Nutrient Uptake, Partitioning, and Production of Two Subspecies of Brassica using Different Solution Concentrates in Floating Hydroponics Systems

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Article Information	ABSTRACT
	In this study, we investigated nutrient uptake, partitioning, and production of two subspecies of Brassica in response to nutrient solution concentration in floating hydroponics systems. This study used a complete randomized block design factorial with two factors. The first factor was two Brassica subspecies consisting of *Brassica rapa* subsp. *chinensis* (Pak Choi) and *Brassica rapa* var. *parachinensis* (Choy Sum). The second factor was the concentration level consisting electrical conductivity (EC) 1 mS cm^{-1} and EC 2 mS cm^{-1}. The results indicated the absorption rates of nitrogen (N,) phosphorus (P), and potassium (K) in leaves, roots and stems were similar in both nutrient concentrations. In general, all combination treatments resulted more accumulation of P followed by N, also K as the smallest proportion. P was mostly accumulated at the root and leaves (19.60 to 25.90 mg g^{-1}), while majority of N was collected in leaves ranging from 18.00 to 24.30 mg g^{-1}. The highest K content was detected in the stem (10.70 to 14.20 mg g^{-1}). P uptake was 1.69 to 2.47 times higher than K, while N uptake was 1.44 to 2.04 times higher than K. Both two subspecies and concentrations performed no significant effects on nutrient uptake. Although same species, the plant growth parameters of Pak Choi and Choy Sum are very different including plant height, leaves number, width and length. Both two subspecies adapted well with both concentrations. However, significant differences were recorded in the combination of subspecies and nutrient concentration on plant growth and production parameters. To achieve higher market portion, Pak Choi would be more suitable to be planted on EC 1 mS cm^{-1}, while Choy Sum was favorable at both concentrations.

INTRODUCTION

Vegetable production needs to be supported using technology to ensure fulfillment of food and to ensure sustainable supply to the market. Conventional cultivation techniques that have been widely used are very volatile due to environmental factors. Conventional technology is also known to have weaknesses due to excessive and inaccurate

nutrient dosage. For this reason, hydroponics is needed to overcome these weaknesses. Hydroponics technology (oilless culture) offers solutions to increase agricultural production. Hydroponics has increased agricultural production throughout the world because this technology enables better efficiency of nutrients and water use as well as climate control and crop protection. One of the most developed hydroponics is the floating system. This system is considered to be easier in application and can be applied in a household scale. Floating hydroponics system can provide the nutrients required by plants, because the submerged roots can uptake nutrient elements from the solution easily and continuously (Subandi et al., 2015).

Nutritional solutions are to be considered to determine the plant products' quantity and quality. Nutrient solutions in hydroponics systems are liquids, which are a mixture of water and inorganic ions derived from dissolved salts, which are important for high-level plants. The essential elements contained in nutrient solutions have a physiological role and their existence plays a role in carrying out the life cycle of plants. In addition to nutrient composition, other factors that determine plant nutrient absorption are chemical variables in the form of electrical conductivity (EC), pH and temperature of the solution. Electrical conductivity describes the ability of the solution to conduct the flow of electricity in mS cm^{-1}, which also describes the concentration of the solution or ions. EC is important because each plant species have the different range.

The Brassica genus consists of 37 different species, which is widely used as food particularly important vegetable, condiment, and edible oil. Pak Choi (*Brassica rapa* L. var. *chinensis*) is a vegetable commodity that is widely consumed in Indonesia. Beside Pak Choi, Choy Sum/Cai Xin (*Brassica rapa* var. *parachinensis*is/*B. chinensis* var. *parachinensis*) is another leafy vegetable, which is used in many types of Indonesian cuisine. These vegetables are widely consumed because of their taste and nutrition. Pak Choi and Choy Sum mostly rich in fiber and vitamins as well as having a short life cycle in a period of a month (Kamarudin et al., 2012).

The response of Brassica on the nutrient availability differs according to species, whereas the solution concentration level can indicate the nutrition availability in hydroponics systems. The availability of nutrient also determines the nutrient uptake. N uptake by plants is determined by soil-water status (Shangguan et al., 2000). The optimal nutrient concentration depends on many factors such as crop species, plant density, growth stage, climatic conditions, and hydroponics systems (Rouphael & Colla, 2005). High nutrient concentration may enhances input costs unnecessarily, and also may lead to osmotic stress, nutrient imbalance, and ion toxicity. On the other hand, too low concentration may generate nutrient deficiencies (Fallovo et al., 2009; Luna et al., 2013). Therefore, this study was undertaken to find out the effects of nutrient concentration level on nutrient uptake, growth and production of 2 subspecies Brassica in floating hydroponics system.

