The Yield of Packchoi and Lettuce under Different Nutrient Formulations with a Hydroponic Raft System

Florentina Kusmiyati, Endang Dwi Purbajanti, Syaiful Anwar, Muhamad Ghazi Agam Sas, Dian Safitri, Fajrin Pramana Putra*

Department of Agriculture, Faculty of Animal and Agricultural Science, Diponegoro University, Indonesia

DOI: 10.29322/IJSRP.13.06.2023.p13813
http://dx.doi.org/10.29322/IJSRP.13.06.2023.p13813

Paper Received Date: 16th April 2023
Paper Acceptance Date: 25th May 2023
Paper Publication Date: 6th June 2023

Abstract- This study examines the yield and quality of packcoy and lettuce with several nutritional formulations. The study was conducted with a 2 x 2 factorial arrangement based on a completely randomized design (CRD) with three replications. This study used Packcoy and Lettuce plants as the first factor, then four nutritional formulations: AB mix (control), Hoagland & Arnond, and Hewitt, Huett's Lettuce. The research focused on observing the weight of dry plant biomass, crop yields, and plant quality as seen from the accumulation of chlorophyll and carotenoid leaves. The results showed that Hoagland & Arnond's nutritional formulations increased plant leaf area weight, plant dry weight, and plant production yield. Meanwhile, Packcoy plants, given AB mix nutrition, could accumulate high levels of leaf chlorophyll and carotenoids. Hoagland & Arnond's nutritional formulation is ideal because it optimizes plant production and accumulates relatively better chlorophyll and carotenoids.

Keywords: Hydroponics, Horticulture, Nutrient, Yield Quality

I. INTRODUCTION

Leaf vegetables consumed as fresh vegetables include lettuce and pakchoi *(Lactuca sativa* var. *Arista* and *Brassica rapa* subsp. *Chinensis*). The market price of lettuce and pakchoi is greatly influenced by quality. A solution to improve production and quality while utilizing the urban environment is hydroponic growth. Compared to the nutrient film technique (NFT) and aeroponic, the hydroponics raft system has advantages as a straightforward hydroponics system for urban farmers. Low dissolved oxygen (DO) and nutritious sediment are two additional weaknesses of the raft system. Plant root growth is impacted by the low oxygen concentration in a nutrient solution, which indirectly influences plant nutrient uptake [1]. A hydroponic raft system with an aerator is now assembled to boost dissolved oxygen. Apart from this, the success of hydroponic cultivation is the application of nutrient solutions to crops.

The small-scale hydroponic system often purchases a nutrient solution from a hydroponics business. A store already sells several kinds of nutrient hydroponic recipes [2]. The choice between many nutrition solutions can occasionally perplex farmers or growers. Each nutrient solution typically has different formulas for crops that produce vegetables or fruits. Every nutrient solution occasionally has varied pricing and distinct formulae. A fertilizer solution's cost and nutritional composition may only sometimes ensure more significant crop development. Resh [3] stated that five aspects must be considered when formulating nutrients: plant variety, growth stage, marketable yield, weather, and climate [4]. The development of the plants was also observed to be impacted by various hydroponic systems [5]. Each element is present in a distinct concentration in each nutritional solution. There still needs to be more knowledge on appropriate and efficient hydroponics nutrients. Urban farmers need this knowledge to boost productivity and optimize profits [5].

According to the description given, a straightforward hydroponic system combined with the use of a proper nutrient composition would produce lettuce (*Lactuca sativa* var. *Arista*) and pakchoi (*Brassica rapa* subsp. *Chinensis*) of high quality [6]. To improve yield and quality, research is required on applying various nutrition formulations to lettuce (*Lactuca sativa* var. *Arista*) and pakchoi (*Brassica rapa* subsp. *Chinensis*). This study aimed to find nutrition formulations that could enhance the quality and yield of lettuce (*Lactuca sativa* var. *Arista*) and pakchoi (*Brassica rapa* subsp. *Chinensis*) grown in a hydroponic raft system.

