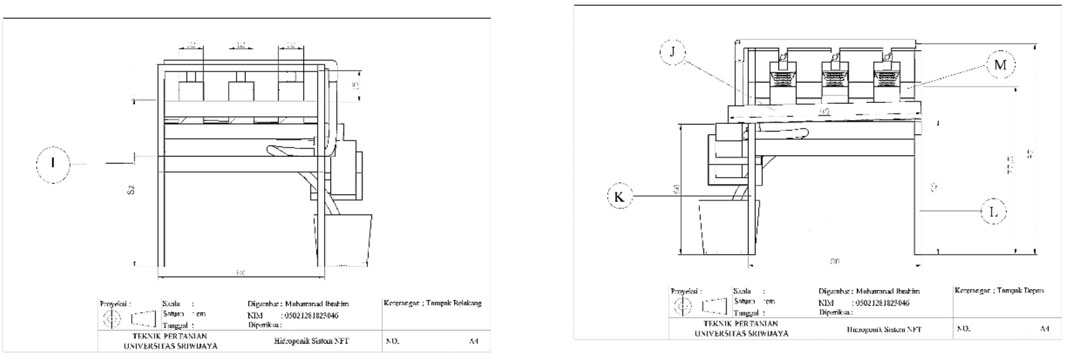
3.1. Hydroponic Installation Design



Right



Up



Behind Front

Figure 2. Design of Hydroponic NFT System

Table 3. The size and description of the hydroponic installation design consists of :

No	Code	Size (cm)	Materials	Description
1	A	97	C-channel mild steel	The installation input foot
2	B	77.5	C-channel mild steel	The installation output foot
3	C	200	C-channel mild steel	The length of the installation support
4	D	80	C-channel mild steel	The width of the installation support
5	E	200	PVC gutter	Hydroponic gutter
6	F	7.5	PVC gutter	Planting hole diameter
7	G	12.5	PVC gutter	Distance between planting holes
8	H	172	PVC gutter	Output gutter
9	I	82	C-channel mild steel	Hydroponic gutter input support height
10	J	89	PVC gutter	Output catchment gutter
11	K	60	C-channel mild steel	Bottom support height of output collection gutter
12	L	62	C-channel mild steel	Top support height of output collection gutter
13	M	77.5	C-channel mild steel	Hydroponic gutter output support height

The hydroponic gutter input support is made with the same height of 82 cm and the hydroponic gutter output support is also made with the same height of 77.5 cm, resulting in a difference of 4.5 cm. The hydroponic gutter is made with a length of 200 cm, resulting in a slope that can be seen in the equation.

Slope=vertical/horizontal×100%..(3.2)
Slope= (4.5 cm)/(200 cm) ×100%
Slope=2.25%
The slope obtained in the NFT hydroponic installation is 2.25%.

3.2. Installation flow discharge

The results of observations of flow discharge in the divider gutter in the NFT hydroponic system installation during the test can be seen in Figure 3.

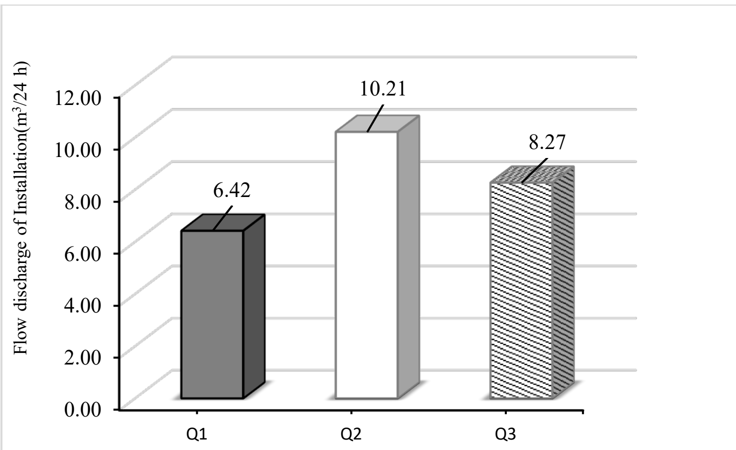


Figure 3. Flow discharge at the divider gutter in NFT Hydroponic Installation

Description:
Q1 = discharge from the divider 1 gutter to the installation gutter
Q2 = discharge from the divider 2 gutter to the installation gutter
Q3 = discharge from divider gutter 3 to the installation gutter

In NFT hydroponic plant cultivation, the uniformity of water flow is very important to get maximum results [10]. The data from the observation of the flow rate in the divider gutter of each flow rate in the installation treatment 1, 2 and 3 for 24 hours resulted in an average of 6.42 m³/day, 10.21 m³/day, and 8.27 m³/day. Discharge affects plant growth, if the flow of water is too heavy it inhibits the absorption of nutrients by the roots [11]. The design of the NFT hydroponic system installation with a 2.25% gutter slope is an important consideration to ensure normal plant growth [12].

