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Optimization of nutrient formulation and medium flow using automatic nutrient film technique hydroponics system on mizuna (*Brassica rapa Nipponisica*) cultivation

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Abstract. Mizuna, or Japanese mustard greens, is a highly popular plant in Indonesia, with wide market availability and high economic price, among other green vegetables. Mizuna cultivation using an automatic nutrient film technique (NFT) hydroponic system will produce better quality and quantity and efficient use of fertilizers and electricity. This study aimed to find the best concentration of nutrients to support the growth of mizuna and determine the flow time of hydroponic media suitable for mizuna cultivation. The study was designed using RCBD with two treatment factors, namely nutrient formulation (four nutrient formulations and water as control) and medium flow time (three levels of switch-off time i.e 15, 45, and 60 min). Growth observation data were analyzed using variance (ANOVA), then the multiple comparison test was continued with the Duncan multiple range test (DMRT) at α level 5%. Different nutrient sources in this study did not significantly affect the growth variables of mizuna, but mizuna grown in a nutrient medium did significantly show better growth than control. This study found that all of the flow time treatments (15, 45, and 60 minutes off) also gave statistically similar results on the growth of mizuna in the NFT hydroponic system.

1 Introduction

Brassicaceae is a vital vegetable cultivated and used worldwide. Fresh mizuna plants contain high amounts of calcium and iodine, a source of folate, phenols, and flavonoids. Mizuna has high antioxidant properties. In medicine, this plant increases blood clotting and bone strength and improves vision and endurance [1]. Mizuna is cultivated in several North America, Europe, and Asia countries. Despite its high nutritional and economic value, mizuna production in Indonesia is still deficient. Hydroponics is a soil-free farming method that can contribute to meeting global food demand, improving food sustainability, and ensuring food availability in a new, efficient, yet low-maintenance way. Agricultural productivity is struggling to meet the increasing food demand associated with the world's growing population, which is expected to grow to 9.5 billion people by 2050. To address this issue,

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high yields from hydroponic farming are expected to increase the compound annual growth rate by 20.7% from 2021 to 2028. In addition, the application of the Internet of Things in hydroponic farming offers farmers various methods to closely monitor and manage their crops with the help of sensors, microcontrollers, website platforms, and mobile applications automatically [2].

Hydroponics refers to a soil-free farming method that uses water-based nutrient solutions. Hydroponic farming has been suggested as one of the potential solutions to the problem of food insecurity at the global level. Several studies have shown that hydroponics can reduce environmental degradation, improve food security, stability, and sustainability, and enhance resilient farming practices [3], [4]. Advanced hydroponic systems with controlled growing environments allow farmers to produce continuous harvests in shorter growing periods, requiring less space, and with higher crop productivity, regardless of climate, soil quality, or arable land availability [5].

The Hydroponics nutrient film technique (NFT) system is a cultivation method in which roots grow directly into a thin, constantly recycled stream of water [3]. This solution runs for 24 hours and contains nutrients adjusted for the plant [4]. Thus, electricity usage can become expensive and less efficient. also, we need to find suitable nutrients for each plant. This study aimed to find the best nutrient formulation to support the growth of mizuna and determine the flow time of hydroponic media suitable for mizuna cultivation. This research is expected to produce mizuna with higher production and more efficient fertilizer, water, and electricity use.

2 Methods

2.1 Design of NFT Hydroponic System

The installation framework of hydroponic NFT is made of galvanized 380 cm long, 90 cm rear height with 80 cm front height, 380 cm pipe length, and 20 spacing between plant holes. The planting medium used in the nursery and plant holder is rock wool. The seedlings are transplanted after 2 weeks of sowing. The nutrient formulation supplied is adjusted to the treatment. The medium flow can be stopped (switch-off time) according to the treatment with a maximum time of 70 minutes so that the roots do not dry out.

2.2 Experimental design and data analysis

The study was designed using randomized complete block design (RCBD) with two treatment factors, namely nutrient formulation (four nutrient formulations and one control) and medium flow time (three levels of switch-off time). Nutrient formulation consisted of four formulations, i.e., nutrient A (modified nutrient), B (Cooper (1979)), C (Steiner (1984)), D (BPTP) [6], [7], [8], and E (control medium using water). The mineral composition of four nutrient formulations is shown in Table 1. Medium flow time treatments (time for circulation off after 15 min on) consisted of three levels of switch-off time, i. e, 15, 45, and 60 min.

