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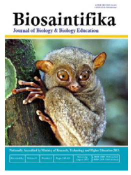

Seedling Production of Pak Choy (*Brassica rapa* L.) using Organic and Inorganic Nutrients

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Abstract

Pak Choy or Bok Choy (*Brassica rapa* L. var. chinensis) is one of favorite Chinese leafy vegetable for various dishes in Indonesia. In this study, it was used as a plant model to identify the appropriate organic hydroponic nutrient solution for leafy vegetable seedling production. The seed was sown on rock wool slabs submerged with 200 ml of a nutrient solution containing biofertilizer of *Beyonic StarTmik@Lob* (0, 25, 50, 75, and 100%). commercial hydroponic solution (0, 25, 50, 75, and 100%) and its combination (25, 50, and 75%). The experiments were arranged in a CRD. Meanwhile, the obtained data was analyzed using ANOVA followed by DMRT. The relationship among growth parameters was observed using Pearson correlation analysis. The result of the study showed that the combination of organic and inorganic nutrient (25% *Beyonic StarTmik@Lob* and 75% commercial hydroponic solution) resulted in the highest seedling growth parameters and leaf indices as well as the perfectly positive correlations among growth parameters. This result indicated that the use of organic nutrient alone was not appropriate for hydroponic seedling production of Pak Choy. Therefore, further study needs to be done to identify the hydroponic solution without inorganic nutrients towards the organic vegetable production.

How to Cite

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INTRODUCTION

Pak Choy or Bok Choy (*Brassica rapa*) was introduced to South-East Asia in the 15th century. Nowadays it is widely cultivated in this region including Indonesia. Pak Choy is one of favorite Chinese leafy vegetable in Indonesia. All above ground part of this vegetable is edible mainly its succulent petiole. It is not commonly eaten raw but used in main ingredients for soup and stir-fried dishes. Each of 100 g edible part of Pak Choy contains protein 1.7 g, fat 0.2 g, Carbohydrate 3.1 g, vitamins and minerals such as β-carotene (2.3 mg), vitamin C (53 mg) and Calcium (102 mg) (Tay & Toxopeus, 1994). The national production of *Brassica* in 2015 is 600,200 tons (Central Agency on Statistics of Indonesia, 2015). This vegetable is commonly produced by conventional farming using inorganic fertilizer to enhance crop productivity. Nowadays, the demand of organic vegetable is increased due to the public concern about healthy food, free from chemical residues. Organic farming of cauliflower (*B. oleacera* var. botrytis) in lowland area showed a better vegetative growth but not for generative growth (Widiatningrum & Pukan, 2010). Organic farming of another *Brassica* species (cauliflower) was successfully done. Therefore, the organic vegetable seedling production plays an important role, because it is the initial step in the practice of biological farming. Moreover, Kubota et al. (2013) stated that the use of high-quality planting materials is critical for success in greenhouse plant production.

The viability of small seed including Pak Coy is usually tested using a paper substrate (Purbojati & Suwarno, 2006). However, seedling production is commonly using a locally organic substrate such as peat and vermicompost (Tuzel et al., 2014), spent mushroom compost (Priadi et al., 2016) on tomato seedling, and coconut coir dust on lettuce (*Lactuca sativa* L.) (Hossain et al., 2016). Moreover, production of organic transplants involves more than organic fertilizer and substrates and avoiding the use of non-approved pesticides. These organic substrates are also as an organic nutrient source with or without the addition of inorganic and organic fertilizer. A study on the feasibility of organic nutrient solution for the hydroponic culture of leafy green vegetable was conducted by Ferguson et al. (2014). Also, the seedling production of peppermint and spearmint using inorganic and organic fertilization was previously performed by Akoumianaki-Ioannidou et al. (2010). In this study, we use both inorganic and organic nutrients using a hydroponic culture technique to identify the appropriate organic nutrient solution for Pak Choy seedling production prior a transplanting to the soil or soilless medium.

METHODS

This study was conducted from October to December 2016 in the screen house of the Germplasm Garden of RC for Biotechnology-LIPI, Cibinong, West Java. The average temperature in the screen house was 33.4°C with the relative humidity (RH) of 60.7%.