3.3 Plant Gutter Flow Discharge

The nutrient flow discharge test results on plant gutters are shown in Figure 4

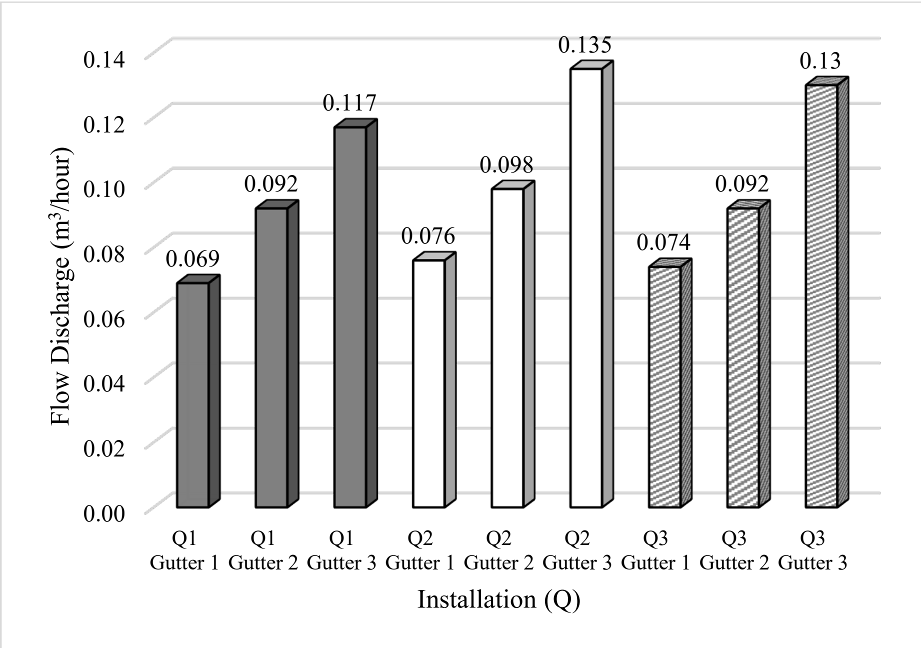


Figure 4. Nutrient flow discharge in plant gutters at installation 1

The circulation and the flow rate of nutrients in the NFT hydroponic system are influenced by the flow rate in the system [13]. Good circulation of nutrient solution can increase the absorption of nutrients by plants in this NFT hydroponic system. The right nutrient solution flow rate results in optimal water thickness (1-3 mm) [14]. This makes it possible for plants to absorb nutrients to grow optimally[15]. Excess or lack of nutrient flow can interfere with the absorption of nutrients and oxygen in the NFT hydroponic system. Different discharges have an impact on plant growth[15]. Measurement data of gutter flow discharge taken at 24 hours during the study resulted in an average Q1T1 of 21.47 m^3 / day, Q1T2 of 28.7 m^3 / day and Q1T3 of 36.44 m^3 / day, at Q2T1 of 23.71 m^3 / day, Q2T2 of 30.58 m^3 / day and Q2T3 of 42.05 m^3 / day, while at Q3T1 of 23.08 m^3 / day, Q3T2 of 28.7 m^3 / day and Q3T3 of 40.56 m^3 / day.

3.4. Temperature, Humidity, and Potential Evapotranspiration in the Plant House

In Figure 5, the temperature, humidity and potential evapotranspiration were observed during the study in the plant house.