Variables of plant observation in this study consisted of plant length (cm), number of leaves, total chlorophyll ($\mu g.mL^{-1}$), root weight (g), root length (cm), stem diameter (mm), fresh weight (g), and dry weight (g). Growth observation data were analyzed using analysis of variance (ANOVA), then the multiple comparison test was continued with the Duncan multiple range test (DMRT) at α level 5%.

Table 1. Mineral composition of the four nutrient formulations

Nutrient (mg.L^{-1})	Modified	Cooper (1979)	Steiner (1984)	BPTP
N	500	350	168	311
P	80	60	100	76
K	250	300	273	349
Ca	150	185	180	286
Mg	100	50	48	157
S	55	68	336	248
Fe	2	12	4	7
Mn	1	2	0.62	2.90
Zn	0.30	0.10	0.11	0.60
B	2.00	0.30	0.44	0.60
Cu	0.10	0.10	0.02	0.10
Mo	0.001	0.20	0.00	0.06
Cl	3	-	-	-

3 Results and Discussion

The nutrient formulation of hydroponic media had a significant effect on the length of mizuna plants 15 to 30 days after planting (DAP). However, different flow times had no significant effect on all observation ages. Different nutrient formulations showed no significant effect on mizuna plant length, but all did show better growth than control (Table 2).

Table 2. Plant height (cm) of mizuna under several nutrient formulations and flow time.

Treatment	Plant length (cm)					
	5 DAP	10 DAP	15 DAP	20 DAP	25 DAP	30 DAP
Nutent formulation						
Modified	6.80a	14.65 a	24.07 b	34.02 b	38.68 b	44.12 b
Cooper 1979	8.56 a	18.06 a	27.00 bc	35.19 b	40.80 b	43.99 b
Steiner 1984	6.97 a	15.74 a	25.18 bc	35.22 b	40.05 b	45.40 b
BPTP	8.86 a	20.59 a	31.15 c	40.19 b	44.10 b	49.45 b
Control	7.21 a	12.38 a	15.74 a	17.73 a	18.00 a	19.39 a
Flow time						
15 mins off	7.66 a	16.46 a	25.18 a	33.48 a	36.86 a	41.61 a
45 mins off	7.87 a	16.18 a	23.89 a	31.46 a	35.48 a	39.51 a
50 mins off	7.50 a	16.21 a	24.81 a	32.47 a	36.38 a	40.29 a

Notes: The mean value, followed by the same letter in the same column, showed that the difference was insignificant based on the DMRT test with α 5%.

Different nutrient formulations and flow time also showed the same effect on the number of leaves variable. There were no significant effects of the treatment combination between nutrient formulation and flow time at all observation times. Nutrient formulation significantly affected the number of mizuna leaves at 15 to 30 DAP, but flow time did not significantly affect the number of mizuna leaves variable at 5 to 30 DAP (Table 3).

Table 3. Number of mizuna leaves under application of several nutrient formulations and flow time.

Treatment	Plant length (cm)					
	5 DAP	**10 DAP**	**15 DAP**	**20 DAP**	**25 DAP**	**30 DAP**
Nutent formulation						
Modified	4.85 a	5.87 a	5.85 a	12.39 b	14.22 b	16.02 bc
Cooper 1979	5.85 a	6.41 a	6.56 b	11.20 b	12.93 b	14.89 b
Steiner 1984	5.09 a	6.07 a	6.11 b	12.72 b	14.56 b	17.63 bc
BPTP	5.93 a	6.83 a	6.72 b	13.76 b	15.76 b	18.31 c
Control	4.91 a	5.28 a	5.26 a	5.20 a	5.56 a	6.00 a
Flow time						
15 mins off	5.23 a	6.08 a	5.98 a	10.97 a	12.18 a	14.13 a
45 mins off	5.37 a	6.14 a	6.22 a	11.24 a	12.56 a	15.04 a
50 mins off	5.38 a	6.06 a	6.10 a	10.96 a	12.40 a	14.53 a

Notes: The mean value, followed by the same letter in the same column, showed that the difference was insignificant based on the DMRT test with α 5%.