MATERIAL AND METHODS

This study used a factorial completely randomized block design with two factors and three repetitions. The first factor was two Brassica subspecies consisting of *Brassica rapa* subsp. *chinensis* var Nauli F1® (Pak Choi) and *Brassica rapa* var. *parachinensis* or *Brassica chinensis* var. *parachinensis* var Tosakan® (Choy Sum). The second factor was the solution concentration level: electrical conductivity (EC) 1 and 2 mS cm^{-1}, respectively. This research was carried out in a greenhouse B, located in the Faculty of Agriculture, Universitas Sebelas Maret (UNS), Indonesia. The greenhouse temperature ranged between 32.9-41.8°C with relative humidity of 41-69%.

Hydroponics nutrient solution was made by dissolving AB Mix nutrition solution. Solution A consisted of $5Ca(NO_3)_2 \cdot NH_4 \cdot NO_3 \cdot 10H_2O$, KNO_3 and 12% Fe-EDTA. While solution B composed of KH_2PO_4, $(NH_4)_2.SO_4$, $MgSO_4$, $MnSO_4 \cdot 4H_2O$, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, H_3BO_3, and $Na_3Mo_7O_2 \cdot 4H_2O$. It contained NO_3/NH_4 ratio: 5.95, Ca/N total: 0.70, P/N total: 0.25, Mg/N total: 0.25, K/N total: 1.20, and S/N total: 0.44. Nutrient solution for EC 1 mS cm^{-1} comprised NO_3: 10.70447 ppm, NH_4: 1.799105 ppm, P: 3.12816

ppm, K: 15.05264 ppm, Ca: 8.747725 ppm, Mg: 3.098956 ppm, S: 5.50684, Fe: 0.228 ppm, Mn: 0.1 ppm, Cu: 0.0052 ppm, Zn: 0.01725 ppm, B: 0.036 ppm, and Mo: 0.0025 ppm. Nutrient solution for EC 2 mS cm^{-1} contained NO_3, NH_4, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B and Mo levels twice that of solution EC 1 mS cm^{-1}. Each hydroponics floating system was arranged using a tub with dimensions of 57.6 cm × 36.1 cm × 10 cm. Each subsystem was supported with a solution reservoir of 6660 ml.

The parameters measured were environmental condition, nutrient uptake, plant growth, and plant yield. Environmental condition consisted of pH, solution temperature (ºC), and EC changes (mS cm^{-1}) during planting period. Nutrient uptake comprised of N total (%), P total (%) and K total (%) from root, stem and leaf. N total was detected by Kjeldahl method, while P total in plant was determined using spectrophotometer at 410 nm. Observation for K total were carried out by atomic absorption spectroscopy. Plant growth parameters included plant height, leaves number, length, and width. Plant yield observation consisted of root length (cm); fresh weight (g) of leaves, stem, and shoot/market portion; dry weight (g) of leaves and stem; also leaf area (cm^2). Leaf area was estimated mathematically based on the comparison of leaf replicas weight with paper weight, using the Sitompul and Guritno formula (1995). Plant samples were subsequently dried at 70ºC. Data were analyzed using ANOVA with SPSS 20 software, then was continued by Duncan's Multiple Range Test when the variables indicated significant difference.

RESULTS AND DISCUSSION

Nutrient Uptake and Partitioning

Results indicated there were no significant variations (P>0.05) in N, P and K absorption at the roots, stems and leaves at both subspecies. The highest P and N content were found in the roots and leaves, respectively at both subspecies (Table 1). Meanwhile, the highest K content was found in the stem. The distribution of nutrients in the Brassica species exhibited a different pattern with the partitioning of nutrients in oil palm seedlings. In oil palm seedlings, the largest nutrient partition was

detected in the shoot compared to the root for N, P and K (Mohidin et al., 2015). Similarly, the accumulation of P was predominantly in shoots at *Lantana camara* (Kim and Li, 2016). The nutrient uptake by the roots and stems of Pak Choi and Choy Sum was dominated by phosphorus. However, the proportion of P uptake was higher in the root than in the stem. The highest P level was obtained in the root by 2.28 ± 0.42%. Conversely, K absorption was the lowest both in the roots and in the leaves reached merely 0.61±0.18%. N content in the roots' tissues varied from 1.35 ± 0.26% in Pak Choi and 1.65 ± 0.24% in Choy Sum. The highest nutrient uptake in the stem was P, followed by K and N, whereas it was N in the leaves. N total in the shoot was a more reliable sign of N status in crop (Hocking 2001). Plant uptake was the most important removal mechanism in N, P_2O_5 and K_2O cycling (Mohidin et al., 2015).

