EFFECTS OF NUTRIENTS ON THE GROWTH OF PAK-CHOI (BRASSICA CHINENSIS L.) SEEDLINGS IN A HYDROPONIC SYSTEM

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ABSTRACT

Pak-choi (Brassica chinensis L.) is one of the most widely consumed leafy green vegetables. In hydroponics, the growth depends upon the composition of nutrient solutions. This study was conducted due to the lack of reported studies on the effect of nutrients towards the hydroponic pak-choi plant. Therefore, this study describes the impact of different types of nutrients on plant growth. The response of the pak-choi plant growth upon the number of leaves per plant, plant height and leaves diameter were measured. The study covers the analysis of the nutrient solutions by x-ray fluorescence (XRF), atomic absorption spectroscopy (AAS) and ion chromatography (IC) as well as the effect of different fertilizers which are fruit waste fertilizer, fertilizer A:B (leafy green nutrient) and the mixture of fruit waste fertilizer with fertilizer A:B on the plant growth. Based on the experimental works, it can be observed that the fertiliser A:B (leafy green nutrient) has a fast response on growth towards the pak-choi plant growth in which it germinated on the second day and within ten days. Fertilizer A:B has additional macronutrients, which are Chlorine and Copper, that is essential for plant growth and development.

Keywords: pak-choi; fertiliser, nutrient solutions, hydroponic, cultivation, germination.

INTRODUCTION

Pak-choi *(Brassica chinensis L.)* is the main leafy vegetable in Asia, especially in China [1]. Pak-choi is also identified as Chinese cabbage, and it is known as an individual from the Cruciferae [2]. One of the beauties of pak-choi is its versatility. The whole plant is edible and can be eaten at almost any stage. Moreover, pak-choi is being an important ingredient in many Chinese recipes. Pak-choi can be cultivated by soils or in a hydroponics system. However, there is a possibility of using areas that are unsuitable for conventional agriculture such as arid, degraded soil and soil pollution. Therefore, the hydroponics system is introduced as one of the best ways to cultivate pak-choi plants.

The hydroponic system has been focused as the technique of cultivation for growing plants in highly oxygenated and nutrient-enriched water rather than soil [3]. The hydroponic system is where the plants grow with their roots within a channel through which the nutrient solutions circulate. Hydroponic has some advantages, such as; activities in hydroponic is more gentle rather than soil, hydroponic shows a quick economic return due to the shortening of the plant cycle, and high environmental benefit as it shows the optimal efficiency in the use of water and nutrients [4]. On the other hand, hydroponic also has some disadvantages; such as; this system consumes a lot of water to grow plants even though the water efficiency is much higher rather than farming in the soil [5] and the need to monitor and control the nutrient solutions [4].

Fundamentals in vegetable productions, for both soils and hydroponics system, it is essential to provide the plants with all the nutrients that the plant needs [4]. The hydroponic nutrient solution is to supply the plant roots with water, oxygen and essential mineral elements in the soluble form [6]. Moreover, nutrient solutions play an important role in the quality and productivity of pak-choi. Therefore, balanced nutrients must consist of macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and Sulphur (S) and micronutrients such as iron (Fe), boron (B), zinc (Zn), nickel (Ni), chlorine (Cl) and copper (Cu) for the growth and in determining the quality of the plants. The objective of this study is to assess the effects of different nutrient solutions solution on the growth and development of pak-choi in a hydroponics system.

METHODOLOGY

Seedlings Culture Conditions

Pak-choi was cultivated using perlite medium at different nutrient solutions.

Nutrient solutions that were used in this study are fruit waste fertiliser, fertiliser A:B (leafy green nutrient) and a mixture of fruit waste fertiliser and fertiliser A:B. The electrical conductivity of the fertilisers for seedlings stage is between 1500 µS/cm–2500 µS/cm. The non-circulating hydroponic growing system was used in which seedlings were transferred to plant pots filled with perlite medium and immersed in nutrient solutions. The schematic diagram of the non-circulating hydroponic system is shown in Figure 1 [7]. Moreover, the pH values of the nutrient solutions need to be maintained between 5.5 and 6.5 because within this range; the plants will have greater availability of nutrients [4].

