Effect of biofertilizer with reduced dose of nutrient solution on yield of Pak Choy on Nutrient Film Technique System

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ABSTRACT

The Nutrient Film Technique (NFT) in hydroponic crop production systems generally uses chemical nutrient solutions to provide plant nutrients, even though biofertilizer inoculation can enrich liquid nutrients. The purpose of this experiment was to observe the effect of liquid biofertilizers applied with chemical nutrient solutions on changes in the acidity and electrical conductivity of nutrient solutions, as well as the growth and yields of pak choy (Brassica rapa L.) grown in Nutrient Film Technique. This experiment was set up in a completely randomized design with three nutrient solution treatments and eight replications. The treatments included the application of 100% chemical nutrient solution (control), and 75% and 50% concentrations of chemical nutrient solution enriched with a consortium biofertilizer. The results showed that at the end of the experiment, the acidity of all nutrient solutions increased, but their electrical conductivity (EC) was reduced. The fresh weight of pak choy shoots in medium B (75% chemical nutrition with biofertilizers) was 34% lower than the control (A), although statistically it was not significant. However, 50% chemical nutrition with biofertilizers produced the same shoot weight as the recommended dose of chemical nutrition. Moreover, 75% chemical nutrient with biofertilizers increased root weight. This current experiment verified that a reduced concentration of nutrient solution enriched with biofertilizer can be used to maintain the yield of pak choy grown in NFT.

Keywords: Consortium biofertilizers, hydroponic, Solution acidity, Shoot weight

1. INTRODUCTION

Hydroponics is a cultivation technology that can be performed in an indoor plant cultivation. This soilless system saves the water use and nutrient, reduce soil borne diseases as well as soil structure and salinity problem (Mhadhbi, 2012). Nowadays limited growers cultivate pak choy (*Brassica rapa* L.) by using hydroponic system. Pak choy is a high demand of vegetables due to the taste and nutrition content. One hundred grams of pakcoy plants contained 105 mg of calcium and 45 mg of vitamin C (United States Department of Agriculture, 2016).

The type of hydroponics that are commonly elaborated in leafy vegetable production is nutrient film technique (NFT). This broadly-used technique applies a stream of water containing dissolved nutrients circulates from the nutrient container to the plant roots; NFT flow the water, nutrients and oxygen continuously with a water current thickness of about 3 mm (Herwibowo and Budiana, 2014). The nutrient solution usually composed of chemically defined nutrients in particular composition to optimize plant growth and yield; which are elements needed by plants include macro nutrients of nitrogen (N), phosphorus (P), potassium, calcium, magnesium and sulfur, as well as micro nutrients of iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel (Bhatla & Lal, 2018; Mohammed, 2018).

The composition of nutrient solution determines is the electrical conductivity (EC) and acidity (pH). The EC of nutrient solution is an appropriate indicator to estimate ion availability for plants in the root zone (Resh 2015). The pH value of the nutrient solution that supports plant growth is between 5.5 and 7. The acidity dictate the nutrient availability for plants uptake. P concentration decreases significantly when the reaction is alkaline or very acidic (Dyœko & Kowalczyk, 2008). For growing leafy vegetable, the optimum range of EC and pH depend on plant species; the EC of 1.5 – 2 and pH 7 were reported to be optimum for pak choy (Singh and Dunn, 2017). Meanwhile, nutrient solution composed of bio-organic fertilizer and chemical nutrients solution with the pH of 5.06-7.20 and EC of 1.5-3.1 ms/cm support pak choy yield in rockwool substrate (Priadi and Nuro, 2017).

Nowadays, the price of chemicals significantly increased so that substitute part of chemicals in nutrient solution is needed. Introducing biofertilizer to chemical nutrient solution has been proposed to sustain crop production in hydroponic since the microbes suspended in the solution (Lee and Lee, 2015). The prominent role of biofertilizer in nutrient solutions was fixing the nitrogen (N) and producing the phytohormone. Chemical nutrient solutions do not contain phytohormones to regulate plant growth. Meanwhile microbes in biofertilizer produce phytohormone that induce plant growth, induce plant immunity, and hence optimize their growth (Maheswari et al., 2015).