Solutions with different concentrations (EC) also did not influence the absorption rates of N, P, and K (Table 2). Therefore, it could be inferred that nutrient uptake by plants was not determined by the solution concentration as the growth environment factor, but more determined by plant ability in accumulating certain nutrients. According to EC treatments, plant's parts demonstrated different patterns of nutrient accumulation. The root exhibited higher total P with very low K, while total N was nearly twice of K content. The higher P content was also found in stem part. The P content in shoots and roots were strongly correlated with supplied phosphate ions (Pi) concentrations (Basirat et al., 2011). In this study, P was supplied from KH_2PO_4 with P concentration of 3.12816 and 6.25632 ppm for EC 1 and 2 mS cm^{-1}, respectively. In such cases, lower P content led to the similar absorption. For this reason, phosphorus utilization efficiency increased with lower P supply (Kim & Li 2016). For leaves, the biggest proportion was nitrogen. The impact of water source on plant growth and mineral nutrition varied regarding species and vegetables variety (Niu et al,. 2018).

N content in the root and P content in the stem was significantly affected by the combination of species and nutrient concentration. The highest N percentage at the root was detected in Pak Choi on EC 1 mS cm^{-1}, Pak Choi on EC 2 mS cm^{-1} and Choy

Sum on EC 1 mS cm^{-1} reaching 1.63±0.35%, 1.56±0.18% and 1.67±0.17%, respectively. Conversely, the greatest P were yielded in Choy Sum on both EC 1 and EC 2 solutions achieving 1.70±0.04% and 1.87±0.16%, respectively (Table 3). In general, based on accumulation in total dry mass, the order of accumulation was P>N>K at all combination treatments (Table 4). P uptake ranged from 17.34 to 21.01 mg g^{-1}, which was 1.69 to 2.47 higher than K (8.52 to 10.24 mg g^{-1}). However, if

focus on nutrition in each part of the plant, the nutrients content order was P in roots > N in leaves > P in leaves (Table 5). P was mostly gathered at the root and leaves of 19.60 mg g^{-1} to 25.90 mg g^{-1}. According to Fernandes and Sorattomore (2012), more P was allocated in roots to ensure plant growth. While majority N was collected in leaves ranging from 18.00mg g^{-1} to 24.30 mg g^{-1}. This N accumulation performed the same pattern in cotton, but P absorbed evenly almost in all parts of cotton crop (Singh et al., 2013).

Table 1. Macronutrient contents in plant parts

Plant part	Species	Nutrient Uptake		
		N (%)	P (%)	K (%)
Root	Pak Choi	1.35±0.26	2.28±0.42	0.68±0.08
	Choy Sum	1.65±0.24	2.34±0.30	0.61±0.18
Stem	Pak Choi	1.14±0.15	1.67±0.28	1.38±0.23
	Choy Sum	1.16±0.02	1.56±0.16	1.19±0.30
Leaves	Pak Choi	2.11±0.87	2.11±0.35	0.68±0.04
	Choy Sum	2.29±0.20	2.21±0.22	0.76±0.08

Note: Values following ± symbol are the standard deviation of the mean

Table 2. Macronutrient contents in different solution concentration

Plant parts	Initial EC (mS cm-1)	N (%)	P (%)	K (%)
Root	1	1.41±0.31	2.50±0.16	0.65±0.03
	2	1.59±0.25	2.11±0.39	0.64±0.20
Stem	1	1.16±0.13	1.79±0.14	1.32±0.10
	2	1.14±0.07	1.44±0.14	1.25±0.39
Leaves	1	2.38±0.18	2.18±0.30	0.74±0.09
	2	2.03±0.84	2.14±0.30	0.70±0.05

Note: Values following ± symbol are the standard deviation of the mean

Environmental Condition

During plant growth, the temperature and pH of the solution were stable (Table 6). The solution daily temperature ranged from 27.10±0.17ºC to 28.10±0.34ºC. This was in accordance with the results by Frantz et al. (2004) which stated temperatures between 27 and 30ºC (nutrient solution and above ground part) yielded greater daily carbon gain and positively influenced the leaves expansion. Water temperature might influence various physiological systems during plant growth and development. Temperatures above or below optimum levels could affect plant metabolic activities negatively or positively. The

optimum temperature of the solution could contribute to improve and promote plant physiological processes (Nxawe et al., 2010). The solution temperature affected the oxygen content. When the temperature elevated more than optimum, it could cause the root to die as well as accelerate the bolding process in lettuce (Cometti et al., 2013).

