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Application of Micro-Nanobubble Aeration in Spinach (*Amaranthus viridis*) and Pakchoi (*Brassica rapa Chinensis*) Cultivation with the Wick System

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ABSTRACT

This study aimed to determine the effect of micro-nanobubble generator (MNBG) aeration on the cultivation of spinach (Amaranthus viridis) and pakchoi (Brassica rapa chinensis) hydroponic wicks. The basic principle of this system is that the axis capillary action flows nutrients to the planting medium. There are no moving parts so the nutrients can settle rapidly and the dissolved oxygen content is limited. Micro-nanobubbles (MNB) have the characteristics of a long residence time in the water so that their generation can operate intermittenttly. This study aims to determine the effect of applying (MNBG) with a flow rate of 0.98 L/minute on root length, plant height, and wet weight of spinach and pakchoi plants in wick hydroponics. Cultivation was hold on a free environment. There are three kinds of treatment; without aeration (N0), aeration 15 minutes x 4 for 24 hours (N15), and aeration 30 minutes x 4 for 24 hours (N30). Variations in the types of materials used in this study were spinach and pakchoi, as per treatment was repeat five samples. The study used a Randomized Block Design (RBD). The measurement results compared by the One-Way ANOVA test (5% level), then continued with Duncan's test to determine the difference. The results showed that there was an effect of applying intermittentt MNBG aeration on the average weight and height of the spinach plants, N15 treatment was more effective than the N0 and N30. Intermittentt MNBG aeration did not show a significant difference in the average weight of pakchoi.

1. INTRODUCTION

Agricultural cultivation activities in Indonesia are still facing the problem of reduced agricultural land due to land conversion (Prihatin, 2015). This has a negative impact on increasing agricultural production which is not proportional to the high market demand. The increase in population will affect the demand for horticultural products and consumption per capita. One of the indicators is the increasing awareness of Indonesian people about vegetable consumption, especially since the Covid-19 pandemic (Aryani *et al*., 2021). Some of the vegetable commodities that are of interest to the public are spinach and pakcoi. Therefore the agricultural sector is encouraged to innovate to achieve higher production quality with limited land without reducing agricultural productivity.

In accordance with economic principles, users will always maximize land use (Saili & Purwadio, 2012), so one solution to address the problem of productive and profitable land conversion is hydroponic technology (Ardian, 2007). Hydroponics is the cultivation of plants without soil (Romalasari & Enceng, 2019). However, one of the disadvantages of hydroponic technology is the high investment and operational costs (Haryanto *et al*., 2007). In this regard, there have been many studies explaining the emphasis on investment costs and operational costs (Ningrum *et al*., 2014).

The most basic and inexpensive system in hydroponic technology is the wick system. Its working principle is based on axial capillary action. Plant roots get nutrients and oxygen from a wick that hangs above the nutrient solution. There are no moving parts in this system so it is easy for nutrient deposits to occur. The absence of circulation in this system makes dissolved oxygen concentrations or dissolve oxygen (DO) worse than the circulatory system (Kurnia, 2018). It is difficult for roots that are submerged in a nutrient solution to obtain oxygen, causing poor respiration and the absorption of nutrients by the roots is not optimal (Fauzi *et al*., 2013). This has an impact on the decline in plant growth performance and yield.

Nutrient solution is a factor that must be optimized for hydroponics, and smooth respiration is beneficial for all cell activities including cell division or plant growth (Genesiska *et al*., 2020). Hydroponic nutrient solutions are considered very good if the DO concentration is around 8 mg/L (Ningrum *et al*., 2014). Many studies discussing the effect of DO concentration on plant productivity has been reported (Racette *et al*., 1990; Shun & Takakura, 1994; Goto *et al*., 1996; Yoshida *et al*., 1997; Bonachela *et al*., 2010; Febriani *et al*., 2012). The tool used to add DO to the nutrient solution is called an aerator. The aerator moves the water, creating more surface contact with the air and preventing sedimentation of the nutrient solution (Farid *et al*., 2018). The application of aerators can improve the quality of nutrient solutions for hydroponics but continuous generation will require large amounts of energy and costs.