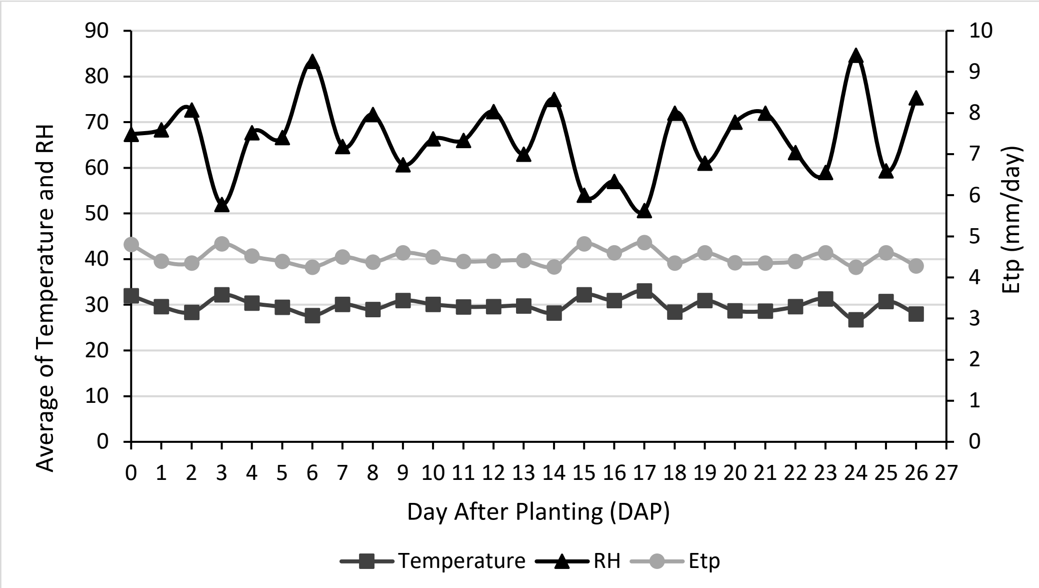


Figure 5. Temperature, Humidity, and Potential Evapotranspiration in the Plant House

Temperature is one of the important factors in the cultivation of vegetable plants in the NFT hydroponic system [16], [17]. In vegetable plants the temperatures for optimal growth range from 23-35ºC, if the temperature exceeds 36ºC then the plant will die [18]. The ambient temperature will increase every hour, this affects the Electrical Conductivity (EC) value [19]. Air humidity in the greenhouse must always be considered so that plant growth can grow optimally [20]. During the day, the temperature in the greenhouse becomes high and the humidity becomes low, making the plants wilt for a moment, but when the temperature decreases and the humidity increases again, the plants will become fresh again [21]. The temperature and humidity of the plant house are optimal during the day. In the afternoon (4:00 pm), it was found that the temperature and humidity of the plant house still stored heat due to the sunlight energy received during the day.

3.5. Nutrient of AB Mix in Tub

The ppm value of nutrients was obtained by measuring the nutrient solution in the reservoir at 7:00 am, 12:00 pm and 4:00 pm using a TDS and EC meter. As shown in Figure 6, Q3 has the highest average when compared to Q1 and Q2. This is because at 1 Week After Planting (WAP) the nutrients given to each reservoir were 500 ppm, then at 2 WAP they were given different nutrients. At Q1 is 600 ppm, Q2 is 700 ppm and Q3 is 800 ppm, at 3 WAP the nutrients given to Q1 is 800 ppm, Q2 is 900 ppm and Q3 is 1000 ppm while at 4 WAP the nutrients given to Q1 is 1100 ppm, Q2 is 1200 ppm and Q3 is 1300 ppm. So as to produce an average in Q1 which is 792.4 ppm, in Q2 produces an average of 864.85 ppm and in Q3 produces an average of 934.91 ppm.