The commercial seed of Pak Choy (*Brassica rapa* Var. Nauli), produced by East-West Seed Company were obtained from a local farm shop in Bogor; West Java was used in this study. The organic nutrient solution was obtained from bio-organic fertilizer of *Beyonic StarTmik@Lob* (25 ml/l water) produced by Research Center for Biology-LIPI, whereas a commercial hydroponic solution (Raja Hidroponik) (5 ml/l) was used for the inorganic nutrient source. The seeds were sown manually on each 1 cm^3 rock wool slabs submerged in a 200 ml of nutrient solution in a plastic container (25 x 20 x 3 cm). Groundwater moistened the rock wool slabs before seed sowing. Each container consists of 25 rock wool slabs containing inorganic and organic nutrient (Table 1).

The degree of acidity (pH) and electrical conductivity (EC) of the nutrient solution were done using water/soil (2:1) extraction method at the beginning and the end of germination period using a digital portable pH and EC meter (Adwa AD1000). Seedling height was measured using a digital caliper (Nankai). Seedling leaf area was calculated using digital image analysis method (Bradshaw et al., 2007). This approach has been used by researchers in a variety of application (Priadi et al., 2016) due to the simple, inexpensive and accurate method. The water content of Pak Coy seedling was measured on a fresh weight basis method according to ISTA (2006) using a drying oven (Zenith Lab DHG9053A) at 130°C for 2 hours.

Germination parameter of the Pak Choy seedlings was germinability and germination rate. Seedling growth was observed daily and taken from 25 seedlings for each replication. Seedling height and diameter, whole leaves and roots, and leaf area were observed at the end of germination period (day-14)taken from five seedlings of each replication. Seedling emergences were recorded per day when a normal seedling was visible above the rock wool slabs. The leaf indices of SLA

Table 1. Composition of nutrient solution for hydroponic seedling production of Pak Choy

Code	Composition
K0-1	100% groundwater
K0-2	100% commercial hydroponic solution
K0-3	*Beyonic StarTmik@Lob* at the producer's recommended concentration*
K1	25% K0-3+75% groundwater
K2	50% K0-3+50% groundwater
K3	75% K0-3+25% groundwater
K4	25% K0-3+75% K02
K5	50% K0-3+50% K02
K6	75% K0-3+25% K02

Note*=25 ml in 1 liter of water

(Specific Leaf Area) and LAR (Leaf Area Ratio) were recorded to evaluate the seedling resistance at transplant (Herrera et al., 2008). The SLA is the ratio of leaf area to leaf dry weight. Meanwhile, LAR is the ratio of leaf area to dry seedling weight.

The experiments were arranged in a Completely Randomized Design (CRD) with 3 replications. Obtained data was analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT). The relationship among growth parameters was observed using Pearson correlation analysis. Data was processed using statistical software SPSS 16.0.

RESULTS AND DISCUSSION

Data in Table 2 showed that pH and EC value of the nutrient solution at the end of germination period were higher than that the initial. The higher pH is caused by anion uptake by the plant during plant growth period. Meanwhile, the higher EC is due to the high level of nutrient due to the additional nutrient solution for adjustment (Hossain et al., 2016).

Seedling Emergence

Seedling emergence is one of the important parameter as well as emergence rate. The highest all seedling growth parameter was obtained by the Pak Choy seed sown on the rock wool slabs containing 100% of groundwater (K0-1). It was not significantly different with K0-1 when the seed was sown on the rock wool slabs containing the mixture of organic and inorganic solution (25% *Beyonic StarTmik@Lob* and 75% commercial hydroponic solution). Contrary, the mixture of 75% *Beyonic StarTmik@Lob* and 25% commercial hydroponic solution (K3) resulted in the lowest seedling growth. A biofilm was formed on the root surface of the seedling in the hydroponic solution containing 100% *Beyonic StarTmik@Lob* (K0-3). Seedling growth of Pak Choy on K-03 was lower due to the biofilm formation. A study conducted by Chinta et al. (2015) found that a biofilm was formed on the root surface of organic hydroponic lettuce; in contrast, chemical hydroponics resulted in a lack of biofilm. Biofilm is formed as an interaction between beneficial microorganism and lettuce roots. Another study conducted by Fujiwara et al. (2012) on tomato seedlings found that a rhizosphere biofilm in the organic hydroponic may be responsible for the suppression of the bacterial wilt. In this study, we found that the use of *Beyonic StarTmik@Lob* alone as a nutrient solution for Pak Choy hydroponic seedling production seemed to be not appropriate to obtain optimal growth (Table 3).