The Soil Biology Laboratory of Universitas Padjadjaran University develope a commercial biofertilizer containing N fixing bacteria (NFB) and P solutilizing microbes (PSM). In NFT with optimum content of nutrient, the role of NFB and PSM are restricted by; but certain microbes in that biofertilizer produce phytohormones. Combining chemical nutrients solution with biological fertilizers in hydroponics is expected to optimize the growth and production of pak choy. Effect of this consortia biofertilizer of leafy vegetable, pak choy has been verified in pot culture with mineral soil (Hindersah et al., 2017) but the research of biofertilizer in NFT hydroponic system is limited. The objective of this in door experiment was to observe the effect of liquid biofertilizers mixed with chemical nutrients solution on the acidity and electrical conductivity of nutrient solutions; growth and yields of pak choy (*Brassica rapa* L.) grown by using Nutrient Film Technique.

2. MATERIAL AND METHOD

The experiment was carried out in the hydroponic production room of the Faculty of Agriculture Unpad Jatinangor Campus with temperature of 24-31^{o}C and humidity 75-90%. The 21-days old pak choy seedlings were growing using the hydroponic method with a nutrient film technique (NFT). The nutrient layer height of NFT was approximately 1.5 cm which was flowed continuously by using pump to ensure constant circulation. Plants get light from red and blue 400 nm LEDs which are placed 50 cm apart above the hydroponic rack (Figure 1). The duration of lighting is 12 hours from 06.00-18.00 that controlled automatically. The slope of the NFT gutter pipe was 5% (Wibowo and Asriyanti, 2013); which is better to produce higher of pak choi growth.

Figure 1 Nutrient film technique equipment before LED installation (a) and with during growing the pak choy with LED (b); and raising seedlings with the LED (c)

2.1 Experimental Design

The experimental was setup in completely randomized design with 8 replications to test the three nutrient solution compositions. The control treatment (A) was recommended dose chemical nutrient solution; the experimental treatments were 75% chemical nutrient solution mixed with consortium biofertilizers (B) and 50% chemical nutrient solution mixed with biofertilizers (C).

Chemical nutrient solutions produced by the Hydroponics Laboratory of the Faculty of Agriculture Unpad consist of macro nutrient solutions $CaNO_3$ (50 g/L), KNO_3(17.5 g/L), KH_2PO_4 (17.5), $MgSO_4$ (40 g/L), and micronutrient solution Mn (1.25 g/L), B (1.25 g/L), Cu (1.25 g/L), Zn (1.25 g/L), Fe (1.25 g/ L), Mo (1.25 g/L). The solution was placed in a 10-L plastic tank. The nutrient solution film were 1-2 mm above the bottom of the hydroponic containers. The electrical conductivity of the solution was maintained between 1-1.5 (mS/cm) during the experiment. Every 3 days the new nutrient solutions were added to the 10-L nutrient tank to maintain the volume.

The consortium biofertilizer developed by the Soil Biology Laboratory, Faculty of Agriculture composed of non-symbiotic N_2 fixing bacteria *Azotobacter chroococcum*, *A. vinelandii, Azospirillum* sp., *Acinetobacter* sp.; and phosphate solubilizing microbes Pseudomonas cepacea and *Penicillium* sp. in balance composition. The population of bacteria and fungi in biofertilizers were about 10^7 CFU/mL and 10^5 CFU/mL. For treatment B and C, as much as 1% (v/v) of biological fertilizer is mixed with a nutrient solution.

