

# THE GRAVITY SYSTEM IN THE PARTITIONED TUB AS PART OF NUTRIENT SOLUTION CIRCULATION SYSTEM USING ELECTRONIC CONTROLS

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## SISTEM GRAVITASI BAK BERSEKAT SEBAGAI BAGIAN DARI SISTEM SIRKULASI LARUTAN NUTRISI YANG MENGGUNAKAN KONTROL ELEKTRONIK

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### ABSTRACT

The nutrient solution circulation system is an important aspect to succeed in hydroponic cultivation. The surface height of the nutrient solution difference in the gravity system is part of the nutrient solution circulation system that uses electronic controls. It consists of a nutrient solution tub with a barrier separating the nutrient solution surface height. The nutrient solution tub is connected via a pipe to a drum containing a nutrient solution where its EC and pH are automatically controlled. The flow of the nutrient solution through the partition is necessary so that there is no shortage of nutrient solution in the tub containing a submersible pump due to pumping.

### ABSTRAK

Sistem sirkulasi larutan nutrisi menjadi salah satu aspek penting dalam kesuksesan budidaya tanaman hidroponik. Sistem gravitasi beda tinggi permukaan larutan nutrisi merupakan bagian dari sistem sirkulasi larutan nutrisi yang menggunakan kontrol elektronik. Alat pemisah pembeda tinggi permukaan larutan nutrisi terdiri dari bak larutan nutrisi dengan sekat pemisah pembeda tinggi permukaan larutan nutrisi. Bak berisi larutan nutrisi untuk budidaya tanaman hidroponik tersebut, terhubung melalui perpipaan dengan drum berisi larutan nutrisi. Aliran larutan nutrisi melalui sekat ini diperlukan agar tidak terjadi kekurangan larutan nutrisi pada bagian Bak berisi pompa submersible dikarenakan pemompaan.

### INTRODUCTION

The worldwide pandemic caused by the outbreak of the coronavirus 19 (*Indonesias strategy to combat covid 19, 2020*), leads to government policies to work at home (*Covid 19 developments in Indonesia, 2020*) and also obtain healthy food (*Mohammed, 2018*). The hydroponic plant cultivation can be conducted at home, both in the yard and outside the house (*AlShrouf, 2017; Sharma et al, 2018*) and even inside the house using LED lights or alike that contain ultraviolet light instead of sunlight (*Al Shrouf, 2017; Kobayashi et al*). To lighten the workload and increase the enthusiasm of hydroponic cultivators, the use of mechanical and electronic control equipment (*Choi et al., 2016; Domingues et al., 2012*) for operational automation of hydroponic cultivation is a very supportive necessity for this purpose. Moreover, when utilizing a mobile device connected to the internet, if the cultivator is outside of the house for personal or other purposes, the control device for hydroponic cultivation can be accessed and controlled by the cultivator from outside the home via cell phone (*Domingues et al, 2012; Kularbphettong et al*).

As stated by several kinds of literature (*Domingues et al., 2012; Pramod et al, 2020; Tellez et al., 2012*), meeting the concentration and pH of nutrient solution needs for optimizing crop yields cultivated hydroponically is an important thing that cultivators must consider. For this reason, the nutrient solution circulation system is an essential aspect of successful hydroponic plant cultivation. The use of automation technology in maintaining the concentration and pH of the nutrient solution at the number required for hydroponic plants to grow can optimize the quality of the crop and ease the workload of cultivators (*Domingues et al., 2012; JSM et al., 2014*).

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As a follow-up in prototyping automatic control equipment that controls the concentration and pH of nutrient solutions for the cultivation of various hydroponic plants (Domingues et al., 2012), it is necessary to make supporting equipment for a nutrient solution circulation system. So, the concentration of TDS or EC and the pH of the nutrient solution is relatively homogeneous (Prasad et al, 2020; Tellez et al., 2012; Crazy pH Swings, 2020) in all nutrient solutions that flow through the circulating system (Sambo et al., 2019).

The supporting equipment is in the form of a tub with a partition in the middle. The partition can be arranged so that the optimal water flows through the partition gaps can be obtained. The optimal water discharge through the tub partition gap is needed to prevent the nutrient solution's receding surface due to the water pump's operation that lifts water from the tub to the top of the hydroponic pipe (Bernoulli's equation, 2020). The water pump is not placed in a mixing drum for water, nutrients, and acid/base solution but separated and placed in a tub containing a partition.