Leaf Indices

The highest leaf number (5.067) was obtained from the hydroponic solution containing 100% commercial hydroponic solution (K0-2). It was not significantly different with those containing both K4 and K5. The mixture of inorganic and organic nutrient solution of K4 and K5 resulted in the best leaf area. The best SLA index was obtained from K4 nutrient solution. According to Herrera et al. (2008), the lower SLA value indicated, the higher transplant stress resistance. The LAR represents the relationship between photosynthetic material and respiratory material in the plant. It is also used for evaluation of seedling resistance at transplant. Higher LAR indicates more biomass production for seedling growth. Table 4 showed that there was not significantly different in both of SLA and LAR among the nutrient solution used except the K0-3.

Table 2. Characteristic of nutrient solution of Pak Choy hydroponic culture

Nutrient Solution	Initial		Final	
	pH	EC (dS m^{-1})	pH	EC (dS m^{-1})
K0-1	5.91	0.0	7.25	0.3
K0-2	4.53	2.2	6.44	9.7
K0-3	3.98	0.7	6.79	4.7
K-1	4.09	0.5	6.88	1.0
K-2	4.12	0.3	6.91	1.5
K-3	4.62	0.1	6.86	2.4
K-4	5.06	1.5	7.20	3.1
K-5	4.86	1.2	7.43	4.1
K-6	4.15	1.5	7.48	4.3

Table 3. Growth parameter of Pak Choy seedlings after 14-days sowing on rock wool slabs containing inorganic and organic nutrient solution in the screen house

Nutrient Solution	Emergence (%)		Rate of emergence		Height (cm)		Diameter (cm)		Total roots	
K0-1	98.667	a	7.047	a	1.580	bcd	0.9933	abc	11.800	a
K0-2	85.333	ab	6.093	ab	1.800	bc	1.0733	a	12.267	a
K0-3	60.000	bcd	4.288	bcd	2.033	b	0.7500	d	6.933	d
K-1	77.333	abc	5.524	abc	1.587	bcd	0.9267	abc	10.467	b
K-2	49.333	cd	3.520	cd	1.373	cd	0.9067	bc	10.400	b
K-3	36.000	d	2.570	d	1.200	d	0.8633	cd	8.733	c
K-4	78.667	abc	5.620	abc	2.847	a	1.0633	ab	12.400	a
K-5	66.667	bcd	4.763	bcd	2.573	a	1.0667	ab	12.067	a
K-6	56.000	bcd	3.997	bcd	1.873	b	0.9600	abc	10.333	b

Note: Means in the same column followed by the different letter are significantly different ($p<0.05$) according to DMRT

Seedling dry weight

The highest Pak Choy seedling dry weight was obtained in the hydroponic solution containing biofertilizer of Beyonic StarTmik@Lob (K-03) (Table 5 and Figure 1). This biofertilizer was supported by PGPR (Plant growth promoting rhizobacteria) (Dewi et al., 2015). It was suggested that the higher seedling dry weight was affected by the hydroponic solution containing PGPR as explained by Bashan & de-Bashan (2010), since PGPR at the very early stage leading to better absorption of water and minerals. The result of this study agrees with a study conducted by Das et al. (2014) on organically cultivated mungbean using the organic manure containing PGPR.

The lower seedling dry weight was obtained on a mixture of organic and inorganic nutrient solution (25% *Beyonic StarTmik@Lob* and 75% inorganic nutrient solution). The dry seedling weight of Pak Choy seems to be affected by the availability of *Beyonic StarTmik* in the nutrient solution. A study conducted by Ferguson et al. (2014) showed that hydroponic culture of Bok Choy using organic nutrient solution resulted in the lower yield compared with those low or high-level inorganic nutrients. Nevertheless, the price of the organic product is much higher than the conventional product.

Correlation among growth parameters

Correlation among Pak Choy seedling growth parameters in the nutrient solution used is varied. There was perfectly positive correlation between total leaves (TL) and both stem dry weight (SW) and whole seedling dry weight (TW) as well as the correlation between leaf area (LA) and TW and between SW and TW on K4 nutrient solution (Table 6). It was reasonable that the increased in the whole seedling dry weight was affected by the increased of total leaves, leaf area and stem dry weight. Table 6 showed that the correlation among those seedling growth pa-

Table 4. Leaf indices of Pak Choy seedlings after 14-days sowing on rock wool slabs containing inorganic and organic nutrient solution in the screen house

Nutrient Solution	Leaf number		Leaf area (mm^2)		SLA (mm^2/mg)		LAR (mm^2/mg)	
K0-1	4.067	c	88.000	c	84.137	a	53.887	a
K0-2	5.067	a	162.365	b	84.767	a	57.170	a
K0-3	2.933	d	52.540	e	9.250	b	5.187	b
K-1	4.000	c	71.111	d	112.763	a	68.903	a
K-2	3.800	c	62.753	de	132.373	a	67.907	a
K-3	3.667	c	53.663	e	132.440	a	65.480	a
K-4	5.000	a	231.022	a	95.697	a	61.287	a
K-5	5.000	a	238.703	a	107.717	a	75.223	a
K-6	4.533	b	154.699	b	119.843	a	75.380	a

