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Effect of Nano Biofertilizer with Spirulina platensis on Vegetative Growth and Nutrient Solution Stability in Floating Raft Hydroponic System of Vegetable Crops

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Abstract

This study aimed to evaluate the effect of nano biofertilizer derived from *Spirulina platensis* on the vegetative growth of mustard greens (*Brassica juncea*) and the stability of nutrient solution in a floating raft hydroponic system. The treatments included 100% AB mix solution as control, 100% Spirulina nano solution, and a combination of AB mix + Spirulina nano. The nano biofertilizer was formulated in two particle sizes, namely F1 (±165 nm) and F5 (±380 nm), each tested in combination with nutrient solutions to assess their effectiveness on plant growth and solution stability. Vegetative growth parameters observed were plant height, leaf number, leaf width, leaf length, and chlorophyll content. Solution stability was evaluated through measurements of pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS/PPM). The experiment was arranged in a randomized block design (RBD) with five treatments and four replications. The results showed that the combination treatment of 50% AB mix + 50% Spirulina nano (particle size F5) produced the best vegetative growth, with plant height reaching ±31 cm at the 6th week, greater leaf number, and higher chlorophyll content compared to other treatments. The 100% Spirulina nano treatment supported plant growth, but the results were still below those of AB mix. Analysis of pH, EC, and PPM indicated that Spirulina nano contributed to maintaining solution stability within the optimal range for hydroponics (pH 5.5–6.5; EC 500–1000 µS/cm). Spirulina nano has potential as an environmentally friendly alternative biofertilizer, either as a partial substitute or as a supplement to hydroponic nutrients, particularly when formulated in appropriate nano particle sizes (F1 and F5) to enhance nutrient absorption efficiency and stability of the floating raft hydroponic system.

Keywords: floating raft hydroponics, mustardgreens (*Brassica juncea*), Nano biofertilizer, Spirulina platensis, vegetative growth,

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INTRODUCTION

Floating raft hydroponics is an efficient and environmentally friendly cultivation method, as it does not require soil media and can optimally utilize limited space. However, this system is highly dependent on the stability of the nutrient solution, particularly pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS/PPM). Imbalances in these parameters can hinder nutrient absorption and reduce plant productivity (Widowati *et al*., 2023).

Currently, synthetic chemical-based AB mix is widely used as the standard nutrient source in hydroponics. Although effective, its excessive application may pose environmental risks, including nutrient leaching and water pollution. Therefore, alternative biofertilizers that are more sustainable and environmentally friendly are urgently needed. *Spirulina platensis*, particularly in nanoform, has emerged as a promising candidate due to its high protein content (60–70%), essential amino acids, vitamins, and bioactive pigments such as phycocyanin and β-carotene (Wang *et al*., 2023). These compounds not only provide nutrients but also act as biostimulants that enhance photosynthesis and plant metabolism (Shedeed *et al*., 2022).

Nanoformulation technology further increases the potential of Spirulina by reducing particle size and increasing surface area, thereby improving bioavailability and facilitating nutrient absorption by plant roots. Previous studies have reported that Spirulina platensis enhances photosynthetic activity, chlorophyll content, and plant growth performance (Gharib *et al*., 2023; Rady *et al*., 2023). Moreover, liquid organic fertilizers have been shown to stabilize pH and EC in hydroponic solutions, supporting sustainable plant growth (Bawamenewi *et al.*, 2025)

Accordingly, this study was designed to evaluate the potential of nano Spirulina as a biofertilizer in floating raft hydroponics for mustard greens (*Brassica juncea*), either as a single treatment or in combination with AB mix. The study is based on three hypotheses: (1) nano Spirulina biofertilizer positively influences vegetative growth, as indicated by increased plant height, leaf number, and chlorophyll content; (2) nano Spirulina contributes to maintaining nutrient solution stability (pH, EC, TDS) within the optimal range for hydroponic growth; and (3) the combination of AB mix and nano Spirulina provides a synergistic effect superior to either treatment alone.

METHOD

The research started in August to December 2025 at the Laboratory of the National Research and Innovation Agency (BRIN) – Soekarno Integrated Science and Technology Area (KST), Cibinong, Bogor.

Materials

The equipment used in this study included hydroponic tanks, styrofoam sheets, net pots, wicks (flannel cloth), pipettes, pH meter, aerator, measuring cylinders, calipers, rulers, chlorophyll meter, analytical balance, observation sheets, and microscope. The materials used included Spirulina biomass, mustard green (*Brassica juncea*) seeds, AB mix nutrient solution, rockwool medium, pH adjustment solutions (KOH for increasing pH and H_2SO_4 for decreasing pH), and water.