The purpose of this research is to make equipment in the form of a tub containing nutrient solution for hydroponic plant cultivation, where the tub is connected via pipes with a drum containing nutrient solution where its EC and pH are automatically controlled. This tub will facilitate the placement of a submersible pump for circulating nutrient solutions. In other words, the submersible pump is not placed on a drum containing a controlled nutrient solution, considering that the drum is equipped with sensors controlling EC, pH, and surface height of the nutrient solution and stirring vanes.

The flow of nutrient solution from the tub to the drum and from the drum back to the tub utilizes the law of gravity from the surface height's nutrient solution difference between the tub and drum. The tub is provided with a separating partition that creates a surface height of the nutrient solution difference in the outlet tub's part of the nutrient solution to the drum against the inlet tub's part of the nutrient solution from the drum. The flow of nutrient solution through this partition is necessary, so that there is no shortage of nutrient solution in the tub due to pumping.

## MATERIALS AND METHODS

### MATERIALS

A nutrient solution circulation system with electronic controls has control equipment of nutrient solution and the pH of hydroponic plants (Fig. 1).

The equipment consists of a water container with a capacity of 300 liters containing irrigation water, a 60 liter capacity bucket containing nutrient solution in AB mix, which is relatively concentrated, a 60 liter capacity bucket containing acidic pH solution and a 60 liter capacity bucket containing alkaline pH solution.

The volume of the concentrated nutrient solution that fills drum I or drum II is controlled by the CCT-5300 TDS Controller, which opens and closes the solenoid valve. The drum has 200 liters capacity. The CT 6659 pH Controller controls the acidic pH and alkaline pH solutions from the container filling drum I or drum II. Suppose the nutrient solution in the drum I is used to cultivate hydroponic plants of the caisim type (*Brassica rapa var. Parachinensis*).

In that case, the CCT-5300 TDS Controller is set in the range of 900 – 1000 ppm, and CT 6659 pH Controller is set at a pH range of 5, 5 - 6.5. Meanwhile, if the nutrient solution in the drum II is used for the cultivation of hydroponic plants of the spinach type (*Amaranthus spp*), the CCT-5300 TDS Controller can be set in the range of 1150 – 1250 ppm and the CT 6659 pH Controller is set in the range of 6.0 – 7.0.



Fig. 1 - Automated Nutrition and pH Controller Equipment for Hydroponic Plant Cultivation



Fig. 2 - Water inlet and water outlet from nutrient and pH controller drum I

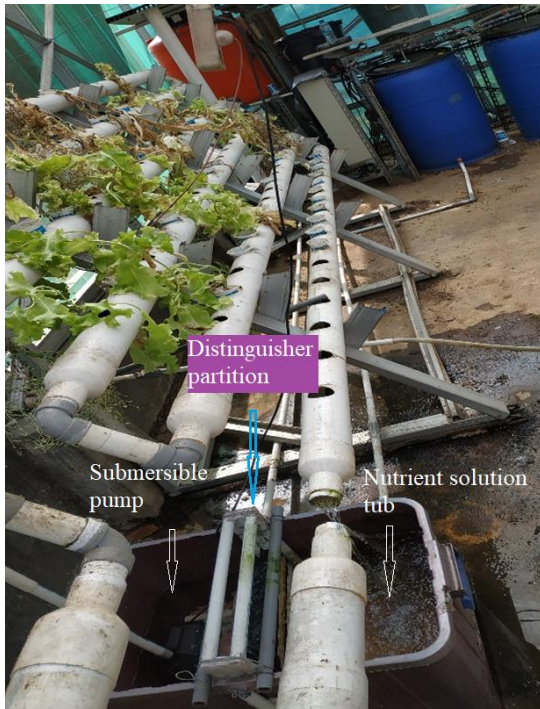


Fig. 3 - The distinguisher partition of the nutrient solution surface height



Fig. 4 - Nutrient solution level in the tub-part containing submersible pump (left) and outlet pipe to the drum (right)