II. MATERIALS AND METHODS

The research was conducted from October to November 2022 in the greenhouse and the Physiology and Plant Breeding Laboratory, Faculty of Animal and Agriculture Science, Diponegoro University, Semarang. This study used a factorial study compiled based on a

Completely Randomized Design (CRD) with two factors. The first factor is the type of plant, including Packcoy and Lettuce, and the second is the hydroponic nutrient formulation, including AB mix, Hoagland & Arnond, Hewitt, and Huett's Lettuce. The combination of treatment factors resulted in 8 treatment combinations carried out in 3 repetitions so that there were 24 experimental units, and each experimental unit contained six plants using a floating raft hydroponic system.

Table 1. Hydroponic nutrient formulations

Nutrient Formula (mg. L^{-1})	N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn	B	Mo
AB Mix	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hoagland & Arnond	210	31	234	160	34	64	2.5	0.02	0.05	0.5	0.5	0.01
Hewitt	168	41	156	160	36	48	2.8	0.064	0.065	0.54	0.54	0.04
Huett's Lettuce Formulation	116	22	201	70	20	26	2.5	0.03	0.15	0.22	0.21	0.01

The plant variables observed were plant leaf area (cm^2), plant dry weight (g. crop^{-1}), crop yield (g. crop^{-1}), leaf chlorophyll content (mg. L^{-1}), and leaf carotenoids (mg. L^{-1}).

Chlorophyll content and carotenoid (mg. L^{-1})
Carotenoid and chlorophyll content analysis According to Lichtenthaler and Wellburn [7], the amount of carotenoid and chlorophyll in leaves was measured (mg. L^{-1}). A spectrophotometer was used to observe at 646 nm, 663 nm, and 470 nm wavelengths. The following formula was used to calculate the levels of carotenoid and chlorophyll:
Chlorophyll-a = -0.00281 x λ646 + 0.01221 x λ663
Chlorophyll-b = 0.02013 x λ646-0.00503 x λ663
Chlorophyll content = Chlorophyll a + Chlorophyll b
Carotenoid = ((1000 × λ470)-(3.27 × Chlorophyll a) – (104 x Chlorophyll-b))/229

The plant variable data were then analyzed by ANOVA based on a completely randomized design (CRD). If the results of the ANOVA analysis show a significant effect (P <0.05), proceed with the Tukey HSD test.

III. Result and Discussion

Result

The leaf area of Packcoy and Lettuce has a significant difference (Table 2). Lettuce has a leaf area of 174.29 cm^2 or 76.06% wider than Packcoy. Then, the nutritional formulations also provided significant differences in leaf area (Table 2). Hoagland & Arnond nutrition provides broader leaf area growth than other nutritional formulations. The average leaf area of plants given Hoagland & Arnond nutrition showed a leaf area of 153.82 cm^2. Although the type of plant and nutrient formulations significantly differed in plant leaf area, the two treatment factors did not show a significant interaction.

Table 2. Leaf area of crops (cm^2) under different nutrient solutions

Treatment	**AB Mix**	**Hoagland & Arnond**	**Hewitt**	**Huett's Lettuce**	**Average**
Packcoy	102.01	108.14	90.81	95.02	98.99 b
Lettuce	179.34	199.52	166.30	152.03	174.29 a
Average	140.67 b	153.82 a	128.55 c	123.52 c	(-)

Note: The numbers in the same column followed by the same letter are not significantly different in the Tukey HSD test at a significant level of 5%.

The dry weight of Packcoy and Lettuce plants had a significant difference (Table 3). Lettuce plants have a plant dry weight of 15.51 g. crop^{-1} and 41.21% lower than Packcoy. Table 3 shows that several nutritional formulations make a significant difference in the formation of plant dry weight. Hoagland & Arnond's nutritional formulation formed the highest plant dry weight, 26.11 g. crop^{-1}. However, the AB mix formulation gave a plant dry weight of 23.18 g. crop^{-1} or relative to the dry weight of plants given the Hoagland & Arnond nutritional formulation. Plants with Huett's Lettuce and Hewit Formulations showed lower dry weight.