The solution's pH ranged from 4.83±0.14 to 5.62±0.75, while recommended pH for hydroponics nutrient solution is 5-6 (Subandi et al., 2015). However, EC began to increase to 0.58 mS cm^{-1} from the 3rd and 4th week. The level of concentration began to rise, possibly due to the use of solutions (nutrients and water) by plants during the maximum

Table 3. N, P, K uptake (%) from root, stem and leaves

Combination	Root			Stem			Leaves		
Species and EC	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Pak Choi in EC 1	1.63a±0.35	2.26±0.46	0.66±0.02	1.15±0.02	1.41c±0.017	1.33±0.06	2.25±0.18	2.31±0.22	0.72±0.06
Pak Choi in EC 2	1.56a±0.18	1.96±0.32	0.71±0.12	1.14±0.11	1.46bc±0.22	1.42±0.35	1.80±1.26	1.97±0.31	0.68±0.02
Choy Sum in EC 1	1.67a±0.17	2.41±0.04	0.64±0.05	1.17±0.02	1.70ab±0.04	1.31±0.15	2.33±0.25	2.11±0.21	0.80±0.08
Choy Sum in EC 2	1.14b±0.10	2.59±0.20	0.57±0.28	1.15±0.21	1.87a±0.16	1.07±0.41	2.43±0.11	2.25±0.40	0.68±0.07

Note: Values following ± symbol are the standard deviation of the mean. EC 1 = electrical conductivity 1 mS cm^{-1}, EC 2 = electrical conductivity 2 mS cm^{-1}

Table 4. N, P, K uptake (mg g^{-1}) from total dry mass and nutrient proportion

Combination	Nutrient uptake (mg g^{-1})			Proportion		
Species and EC	N	P	K	P/N	P/K	N/K
Pak Choi in EC 1	17.56	19.47	9.57	1.11	2.03	1.83
Pak Choi in EC 2	14.79	17.34	10.24	1.17	1.69	1.44
Choy Sum in EC 1	17.97	19.55	10.06	1.09	1.94	1.79
Choy Sum in EC 2	17.36	21.01	8.52	1.21	2.47	2.04

Note: EC 1 = electrical conductivity 1 mS cm^{-1}, EC 2 = electrical conductivity 2 mS cm^{-1}

Table 5. The weight of N, P, K uptake (mg g^{-1}) in root, stem and leaves on combination of species and electrical conductivity

Combination	Root			Stem			Leaves		
Species and EC	N (mg g^{-1})	P (mg g^{-1})	K (mg g^{-1})	N (mg g^{-1})	P (mg g^{-1})	K (mg g^{-1})	N (mg g^{-1})	P (mg g^{-1})	K (mg g^{-1})
Pak Choi in EC 1	16.30	22.60	6.60	11.50	14.10	13.30	22.50	23.10	7.20
Pak Choi in EC 2	15.60	19.60	7.10	11.40	14.60	14.20	18.00	19.70	6.80
Choy Sum in EC 1	16.70	24.10	6.40	11.70	17.00	13.10	23.30	21.10	8.00
Choy Sum in EC 2	11.40	25.90	5.70	11.50	18.70	10.70	24.30	22.50	6.80