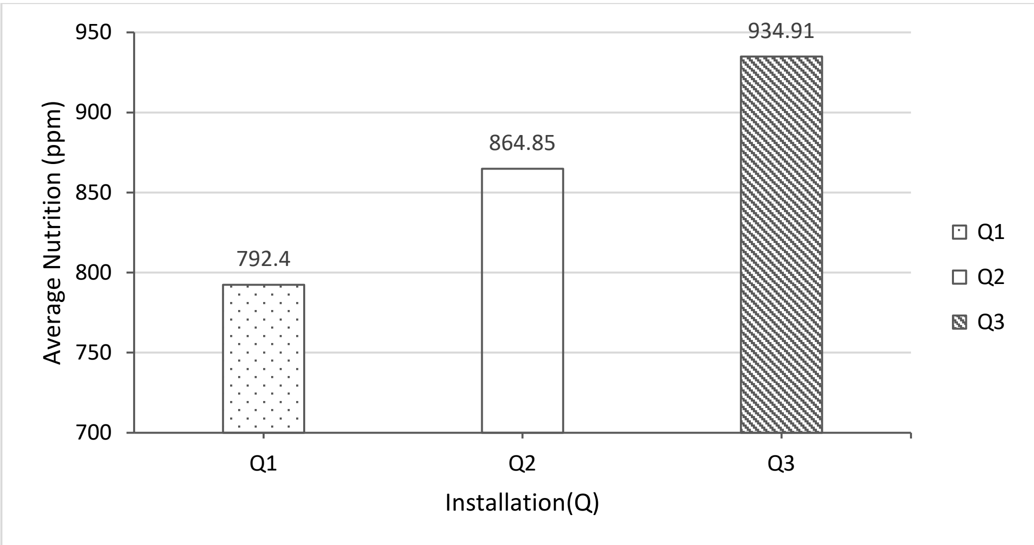


Figure 6. Nutrient of AB Mix in tub

The more concentrated the nutrient solution given to the plants, the more nutrients in the solution. The concentration of AB mix is adjusted to the needs of plants at each growth level [22]. Hydroponic nutrients consist of macro elements (N, P, K, Ca, Mg, S) which are needed in large quantities, and micro elements (Fe, Mn, Zn, Cu, B, Mo, Cl) which are needed in low concentrations [23].

3.6 Electrical Conductivity in tub

In hydroponic systems, the concentration of nutrient solution is one of the parameters that determine the quality and yield of the crop. The concentration of the solution expresses the amount of nutrient solution contained in water and the value changes due to differences in nutrient and water uptake by plants. The concentration of the nutrient solution is represented by the Electrical Conductivity (EC) value. The measurement results of the Electrical Conductivity (EC) value of AB Mix in the tanks during the study can be seen in Figure 7.

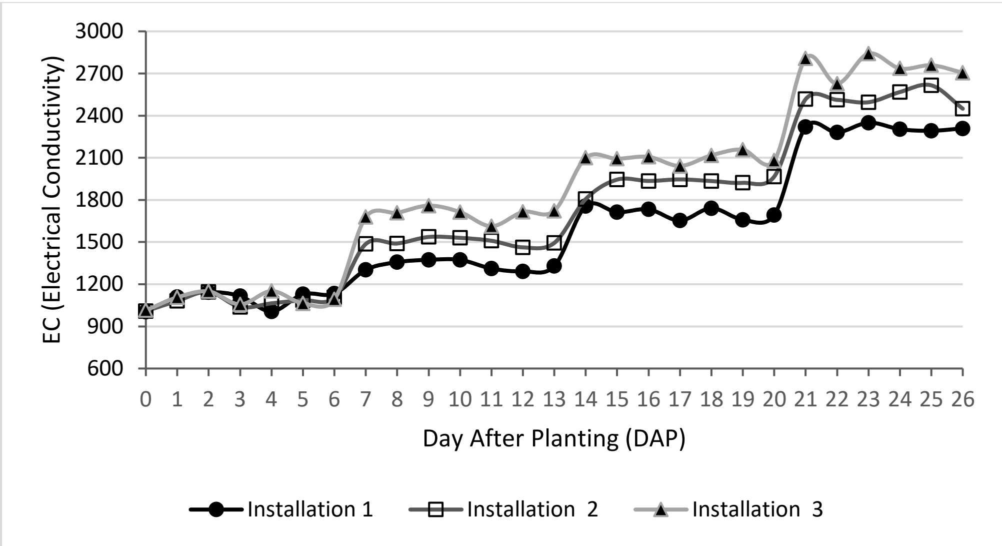


Figure 7. Electrical Conductivity in tub

A concentration of EC of nutrient solution that is too high results in slow plant growth and high production costs. Meanwhile, nutrient solution concentrations that are too low will cause plant productivity to decrease [24]. Therefore, it is necessary to control the concentration of the solution so that the cultivation results of the NFT technique can reach the maximum level [24].

3.6 pH and Nutrient of AB Mix in tub

The average pH value of the AB Mix nutrient solution in the tub can be shown in Figure 8.