Fine bubble technology is gaining popularity in many areas of water treatment including aeration. The bubbles in question are microbubbles (MBs) with an average diameter of less than 50 µm (Takahashi, 2005) and nanobubbles (NBs) with a size smaller than 1 µm (Xu & Xiao, 2020). The pressurized dissolution technique is one of the two main NBs generation techniques, and this method is very good at producing high density MB bubbles (Tomiyama *et al*., 2015). Based on research conducted by Alam *et al*. (2021), which is the basis of this research, the breaking of MBs smaller than 50 µm is a method for generating NBs.

The average NBs diameter is stable within 3 weeks after generation (with an optimal generation time of 30 minutes) (Alam *et al*., 2021). Reported in a related study, NB decreased DO concentration from 31.7 mg/L to 8.7 mg/L within 5 hours after generating. The addition of DO to the planting medium was reported as a growth stimulant for plants (Ebina *et al*., 2013). Aeration with micro-nanobubble generator (MNBG) then becomes one of the ways that is considered efficient to produce more DO in nutrients for nutrient solutions with a relatively short ignition duration.

Research on the effect of aeration and intermittent flow of nutrient solution in the wick system for spinach and pakcoi vegetables with MNBG has never been done before. The purpose of this study was to examine the effect of MNBG aeration on the growth of vegetable plants cultivated in hydroponic wick and as a solution to accelerating the growth of vegetable plants for the problem of limited land in Indonesia.

2. MATERIALS AND METHODS

2.1. Research Arrangement

This research was conducted from September to December 2022 at the Rooftop and Intelligent Instrumentation Laboratory, Cisitu BRIN Area, Bandung. The materials used in this study were spinach seeds, pakcoi seeds, water, rockwool, and nutrients consisting of stock A and stock B solutions (AB Mix). The experiment was carried out on a rooftop – an uncontrolled environment, which was placed on an iron frame shelter with a transparent PVC corrugated roof (Figure 1).

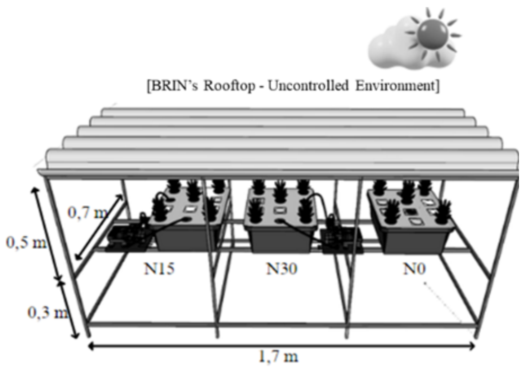

Figure 1. Experimental layout scheme

Before the study started, MNBG was characterized with 500 ml of water generated for 15 minutes in the laboratory. The NB size distribution was determined using a ZetaSizer Nano ZS (Malvern Instruments, UK) particle size analyzer based on the Dynamic Light Scattering (DLS) method. The DLS method is capable of characterizing dispersed particles in aqueous media. Particles moving with Brownian Movement scatter light at different intensities. The resulting light intensity fluctuations will be detected and converted into a particle size based on the Stokes-Einstein equation. The intensity of the scattered light refers to Rayleigh's law of light scattering (Alam *et al*., 2021).