2.2 Experimental Establishment in NFT

Single pak choi seeds were planted on moist rockwool sheets with a spacing of 3 cm x 3 cm and placed in plastic trays. The nursery was covered with perforated plastic to reduce evaporation. Two days later, the seedlings were placed in plastic house for 7 days and under was moved to nursery room with LED lights for up to 21 days (Figure 1c). Before transplanting. the rockwool with seedlings was cut with the dimensions of 3x3 cm.

Seedlings in rockwool were transferred into perforated hydroponic pots. stored in hydroponic rack holes, nd maintained for 25 days until harvest time. Before planting, the room, the walls and roof of the room and the tables are cleaned and disinfected. The hydroponic racks were cleaned with a cloth dampened with 70% alcohol and then left for 15 minutes until the alcohol evaporates. Observations of pest attacks are carried out every day. Pest and disease controlled by manually before the disease spreads.

2.3 Parameters and Statistical Analysis

Nutrient solution acidity (pH) and EC were measured daily in 25-mL sample solutions taken up from the nutrient tanks. Plant height was measured from stem base to the tip of the top leaf; and number of leaves counted at 7, 14 and 21 days after planting (dap). Harvesting was carried out at the day 25 dap in the morning. All plant pots were removed from the hydroponic medium and the roots carefully separated from the rockwool. The plant crown is separated from the roots and weighed; Plant dry weight was measured after heating for 48 hours at 70oC to constant weight.

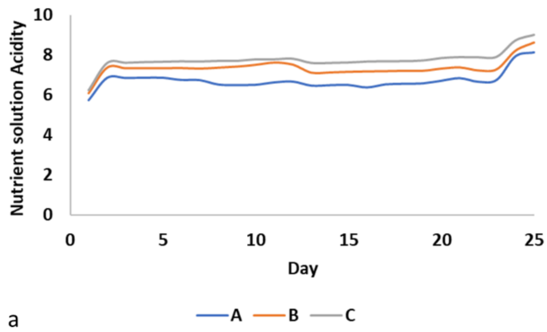
The pH and EC data of the three nutrient solutions are presented in continuous graphical form to observe changes in the two parameters in the NFT system during the planting of pak choy. Growth and yield data were subjected to analysis of variance ($p<0.05$); if the treatment affected the parameters significantly, then Duncan's multiple range (DMR) test ($p<0.05$) were performed.

3. RESULTS AND DISCUSSION

3.1 Acidity and Electrical Conductivity of Nutrient Solution

Both the acidity and the EC of nutrient solution were fluctuated during the experiment. On the first day, the pH of the three nutrient solutions was different; 5.8, 6.1 and

6.2 for chemical solutions, 75% nutrient solution mixed with biofertilizers and 50% nutrient solution mixed with biological fertilizers respectively (Figure 2a). On the second day of the experiment, the pH increased sharply and minor fluctuation were observed until day 23. Acidity was increased sharply at day 23-25. At the harvest time the acidity of A, B and C nutrient solution were 8.2, 8.6 and 9.0 respectively.



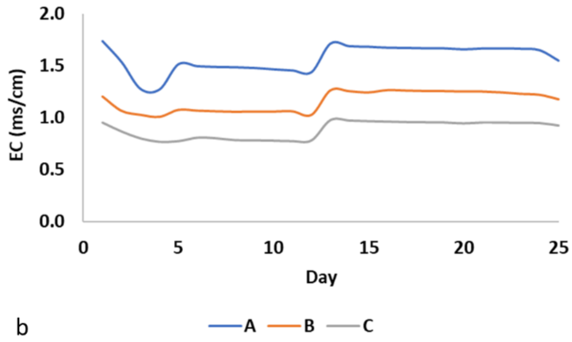


Figure 2 The change of acidity (a) dan electrical conductivity, EC (b) of nutrient solution during growing pak choy for 25 days by using NFT