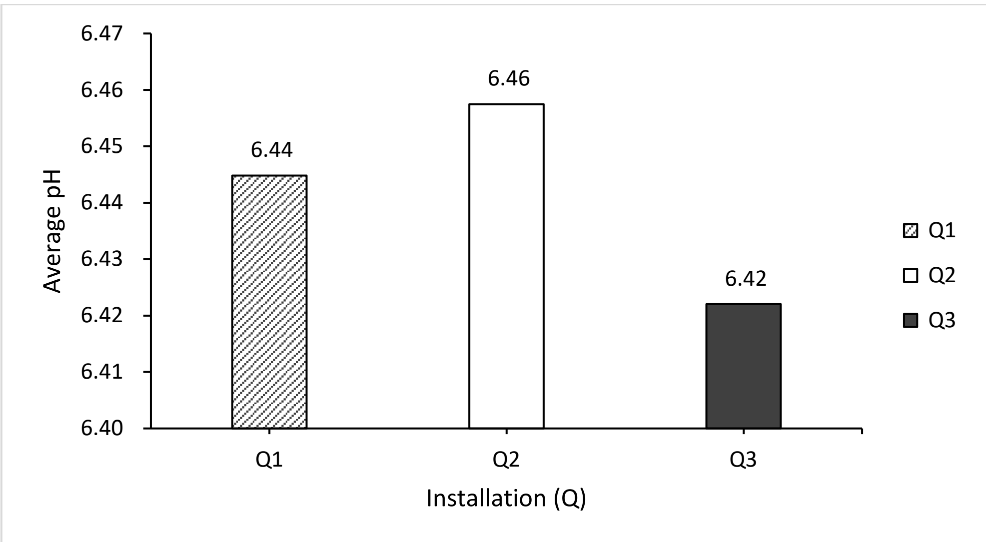


Figure 8. The average pH value of the AB Mix nutrient solution in the tub

The nutrients given to plants are closely related to the pH of the water or the acidity of the water. The pH parameter of hydroponic nutrition is very important because it affects the availability and absorption of nutrients needed for plant growth [25]. Plant nutrition is influenced by the pH of the water, which affects the solubility of nutrients and plant fertility. The pH value of nutrients is always changing due to various factors such as growing media, photosynthesis, respiration, and bacteria. Therefore, the pH needs to be maintained at 5.5-6.5 according to the type of plant.

3.7 **Height of Caisim (cm)**

The test results showed that the concentration of Nutrient AB Mix affects the growth of Caisim plant height, so further tests on the concentration of Nutrient AB Mix (Table 4).

Table 4. Results of 5% BNJ test on the Effect of AB Mix Nutrition Concentration on Caisim Plant Height Growth

Height of Caisim			
Nutrient Concentration of AB Mix	N	Average height (cm)	BNJ 5% = 15,92
N3	60	15,74	a
N2	150	16,80	b
N1	60	17,64	b

Description: Numbers followed by letters that are not the same in the same column show significant differences..

Plants need 16 macro and micro nutrients to support their growth: C, H, O, N, S, P, K, Ca, Cl, Mg, Fe, Cu, Zn, B, Mo, and Mn. The elements C, H, and O are obtained from water and air, while others from nutrient solutions. N, P, and K are essential and required in large amounts. N deficiency causes slow growth, while P deficiency inhibits root development [26].

The results of the 5% BNJ test showed that the height of caisim plants increased from 0 Day After Planting (DAP) to 15 DAP. The gutter flow discharge of 0.069-0.076 m^3/h (T1) resulted in a higher increase in plant height compared to the discharge of 0.092-0.098 m^3/h (T2) and 0.117-0.135 m^3/h (T3).

Table 5. Results of 5% BNJ Test on the Effect of Gutter Flow Discharge on Caisim Plant Height Growth.

Height of Caisim			
Flow Discharge of Gutter	N	Average	BNJ 5% = 15,92
T3	90	15,58	a
T2	90	16,76	b
T1	90	17,90	c

Description: Numbers followed by letters that are not the same in the same column show significant differences.

Water flow rate affects circulation and nutrient velocity. Good circulation enhances nutrient uptake. Appropriate flow velocity promotes optimal nutrient uptake and low temperature fluctuations, which have a direct impact on plant height growth. Different flow discharge treatments produce different effects on plant height [27].

3.8 Number of Leaves of Caisim (strands)

The average number of leaves of caisim plants measured every 3 days during the study showed the final results: Q1T1=13 leaves, Q1T2=12 leaves, Q1T3=11 leaves; Q2T1=13 leaves, Q2T2=14 leaves, Q2T3=12 leaves; Q3T1=11 leaves, Q3T2=12 leaves, Q3T3=10 leaves. The 5% BNJ test results showed the number of leaves increased with plant age from 0 DAP to 27 DAP. Nutrition 1200 ppm (Q2) produced more leaves compared to 1100 ppm (Q1) and 1300 ppm (Q3).

Table 6. 5% BNJ Test Results of the Effect of AB Mix Nutrient Concentration on the Number of Leaves of Caisim Plants.

Number of Leaves of Caisim			
Concentration of AB Mix	N	Average	BNJ 5% = 15,92
N_2	150	7,20	a
N_3	60	7,23	a
N_1	60	7,58	b

Description: Numbers followed by letters that are not the same in the same column show significant differences.