There are 3 kinds of treatment, namely N0 (control), N15 (aerator with 15 minutes x 4 generation for 24 hours, or a total generation duration of 1 hour per day), N30 (aerator with 30 minutes x 4 generation for 24 hours, or a total generation duration 2 hours per day) with 5 repetitions each (Figure 2). The volume of the nutrient solution was maintained at 7 L which was observed every 2 days while simultaneously observing nutritional parameters including; degree of acidity (pH), and electrical conductivity (EC). The DO parameter in the nutrient solution was taken 3 times per treatment and recorded for 24 hours. Plant parameters include; plant height (cm), root length (cm), and plant fresh weight (g) at harvest. Cultivation was stopped at 14 HST. Nutrient parameter measurements were taken using a multi water quality meter Lutron WA-2017SD (Lutron Instruments, Taiwan), plant height and root length parameters were taken manually using a ruler, and plant fresh weight parameters were taken using a digital scale. The aerator used is MNBG with a diaphragm pump and pressurized dissolution nozzle.

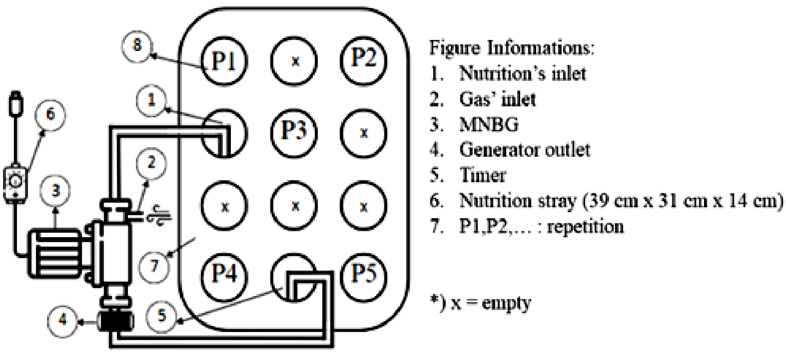

Figure 2. Generator application scheme

2.2. Data Analysis

The research was carried out using a randomized block design (RBD). The measurement results were compared with the one-way ANOVA test with a level of 5% and continued with Duncan's test to test the differences between all treatment pairs.

3. RESULTS AND DISCUSSION

3.1. MNBG Characterization

The first evidence of the presence of MB in generated water is the appearance of water which turns cloudy (milky) due to residue (Alam *et al*., 2021). Shortly after that the water will return to being transparent, indicating a reduction in the size of the bubbles to NB – the residue of MB generation by MNBG (Figure 3).

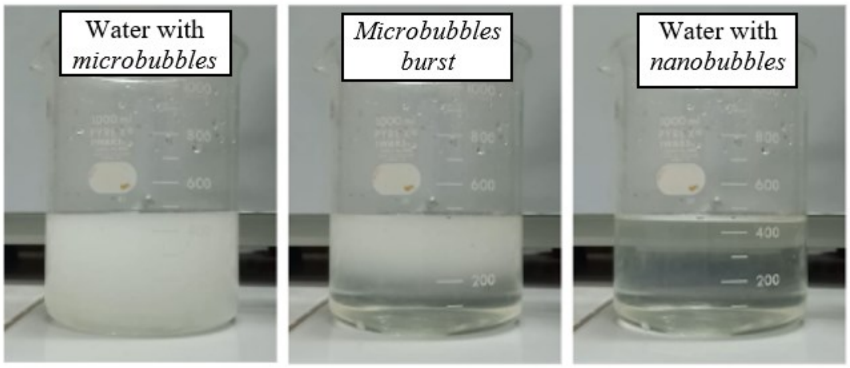

Figure 3. MNBG characterization

The theory that supports the evidence for the presence of NB in water as has been reported in many related studies is the Tyndall Effect (Etchepare *et al*., 2017; Alam *et al*., 2021). Based on the number of bubbles, the size distribution after conversion shows that most of the bubbles are less than 200 nm in size (Figure 4). The size distribution is based on the three mean values of 29 measurements per sample.

3.2. DO Conditions for Each Treatment

The observed results (3 times) of the average DO at each generation time (N0, N15, N30) are presented in the graph in Figure 5.