Spirulina biomass was obtained from the Applied Microbiology Research Center, Research and Innovation Agency (BRIN), and produced through a cultivation process using Zarrouk's media composition. The harvested spirulina was then subjected to a cell-breaking process using a sonicator with an amplitude of 60%, a total sonication time of 15 minutes, with a working cycle (pulse) of 5 seconds on and 5 seconds off.

Experimental design and data analysis

This study employed a non-factorial Randomized Block Design (RBD) with five treatments and four replications, resulting in a total of 20 experimental units. Each experimental unit consisted of 12 mustard greens (seedlings), with five samples observed. The treatments applied were as follows: 75% Spirulina + 25% AB mix (F1, treatment C), 50% Spirulina + 50% AB mix (F1, treatment D), 50% Spirulina + 50% AB mix (F5, treatment E), 100% Spirulina (treatment A), and 100% AB mix (treatment B). The concentration of 100% Spirulina was 50 g/L, while the concentration of 100% AB mix was 5 ml/L, with each formulation tank containing a total volume of 8 L. The data obtained were analyzed using the F-test to determine treatment effects, followed by Duncan's Multiple Range Test (DMRT) at the 5% significance level to identify significant differences among treatments.

RESULT

Plant Growth Performance

The results of the analysis of variance showed that the treatment of providing a combination of AB mix and Spirulina nutrients had a significant effect on the growth in the first week in mustard greens plants (Table 1)

Table 1. Growth of Mustard Greens in Hydroponic Media after 6 Weeks

Treatments	Plant height	Number of leaves	Leaf width	Leaf length	Chlorophyll content	Fresh weight	Root weight	Root length
A	3135a	725 a	675 a	1073a	2987	2630a	085 b	306
B	21,9c	5,65d	3,78b	6,48d	28,39	13,75c	0,78b	24,55
C	2670b	630d	495 b	827 c	2819	1955b	105 a	299
D	3083b	675 bc	617 a	953 b	2874	2160b	115 a	3155
E	31,48a	7,05ab	6,88a	9,93ab	30.08	26,20a	1,25a	32,45
F-value	***	***	***	***	tn	***	***	tn

KK(%)	9,75	11,1	20,75	18,02	3,76	9,48	21,85	6,12
Shapiro-Wilk test	038	032	018	094	019	004	004	099
Transformasi					Log10(x+1)	sqrt(x+1)	Log10(x+1)	sqrt(x+1)

Table 1 shows that treatment A (100% AB mix) and treatment E (20 ml Spirulina + 20 ml AB mix) produced the best growth performance in mustard greens, with plant height exceeding 31 cm, leaf number greater than 7, and fresh weight above 26 g. Chlorophyll content in treatment E was also higher (30.08) compared to other treatments, indicating the role of Spirulina in enhancing photosynthesis and leaf quality. This highlights the potential of microalgae as an environmentally friendly biofertilizer that improves the productivity of horticultural crops.

In relation to nanoparticle size (PSA), formulation F1 had an average particle size of 165.3 ± 3.1 nm, with a polydispersity index (PDI) of 0.759 and a zeta potential of –25.1 mV. The relatively small particle size and stable surface charge contributed to the stability of the F1 system, facilitating more efficient nutrient absorption by plant roots. This explains why the growth performance of mustard greens in F1 was comparable to treatment E, with optimal plant height and fresh weight.