Nutrient Solutions Analysis

Macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Cu, B, Zn, Cu, Ni, Cl) of nutrient solutions were determined using several analyses. Ion chromatography (IC), atomic absorption spectroscopy (AAS) and x-ray fluorescence (XRF) are the analysis that was used to determine the ion and the elemental composition of the nutrient solutions and also their concentrations. The electrical conductivity of the nutrients was measured by using an electrical conductivity meter to control the concentration of the nutrients [8]. Moreover, the pH meter was used to measure the pH value of the nutrient solutions.

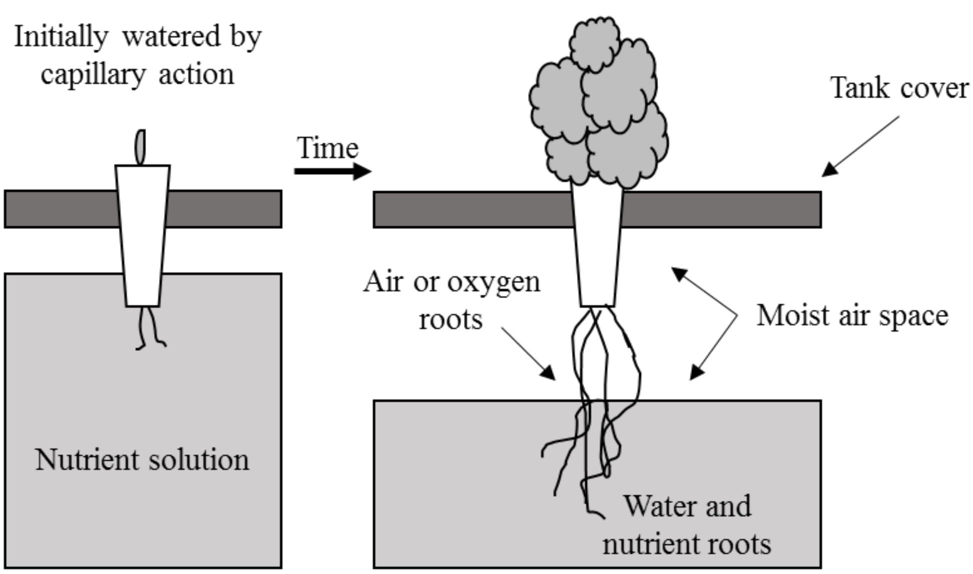


Figure 1 Schematic diagram of the non-circulating hydroponic system [7]

The response of Pak-choi on the Growth Performance in Different Nutrient Solutions

The growth of pak-choi was observed in three different hydroponic nutrient solutions; hydroponics fruit waste fertiliser, fertiliser A:B (leafy green nutrient) and the mixture of fruit waste fertiliser and fertiliser A:B. The ratio of the fertiliser to water was taken into consideration. The hydroponic nutrient solutions were in soluble form and were dissolved in the water. The objective of this experiment is to determine the best nutrient solution in enhancing the growth of pak-choi. The number of leaves per plant and plant height was measured and recorded within ten days. The flowchart of plant growth monitoring is shown in Figure 2.

Statistical Analysis

Data from each experiment were analysed by analysis of variance (ANOVA) to detect any significant differences of error. A least significant difference ($p = 0.05$) was calculated for variables exhibiting significance in the ANOVA.

RESULTS AND DISCUSSION

Pak-Choi Growth Observation

The application of different liquid fertilisers had significantly influenced the growth of pak-choi, especially during germination, the height of each plant and also the number of leaves. For this experiment, it