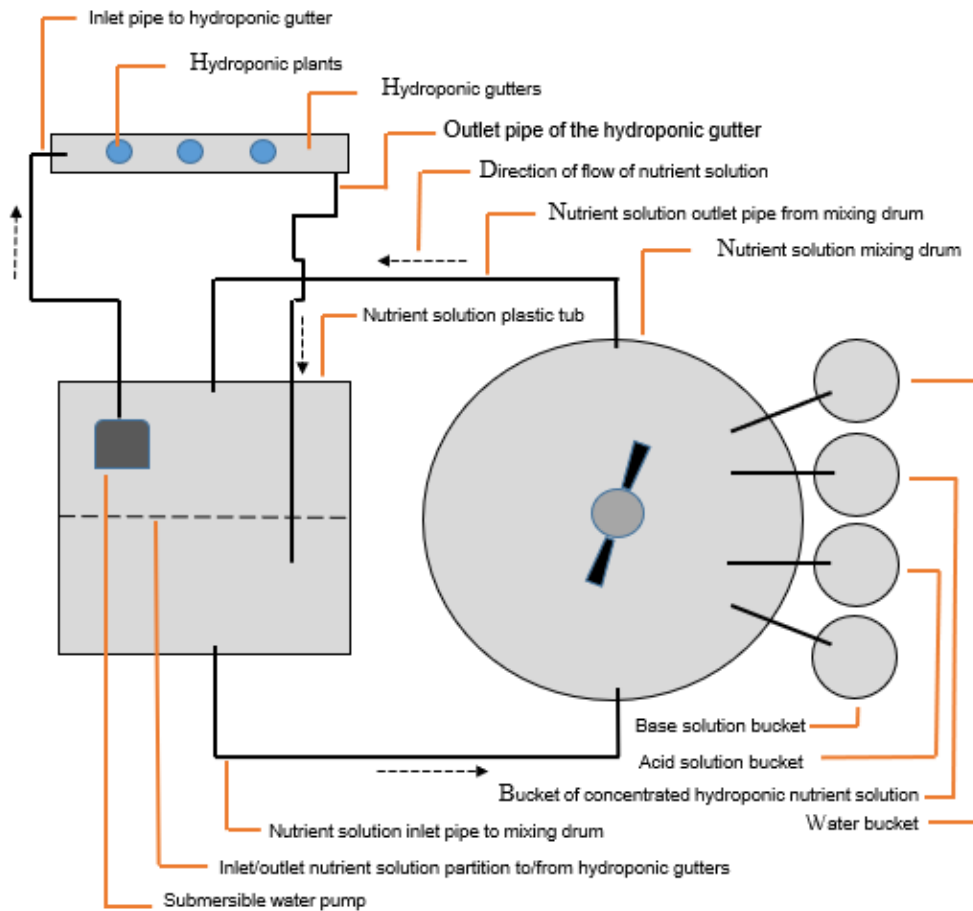


Fig. 5 - The scheme of the nutrient solution circulation direction - top view

Meanwhile, the surface height difference in the gravity system of the nutrient solution (Fig. 2, 3, and 4) is part of the nutrient solution circulation system that uses electronic controls. The nutrient solution's surface height separator consists of a nutrient solution tub with a divider separating the nutrient solution surface height (Fig. 3 and 4). Nutrient solutions with controlled electro conductivity (EC) and degree of acidity (pH) in the nutrient solution mixing drum (Fig. 1 and 2) need to flow into a nutrient solution tub for hydroponic cultivation purposes. A submersible water pump is required (Fig. 3) to circulate the nutrient solution from the nutrient solution mixing drum to the nutrient solution tub. Then it goes to the pipes containing the hydroponic plants, returns to the nutrient solution tub to continue flowing into the nutrient solution mixing drum to control the amount of electro conductivity (EC) and the degree of acidity (pH).

To circulate the nutrient solution, a combination of submersible water pumps placed in a nutrient solution tub and the flows of a nutrient solution by gravity is also required. For this reason, potential energy is needed. That is obtained by the difference in surface height of the nutrient solution in the nutrient solution tub, between the part of the nutrient solution tub containing the nutrient solution outlet pipe to the controller EC/pH drum, with the surface height of the nutrient solution part of the nutrient solution tub containing the submersible pump (Fig. 4 and 5).

The partition (Fig. 3), placed in the middle of a nutrient solution tub, is made of ½ inch PVC pipe arranged between two ½ inch PVC vertical pipes, reinforced with a plastic layer placed between the partition pipes thus minimizing partition leakage. The partition pipes can be added or subtracted so that the optimal difference in the surface of the nutrient solution to circulate the nutrient solution can be obtained. The water level in the tub containing the water pump must not be less than that required for the operation of the water pump.