Note: Means in the same column followed by the different letter are significantly different ($p<0.05$) according to DMRT

Table 5. Dry weight of Pak Choy seedlings after 14-days sowing on rock wool slabs containing inorganic and organic nutrient solution in the screen house

Nutrient Solution	Stem (mg)		Leaves (mg)		Roots (mg)		Whole (mg)	
K0-1	0.157	cd	1.047	de	0.437	b	1.637	cd
K0-2	0.523	cd	2.017	bcd	0.457	b	2.993	bc
K0-3	1.900	a	5.687	a	2.640	a	10.227	a
K-1	0.090	d	0.633	e	0.313	b	1.033	d
K-2	0.137	cd	0.483	e	0.317	b	0.937	d
K-3	0.140	cd	0.380	e	0.250	b	0.767	d
K-4	1.017	b	2.993	b	0.550	b	4.560	b
K-5	0.607	bc	2.277	bc	0.380	b	3.267	bc
K-6	0.467	cd	1.433	cde	0.327	b	2.227	cd

Note: Means in the same column followed by the different letter are significantly different ($p<0.05$) according to DMRT

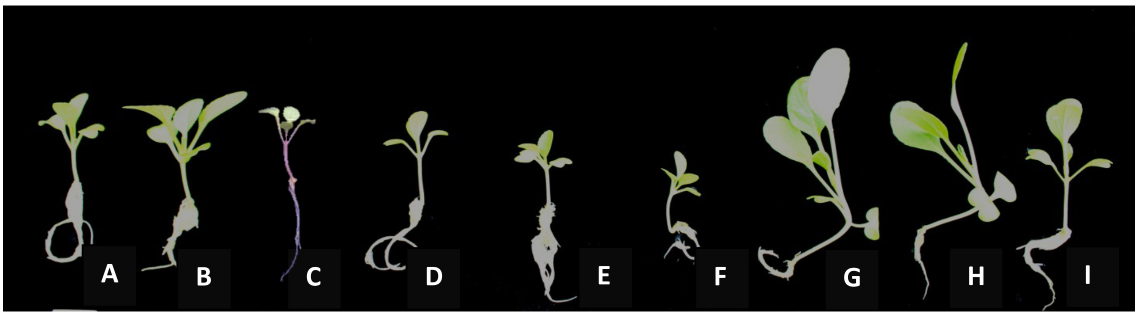

Figure 1. Seedling performance of Pak Choy after 14-day sowing in various hydroponic nutrient solution (A= K0-1, B= K0-2, C= K0-3, D=K1, E=K2, F=K3, G=K4, H=K5, I=K6)

rameters seemed to be affected by the biofertilizer and inorganic nutrient proportion in the hydroponic solution of K-4 (25% K0-3+75% K02). In contrast, there was not any significant difference correlation among growth parameters in K-6 (75% K0-3+25% K02). A different result showed by tomato seedling grown on various compost types; there was a very significant correlation between leaf area and both dry leaf weight and whole seedling dry weight, as well as seedling height and diameter (Priadi et al., 2016). The correlation among seedling growth parameters seemed to

Tabel 6. Correlation of growth parameters of Pak Choy seedling in various nutrient solution