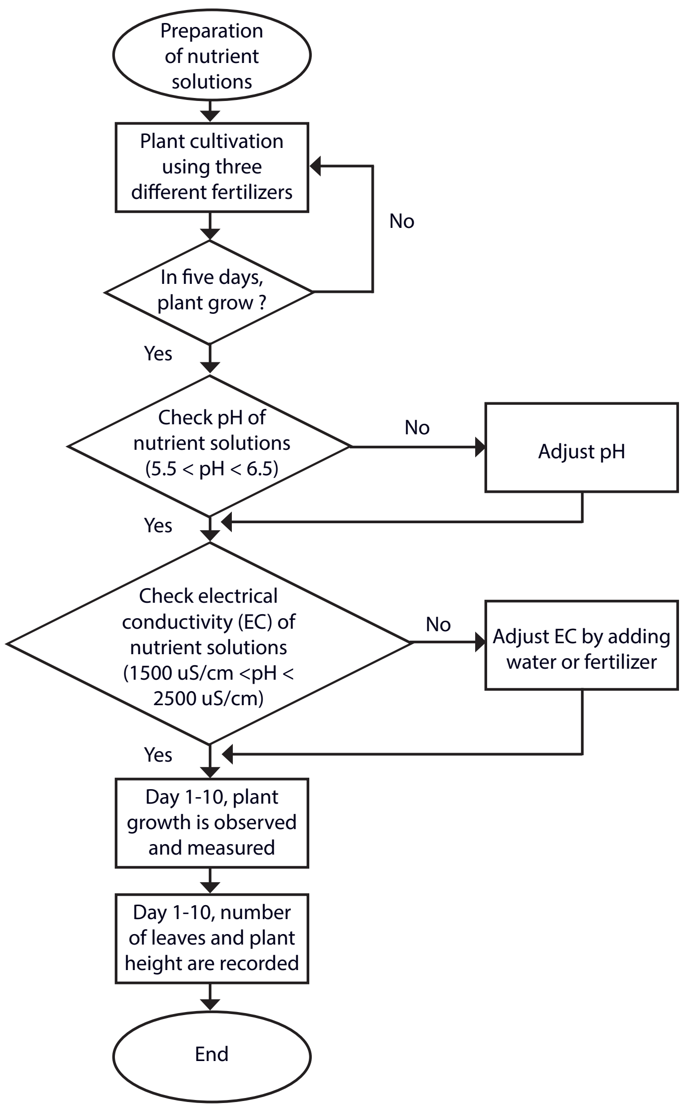


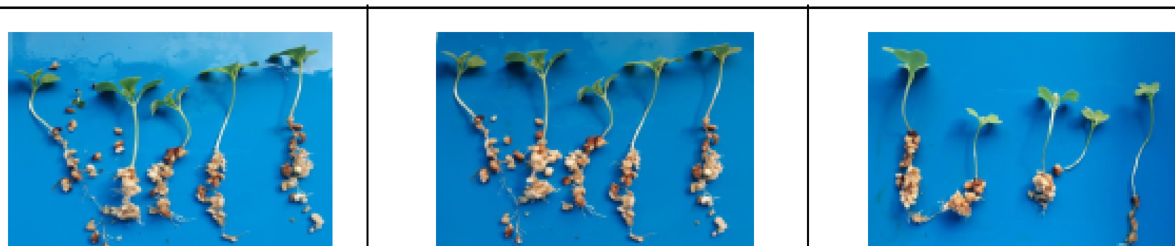
Figure 2 Flowchart of plant growth monitoring

was observed that the pak-choi seedling germinates faster in fertiliser A:B (leafy green nutrient) as it takes only two days for all the five pots of seedlings to grow compared to the fruit waste fertiliser and mixture of fruit waste fertiliser and fertiliser A:B. The seedlings of pak-choi showed a great response in fertiliser A:B (leafy green nutrient) because most of the macronutrients and micronutrients are found in commercial hydroponic solutions [9]. Besides, it is observed that the numbers of leaves of pak-choi plants in different nutrient solutions increase on the eighth day, and as shown in Figure 3. Most number of leaves on plants that were cultivated in fertiliser A:B in which the pak-choi has the highest leaf number when cultivated in 100% commercial hydroponic solution [10].

Meanwhile, Figure 4 illustrates the height of the pak-choi plants in the three different nutrient solutions. It is noticed that the plants' height is the highest for fertiliser A:B (leafy green nutrient) ($p = 0.5$). Within ten days, the plants' height and the number of leaves of pak-choi plants in different nutrient solutions were observed, measured and tabulated in the graphical method, as shown in Figure 5.

