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Original Article

Using Nutrient Solution Instead of Fertilizer to Grow Bok Choy *(Brassica chinensis)* in Thu Dau Mot City

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Abstract: Vegetables are an indispensable food in every family's daily meals because of their nutritional ingredients for the human body. The objective of the study is to evaluate the possibility of growing Bok choy in pots in Thu Dau Mot city and determine the appropriate nutrient concentration for vegetables grown in the spring crop from January to March 2024. Research method includes: i) Preparation of nutrient solution to grow vegetables; and ii) Growing Bok choy and evaluating their growth: using nutrient solution from experiment 1 to grow with 6 treatments: NT1 to NT6 (where NT1 is the control and NT2 to NT6 correspond to nutrient concentrations of 1,200, 1,300, 1,400, 1,500 and 1,600 ppm). The results show that the highest yield of Bok choy was 25.2 ton/ha/crop, which was achieved at NT4 using the nutrient concentration of 1,400 ppm, and the lowest yield was at NT1 with 24.9 ton/ha/crop. Research suggests that nutrient concentrations at 1,400 ppm are suitable for Bok choy cultivation. The nutrient solutions show the potential to commercialize in the urban areas and serve as a reference for gardeners who use automatic methods of providing nutrients to plants through a drip irrigation system, saving water, fertilizer and reducing labor.

Keywords: Bok choy, fertilizer, growth, nutrient solution, yield.

1. Introduction

Vegetables and fruits provide nutrients with high biological activity, especially vitamin C, minerals and trace minerals for human needs. The demand for green vegetables on the market is increasing. In order to get high quality, productivity and profit, farmers used to apply growth stimulants and plant protection substances (pesticides, herbicides, parasiticides) on their crops.

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Soil cultivation is a traditional farming form that has been practiced for a long time. In this farming, farmers often use granular multi-nutrient fertilizers which main ingredients are N, P and K to supplement minerals for plants. However, according to studies, only N, P and K minerals are not enough to meet the secondary and trace mineral needs for plants. Therefore, to grow well, the plant needs to be provided with sufficient other nutrients such as: C (carbon), H (hydrogen), O (oxygen), N (nitrogen), K (potassium), P (phosphorus), and some other elements [1].

Hydroponics technique appeared around 1860 [1], in which plants are grown on or in nutrient solutions with growing medium. Depending on the technique, all or part of the plant's root system is soaked in nutrient solution [2]. This is one of the advanced techniques of modern gardening. In particular, reasonable use of nutrients is necessary for the growth and development of plants, helps to avoid the growth of weeds, insects and soil-borne diseases. In recent years, hydroponic farming has developed strongly thanks to its flexibility, being able to be deployed in barren lands such as islands, remote rocky mountains and especially in urban areas, where people take advantage of space on terraces and balconies to grow crops.

There are some studies on using nutrient solutions for growing some vegetables. In a study published in 2023 on white mustard, it was shown that nutrient solution concentrations of 900 ppm and 1,200 ppm gave similar results in terms of plant weight (180 and 183 g/plant), higher than the concentration of 600 ppm (154 g/plant) but not statistically different from the concentration of 1,500 ppm (163 g/plant) [3]. Another study in 2021 on curly lettuce showed that at concentrations of 600 and 1,200 ppm, total yield (1.75 and 1.77 kg/m^2), commercial yield (1.69 and 1.72 kg/m^2), average plant weight (23.3 and 23.6 g/plant) were all higher than the concentration of 1,800 ppm and 2,400 ppm [4]. In 2021, the study on celery showed that at a concentration of 1,200 ppm, the plant gave the highest net yield (439.29 kg/100 m^2) compared to the concentration of 800 ppm, 1,000 ppm and 1,400 ppm [5]. In another study on lettuce, the nutritional formula D ($MgSO_4$: 500 g/1,000 L; KH_2PO_4: 270 g/1,000 L; KNO_3: 200 g/1,000 L; $Ca(NO_3)_2$: 680 g/1,000 L; $FeSO_4$: 12.5 g/1,000 L; H_3BO_3: 7.50 g/1,000 L; $MnSO_4$: 6.75 g/1,000 L; $CuSO_4$: 0.37 g/1,000 L; Na_2MoO_4: 0.15 g/1,000 L and $ZnSO_4$: 1.18 g/1,000 L) had better results in plant weight (7.29 g/plant), total yield (0.51 kg/tray), commercial yield (0.43 kg/tray) and the quality indicators than the remaining treatments [6]. The above studies have initially shown the advantages of using nutrient solutions for hydroponic cultivation. Growing plants in a soilless environment really brings many advantages such as: Maximum saving of planting area, maximum limitation of the use of pesticides, active and effective crop rotation, and increasing crop productivity. Growth, yield and quality indicators of hydroponic plants are higher than those grown on soil in tomatoes [7] and in broccoli [8]. However, no research has been conducted on bok choy with a complete sequence of steps from preparing nutrient solution ingredients to arranging vegetable growing experiments and monitoring growth and yield indicators of vegetable plants.