The difference in the number of leaves of caisim plants is influenced by the nutrients in the AB Mix solution. A balanced nutrient solution according to plant needs supports optimal and rapid growth [28]. The results of the 5% BNJ test showed that the number of leaves increased with plant age from 0 DAP to 27 DAP. The gutter flow discharge of 0.0688-0.074 m³/h (T1) produced more leaves than the discharge of 0.092-0.098 m³/h (T2) and 0.1168-0.1348 m³/h (T3).

Table 7. Results of 5% BNJ Test on the Effect of Gutter Flow Discharge on the Number of Leaves of Caisim Plants

Height of Caisim			
Flow Discharge of Gutter	N	Average	BNJ 5% = 15,92
T3	90	6,85	a
T2	90	7,48	b
T1	90	7,53	b

Description: Numbers followed by letters that are not the same in the same column show significant differences.

Flow discharge affects nutrient circulation and uptake. The right discharge rate makes nutrient uptake optimal, which impacts plant growth [29].

3.9 Average Fresh Weight of Caisim (g)

The results of fresh weight measurements of caisim mustard plants can be seen in Figure 9.

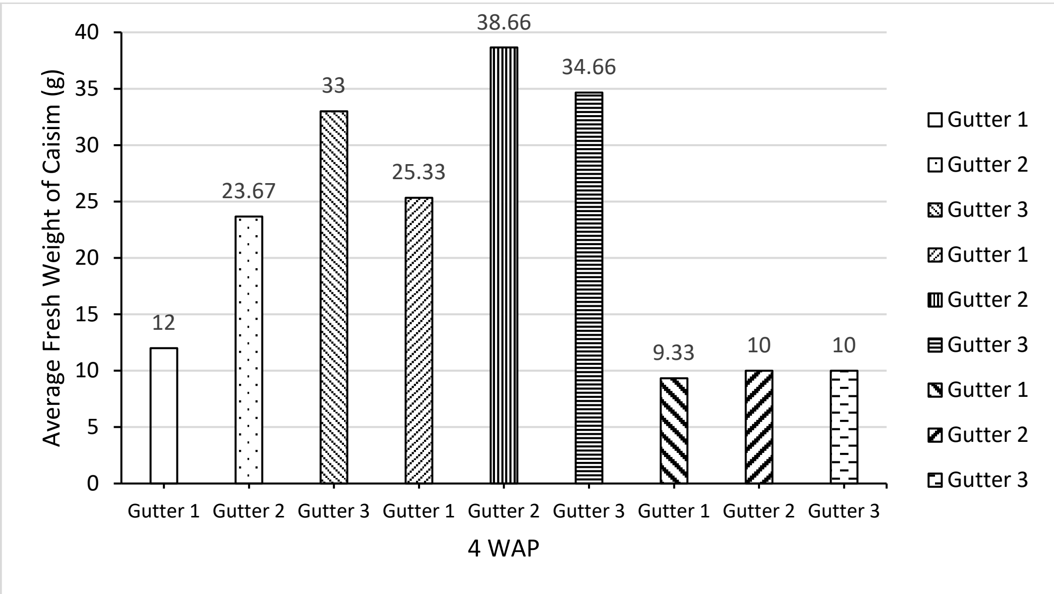


Figure 9. Average Fresh Weight of Caisim

The treatment (Q2) can produce the heaviest plant weight due to the appropriate amount of nutrient solution concentration. Lack of nutrients can cause plant productivity to decrease while excess nutrients can inhibit plant growth [29], [30] as in treatment (Q3). From the explanation above, it is suspected that treatment (Q2) is the best application in this research.

CONCLUTION

Conclusion

1. The treatment of water flow discharge and concentration of nutrient solution significantly affects the growth of caisim plant height, number of leaves and fresh weight of plants.
2. The growth of caisim plants in the second installation tends to be better than the first installation and the third installation.

3. The treatment of the third installation on caisim plants is the lowest value in plant height, number of leaves, fresh weight of plants and plant productivity.

Suggestion

We recommend that for the regulation of gutter flow discharge an automatic device be used in order to get the same unit of discharge. Further research needs to be done using different plants and treatments.

REFERENCES

[1] S. A. Gillani, R. Abbasi, P. Martinez, and R. Ahmad, "Comparison of Energy-use Efficiency for Lettuce Plantation under Nutrient Film Technique and Deep-Water Culture Hydroponic Systems," in *Procedia Computer Science*, Elsevier B.V., 2022, pp. 11–19. doi: 10.1016/j.procs.2022.12.197.