## METHODS

AB mix nutrients (*Koesriharti, 2016*) are inserted into a nutrient solution mixing drum. The drum is provided by EC and pH sensors. Its values can be seen on the EC and pH monitor on the front of the Automated Nutrient and pH Controller Equipment for Hydroponic Plant Cultivations panel box in Fig. 1. After about 10 minutes, the EC and pH of the nutrient solution in the drum and tub are measured. The EC and pH of the nutrient solution in the drum can be seen by using an EC and pH meter. The EC and pH meter numbers are adjusted to the EC and the pH numbers of the nutrient solution, which is shown on the EC and pH monitor screen on the panel box. The mean EC and pH values in the drum and the nutrient solution tub were relatively the same after about 10 minutes of mixing.

Suppose the EC of the nutrient solution in the drum is smaller than desired, then add the AB mix nutrient solution manually into the drum to obtain the desired EC amount. Meanwhile, if the EC number is greater than desired, add water manually into the drum to obtain the desired EC number. Meanwhile, if the pH of the nutrient solution in the drum is smaller than desired, add pH up solution manually into the drum to obtain the desired pH value. Meanwhile, if the pH is greater than desired, add pH down solution manually into the drum to obtain the desired EC number.

Furthermore, after the water source in the container and the source of nutrient solution and the pH up / down solution reach a certain level, the nutrient solution and pH plant control equipment for hydroponic plants (Fig. 1) is operated. The user sets the desired TDS value, maximum pH (high pH), and minimum pH (low pH). These values select from ranges that are suitable for plant growth. Operational equipment is provided with an electronic module containing a programmable logic controller (PLC) (*Dewi et al., 2014*).

Measurement of the surface height of the nutrient solution in the drum and the part of the nutrient solution tub containing the water pump, and the part of the nutrient solution tub that holds the nutrient solution from the hydroponic pipe, is carried out regularly (*Bernoullis equation, 2020*). Likewise, the measurement of the surface height of the nutrient solution source, pH up and pH down the source in the bucket, is carried out periodically.

## RESULTS

### The surface height of the nutrient solution in the Tub and Drum

The surface height of the nutrient solution in Tub Ia and Tub Ib can be seen in Fig. 4. Part of the nutrient solution will flow from Tub Ia to Drum I (Fig. 1 and 2) and from Drum I to Tub Ib through a ½ inch diameter PVC pipe by gravity. A part of the nutrient solution will flow from Tub Ia to Tub Ib through the separator partition gap (Fig. 3) and can also pass through the upper boundary of the separator partition.

The flow of nutrient solution through this partition is necessary, so there should be no shortage of nutrient solution in the Ib Tub due to pumping.

The graph in Fig. 6 shows that the surface height of the nutrient solution in the Tub Ia is greater than the surface height of the nutrient solution in Drum I. Likewise, the surface height of the nutrient solution in Drum I is greater than the surface height of the nutrient solution in Tub Ib. The flow of nutrient solution occurs from Tub Ia to Drum I and from Drum I to Tub Ib through a ½ inch diameter PVC pipe. Likewise, the graph in Fig. 7 shows the flow of nutrient solution from Tub IIa to Drum II and then from Drum II to Tub IIb.

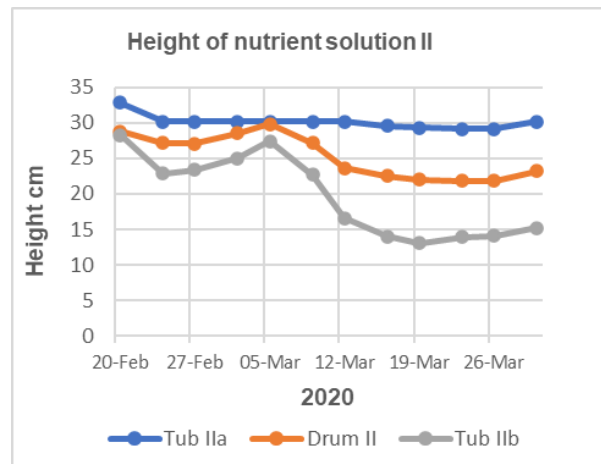
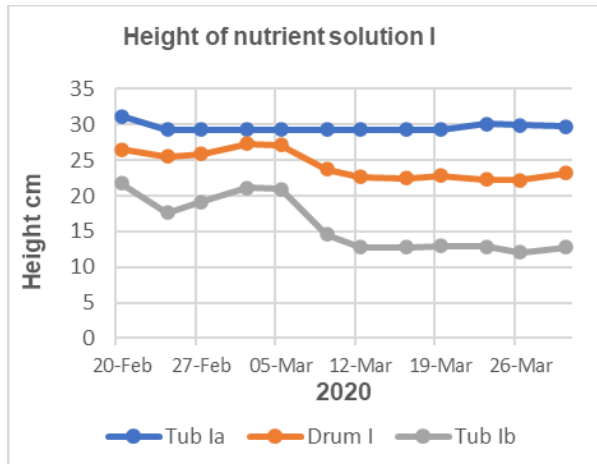