Table 3. The total dry weight of crops (g. crop^{-1}) under different nutrient solutions

Treatment	**AB Mix**	**Hoagland & Arnond**	**Hewitt**	**Huett's Lettuce**	**Average**
Packcoy	29.17	34.04	20.90	21.42	26.38 a
Lettuce	17.19	18.19	13.96	12.70	15.51 b

Average	23.18 ab	26.11 a	17.43 b	17.06 b	(-)

Note: The numbers in the same column followed by the same letter are not significantly different in the Tukey HSD test at a significant level of 5%.

The results of Packoy and Lettuce plants had significant differences (Table 4). Packcoy plants have a higher yield than lettuce, which is 134.08 g. crop^{-1}. The difference in production between Packcoy and Lettuce is 30.09%. Then the nutritional formulation also provides a significant difference in crop production results. Hoagland & Arnond's nutritional formulation obtained the highest plant yield, 144.52 g. crop^{-1}. Plant yields in Hoagland & Arnond's nutritional formulation were higher than AB mix, Hewitt, and Huett's Lettuce by 16.85%, 38.58%, and 41.94%, respectively. However, the interaction between plant species and nutrient formulations did not make a significant difference (Table 4).

Table 3. The yield of crops (g. crop^{-1}) under different nutrient solutions

Treatment	AB Mix	Hoagland & Arnond	Hewitt	Huett's Lettuce	Average
Packcoy	137.22	158.87	114.80	125.46	134.08 a
Lettuce	110.15	130.17	93.79	78.20	103.07 b
Average	123.68 b	144.52 a	104.29 c	101.82 c	(-)

Note: The numbers in the same column followed by the same letter are not significantly different in the Tukey HSD test at a significant level of 5%.

Interactions Types of plants with nutrient formulations provide a significant difference in plant leaf chlorophyll content. The highest chlorophyll content was produced in Packcoy plants by administering the AB mix nutritional formulation, namely 19.55 mg. L^{-1}. However, the Hoagland & Arnond and Huett's Lettuce nutritional formulations yielded the chlorophyll content of the packcoy plant leaves, which were relatively the same as the AB Mix nutritional formulation. The lowest chlorophyll content was produced in the Lettuce plant with the AB mix formulation, 8.17 mg. L^{-1}. Compared to Lettuce, packcoy are able to form 73.60% higher leaf chlorophyll.

Table 4. Chlorophyll content (mg. L^{-1}) under different nutrient solutions

Treatment	AB Mix	Hoagland & Arnond	Hewitt	Huett's Lettuce	Average
Packcoy	19.55 a	18.10 ab	13.76 bcd	15.67 abc	16.77
Lettuce	8.17 e	9.92 de	11.17 cde	9.36 de	9.66
Average	13.86	14.01	12.47	12.52	(+)

Note: The numbers in the same column followed by the same letter are not significantly different in the Tukey HSD test at a significant level of 5%.

The interaction between the type of plant and the nutrient formulation gave a significant difference in the levels of leaf carotenoids in plants. The highest levels of carotenoids were produced in Packcoy plants by administering the AB mix nutritional formulation, namely 3.08 mg. L^{-1}. However, the Hoagland & Arnond and Huett's Lettuce nutritional formulations form carotenoids in the leaves of the packcoy plant, which are relatively the same as the AB Mix nutritional formulation. The lowest leaf carotenoid content was produced in Lettuce plants with the AB mix formulation, 1.62 mg. L^{-1}. Compared to Lettuce plants, packcoy plants are able to form 28.87% higher leaf chlorophyll.