[2] S. Wibowo and A. Asriyanti S, "Aplikasi Hidroponik NFT pada Budidaya Pakcoy (Brassica rapa chinensis)," *Jurnal Penelitian Pertanian Terapan*, vol. 13, no. 3, pp. 159–167, 2013.

[3] R. N. Maulido, O. L. Tobing, and S. A. Adimihardja, "Pengaruh Kemiringan Pipa Pada Hidroponik Sistem NFT Terhadap Pertumbuhan Dan Produksi Selada (Lactuca sativa L.)," *Jurnal Agronida*, vol. 2, no. 2, pp. 62–68, 2016.

[4] N. J. Langenfeld, D. F. Pinto, J. E. Faust, R. Heins, and B. Bugbee, "Principles of Nutrient and Water Management for Indoor Agriculture," Aug. 01, 2022, *MDPI*. doi: 10.3390/su141610204.

[5] M. R. N. Irawan, N. Badriyah, S. Lathifi, and S. N. Hanis, "Strategi Pengembangan Potensi Desa Dengan PenerapanSistem Hidroponik Pada Tanaman Hortikultura DalamUpaya Peningkatan Perekonomian Masyarakat Di Desa Kawistolegi Kecamatan Karanggeneng Kabupaten Lamongan," *Karya Abadi*, vol. 4, no. Nomor 3, pp. 715–719, 2020.

[6] S. Suprayogi and S. Suprihati, "Pengaruh Kemiringan Talang terhadap Pertumbuhan dan Hasil Dua Varietas Pakcoy (Brassica rapa L.) dengan Sistem Hidroponik Nutrient Film Technique," *Jurnal Teknik Pertanian Lampung (Journal of Agricultural Engineering)*, vol. 10, no. 1, p. 96, Mar. 2021, doi: 10.23960/jtep-l.v10i1.96-103.

[7] P. Delgadoa, C. Vargasb, R. Ackermanc, and L. Salmerón, "Don't throw away your printed books: A meta-analysis on the effects of reading media on reading comprehension," *Educ Res Rev*, vol. 25, pp. 23–38, 2018, doi: 10.1016/j.edurev.2018.09.003.

[8] F. Reichert, D. Lange, and L. Chow, "Educational beliefs matter for classroom instruction: A comparative analysis of teachers' beliefs about the aims of civic education," *Teach Teach Educ*, vol. 98, pp. 1–13, 2020, doi: 10.1016/j.tate.2020.103248.

[9] G. Ocak and A. Yamaç, "Examination of the relationships between fifth graders' self-regulated learning strategies, motivational beliefs, attitudes, and achievement," *Educational Sciences: Theory and Practice*, vol. 13, no. 1, pp. 380–387, 2013.

[10] M. S. Asmana, S. H. Abdullah, and G. M. D. Putra, "Analisis Keseragaman Aspek Fertigasi Pada Desain Sistem Hidroponik Dengan Perlakuan Kemiringan Talang," *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, vol. 5, no. 1, pp. 303–315, 2017.

[11] T. Yang, U. Samarakoon, and J. Altland, "Growth, phytochemical concentration, nutrient uptake, and water consumption of butterhead lettuce in response to hydroponic system design and growing season," *Sci Hortic*, vol. 332, Jun. 2024, doi: 10.1016/j.scienta.2024.113201.

[12] M. Sopian Asmana, S. H. Abdullah, G. Mahardhian, and D. Putra, "Analisis Keseragaman Aspek Fertigasi pada Desain Sistem Hidroponik dengan Perlakuan Kemiringan Talang," 2017.

[13] A. Say Morite *et al.*, "Water Circulation and Control of Hydroponic Using The Internet of Things," *Sci.Int.(Lahore)*, vol. 35, no. 3, pp. 299–305, 2023, [Online]. Available: https://www.researchgate.net/publication/371874429

[14] N. J. Langenfeld, D. F. Pinto, J. E. Faust, R. Heins, and B. Bugbee, "Principles of Nutrient and Water Management for Indoor Agriculture," Aug. 01, 2022, *MDPI*. doi: 10.3390/su141610204.

[15] M. R. Fayezizadeh, N. A. Z. Ansari, M. Albaji, and E. Khaleghi, "Effects of hydroponic systems on yield, water productivity and stomatal gas exchange of greenhouse tomato cultivars," *Agric Water Manag*, vol. 258, Dec. 2021, doi: 10.1016/j.agwat.2021.107171.

[16] M. A. Abul-Soud, M. S. A. Emam, and Sh. M. Mohammed, "Smart Hydroponic Greenhouse (Sensing, Monitoring and Control) Prototype Based on Arduino and IOT," *Int J Plant Soil Sci*, pp. 63–77, Apr. 2021, doi: 10.9734/ijpss/2021/v33i430430.