Note: EC 1 = electrical conductivity 1 mS cm^{-1}, EC 2 = electrical conductivity 2 mS cm^{-1}
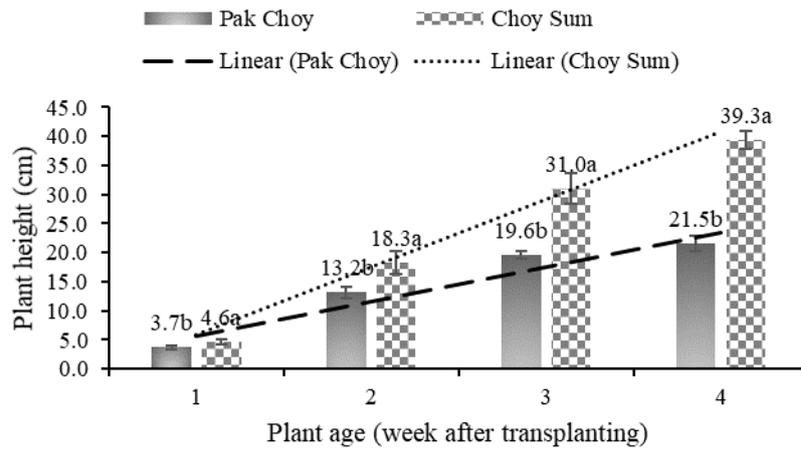
Figure 1   Plant Height on 2 Subspecies Brassica during plant growth. Values followed by the same letter in the same age are not significantly different (p < 0.05) by Duncan's multiple range test at 5%
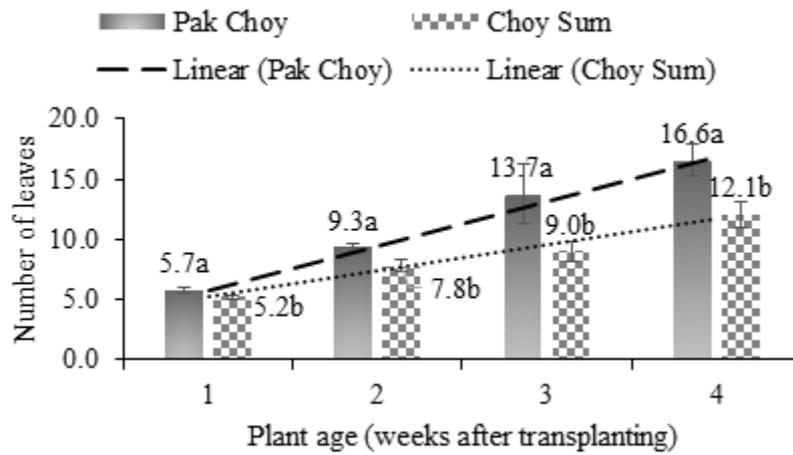

Figure 2   Number of leaves on 2 subspecies Brassica during plant growth. Values followed by the same letter in the same age are not significantly different (p < 0.05) by Duncan's multiple range test at 5%

Table 6. Temperature, pH and electrical conductivity condition based on the initial electrical conductivity

Plant age (Week)	Initial EC (mS cm^{-1})	Temperature (°C)	pH	EC (mS cm^{-1})
1	1	27.10 ±0.17	5.5±0.33	1.10±0.00
	2	27.13 ±0.22	5.62±0.75	2.10±0.00
2	1	27.33±0.26	4.98±0.26	1.10±0.00
	2	27.22±0.31	5.52±0.19	2.08±0.04
3	1	27.6±0.26	4.83±0.14	1.57±0.05
	2	27.55±0.25	5.08±0.41	2.58±0.04
4	1	27.95±0.32	5.37±0.52	1.53±0.05
	2	28.10±0.34	5.17±0.33	2.55±0.05

Note: Values following ± symbol are the standard deviation of the mean

canopy formation. According to Steidle Neto et al. (2005), EC was also determined by the nutrient solulution temperature, if the temperature increases, the solution resistance on electric current declines, yielding in higher conductivity.

Plants Growth

The plant growth parameters (height; leaves number, width and length) of Pak Choi and Choy Sum were significantly different. Choy Sum grew higher than Pak Choi every week (Figure 1). In the 4th week, Choy Sum was 82.79% higher than Pak Choi, but Pak Choi had more leaves number (Figure 2). From the first week, the number of Pak Choi leaves were more than Choy Sum until the fourth week. However, the leaves length and width were produced more in Choy Sum (Figure 3 and 4). Hence, this study revealed that the performance of plants was largely determined by the character of each species.

In contrast to subspecies effects, the application of EC 1 and EC 2 produced similar growth performance in terms of plant height, leaves number, leaves width and length from the first week to the harvest period (Table 7). This result was inconsistent with Andriolo (2009) that the increasing nutrient solution concentration reduced plant growth of strawberry in a closed hydroponics growing system.