Bok choy (*Brassica chinensis*) or Pak Choy are in the same family as Napa cabbage and Mustard greens. The stems are thick, ribbed and succulent. Its flowers are small, yellow and on the top of the stems [6]. Bok choy plants have roots that grow in shallow clusters in the top layer of soil at a depth of about 20 cm. Bok choy leaves grow single, have no stipules, and thin leaf sheaths, so they have poor drought tolerance and are easily damaged by pests. Bok choy is a temperate vegetable so it needs appropriate lighting with low light intensity and long daylight hours. The suitable temperature for its growth is from 15 to 22 ^{o}C. The growth period of bok choy is 35 - 40 days, and can be grown all year round.

Bok choy is suitable for growing on loam, sandy loam, loose soil rich in humus and nutrients with a pH range of 5.5 - 6.5. The amount of water in the plant is very high, accounting for 80-90%, so Bok choy needs a lot of water to grow and develop. However, if it rains for a long time or is flooded, it will affect the growth and development of the plants [6, 7]. According to the results of some studies, the nutritional needs of some hydroponic vegetables range from 800 to 1,400 ppm depending on the growth stages [3, 5].

Thu Dau Mot City (TDMC) is the administrative center of Binh Duong province. Due to the large population and labor force, the demand for food is very large. However, most food originates from outside the province. Therefore, it is extremely necessary to take advantage of agricultural land and urban gardens to grow vegetables to partly meet people's needs as well as increase urban green area.

To explore alternative farming methods to traditional farming methods, promoting automation in the farming process, especially fertilizing and controlling the nutritional needs of the plants, "Research on growing Bok choy *(Brassica chinensis)* in pots with nutrient solution instead of fertilizer in Thu Dau Mot city" was carried out.

2. Materials and Methods

2.1. Materials

Chemicals: inorganic substances used to prepare 1 L of concentrated nutrient solution A (Bottle A) and 1 L of concentrated nutrient solution B (Bottle B) are presented in Table 1, Figure 1 (a).

Bok choy seeds: packaged in sealed bags with a net weight of 20 g and produced by Phu Nong Company and still within expiration date.

Place and time of implementation: nutrient solution was mixed at the Biology Laboratory of Thu Dau Mot University. Bok choy plants were grown in Mr. Hieu's household vegetable garden at 128, DX.022 Street, Phu My ward, TDMC in the spring crop from January to March 2024.

(a)

(b)

Figure 1. Chemicals for preparation of nutrient solution (a) and bag of Bok choy seeds (b).

2.2. Methods

2.1.1. Preparation of Nutrient Solution

Concentrated nutrient solutions mixed into 2 bottles and marked as bottle A and bottle B [3, 4, 7].

Bottle A: weighed 95.5 g of $Ca(NO_3)_2$ into a 200mL glass beaker, poured 100 mL of water into the beaker, then used a glass rod to gently stir the chemical to dissolve with the water, then poured the above solution into a plastic bottle and added distilled water to 1 L marked bottle A (Figure 2a).