Total chlorophyll, root weight, root length, and stem diameter were determined at the end of observation time during harvesting. The nutrient formulation significantly affected those variables, although the single effect of flow time had no significant effect on all of them. A nutrient medium with different formulations showed significantly better mizuna growth than a control medium, although different effects between nutrient formulations were not seen on total chlorophyll, root weight, and stem diameter variables (Table 4).

Table 4. Total chlorophyll, root weight, root length, and stem diameter of mizuna under the application of several nutrient formulations and flow times.

Treatments	Total chlorophyll ($\mu g.mL^{-1}$)	Root weight (g)	Root length (cm)	Stem diameter (mm)
Nutrient formulation				
Modified	30.43 b	2.50 b	28.58 a	14.07 b
Cooper 1979	33.48 b	2.44 b	28.75 a	17.08 b
Steiner 1984	30.40 b	2.52 b	30.58 a	18.94 b
BPTP	28.15 b	2.22 b	29.19 a	18.62 b
Control	23.18 a	0.84 a	27.08 a	6.61 a
Flow time (15 mins on)				
15 mins off	28.68 a	5.76 a	29.20 a	14.91 a
45 mins off	27.34 a	4.94 a	28.17 a	15.65 a
50 mins off	31.36 a	5.10 a	29.15 a	14.63 a

Notes: The mean value, which was followed by the same letter in the same column, showed that the difference was not significant based on the DMRT test with α 5%.

Fresh and dry weights of mizuna were significantly affected by nutrient formulation treatment but were not significantly affected by flow time treatment (Fig. 1 and Fig. 2). Different flow times did not show significantly different mizuna fresh and dry weights. A nutrient medium with different formulations showed significantly better mizuna growth than the control medium, although different effects between nutrient formulations were not seen on fresh and dry weight variables.

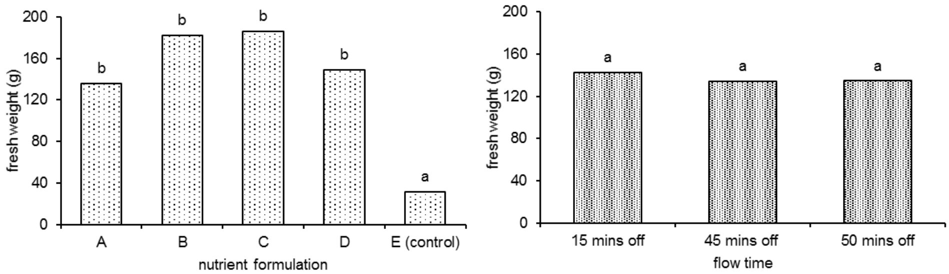

Fig. 1. Fresh weight of mizuna leaves under application of several nutrient formulation and flow time. (Note: Nutrient A (modified nutrient), B (Cooper 1979), C (Steiner 1984), D (BPTP), and E (control)).

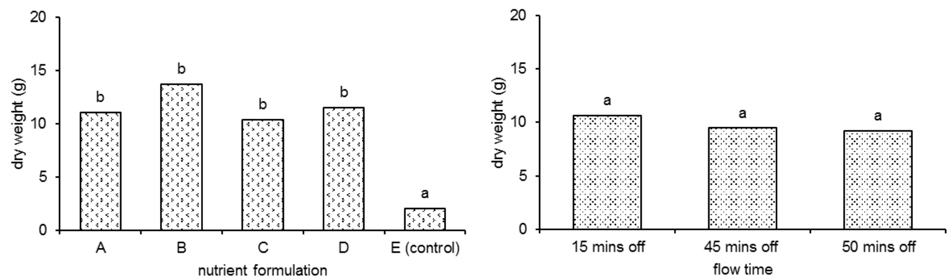

Fig. 2. Dry weight of mizuna leaves under application of several nutrient formulation and flow time. (Note: Nutrient A (modified nutrient), B (Cooper 1979), C (Steiner 1984), D (BPTP), and E (control)).

Macronutrients are nutrient elements that are needed in large quantities for normal plant growth and development. According to Kumari *et al.* [9], macronutrients such as N, P, and K are essential in plant vegetative growth. The four nutrient formulations used in this study may have met the needs of mizuna in these three elements so that the results are not significantly different but are much better than the control.