Slight fluctuation of EC was recorded in the three nutrients solution. The EC of all solutions were decreased at first four day of pak choy growth that was lasted until day 13 (Figure 2b). At the end of experiment, the EC of chemical solution was lower than that at the beginning, but the EC of chemical solution combined with biofertilizer were similar to the pH at the transplanting time. At day 23, the pH of 50% nutrient solution mixed with biofertilizer was increased up to 8 and at the harvest the pH was more than 8, which is not suitable for growing pak choy in hydroponic system (Singh and Dunn, 2017). The acidity A and B solutions were lower, and the pH of A solution was 8.15; which is higher than optimum pH in hydroponic for pakcoy (Priadi and Nuro, 2017). The EC of chemical nutrient solution at the end of experiment was 1.5 ms/cm but that of 75% and 50% of chemical solution was 1.11 and 0.97 ms/cm. This is showed that pH and EC adjustment are needed when the reduced concentration of nutrient solution will be used for next pak choy production.

3.2 Plant Growth and Yield

Various nutrient solution did not affect shoot height and leaves number of pak choy at 7 – 14 days after transplanting but plant with recommended-dose chemical solution had higher shoot height at day 14 (Table 1).

Table 1 Effect of various nutrient solution on shoot height and leaves number of pak choi

Nutrient solutions	Shoot height (cm)			Leaves number		
	day 7	day 14	day 21	day 7	day 14	day 21
A: chemical solution	4.5±0.9 a	10.5±1.4 b	11.5±1.9 a	4.1± 0.6 a	6.1±0.6 a	6.3±1.0 a
B: 75% A + Biofertilizer	4.3±1.0 a	8.1±1.5 a	9.6±2.2 a	4.3±1.0 a	5.3±1.5 a	5.4±1.4 a
C: 50% A + Biofertilizer	3.5±0.5 a	8.4±1.1 a	9.5±2.0 a	4.1± 0.8 a	5.6±0.9 a	5.9±1.4 a

Annotation: Numbers in a column followed by the same letter were not significantly difference based on DMR test at $p < 0.05$

The use of chemical solution enhances shoot height up to 19.7% even though the increment was not statistically significant based on DMR test at $p < 0.05$. Vegetative plant growth depens on the nitrogen for cell proliferation and biomass accumulation (Leghar et al., 2016). In this experiment, the concentration of N in chemical solution at planting time and at harvest were higher than other solutions; which is 25% and 100% higher than B and C. This current research verified that reduced concentration of chemical nutrient solution combined with consortium biofertilizer had not affected the shoot height and leaves number at day 21, which is four days before harvest. Biofertilizer contained N-fixing bacteria that provide available N; moreover, N-fixer bacteria as well as P-solubilizer bacteria used in this experiment enable to produce the phytohormone auxin cytokinin. It is proved elsewhere these hormones regulate and control the cell proliferation and development (El-Esawi, 2017).

Analysis of variance showed that nutrient solution did not influence shoot fresh and weight (Figure 3a and 3b) but affect roots fresh weight and length (Figure 3c and 3d). The standard errors of shoot biomass treatments were relatively high due to high-variability value. In contrast, shoot parameters were affected by nutrient solution. Mixing biofertilizer with 75% strength of chemical nutrient enhanced root weight and resulted in similar roots length compared to plant with chemical nutrient (Figure 3c and 3d).

Nonetheless plant grown in reduced strength of nutrient solution up to 50% mixed with biofertilizer decreased roots length by 54.2% and 44.8% compared to recommended NS and 75% NS + biofertilizer. This result found the effectivity of biofertilizer to increase the roots formation. All N-fixer and P-solubilizer bacteria in biofertilizer produced phyto-hormones (Hindersah et al., 2021). The result agreed with the root growth stimulation effect of Azotobacter on various bean and Azospirillum on tomato (Hindersah and Asmiran, 2019; Molina-Favero et al., 2008).