Table 5. Carotenoid content (mg. L^{-1}) under different nutrient solutions

Treatment	AB Mix	Hoagland & Arnond	Hewitt	Huett's Lettuce	Average
Packcoy	3.08 a	2.77 ab	1.92 bc	2.23 abc	2.50
Lettuce	1.62 c	1.97 bc	2.19 abc	1.95 bc	1.94
Average	2.35	2.37	2.06	2.09	(+)

Note: The numbers in the same column followed by the same letter are not significantly different in the Tukey HSD test at a significant level of 5%.

Discussion

Based on research results on hydroponic nutrient formulations on Packcoy and Lettuce plants. The Hoagland & Arnond formulation has a high nitrogen content of 210 mg L^{-1}. Nitrogen is a macronutrient needed by plants in the process of growth. Several studies on the impact of providing sufficient nitrogen can optimize the rate of plant photosynthesis [8; 9]. Wang et al. [8] showed in their research that giving sufficient nitrogen doses to plants can form optimal leaf area, and when the formation of optimal leaf area will positively impact the process of plant photosynthesis. So that the results of photosynthesis will be used as energy to increase plant growth [10]. In this

study, it was shown that using Hoagland & Arnond's nutritional formulations was able to increase plant leaf area compared to other nutritional formulations (Table 2). Increasing nitrogen levels in a study increased the index of plant leaf area and plant dry weight [11]. Then Liu et al. [12] explained that the increase in plant dry weight was influenced by optimal canopy growth, so the photosynthate formation process was more optimal. It would form optimal dry matter in plants.

Based on the results of this study, it was found that by administering Hoagland & Arnond Nutrition, which had the highest levels of N, the lowest P, and the highest K compared to other formulations, it showed more optimum plant production results (Table 3). There is an emphasis on the research of Hong et al. [13] that guarantees the provision of ideal nitrogen is the creation of optimal plant growth, which will follow with optimal production results and high-quality crop production. Then high levels of potassium will help improve the quality of plants at the time of harvest. The quality of the plant will decrease, such as yield, vitamin content, and other mineral content is affected due to a deficiency of nutrients N, P, and K [14; 15]. The quality of the Packcoy and Lettuce plants was seen from the accumulation of leaf chlorophyll and carotenoids (Tables 4 and 5). According to Ferruzzi and Blakeslee [16], carotenoids and chlorophylls are significant plant pigments found in green leafy vegetables and are becoming more and more connected to some of the health benefits of consuming vegetables, including their potential to prevent cancer. The use of AB mix nutrition showed that the Packcoy plants could accumulate high levels of leaf chlorophyll and carotenoids, although the production yields achieved could have been better.

IV. CONCLUSION

Packcoy and lettuce had different growth in leaf area and dry weight and yield. Lettuce plants have a wider leaf area than Packcoy, but pakchoi plants can provide higher biomass dry weight and plant yields than lettuce. Hoagland & Arnond's nutritional formulation can provide better plant growth and yield than other formulations. Packcoy plants combined with AB Mix were able to form the best leaf chlorophyll and carotenoids compared to other treatment combinations.