Fig. 6 - The height of the nutrient solution in Tub Ia – Drum I - Tub Ib

Fig. 7 - The height of the nutrient solution in Tub IIa – Drum II - Tub IIb

**Discharge of nutrient solution through tub partition, ½ inch PVC pipe, and pump**

Assuming that the flow rate of the nutrient solution from Tub Ia to Drum I is relatively equal to the flow rate of the nutrient solution from Drum I to Tub Ib. The flow of nutrient solution is measured on the flow of nutrient solution from Tub Ia to Drum I by measuring the flow rate of the nutrient solution in a ½ inch diameter PVC pipe from Tub Ia to Drum I.

Using the Conservation of Mass Principle and the Bernoulli equation (*Bernoullis equation, 2020*), it is also possible to obtain the flow rate of nutrient solution from Tub Ia through the partition to Tub Ib. Assume that the nutrient solution pump discharge to the hydroponics pipe is relatively constant, namely 275.8 cm<sup>3</sup> / second, as shown in Fig. 8. From the measurement results, the height difference in the Ib tank does not significantly affect the pump discharge.

The same calculation principle applies to the flow of nutrients from Tub IIa to Drum II, which then goes to Tub IIb through a ½ inch PVC pipe. Using the same formula and the pump discharge of the nutrient solution to the hydroponic pipe, which is relatively constant, it is also possible to obtain the flow of nutrient solution from Tub IIa through the partition to Tub IIb.

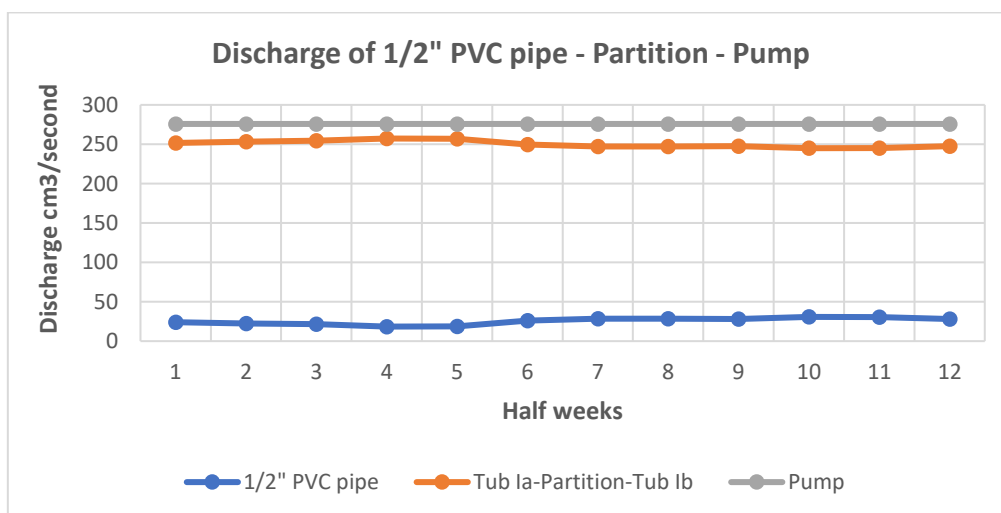
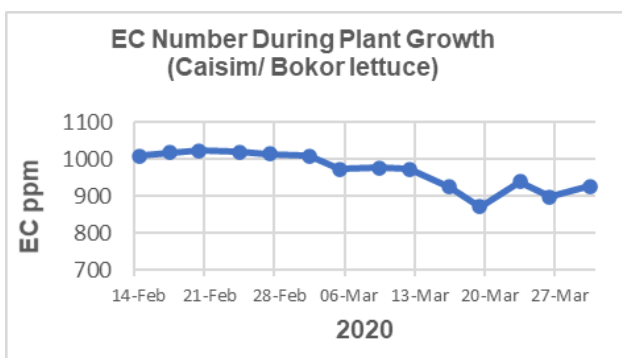