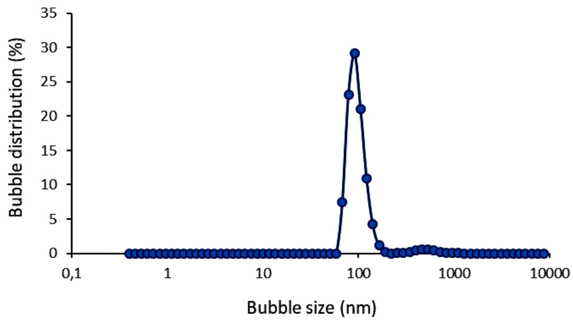

Figure 4. Graph of size distribution data

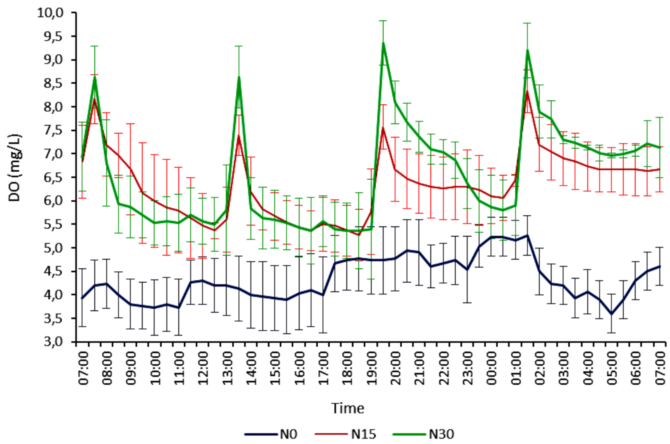

Figure 5. DO concentration for each treatment in 24 hours (error bars are standard deviation)

Figure 5 shows that the N0 treatment has the lowest average dissolved DO. Plants with water culture require dissolved oxygen of at least 4 ppm or 4 mg/L and the largest is 10 mg/L (Ningrum *et al*., 2014), so the availability of DO at N0 is still sufficient even though it is the lowest compared to the N15 and N30 treatments. There was an increase in DO at 4 times with the same on-off interval according to the activation time of MNBG in the N15 and N30 treatments. The N30 treatment had the highest average concentration of DO generated among the other treatments.

3.3. The Effect of MNBG on Cultivation Results

In this study, the pH and EC values were not included in the treatment so it was expected that the values would be similar between the treatments for each plant. Observation of pH and EC values is solely to see the homogeneity of nutrient solutions because pH and EC values are affected by evapotranspiration, nutrient absorption, and others.

Treatments N15 and N30 generally obtained results that were not much different from one another, so that it can be said both treatments accelerate growth. However, the absence of aeration reduces all parameters as do with the N0 treatment. This is in accordance with research reported by (Ningsih & Aini, 2020). The application of MNBG with a flow rate of 0.98 L/minute is sufficient because plants are reported to be able to absorb nutrients well at a nutrient flow rate of 0.97 L/min (Harjoko, 2009). MNBG in nutrient solution did not make EC and pH values different between conditions at any time during the experiment, this is in accordance with previous studies (Park & Kurata, 2009).

3.3.1. Spinach

In Table 1, it shows that the application of MNBG with intermittent lighting in hydroponic wick spinach cultivation experienced faster growth with greater yields than plants without treatment (N0).

Table 1. Effect of MNBG on spinach cultivation

Treatment	Daily measurement		at harvesting time		
	EC (mS)	pH	Root lenth (cm)	Plant height (cm)	Fresh weight (g)
N0	2.43^{a}	7.00^{a}	13.3^{a}	21.7^{a}	66.60^{a}
N15	2.49^{a}	6.83^{a}	16.5^{a}	25.9^{b}	87.80^{b}
N30	2.48^{a}	6.59^{a}	17.6^{a}	24.6^{ab}	88.60^{b}

Note: The same letter notation means that there is no significant difference in DMRT at a = 5%

This research resulted in the fresh weight of spinach cultivated with intermittent MNBG. The average DO gain after generation was above 8.5 mg/L for N30 as can be observed in Figure 5. This is in contrast to the highest MNBG average DO achievement below 8.5 mg/L for N15 treatment. This is in accordance with previous studies (Ningrum *et al*., 2014), which reported the best DO for plants was 8 mg/L. The N15 treatment with a shorter generation time was considered more effective in accelerating the growth of fresh weight parameters of spinach. The average fresh weight of spinach is 24.7% greater than without aeration (N0).