However, the interaction of subspecies and nutrients concentration was significant on all growth parameters. From the first week to harvest period, Pak Choi and Choy Sum on EC1 generated higher plants performance (Table 8). Pak Choi on EC 1 was 90% higher than on EC2, while Choy Sum on EC1 was 60% higher than on EC2. However, plant height was inversely proportional to the number of leaves. Pak Choi and Choy Sum on EC1 produced less leaves than on EC2 (Table 9). This started from the first week after transplanting and reached the highest number in the harvest period. This response was also confirmed by Schwarz et al. (2002) that the increasing EC reduces tomato's growth, inhibit photosynthesis, and decrease the yield. Although less leaves number, but the use of Pak Choi and Choy Sum on EC 1 generated larger leaves indicated by significantly wider and longer leaves (Table 10). This suggested that Pak Choi and Choy Sum on a hydroponics floating system with nutrient concentration of 1 mS cm^{-1} had sufficiently fulfilled the needs for plant growth. In addition, the Brassica crops in this study tolerated the EC concentration of all treatments, because the EC threshold of most vegetable crops was low (Machado & Serralheiro, 2017).
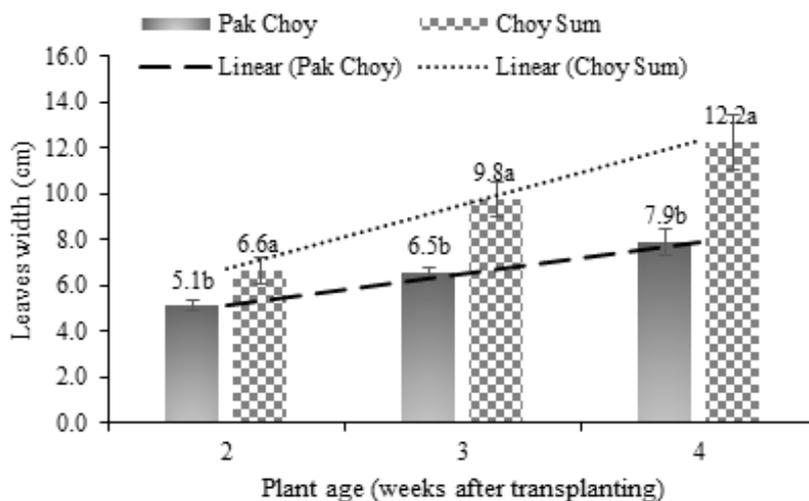

Figure 3   Leaves width on 2 subspecies Brassica during plant growth. Values followed by the same letter in the same age are not significantly different (p < 0.05) by Duncan's multiple range test at 5%
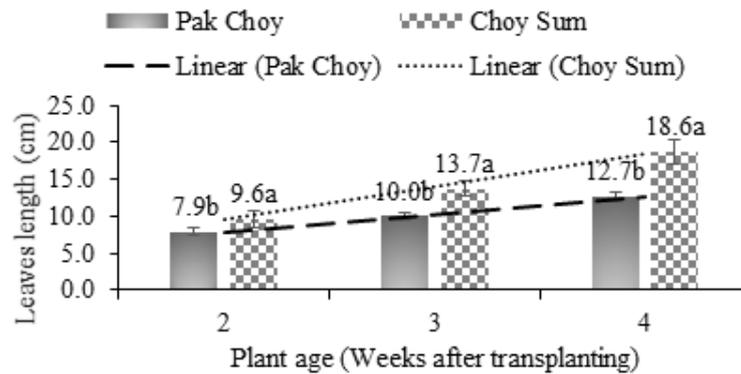
Figure 4   Leaves length on 2 subspecies Brassica during plant growth. Values followed by the same letter in the same age are not significantly different (p < 0.05) by Duncan's multiple range test at 5%

Table 7. Effect of initial electrical conductivity on plant height, number of leaves, leaves length, and leaves width during plant growth

Plant age (Week)	Initial EC (mS/cm)	Plant Height (cm)	Number of Leaves	Leaves length (cm)	Leaves width (cm)
1	1	4.18±0.35	5.5±0.4	-	-
	2	4.19±0.83	5.5±0.4	-	-
2	1	15.42±2.42	8.5±1.1	8.74±0.82	5.88±0.89
	2	16.07±3.81	8.6±0.7	8.75±1.63	5.81±0.99
3	1	25.60±6.36	11.0±2.2	11.82±1.87	8.05±1.81
	2	25.08±6.68	11.8±3.9	11.90±2.44	8.27±1.89
4	1	30.86±9.34	14.5±3.1	15.21±2.97	9.83±2.25
	2	29.97±10.31	14.1±2.3	16.10±3.87	10.27±2.83

Note: Values following ± symbol are the standard deviation of the mean

Table 8. Effect of combination of species and initial electrical conductivity on plant height

Combinations of species and initial EC	Plant height (cm)			
	1st week	2nd week	3rd week	4th week
Pak Choi in EC 1	4.85±0.59a	19.33±1.82a	30.77±3.71a	39.28±2.07a
Pak Choi in EC 2	3.53±0.27c	12.80±0.97b	19.39±0.68b	20.66±1.14b
Choy Sum in EC 1	4.43±0.31ab	17.28±1.83a	31.31±1.73a	39.35±1.13a
Choy Sum in EC 2	3.94±0.21bc	13.56±0.94b	19.89±0.66b	22.37±0.79b