Fig. 8 - The discharge of nutrient solution in a ½ inch diameter PVC pipe from Tub Ia to Drum I and Tub Ib, the discharge through the partition, and the submersible pump

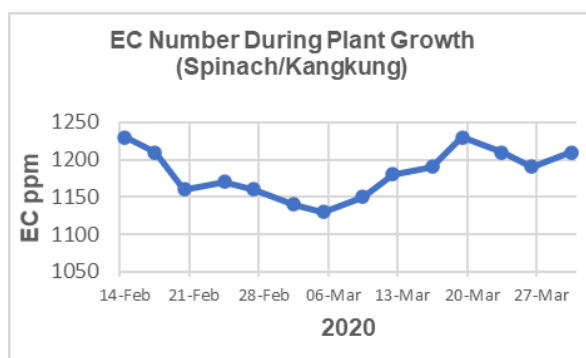
**EC number during plant growth**

The monitor setting on the panel box for the first TDS / EC controller is high: 1000 ppm and low: 900 ppm with hydroponic plants caisim (*Brassica rapa var. Parachinensis*) and bokor lettuce (*Lactuca sativa*). While the second TDS / EC controller is high: 1250 ppm and low: 1150 ppm with hydroponic plants spinach (*Amaranthus spp*) and kangkung (*Ipomea aquatic Forsk*). The graph of the results measuring the EC magnitude on the first TDS / EC controller during caisim and bokor lettuce cultivation is shown in Fig. 9. At the same time, the graph of the EC magnitude on the second TDS / EC controller during the cultivation of spinach and kangkung is shown in Fig. 10 periodically between 08.00 - 11.00 a.m. So, some EC numbers outside the EC numbers have been set, where the EC numbers take some time to readjust to the EC numbers set on the monitor in the panel box. From observations during the test, it took about 10 minutes to reach the EC nutrient solution, which was relatively the same between the tub and the drum.

During the hydroponic cultivation of caisim, bokor lettuce, spinach, and kangkung (February 14 to March 30, 2020) with the TDS controller application, the additional nutrient solution is required automatically from a nutrient solution source as much as 102.4 liters. The application of the nutrient solution EC controller in the field can be seen in the results on graphs and on images/photos of growth and yields of the two types of hydroponic plants (Fig. 16 and 17).



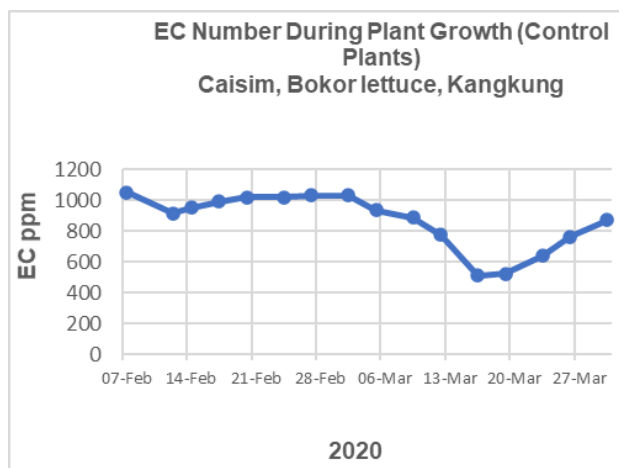
**Fig. 9 - Setting monitor I, EC: High: 1000 ppm. Low: 900 ppm**



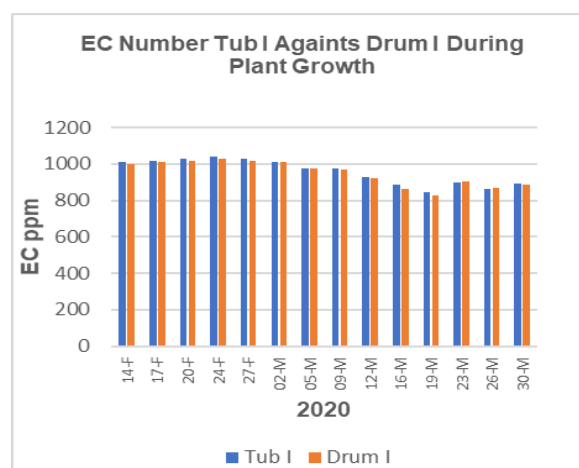
**Fig. 10 - Setting monitor II, EC: High: 1250 ppm. Low: 1150 ppm**

Meanwhile, for control plants, the magnitude of the EC number during the cultivation of Casim, bokor lettuce, and kale can be seen in Fig. 11. The addition of nutrient solutions during hydroponic cultivation is done manually.