Nitrogen stimulates plant growth and gives green color (chlorophyll) to the leaves. If its needs are unmet, the leaves turn yellow or yellowish green and fall off quickly. Masclaux-Daubresse *et al.* [10] stated that an increase in the number of leaves indicates the activity of plant cell division and an increase in the number of leaves requires a sufficient amount of N. Labra *et al.* and Subramanian *et al.* [11], [12] also added that the optimal nutrient content or availability of nitrogen nutrients in plants will affect the increase in leaf area, leaf chlorophyll, and the number of plant leaves. However, Wang *et al.* and Sun *et al.* [13], [14] added that giving excessive N to plants will slow down plant maturity, weak stems, easy to fall, and reduced plant resistance to disease. Although the concentration of N in Nutrient A (modified nutrient) is higher than that of other nutrient formulations, this study showed that the amount is still by the needs and thresholds of mizuna. Furthermore, Lopez *et al*. and Razaq *et al.* [15], [16] also revealed that P and N deficiencies can affect root growth. Root growth (root weight and length) in all nutrient formulation treatments also shows that Mizuna's P needs are met.

Plants can effectively absorb a balanced nutrient formula and produce better growth. Macro and micronutrients, if not completely available, can inhibit the growth and development of the plant. Providing nutrients in the right amount and formula will increase plant growth. Deficiency or excess nutrients will disrupt plant growth, and the production results obtained will be less than optimal [17], [18], [19].

Fresh and dry plant weight can be used to indicate plant growth rate. The control medium showed significantly lower mizuna growth compared to the nutrient medium of all formulations (Fig. 3). According to Al Meselmani [20], water as a plant growth medium does not have enough nutrient content to meet the needs of mizuna plants, which play an essential role in plant growth. This can be seen in all mizuna growth variables represented in the economic value of mizuna production.

Nutrient formulation Control

Fig. 3. The comparison of mizuna growth between nutrient medium (modified, Cooper 1979, Steiner 1984, and BPTP) and control medium

In summary, the nutrient formulation significantly affected mizuna's growth variables of mizuna but flow time did not show the same effect. Different time circulation switch-offs (15 to 50 min off) after 15 minutes showed no significantly different results on growth variables of mizuna. This finding revealed that the flow time medium can be optimized by using time circulation with a 50-minute switch-off after a 15-minute switch-on. This result has a broader impact on the efficiency of electricity use.

Nutrient formulations tested in this research are common mediums used for growing vegetables in hydroponic systems. Nevertheless, the result showed that all formulations produce significantly better mizuna growth than the control medium. This finding emphasizes and encourages the farmer to use the formulation by adjusting the availability of the medium or nutrient solution.

References

1. M. Daryadar, S. Mairapetyan, J. Alexanyan, A. Tadevosyan, B. Stepanyan, A. Tovmasyan, The Growth Possibility and Yield of the Vegetable Mizuna (Brassica juncea var Japonica) in Open-Air Hydroponics. J Food Nutr Disor. **9**(3), 2 (2020).
2. Y. S. Goh, Y. C. Hum, Y. L. Lee, K. W. Lai, W.-S. Yap, Y. K. Tee, A meta-analysis: Food production and vegetable crop yields of hydroponics. Scientia Horticulturae. **321**, 112339 (2023). doi: 10.1016/j.scienta.2023.112339.
3. R. Naresh, S.K. Jadav, M. Singh, A. Patel, B. Singh, S. Beese, S.K. Pandey, Role of Hydroponics in Improving Water-Use Efficiency and Food Security. International Journal of Environment and Climate Change. **14**(2), 608-33 (2024). doi: 10.9734/IJECC/2024/v14i23976
4. G. Rajaseger, K.L. Chan, K.Y. Tan, S. Ramasamy, M.C. Khin, A. Amaladoss, P.K. Haribhai, Hydroponics: current trends in sustainable crop production. Bioinformation. **19**(9), 925 (2023). doi: 10.6026/97320630019925
5. F.A. Khan, A review on hydroponic greenhouse cultivation for sustainable agriculture. International Journal of Agriculture Environment and Food Sciences. **2**(2), 59-66 (2018). doi: 10.31015/jaefs.18010.
6. G. De Rijck, E. Schrevens, Comparison of the mineral composition of twelve standard nutrient solutions. Journal of Plant Nutrition. **21**(10), 2115-25 (1998). doi: 10.1080/01904169809365548