Note: Values following ± symbol are the standard deviation of the mean. Values in the same column followed by the same letter are not significantly different (p < 0.05) by Duncan's multiple range test at 5%

Table 9. Effect of combination of species and initial electrical conductivity on number of leaves

Combinations of species and initial EC	Number of leaves			
	1st week	2nd week	3rd week	4th week
Pak Choi in EC 1	5.27±0.12bc	8.07±0.46b	9.00±1.20b	12.40±1.44b
Pak Choi in EC 2	5.67±0.42ab	9.13±0.42a	14.56±3.58a	15.87±1.50a
Choy Sum in EC 1	5.13±0.12c	7.53±0.31b	9.00±0.35b	11.73±0.70b
Choy Sum in EC 2	5.80±0.00a	9.53±0.31a	12.93±0.81a	17.27±0.81a

Note: Values following ± symbol are the standard deviation of the mean. Values in the same column followed by the same letter are not significantly different (p < 0.05) by Duncan's multiple range test at 5%.

Table 10. Effect of combination of species and initial electrical conductivity on width and length of leaves

Combinations of species and EC	Leaves width			Leaves length		
	2nd week	3rd week	4th week	2nd week	3rd week	4th week
S1E1	6.56±0.83a	9.93±0.75a	12.75±1.04a	9.89±1.60a	14.07±0.74a	19.45±1.73a
S1E2	5.05±0.22b	6.61±0.37b	7.79±0.70b	7.61±0.46b	9.74±0.56b	12.74±0.84b
S2E1	6.65±0.36a	9.62±0.87a	11.70±1.36a	9.37±0.45ab	13.37±1.16a	17.79±1.39a
S2E2	5.11±0.27b	6.48±0.10b	7.95±0.52b	8.11±0.55ab	10.27±0.48b	12.63±0.47b

Note: Values following ± symbol are the standard deviation of the mean. Means in the same column followed by the same letter are not significantly different ($p < 0.05$) by Duncan's multiple range test at 5%. S1=Pak Choi, S2 = Choy Sum, E1 = electrical conductivity 1 mS cm^{-1}, E2 = electrical conductivity 2 mS cm^{-1}

Plant Yield

Among all plant yield parameters, root length and leaves area confirmed the effects of subspecies on yield performance (Table 11). Choy sum produced longer root and wider leaves compared to Pak Choi. The root and leaves of Choy Sum was 31% longer and 67.6% wider than Pak Choi, respectively.

Table 12 indicates EC treatment resulting in similar performance of yields. However, the application of 1 mS cm^{-1} EC obtained higher market portion or shoot fresh weight than that of 2mS cm^{-1}.

It implies 1 mS cm^{-1} EC is optimum for most of the agronomic parameters and Brassica growth. Nutrient solution with low EC concentration (approximately 1.0 dS m^{-1}) could be applied in the hydroponics for potato mini tubers production (Novella et al., 2008). But, this result was different from previous research conducted by Subandi et al. (2015) which reported that the highest growth and yield of spinach on floating hydroponics were resulted from 3.0 mS cm^{-1} EC of nutrient solution. However, this finding also reaffirmed Kang & Iersel (2002) that plant growth of alyssum (*Lobularia maritima* (L.) Desv. 'New Carpet of Snow') was maximum in 2.1 dS m^{-1} EC of growing medium. Besides, the highest shoot dry mass of celosia (*Celosia argentea* L. 'Gloria Scarlet') was achieved when plants were in a growing medium EC of 1.1–2.5 dS m^{-1}.

EC treatment did not affect the root length. This finding was in line with Subandi et al. (2015) which stated that the use of solutions with EC 1.5 mS cm^{-1} to 3.0 mS cm^{-1} did not affect the length of the root of the spinach which was cultivated with a floating hydroponics system.

Table 13 shows the combination of subspecies and EC concentration treatments yielded the highest leaves area of Pak Choi and Choy Sum on 1 mS cm^{-1} EC were 1061.57±182.88 and 826.02±85.62 cm^2 plant^{-1}, respectively. According to the combination treatment, for producing high market portion, Pak Choi in EC 1 generated higher market portion of 62.52±6.60 g. On the other hand, cultivating Pak Choi in EC 2 would reduce the market portion of 28.7%. However, for achieving higher market portion in Choy Sum, both EC1 or EC 2 could be applied in Floating Hydroponics Systems with the yield ranging from 54.83±3.35 to 61.31±11.09 g.