The graph of the results of periodic measurements of the EC number of the nutrient solution in Tub I and Drum I is shown in Fig. 12. There is no significant difference between the EC number of the solution in Tub I and the EC number in Drum I. Thus, the EC number of controlled nutrient solutions in Drum I is homogeneous with the EC nutrient solution in Tub I, which is circulated using a submersible pump for hydroponic cultivation of plants. This situation also applies to the magnitude of the EC number of the nutrient solution in Tub II and Drum II.



**Fig. 11 - The EC number of nutrient solution for control plants during cultivation**

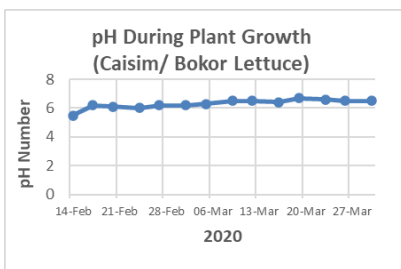


**Fig. 12 - The EC number of nutrient solution in Tub I and Drum I during hydroponic cultivation**

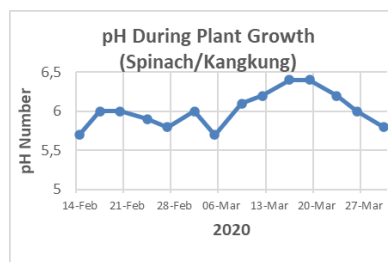
**PH during plant growth**

The monitor setting in the panel box for the first pH controller is high: 7.0 and low: 6.0 with hydroponic plants caisim and bokor lettuce. The second pH controller is high: 6.5 and low: 6 with hydroponic plants spinach and kangkung. The graph of the pH measurement results on the first pH controller during the cultivation of caisim and bokor lettuce is shown in Fig. 13. The graph of the pH value on the second pH controller during spinach and kangkung cultivation is shown in Fig. 14.

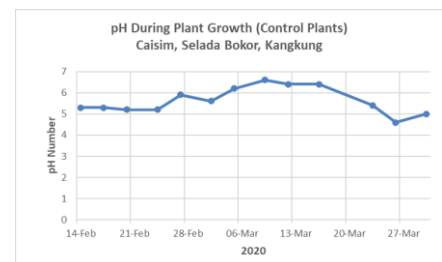
The measurements are carried out periodically between 08.00 - 11.00 a.m. so that several pH numbers outside the pH value have been set. The pH number takes some time to adjust back to the pH number that has been set on the monitor on the panel box. From observations during the test, it took about 10 minutes to reach the pH of the nutrient solution, which was relatively the same between the tub and the drum. During the cultivation of caisim, bokor lettuce, spinach, and kangkung hydroponically (February 14 to March 30, 2020) with the application of a pH controller, an additional pH up solution is required automatically as much as 91.1 liters. Meanwhile, there is no additional pH down solution. The graph of the pH number of the control plant nutrient solution during conventional hydroponic cultivation can be seen in Fig. 15. There is no addition of pH up or pH down solution to the control plant nutrient solution.