Bottle B: weighed the remaining 9 inorganic substances in the order shown in Table 1 and put them into a 200 mL glass beaker, poured 100 mL of water into the beaker, then used a glass rod to stir gently until the chemical dissolves with the water, then poured the above solution into a plastic bottle and added distilled water to obtain 1 L, marked bottle B (Figure 2b).

Table 1. Inorganic substances and ratios used to prepare nutrient solutions

No.	Chemicals	Chemical formula	Mass (g)	Solution volume (L)
	Bottle A			
1	Calcium nitrate	$Ca(NO_3)_2$	95.5	1.0
	Bottle B			
2	Potassium nitrate	KNO_3	9.2	1.0
3	Mono potassium phosphate	KH_2PO_4	27.1	
4	Magnesium sulfate	$MgSO_4$	30.5	
5	Zinc sulfate	$ZnSO_4$	0.015	
6	Cooper sulfate	$CuSO_4$	0.01	
7	Ferric sulfate	$FeSO_4$	0.65	
8	Boric acid	H_3BO_3	0.02	
9	Kali sulfate	K_2SO_4	42.3	
10	Disodium ethylenediamine tetraacetate	Na-EDTA	0.86	

2.2.2. Bok Choy Planting

Bok choy was grown in plastic pots 40 cm wide and 32 cm high. The substrate used was coconut fiber soaked in diluted lime water for 72h, then mixed with rice husk ash in a ratio of 7:3, the substrate weight was 3 kg for each pot. There were 5 plants planted in each pots. There were 6 treatments (NT), each treatment was repeated 3 times so the total plastic pots was 18 pieces:

- NT1 (control): used N.P.K multi-nutrient granular fertilizer and organic fertilizer. According to the recommendation of the Ho Chi Minh City Agricultural Extension Center in 2009, the amount of fertilizer used for 1 ha of cultivation is 55 kg N, 75 kg P and 60 kg K and 20 tons organic fertilizer. It meaned that the amount of fertilizer used for 1 m^2 is: 5.5 g N, 7.5 g P and 6.0 g and 2,000 g organic fertilizer.
- NT2: using nutrient solution at the concentration of 1,200 ppm;
- NT3: using nutrient solution at the concentration of 1,300 ppm;
- NT4: using nutrient solution at the concentration of 1,400 ppm;
- NT5: using nutrient solution at the concentration of 1,500 ppm;
- And NT6: using nutrient solution at the concentration of 1,600 ppm.

Planting method: soaked seeds at a temperature of about 40-45 ℃ for 3-4 h, then washed and incubated them overnight. After that, sowed the soaked seeds in the nursery tray, covered with a thin layer of soil and watered with a light mist sprayer.

Care method: In all 6 treatments, water and nutrients were applied by drip irrigation directly to the roots of the vegetable plants. Nutrient solution was added to the irrigation water 7 days after planting, then continued to irrigate with nutrient solution daily and stopped adding nutrients to the water 7 days before harvest. Automatic watering was controlled by a timer with a watering time of 30 min and a 30-minute break for 12 h during the day, and stopped watering at night.

2.2.3. Monitor the Growth of Bok Choy Plants

Plant length and number of leaves of bok choy plants were measured four times during one crop cycle at 14, 21, 28 and 35 days after planting (DAP). In which: plant height was calculated from the part of the tree above the ground to the tip of the longest leaf, leaf length was calculated from the green leaf bordering the leaf petiole to the tip of the leaf, leaf width was the widest part along the width of the leaf. Measurement criteria are presented in Table 2.

The bok choy plants are harvested by pulling the entire plant. The stems and leaves are edible parts of the plant. The base and roots (from the first leaf slide of the plant down) are the discarded parts of the plant. The plants were harvested during cool times from 4 – 6 PM.

Track the index to calculate the average of 5 trees in each plot using the diagonal method. Data were compiled using Excel software and statistically processed using SPSS Stats v.22 software.