Meanwhile on the plant height parameter, the N15 treatment was quite different. Through this research, it is possible for plants that are shorter at N30 to store more supporting factors than N15. This is in accordance with previous research (Wendi, 2017), which reported that there were differences in the provision of aeration for the variable height of spinach plants (Deep Flow Technique system). Meanwhile, there was no significant difference between each treatment. Therefore, the use of N15 treatment can be the best choice.

The DO value showed a difference, while the nature of the EC and pH solutions did not cause differences in the growth of spinach in the three conditions. So it can be concluded that, MNBG is beneficial in the wick hydroponic culture system, because it strongly encourages the growth of spinach.

3.3.2. Pakchoi

In Table 2, it shows that the application of MNBG with intermittent lighting in the wick hydroponic pakcoi cultivation obtained results that did not have a significant difference in the observations of root length and weight. Meanwhile, on plant height, pakcoi cultivation using MNGB has a significant effect.

Table 2. Effect of MNBG on pakcoi cultivation

Treatment	Daily measurement		at harvesting time		
	EC (mS)	pH	Root lenth (cm)	Plant height (cm)	Fresh weight (g)
N0	2,52^{a}	5,78^{a}	13,3^{a}	13,1^{a}	65,00^{a}
N15	2,52^{a}	5,79^{a}	15,6^{a}	21,9^{b}	67,00^{a}
N30	2,50^{a}	5,57^{a}	15,2^{a}	22,3^{b}	74,00^{a}

Note: The same letter notation means that there is no significant difference in DMRT at a = 5%

Based on Table 2, the wet weight of wick hydroponic pakcoi with the application of N15 and N30 aeration was not significantly different from the cultivation without N0 aeration. This also happened to the results of observing the root length of the pakcoi plant. However, the growth of pakcoi plants was better with the application of aeration (N15 and N30), indicated by the whiter (healthier) root color compared to without the application of aeration (N0). The root color of the N0 treatment was observed to be brownish. The height of the nutrients is less than 6 cm or does not touch the planting medium so that the roots are not completely submerged in this wick system. Hanging roots (attached to the wick) obtain oxygen from their surroundings, while submerged roots obtain oxygen from their nutrient DO. Browning of the roots of the N0 treatment is a response of the roots to the lack of oxygen in the nutrient solution (Surtinah, 2016).

In this study, the intensity of aeration on pakcoi only gave a significant difference in the plant height parameter of the pakcoi plant, this is because pakcoi is quite tolerant to DO values according to previous studies (Surtinah, 2016). The application of MNBG with a flow rate of 0.98 L/min did not cause differences in EC and pH properties, as well as on plant growth (Park & Kurata, 2009). So, based on this study MNBG with intermittent generation in the hydroponic wick system did not result in a significant fresh weight gain rate in pakcoi.

4. CONCLUSION

Intermittent aeration treatment with MNBG (flow rate 0.98 L/min) on accelerating growth of plants cultivated in hydroponic wick had a significant effect on spinach and no significant effect on pakcoi. In spinach, the N30 treatment was not significantly different to produce the largest plant fresh weight with N15, respectively 87.80 g and 88.60 g. The N15 treatment had a very significant effect on the height of the spinach plants and the three treatments did not differ significantly in the parameter of plant root length. In pakcoy, the three treatments had no significant effect on the parameters of root length and plant fresh weight. The aeration treatment (N15) on pakcoi only had a significant effect on plant height. Further studies will be needed to determine the relationship between the application of MNBG in other hydroponic systems to the accelerated growth of cultivated plants.

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