**Fig. 13 - Setting Monitor I.  
PH:  
High: 7.0 Low: 6. 0**



**Fig. 14 - Setting monitor II,  
PH:  
High: 6.5 Low: 6.0**

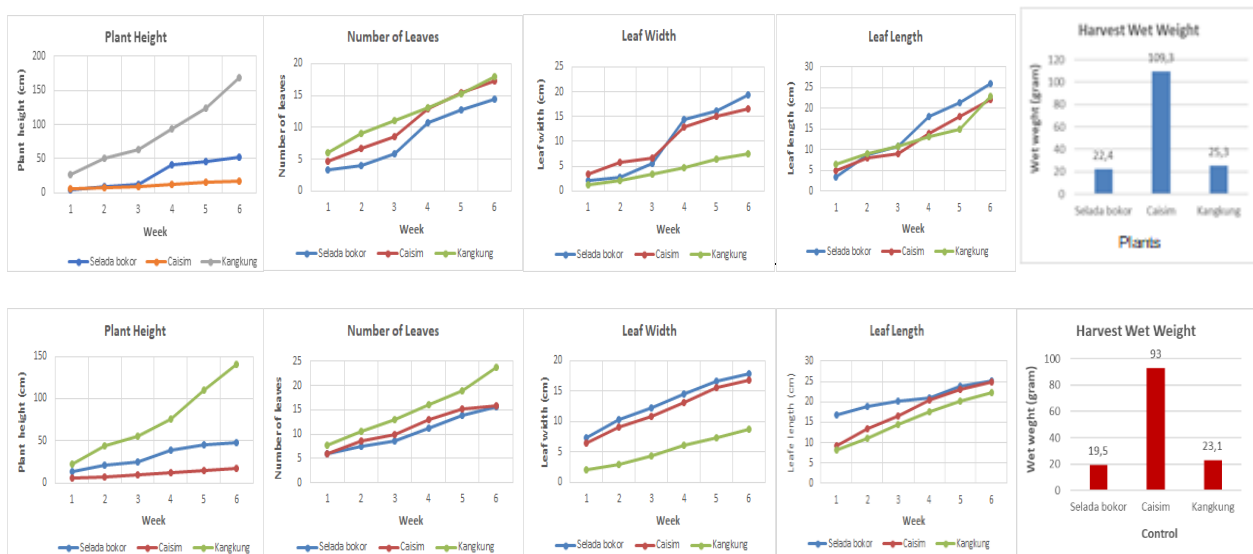


**Fig. 15 - The pH number of the control plant**

**Irrigation water requirement**

There is an 80.7 cm difference in the height of the water surface in the water container or 305.1 liters of water to reduce the EC number of the nutrient solution in the nutrient solution mixing drum and evapotranspiration of hydroponic plants (kangkung, spinach, caisim, bokor lettuce ) during cultivation (February 20 to March 30, 2020).

**Plant**



**Fig. 16 - Growth graph of the plants (top row image) and control plants (bottom row image)**

From the graph of plant growth (plant height, number of leaves, leaf width, and length) in Fig. 16, the growth of plants at week 6<sup>th</sup> was relatively higher than that of control plants. The number of leaves of caisim in the plants was relatively higher than that of the control plants, except for bokor lettuce and kangkung, the number of leaves in the plants was somewhat less than the control plants. The leaf width of the plants is relatively the same as the control plants, except that the leaf width of the plants is wider than that of the control plants. The leaf length of the plants was relatively the same as of the control plants, except that the caisim leaf length of the control plant was longer than that of the plant. It can also be seen in Fig. 16. That the graph of the yield of the plants weighs heavier than the control plants.



Fig. 17 - From left to right: bokor lettuce, caisim, kangkung and control plants consist of bokor lettuce, caisim and kangkung.

Visually, it is shown in Fig. 17 that at week 6<sup>th</sup>, the growth of bokor lettuce (*Lactuca sativa*), caisim (*Brassica rapa var. Parachinensis*), and kangkung (*Ipomea aquatic Forsk*) the plants grew relatively better, and the harvest seemed heavier than the control plants. In Fig. 16, the graph shows the yield of the plants weighing heavier than the control plants. For spinach, no planting was done as a control.

## CONCLUSIONS

A tub provided with a separator partition has functions creating a difference in the surface height of the nutrient solution between the outlet of the nutrient solution tub and the inlet of the nutrient solution from the drum so that the nutrient solution flows according to the law of gravity. It is part of the nutrient solution circulation system that uses electronic controls. The flow of nutrient solution through this partition is necessary so that there is no shortage of nutrient solution in the tub containing the submersible pump due to pumping. It takes about 10 minutes to reach the nutrient solution's EC and pH, relatively the same between the tub and drum. During hydroponic plants cultivation using TDS and pH controller applications, automatic addition of nutrient solution from a nutrient solution source as much as 102.4 liters is required, and an additional automatic pH up solution from a pH up solution source 91.1 liters. No additional pH down solution is automatically added from the source of the pH down solution. 305.1 liters of water is needed to decrease the EC number of the nutrient solution in the nutrient solution mixing drum and evapotranspiration of hydroponic plants during cultivation.

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