3. Results and Discussion

3.1. Nutrient Solution

The concentrated nutrient solutions were mixed into 2 bottles A and B. The pH of the mixed nutrient solutions was 5.8.

These concentrated solutions were diluted 1/100 with tap water to periodically water the plants. Specifically, to get 10 L of nutrient solution for growing vegetables, put 10 L of water into a bucket, poured 100 mL of solution A into the bucket and stirred well, then poured 100 mL of solution B into that bucket and continued stirring until they dissolved evenly in water.

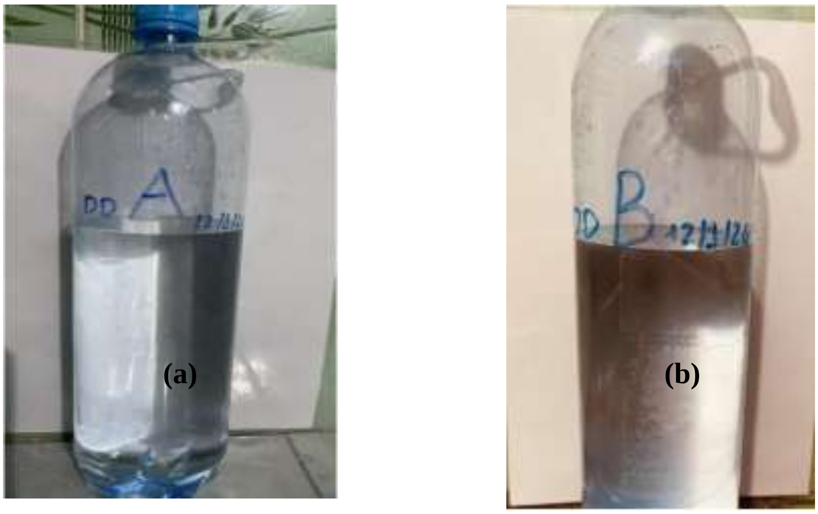

Figure 2. Concentrated nutrient solutions: Bottle A (a) and Bottle B (b).

The solution concentration was increased by adding more concentrated nutrient solution and was decreased by adding more distilled water. The adjusted solution concentration was then checked by a TDS meter (ppm) and a pH meter to achieve the desired nutrient concentration for growing vegetables.

3.2. Growth of Bok Choy Plants

The data in Table 2 shows that the growth characteristics of bok choy plants in NT2, 3, 4, 5 and 6 are all higher than NT1 (control), proving that using nutrient solutions dissolved in irrigation water helps the plants grow better than traditional fertilization methods. Especially in NT4, most monitoring indicators showed that the plants had a superior growth rate compared to the remaining treatments. This difference is statistically significant with $p < 0.05$. The growth indicators of vegetable plants in terms of plant height and leaf width in this study are similar to the research results of Nguyen Huu Thien et al., [8].