Fertilizer A:B	Fruit: waste	A : B : Fruit waste

Figure 3 Number of leaves of pak-choi plants in different fertilisers



Fertilizer A:B	Fruit: waste	A : B : Fruit waste

Figure 4 Height of pak-choi plants in different fertilisers

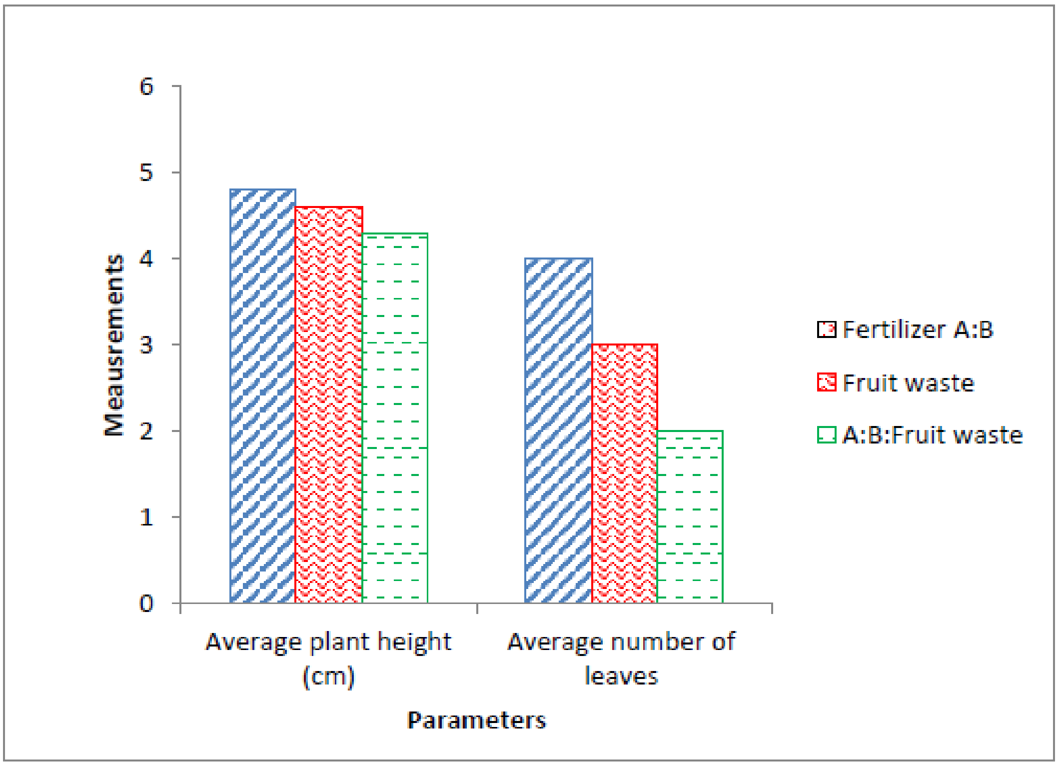


Figure 5 Measurements of plant height and average number of leaves in different fertilisers

Nutrient Solutions Analysis

The growth performance of pak-choi plants did not differ significantly between A:B fertiliser, fruit waste fertiliser and the mixture of fertiliser A:B with fruit waste. There were slightly different in growth performance of the plants because all nutrient solutions consist of macronutrients, which are P, Ca and ammonium nitrogen. These elements and ions of the nutrient solutions were being analysed by using x-ray fluorescence (XRF), atomic absorption spectroscopy (AAS) and ion chromatography (IC) to observe the effect of elements and ions on the growth performance of the plants.

X-Ray Fluorescence (XRF)

X-ray fluorescence (XRF) is one of the non-destructive analytical technique that has been used to determine the elemental composition of materials. In this project, perlite as a growing medium and nutrient solutions, which are fertiliser A:B and fruit waste and also a mixture of fertiliser A:B and fruit waste were sent for characterisation using XRF. The concentration of the samples was analysed in the percentage of parts per million as tabulated in Table 1.

There were slightly different in the growth performance of the plants because all nutrient solutions consist of macronutrients, which are phosphorus and calcium. Phosphorus helps in increasing the straw and stalk strength while the calcium helps in improving the root formation. Pak-choi plants grown better in fertiliser A:B compared to others because based on the XRF analysis, the presence of chlorine is found in A:B fertiliser. Chlorine functions in growth and development of plants where chlorine has few roles in the plants such as photosynthesis, osmotic changes and destruction of plant disease [11]. Even though mixture of fertilizer A:B with fruit waste had the most elements which are sulphur (S), silicon (Si) and rubidium (Ru) but the concentration is very low, and moreover, the presence of Si and Ru is not necessary for the plant as both are not the elements of macronutrients or micronutrients.