7. S. Swastika, A. Yulfida, Y. Sumitro, Budidaya Sayuran Hidroponik (Bertanam Tanpa Media Tanah), 2nd ed. Pekanbaru: Kementrian Pertanian: BPTP Riau, (2018).
8. L.I. Trejo-Téllez, F.C. Gómez-Merino, Nutrient solutions for hydroponic systems. Hydroponics-a standard methodology for plant biological researches. **1**, 1-22 (2012). doi: 10.5772/37578.
9. A. Kumari, H. Sharma, A. Kumari, P. Sharma, N. Pathak, R. Singh, A.R. Al-Tawaha, D.K. Pandey, M.S. Shekhawat, S. Mandal, Current understanding and interface between micro-and macronutrients in the plant–soil system: an overview. Essential Minerals in Plant-Soil Systems. 53-92 (2024). doi: 10.1016/B978-0-443-16082-0.00014-X.
10. C. Masclaux-Daubresse, F. Daniel-Vedele, J. Dechorgnat, F. Chardon, L. Gaufichon, A. Suzuki, Nitrogen uptake, assimilation and remobilization in plants: challenges for sustainable and productive agriculture. Annals of Botany. **105**(7), 1141–1157 (2010). doi: 10.1093/aob/mcq028.
11. M. H. Labra, P. C. Struik, D. F. Calderini, J. B. Evers, Leaf Nitrogen Traits in Response to Plant Density and Nitrogen Supply in Oilseed Rape. Agronomy. **10**(11), 1780 (2020). doi: 10.3390/agronomy10111780.
12. D. Subramanian, R. Subha, A.K. Murugesan, Accumulation and translocation of trace elements and macronutrients in different plant species across five study sites. Ecological Indicators. **135**, 108522 (2022). doi: 10.1016/j.ecolind.2021.108522.
13. S. Wang, Y. Liu, L. Chen, H. Yang, G. Wang, C. Wang, X. Dong, Effects of excessive nitrogen on nitrogen uptake and transformation in the wetland soils of Liaohe estuary, northeast China. Science of the Total Environment. **791**, 148228 (2021). doi: 10.1016/j.scitotenv.2021.148228.
14. J. Sun, W. Li, C. Li, W. Chang, S. Zhang, Y. Zeng, C. Zeng, M. Peng, Effect of different rates of nitrogen fertilization on crop yield, soil properties and leaf physiological attributes in banana under subtropical regions of China. Frontiers in Plant Science. **11**, 613760 (2020). doi: 10.3389/fpls.2020.613760
15. S. Tracy, F.H. Masias, K. Liu, G. Lopez, S.J. Seidel, G. Lopez, S.H. Ahmadi, W. Amelung, M. Athmann, F. Ewert, T. Gaiser, Nutrient deficiency effects on root architecture and root-to-shoot ratio in arable crops.Front Plant Sci. **13**, 1067498 (2023). doi: 10.3389/fpls.2022.1067498.
16. M. Razaq, P. Zhang, H.L. Shen, Salahuddin, Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono. PloS one. **12**(2), 0171321 (2017). doi: 10.1371/journal.pone.0171321.
17. W. Grzebisz, W. Zielewicz, K. Przygocka-Cyna, Deficiencies of Secondary Nutrients in Crop Plants—A Real Challenge to Improve Nitrogen Management. Agronomy **13**(1), 66 (2022). doi: 10.3390/agronomy13010066.
18. B. Francis, C. T. Aravindakumar, P. B. Brewer, S. Simon, Plant nutrient stress adaptation: A prospect for fertilizer limited agriculture. Environmental and Experimental Botany. **213**, 105431 (2023). doi: 10.1016/j.envexpbot.2023.105431.
19. S. Kulkarni, A. Goswami, Effect of excess fertilizers and nutrients: a review on impact on plants and human population. InProceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India (2019). doi: 10.2139/ssrn.3358171.
20. M. Ali Al Meselmani, Nutrient Solution for Hydroponics, in Recent Research and Advances in Soilless Culture, M. Turan, S. Argin, E. Yildirim, A. Güneş, Eds., IntechOpen. (2023). doi: 10.5772/intechopen.101604.