Table 2. Growth characteristics of the plants according to the treatments

DAP	Indicators	NT1	NT2	NT3	NT4	NT5	NT6
14	Tree height (cm)	5.9±0.1^{d}	6.2±0.2^{b}	6.2±0.1^{b}	6.3±0.1^{a}	6.0±0.1^{cd}	6.0±0.1^{cd}
	Leaf length (cm)	2.8±0.1^{c}	3.1±0.1^{b}	3.2±0.1^{b}	3.4±0.1^{a}	3.1±0.1^{b}	2.9±0.1^{c}
	Leaf width (cm)	2.4±0.1^{c}	2.6±0.1^{b}	2.6±0.1^{b}	2.8±0.1^{a}	2.7±0.1^{b}	2.5±0.1^{bc}
	Number of leaves (pcs)	5^{a}	5^{a}	5^{a}	5^{a}	5^{a}	5^{a}
21	Tree height (cm)	11.0±0.1^{e}	11.2±0.2^{cd}	11.4±0.2^{b}	11.8±0.2^{a}	11.3±0.2^{bc}	11.1±0.1^{de}
	Leaf length (cm)	5.0±0.1^{c}	5.2±0.1^{b}	5.2±0.1^{b}	5.4±0.1^{a}	5.2±0.1^{b}	5.0±0.1^{c}
	Leaf width (cm)	4.2±0.1^{c}	4.6±0.1^{b}	4.7±0.1^{b}	4.8±0.1^{a}	4.6±0.1^{b}	4.3±0.1^{c}
	Number of leaves (pcs)	8^{b}	8^{b}	8^{b}	9^{a}	8^{b}	8^{b}
28	Tree height (cm)	18.8±0.1^{c}	19.3±0.2^{b}	19.4±0.2^{b}	19.8±0.2^{a}	19.3±0.^{b}	18.9±0.1^{c}
	Leaf length (cm)	9.0±0.1^{c}	9.2±0.2^{c}	9.4±0.2^{b}	9.6±0.1^{a}	9.3±0.1^{bc}	9.1±0.1^{c}
	Leaf width (cm)	6.1±0.1^{d}	6.5±0.1^{c}	6.7±0.1^{b}	6.8±0.1^{a}	6.5±0.1^{c}	6.2±0.1^{d}
	Number of leaves (pcs)	12^{a}	12^{a}	12^{a}	12^{a}	12^{a}	12^{a}
35	Tree height (cm)	24.1±0.2^{d}	25.1±0.2^{c}	26.1±0.2^{b}	26.8±0.2^{a}	26.0±0.1^{b}	24.2±0.2^{d}
	Leaf length (cm)	12.1±0.1^{d}	13.0±0.2^{c}	13.2±0.2^{b}	13.5±0.2^{a}	13.1±0.1^{bc}	12.2±0.1^{d}
	Leaf width (cm)	8.0±0.1^{d}	8.3±0.2^{c}	8.6±0.2^{b}	8.8±0.2^{a}	8.6±0.2^{b}	8.1±0.1^{d}
	Number of leaves (pcs)	13^{b}	13^{b}	13^{b}	14^{a}	13^{b}	13^{b}

Notice: NT1: control, NT2: 1.200 ppm, NT3: 1.300 ppm, NT4: 1.400 ppm, NT5: 1.500 ppm and NT6: 1.600 ppm. The letters a, b, c, d represent statistically significant differences between values in the same row with $p<0.05$.

Table 3. Yield and edible weight of the plants according to the treatments

DAP	Indicators	NT1	NT2	NT3	NT4	NT5	NT6
40	Plant weight (g/plant)	132.7±8.3^{e}	134.3±8.3^{c}	134.8±8.1^{b}	135.1±8.0^{a}	134.5±8.2^{c}	133.8±8.2^{d}
	Edible weight (g/plant)	103.5±6.2^{e}	104.9±6.2^{d}	105.4±6.0^{b}	105.7±6.0^{a}	105.2±6.1^{c}	103.6±6.2^{e}
	Edible rate (%)	78.0±3.4^{c}	78.1±3.5^{b}	78.2±3.4^{a}	78.2±3.3^{a}	78.2±3.3^{a}	77.4±3.4^{d}
	Productivity (ton/ha)	24.9±1.0^{b}	25.0±1.0^{b}	25.0±1.0^{b}	25.2±1.0^{a}	25.0±1.0^{b}	25.0±1.0^{b}
	Productivity (g/m^2)	2,490±100^{b}	2,500±100^{b}	2,500±100^{b}	2,520±100^{a}	2,500±100^{b}	2,500±100^{b}

Note: The letters a, b, c, d represent statistically significant differences between values in the same row with p=0.05.