CONCLUSION AND RECOMMENDATIONS

The absorption rates of N, P, and K in leaves, roots and stems were similar in both nutrient concentrations. In general, all combination treatments accumulated more phosphorus, nitrogen at the second position and potassium as the smallest proportion. P mostly accumulated at the root and leaves of 19.60 mg g^{-1} to 25.90 mg g^{-1}. While majority N was collected in leaves ranging from 18.00 mg g^{-1} to 24.30 mg g^{-1}. The highest K was detected in the stem of 10.70 mg g^{-1} to 14.20 mg g^{-1}. P uptake was 1.69 to 2.47 times higher than K. While N uptake was 1.44 to 2.04 times higher than K. Both 2 Brassica subspecies and 2 nutrient concentrations performed no significant effects on nutrient uptake, but influenced the growth parameters including plant height, number of leaves, leaves width and leaves length. Both 2 subspecies adapted well on both solution concentrations, however, the combination of subspecies and nutrient concentration effected plant growth and production. To achieve higher market -

Table 11. Effect of 2 species of brassica on root length, leaves fresh weight, stem fresh weight, shoot fresh weight (market portion), root dry weight, leaves dry weight, stem dry weight and leaves area

Species	Root length (cm)	Leaves fresh weight (g)	Stem fresh weight (g)	Shoot fresh weight/ market portion (g)	Root dry weight (g)	Leaves dry weight (g)	Stem dry weight (g)	Leaves area (cm2)
Pak Choi	22.99b±3.34	20.90±4.04	33.30±7.05	52.96±12.09	1.72±0.48	10.67±1.92	10.64±2.47	563.10b±136.26
Choy Sum	30.17a±4.41	26.23±4.58	31.09±4.52	58.67±6.30	1.98±0.97	13.11±2.84	10.50±1.48	943.80a±181.54

Note: Values following ± symbol are the standard deviation of the mean

Table 12. Effect of initial electrical conductivity on root length, leaves fresh weight, stem fresh weight, shoot fresh weight (market portion), root dry weight, leaves dry weight, stem dry weight and leaves area

Initial EC (mS cm^{-1})	Root length (cm)	Leaves fresh weight (g)	Stem fresh weight (g)	Shoot fresh weight/ market portion (g)	Root dry weight (g)	Leaves dry weight (g)	Stem dry weight (g)	Leaves area (cm2)
1.0	24.92±4.82	23.53±2.81	32.95±7.18	58.07±8.14	1.78±0.41	12.09±1.03	11.09±2.18	737.82±130.04
2.0	28.24±5.63	23.59±6.82	31.44±4.48	53.56±11.27	1.92±1.02	11.69±3.76	10.05±1.71	769.07±347.83

Note: Values following ± symbol are the standard deviation of the mean

Table 13. Effect of combination of species and initial electrical conductivity on root length, leaves fresh weight, stem fresh weight, shoot fresh weight (market portion), root dry weight, leaves dry weight, stem dry weight and leaves area

Combinations of species and initial EC	Root length (cm)	Leaves fresh weight (g)	Stem fresh weight (g)	Shoot fresh weight/ market portion (g)	Root dry weight (g)	Leaves dry weight (g)	Stem dry weight (g)	Leaves area (cm2)	Shoot Root Ratio
S1E1	31.75a±5.69	28.73a±5.54	33.51±3.39	62.52a±6.60	2.48±1.26	14.06±4.20	10.94±2.03	1061.57a±182.88	11.8±1.7ab
S1E2	24.74ab±3.16	18.45b±2.51	29.37±5.09	44.60b±5.76	1.36±0.20	9.32±1.33	9.16±0.87	476.57c±111.11	13.6±0.5ab
S2E1	28.60ab±2.96	23.72ab±1.74	28.67±4.69	54.83ab±3.35	1.49±0.12	12.16±0.78	10.05±0.88	826.02ab±85.62	15.0±1.5a
S2E2	21.23b±2.93	23.34ab±4.07	37.23±7.20	61.31a±11.09	2.07±0.39	12.01±1.42	12.13±2.8	649.63bc±107.75	11.0±2.7b

Note: Values following ± symbol are the standard deviation of the mean. Means in the same column followed by the same letter are not significantly different ($p < 0.05$) by Duncan's multiple range test at 5%. S1=Pak Choi, S2 = Choy Sum, E1 = electrical conductivity 1 mS cm^{-1}, E2 = electrical conductivity 2 mS cm^{-1}

portion, nutrient concentration of 1mS cm^{-1} EC would be more favorable for Pak Choi, while it was both 1 mS cm^{-1} and 2 mS cm^{-1} EC for Choy Sum.

ACKNOWLEDGMENT

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