Table 1 X-Ray Fluorescence (XRF) results

Fertilizer Composition	Concentration (% ppm)		
	A:B	Fruit Waste (FW)	A:B:FW
P	29.5	39.2	25.1
K	-	-	16.6
S	-	-	3.20
Ca	28.2	35.7	43.6
Fe	11.0	11.4	-
Ce	10.8	-	-
Cl	5.64	-	-
Cu	3.20	-	5.94
Si	-	-	1.49
Ru	-	-	4.04

Atomic Absorption Spectroscopy (AAS)

Atomic absorption spectroscopy (AAS) is one of the analytical techniques that measure the concentrations of the elements. The samples that were analysed are fertiliser A:B, fruit waste fertiliser and the mixture of fruit waste fertiliser with fertiliser A:B. The presence of heavy metals, which are copper (Cu), iron (Fe) and zinc (Zn) was analysed in all samples. From AAS analysis, it was found that the Cu element only presents in fertiliser A:B with concentration reading of 1.28 ppm meanwhile in fruit waste fertiliser and the mixture of fertiliser A:B and fruit waste, there is no Cu element detected. The result is then being tabulated in Table 2. With Cu presents in fertiliser A:B, the nutrient element can promote enzymes and light reactions for the plant growth [12]. Process of photosynthesis also required Cu as an additional nutrient [13], which can also assist in plant metabolism of carbohydrates and proteins. It is also showed that fertiliser A:B promoted the growth of the pak-choi because this fertiliser had a high concentration of Zn as the Zn helps in enzyme activation that is responsible for the synthesis of certain proteins. Besides, the presence of Zn promotes the formation of plant hormones such as auxin and tryptophan, which help with growth regulation and stem elongation [14].

Ion Chromatography (IC)

Ion chromatography on anion as tabulated in Table 3 shows that fertiliser A:B had a high concentration of nitrate. Fertilizer A:B exceeds the concentration limit of nitrate on the plant as Liu et al. [1] claimed that it is essential to cultivate the edible crops with low nitrate content in which the concentration must be within 10 - 300 ppm. The fruit waste fertiliser has a suitable concentration of nitrate, and hence, the plant has rapid growth, and chlorophyll formation also can be promoted. Because of that, the growth performance of fruit waste fertiliser and fertiliser A:B did not differ significantly. Moreover, compromising between crop production and environment conservation can be achieved when using organic fertiliser for plant growth [15]. As for ion chromatography on cation, as tabulated in Table 4, it is shown that the nitrate and ammonium could be found in all fertilisers. Both forms of nitrogen (N) give a different effect on plant growth. Ammonium contributes to better, long-lasting control of pH for the root environment [16]. This is because both process of nitrification and a preferential ammonium uptake, in which it is accompanied by the hydrogen released by the roots. Nitrate is taken up from the soil by plants and then is accumulated in the stems and leaves when nitrate amount is high. Young plants are preferred to have more levels of nitrates compared to mature plants [17]. The results described that all pak-choi plants received the macronutrients of nitrogen from the fertilisers. Table 4 shows the results of ion chromatography of cation.

Table 2 Atomic Absorption Spectroscopy (AAS) Results

Elements/Fertilizers	Concentration (ppm)		
	A:B	Fruit Waste (FW)	A:B:FW
Cu	1.28	-	-
Fe	0.87	1.70	1.40
Zu	0.98	0.43	0.83

Table 3 Ion Chromatography (IC) of Anion Results

Elements/Fertilizers	Concentration (ppm)		
	A:B	Fruit Waste (FW)	A:B:FW
Fluoride	0.627	-	-
Chloride	5.324	-	-
Bromide	0.274	-	0.651
Nitrate	1763.705	12.397	1.359

Table 4 Ion Chromatography (IC) of Cation Results

Elements/Fertilizers	Concentration (ppm)		
	A:B	Fruit Waste (FW)	A:B:FW
Ammonium	33.636	3.386	3.177
Magnesium	-	15.467	-

CONCLUSION

The response of pak-choi plants is excellent as the plants are fed with sufficient nutrient solutions. Hence, fertiliser A:B is the best nutrient solution since it enhances the plants' growing in which the plants have the most germination of seedlings on the second day compared with others. Moreover, pak-choi plants had excellent growth performance when cultivated in fertiliser A:B as it has a high number of leaves and plant height. The elements and ions in the fertilizer A:B, fruit waste fertilizer and fertilizer A:B: fruit waste were also analyzed by x-ray fluorescence (XRF), atomic absorption spectroscopy (AAS) and ion chromatography (IC) and hence it showed that additional elements and ions present in A:B fertilizer such as Chlorine and Copper help the pak-choi to grow better.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial assistance from Universiti Teknologi PETRONAS and facilities support from Centre for Biofuel and Biochemical Research (CBBR) and Chemical Engineering Department, Universiti Teknologi PETRONAS.

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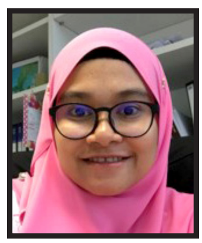

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