[17] P. A. Y. Ampim, E. Obeng, and E. O. Gonzalez, "Indoor Vegetable Production : An Alternative Approach to Increasing Cultivation," *Plants*, vol. 11, no. 2843, pp. 1–28, 2022.

[18] M. Chowdhury *et al.*, "Effects of temperature, relative humidity, and carbon dioxide concentration on growth and glucosinolate content of kale grown in a plant factory," *Foods*, vol. 10, no. 7, Jul. 2021, doi: 10.3390/foods10071524.

[19] A. Chrysargyris, M. Prasad, A. Kavanagh, and N. Tzortzakis, “Biochar type, ratio, and nutrient levels in growing media affects seedling production and plant performance,” *Agronomy*, vol. 10, no. 9, Sep. 2020, doi: 10.3390/agronomy10091421.
[20] A. Sapounas, N. Katsoulas, B. Slager, R. Bezemer, and C. Lelieveld, “Design, control, and performance aspects of semi-closed greenhouses,” Nov. 01, 2020, *MDPI AG*. doi: 10.3390/agronomy10111739.
[21] A. GHANNEM, I. BEN AISSA, and R. MAJDOUB, “Effects of regulated deficit irrigation applied at different growth stages of greenhouse grown tomato on substrate moisture, yield, fruit quality, and physiological traits,” *Environmental Science and Pollution Research*, vol. 28, no. 34, pp. 46553–46564, 2021, doi: 10.1007/s11356-020-10407-w.
[22] A. A. Stegelmeier, D. M. Rose, B. R. Joris, and B. R. Glick, “The Use of PGPB to Promote Plant Hydroponic Growth,” Oct. 01, 2022, *MDPI*. doi: 10.3390/plants11202783.
[23] K. Korkmaz, M. Akgün, M. M. Özcan, F. Özkutlu, and Ş. M. Kara, “Interaction effects of phosphorus (P) and zinc (Zn) on dry matter, concentration and uptake of P and Zn in chia,” *J Plant Nutr*, vol. 44, no. 5, pp. 755–764, Mar. 2021, doi: 10.1080/01904167.2020.1845373.
[24] M. A. Harahap, F. Harahap, and T. Gultom, “The effect of ab mix nutrient on growth and yield of pak choi (brassica chinensis l.) plants under hydroponic wick system condition,” in *Journal of Physics: Conference Series*, Institute of Physics Publishing, May 2020. doi: 10.1088/1742-6596/1485/1/012028.
[25] I. L. van Rooyen and W. Nicol, “Nitrogen management in nitrification-hydroponic systems by utilizing their pH characteristics,” *Environ Technol Innov*, vol. 26, p. 102360, May 2022, doi: 10.1016/J.ETI.2022.102360.
[26] L. A. Msimbira and D. L. Smith, “The Roles of Plant Growth Promoting Microbes in Enhancing Plant Tolerance to Acidity and Alkalinity Stresses,” Jul. 10, 2020, *Frontiers Media S.A.* doi: 10.3389/fsufs.2020.00106.
[27] M. R. Rozilan, A. S. Mohd Rodzi, A. Faiz Zubair, A. R. Hemdi, R. Deraman, and N. D. Md Sin, “Design and Fabrication of Nutrient Film Technique (NFT) Hydroponic System,” in *Technological Advancement in Instrumentation & Human Engineering*, M. H. A. Hassan, M. H. Zohari, K. Kadirgama, N. A. N. Mohamed, and A. Aziz, Eds., Singapore: Springer Nature Singapore, 2023, pp. 123–144.
[28] M. M. Selim, “Introduction to the Integrated Nutrient Management Strategies and Their Contribution to Yield and Soil Properties,” 2020, *Hindawi Limited*. doi: 10.1155/2020/2821678.
[29] M. Rufí-Salís *et al.*, “Recirculating water and nutrients in urban agriculture: An opportunity towards environmental sustainability and water use efficiency?,” *J Clean Prod*, vol. 261, Jul. 2020, doi: 10.1016/j.jclepro.2020.121213.
[30] S. S. Rukmi, Aiyen, and A. Rauf, “Pertumbuhan Tanaman Bayam (Amaranthus tricolor L .) dengan Pemberian Konsentrasi Nutrisi Berbeda pada Sistem NFT (Nutrient Film Technique),” *Agrotekbis*, vol. 5, no. April, pp. 222–230, 2017.