REFERENCES

[1] Suyantohadi A, Kyoren T, Hariadi M, Purnomo M H, and Morimoto T. 2010. Effect of highly concentrated dissolved oxygen on the plant growth in a deep hydroponic culture under a low-temperature IFAC Proc. Vol. 3 no. PART 1
[2] Mason J. 2014. Commercial Hydroponics, 3rd ed. (Tennessee: Kangaroo Press)
[3] Resh H M. 2013. Hydroponic Food Production, 7th ed. (New York: CRS Press)
[4] Sesanti R N and Sismanto S. 2016. Pertumbuhan dan Hasil Pakchoi (*Brasicca rapa L.*) Pada Dua Sistem Hidroponik Hidroponik dan Empat Jenis Nutrisi. *J. Kelitbangan* 04 (01). pp. 1–9
[5] Wortman S E. 2015. Crop physiological response to nutrient solution electrical conductivity and pH in an ebb-and-flow hydroponic system Sci. Hortic. (Amsterdam) 194 pp. 34–42
[6] Nowaki R H, Parent S É, Cecílio Filho A B, Rozane D E, Meneses N B, Silva J A, Natale W, and Parent L E. 2017. Phosphorus Over-Fertilization and Nutrient Misbalance of Irrigated Tomato Crops in Brazil Front. *Plant Sci.* 8 no. May pp. 1–11
[7] Lichtenthaler HK, Wellburn AR. 1983. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem Soc Trans 11 (5): 591-592. DOI: 10.1042/bst0110591
[8] Wang D, M. W. Maughan, J. Sun, X. Feng, F. Miguez, D. Lee And M. C. D Ietze. 2012. Impact of nitrogen allocation on growth and photosynthesis of Miscanthus (*Miscanthus* x *giganteus*). *GCB Bioenergy* 4: 688–697, doi: 10.1111/j.1757-1707.2012.01167.x
[9] Zhaoa D, K. R. Reddya, V. G. Kakania, V.R. Reddy. 2005. Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyperspectral reflectance properties of sorghum. *Europ. J. Agronomy* 22: 391–403, doi:10.1016/j.eja.2004.06.005
[10] Gastal F, Lemaire G. 2002. N uptake and distribution in crops: an agronomical and ecophysiological perspective. *Journal of Experimental Botany* 53: 789–799.
[11] Zhai J., Zhang G., Zhang Y., Xu W., Xie R., Ming B., Hou P., Wang K., Xue J., Li S. 2022. Effect of the Rate of Nitrogen Application on Dry Matter Accumulation and Yield Formation of Densely Planted Maize. *Sustainability* 14, 14940. doi: https://doi.org/10.3390/su142214940
[12] Liu W.M., Hou P., Liu G.Z., Yang Y.S., Guo X.X., Ming B., Xie R.Z., Wang K.R., Liu Y.E., Li S.K. Contribution of total dry matter and harvest index to maize grain yield-a multisource data analysis. *Food Energy Secure* 9, e256.
[13] Hong, J.; Xu, F.; Chen, G.; Huang, X.; Wang, S.; Du, L.; Ding, G. 2022. Evaluation of the Effects of Nitrogen, Phosphorus, and Potassium Applications on the Growth, Yield, and Quality of Lettuce (*Lactuca sativa L.*). *Agronomy* 12, 2477. https://doi.org/10.3390/ agronomy12102477
[14] Bottoms, T.G.; Smith, R.F.; Cahn, M.D.; Hartz, T.K. 2012. Nitrogen requirements and N status determination of lettuce. *HortScience* 47, 1768–1774
[15] Thapa, U.; Nandi, S.; Rai, R.; Upadhyay, A. 2022. Effect of nitrogen levels and harvest timing on growth, yield, and quality of lettuce under the floating hydroponic system. *J. Plant Nutr.* 45, 2563–2577
[16] Ferruzzi MG, Blakeslee J (2007) Digestion, absorption, and cancer preventative activity of dietary chlorophyll derivatives. Nutr Res. Doi:10.1016/j.nutres.2006.12.003.

AUTHORS

First Author – Florentina Kusmiyati, conception and data collection, and fkusmiyati@live.undip.ac.id.
Second Author – Endang Dwi Purbajanti and data collection.
Third Author – Syaiful Anwar and data collection.
Fourth Author – Muhamad Ghazi Agam Sas, data analysis, and muhamadghaziagamsas@lecturer.undip.ac.id.
Fifth Author – Dian Safitri and data collection.
Sixth Author – Fajrin Pramana Putra, conceptor and writing manuscript, and fajrin.pramana.p@gmail.com

Correspondence Author – Fajrin Pramana Putra, fajrin.pramana.p@gmail.com