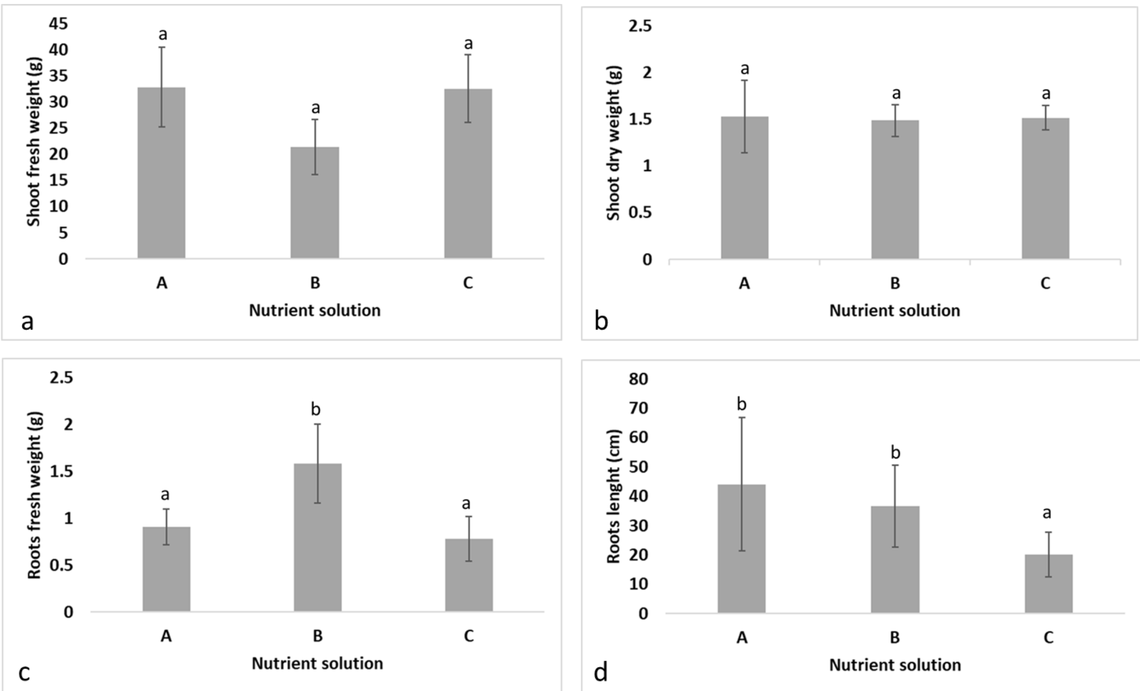


Figure 3 Effect of various nutrient solutions on shoot fresh weight (a), shoot dry weight (b), roots fresh weight (c) and roots length (d) of pak choy grown in NFT hydroponic system at day 25. The nutrients solution treatments composed of 100 % concentration of chemical nutrient solution (A); 75% of nutrient solution with biofertilizer (B) and 50% if nutrient solution with biofertilizer (C). Error bars represent the standard error of the mean. The letters above the error bars indicate significantly different based on the LSD test ($p \leq 0.05$).

4. CONCLUSION

At 25 days after planting the pH of nutrient solutions was increased while the EC was reduced compare to initial condition. Higher pH (9.0) was recorded in 50% nutrient solution enriched with biological fertilizers, while the pH of chemical nutrient and 75% chemical nutrient solutions with biofertilizer was approximately 8. The EC of chemical nutrient solution at the end of experiment was 1.5 ms/cm but that of 75% and 50% of chemical solution was 1.11 and 0.97 ms/cm. Fresh weight of pak choy shoots grown in 75% chemical nutrition with biofertilizers was 34% lower than control (A) even though it is not differ significantly. In this experiment, 50% chemical nutrition with biofertilizers produced the same shoot weight with the recommended dose of chemical nutrition; but 75% chemical nutrient with biofertilizers increased root weight. This current experiment verified that reduced concentration of nutrient solution enriched with biofertilizer can be used to maintain yield of pak choi grown in NFT.

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