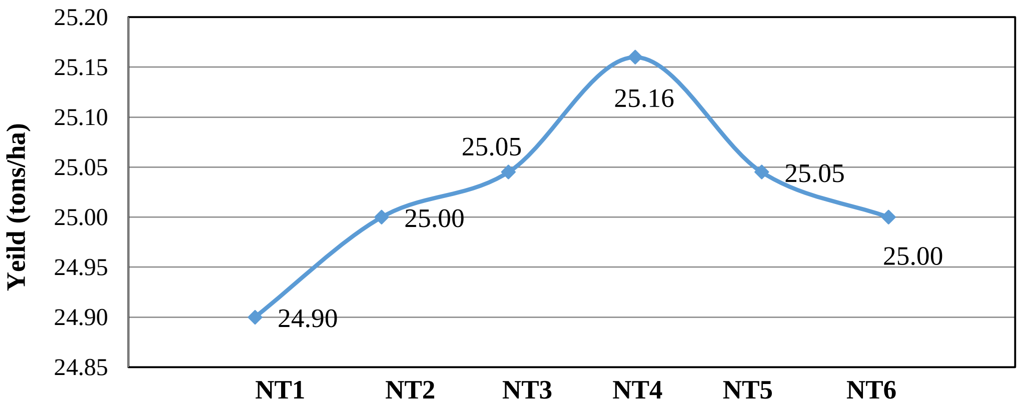

Figure 3. Yield of the plants according to the treatments.

3.3. Yield and Edible Weight of the Plants

Data in Table 3 and Figure 3 show that the yield (ton/ha) gradually increased from NT1 to NT4 and then tended to decrease in NT5 and NT6. Thus, the concentration of 1,400 ppm is suitable for the plant growth. Moreover, the highest vegetable yield has statistical significance with $p < 0.05$.

Corresponding to the monitored yield, the edible weight of the plants (g/plant) also gradually increased from NT1 to NT4 and then tended to gradually decrease in NT5 and NT6. The edible weight of vegetable plants was highest in NT4 and statistical significance (Table 3, Figure 4).

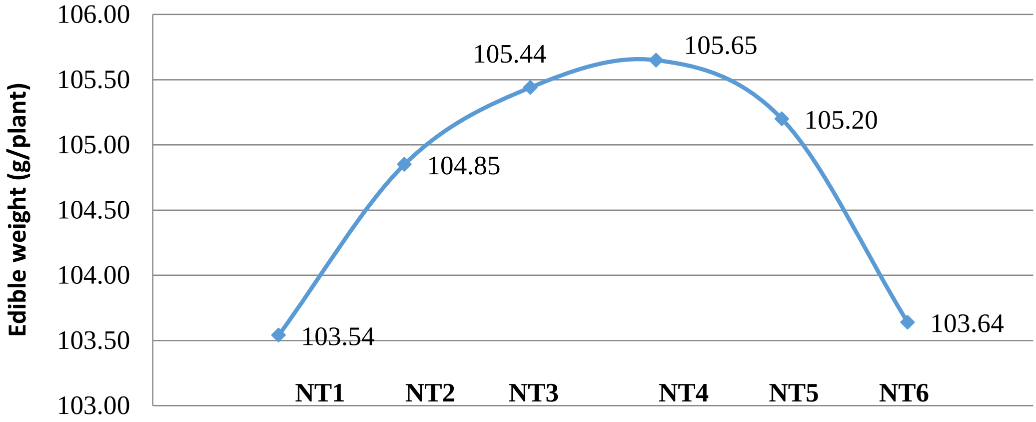

Figure 4. Edible weight of the plants according to the treatments.

4. Conclusion

Using the nutrient solution helps the bok choy plant grow well and achieve higher yield compared to the control treatment using NPK granular fertilizer. Specifically, in NT4 corresponding to the nutrient concentration of 1,400 ppm, the vegetable plant grew best with the highest indicators of plant height, leaf length, leaf width after 35 days of planting, the harvested plant weight reached 135.1 g/plant and the highest yield was 25.2 ton/ha/crop, statistically significant with $p < 0.05$.

Using the nutrient solution dissolved in water combined with the drip irrigation system will help the plant easily absorb nutrients, saving water, fertilizer and labor. Proposed future research directions: apply to many different crops and analyze heavy metals in crop products.

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