Parameter K01		Nutrient Solution								
		K02	K03	K1	K2	K3	K4	K5	K6	
HT	DM	-1.000*	-0.993	-.905	-0.954	-0.422	0.723	0.347	0.854	0.589
	TL	0.596	-0.596	0.270	n/a	0.973	0.827	0.667	n/a	-0.858
	LA	0.885	0.924	0.919	-0.034	0.614	-0.127	0.951	0.123	-0.536
	TR	0.986	0.993	0.969	0.019	1.000**	0.667	-0.950	-0.979	0.225
	SW	0.984	0.979	-0.248	1.000*	-0.229	0.205	0.659	-0.881	-0.988
	LW	0.255	0.931	0.460	-0.987	0.989	-0.006	0.707	-0.498	-0.967
	RW	0.966	0.998*	0.237	-0.985	0.993	-0.418	0.228	-0.962	-0.944
	TW	0.985	0.958	0.200	0.345	0.999*	-0.175	0.659	-0.655	-0.969
DM	TL	-0.610	0.500	-0.655	n/a	-0.619	0.986	0.930	n/a	-0.091
	LA	-0.893	-0.962	-0.999*	-0.266	0.456	0.594	0.039	-0.412	0.366
	TR	-0.989	-1.000**	-0.982	-0.317	-0.412	0.997*	-0.622	-0.942	-0.655
	SW	-0.987	-0.996	-0.189	-0.948	-0.786	0.825	0.934	-0.999*	-0.456
	LW	-0.272	-0.966	-0.795	0.893	-0.287	0.686	0.909	-0.877	-0.364
	RW	-0.961	-0.985	-0.629	0.991	-0.524	0.325	0.992	-0.963	-0.289
	TW	-0.988	-0.984	-0.599	-0.610	-0.376	0.554	0.934	-0.953	-0.371
TL	LA	0.901	-0.243	0.628	n/a	0.417	0.453	0.403	n/a	0.894
	TR	0.721	-0.500	0.500	n/a	0.971	0.971	-0.866	n/a	-0.693
	SW	0.731	-0.419	0.866	n/a	0.000	0.721	1.000**	n/a	0.928
	LW	0.929	-0.261	0.979	n/a	0.930	0.558	0.998*	n/a	0.961
	RW	0.367	-0.640	0.999*	n/a	0.993	0.165	0.877	n/a	0.980
	TW	0.724	-0.339	0.997*	n/a	0.961	0.410	1.000**	n/a	0.959
LA	TR	0.950	0.962	0.988	0.999*	0.623	0.654	-0.807	0.082	-0.943
	SW	0.955	0.983	0.155	-0.053	-.909	0.945	0.394	0.362	0.662
	LW	0.676	1.000*	0.773	0.195	0.722	0.993	0.453	0.799	0.734
	RW	0.734	0.901	0.601	-0.137	0.519	0.954	-0.085	0.152	0.785
	TW	0.951	0.995	0.570	0.926	0.653	0.999*	1.000**	0.669	0.729
TR	SW	1.000**	0.996	0.000	0.000	-0.240	0.866	-0.861	0.959	-0.375
	LW	0.412	0.966	0.666	0.143	0.991	0.741	-0.892	0.665	-0.466
	RW	0.910	0.985	0.470	-0.189	0.992	0.397	-0.520	0.997*	-0.534
	TW	1.000**	0.984	0.437	0.945	0.999*	0.617	-0.860	0.796	-0.459
SW	LW	0.426	0.986	0.746	-0.990	-0.367	0.977	0.998*	0.849	0.995
	RW	0.903	0.966	0.882	-0.982	-0.115	0.803	0.882	0.977	0.984
	TW	1.000**	0.996	0.900	0.327	-0.277	0.928	1.000**	0.935	0.996
LW	RW	-0.004	0.908	0.972	0.945	0.966	0.911	0.850	0.716	0.997
	TW	0.416	0.997	0.962	-0.189	0.995	0-.006	0.998*	0.981	1.000**
RW	TW	0.908	0.940	0.999*	-0.500	0.986	0.967	0.883	0.837	0.996

Note: HT=Height; DM=Diameter; TL=Total leaves; LA=Leaf area; TR=Total roots; SW=Stem dry weight; LW=Leaf dry weight; RW=Root dry weight; TW=Whole seedling dry weight; Means in the same column followed by the same letter are not significantly different ($p<0.05$)*) or very significantly different ($p<0.01$) **), n/a =not available be affected by the plant species and growing medium types. Furthermore, a study conducted by Shangjie et al. (2011) on a hydroponic of lettuce and Pak Choy showed that the vegetable types varied on optimal solution concentration, and different vegetable cultivars exhibited specific growth characteristics.

The result of the study as explained above, found that the inorganic nutrient in the hydroponic solution could be decreased by using biofertilizer. However, further study needs to be done to obtain organic substances from inexpensive, and easily available materials for hydroponic seedling production towards the organic product since the hydroponic culture of vegetable crops is commonly applied by the urban community which has no space for conventional farming. By using the organic nutrient in the hydroponic solution is expected to be produced more healthy vegetable.

CONCLUSIONS

From this study, we concluded that the nutrient solution containing 25% Beyonic *StarTmik@Lob* and 75% commercial hydroponic solution (K4) was the appropriate nutrient solution for hydroponic seedling production of Pak Choy. The organic seedling production plays an important role because it is the initial step in the practice of biological farming. Therefore, further study needs to be done to obtain organic substances for hydroponic seedling production towards the organic product.

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