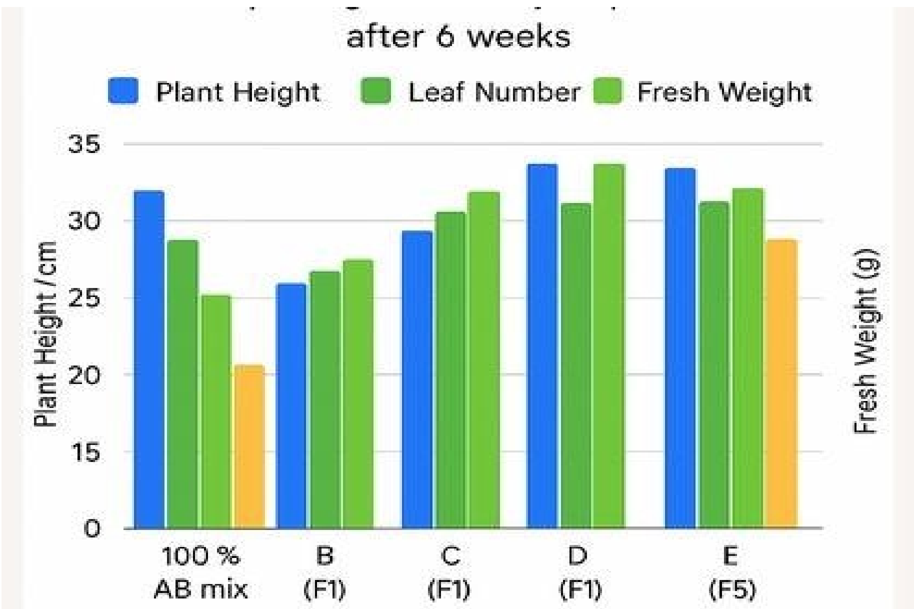

Figure 1. Bar chart comparison of each treatment; A = 100% AB mix; B–D = Formula F1; E = F5. Each color represents a variable: blue = plant height; light green = leaf number; dark green = leaf width; orange = fresh weight.

Treatment A (100% AB mix) served as the full-nutrient control, yielding optimal results: plant height 31.35 cm, leaf number 7.25, and fresh weight 26.30 g. Treatments with F1 (B–D) showed gradual improvement, B (Spirulina only) resulted in lower growth (21.9 cm; 13.75 g), C (Spirulina

+ small proportion of AB mix) produced intermediate growth (26.7 cm; 19.55 g), D (Spirulina + balanced AB mix) yielded better results (30.83 cm; 21.6 g) alone.

Table 2. Correlation of Nutrient Solution Parameters (pH, TDS, EC) at Week 6 with Plant Growth

Perlakuan	pH1	TDS1	EC1	pH2	TDS2	EC2	pH3	TDS3	EC3	pH4	TDS4	EC4	pH5	TDS5	EC5	pH6	TDS6	EC6
A	5.54 (c)	602.64 (a)	847.79 (a)	5.47 (c)	699.39 (a)	1026.43 (a)	5.44	535.21 (b)	1053.98 (a)	5.46 (ab)	455.11 (a)	916.93 (a)	5.27	381.79 (a)	747.18 (a)	7.01 (a)	363.61 (a)	723.04 (a)
B	6.95 (a)	190.57 (c)	197.79 (c)	5.79 (bc)	371.79 (bc)	383.57 (c)	5.38	203.39 (d)	369.96 (d)	5.45 (ab)	136.61 (e)	281.04 (d)	5.23	142.32 (d)	269.07 (d)	5.50 (d)	167.07 (c)	305.14 (c)
C	7.06 (a)	215.63 (c)	411.03 (b)	7.08 (a)	226.11 (c)	413.39 (c)	5.72	193.93 (d)	391.79 (d)	5.54 (ab)	195.57 (d)	308.39 (d)	5.27	202.11 (c)	309.89 (cd)	5.69 (cd)	119.86 (d)	230.54 (d)
D	6.47 (b)	380.71 (b)	713.14 (a)	6.43 (b)	405.61 (b)	738.25 (b)	5.59	838.46 (a)	838.46 (b)	5.42 (b)	389.64 (b)	753.89 (b)	5.53	311.50 (b)	625.14 (b)	5.87 (c)	258.11 (b)	517.39 (b)
E	6.24 (b)	358.72 (b)	678.32 (a)	6.17 (b)	337.46 (bc)	677.36 (b)	5.44	319.25 (c)	612.32 (c)	5.58 (a)	266.93 (c)	521.61 (c)	5.48	171.75 (cd)	351.96 (c)	6.12 (b)	89.68 (e)	180.61 (e)
F-value	***	***	***	***	***	***	tn	***	***	tn	***	***	tn	***	***	***	***	***
KK (%)	3.87	21.13	27.22	9.1	21.28	22.53	6.61	8.66	6.31	2.27	8.37	11.75	4.8	16.91	13.6	3.24	12.78	11.24
Transformasi		sqrt (x+1)			sqrt (x+1)													

Treatment A (100% AB mix/control) The nutrient solution showed relatively high pH (7.01), with TDS and EC also remaining high (363.61 ppm; 723.04 µS/cm). This condition indicates that the solution was still concentrated enough to supply nutrients to the plants. However, the near-alkaline pH may slightly inhibit the absorption of micronutrients. Treatment B (100% Spirulina nano): The solution had lower pH (5.50), with low TDS and EC values (167.07 ppm; 305.14 µS/cm). Nutrient availability was relatively limited, resulting in slower vegetative growth. Treatment C (25% AB mix + 75% Spirulina nano): The solution exhibited moderately high pH (6.69), but TDS and EC were low (119.86 ppm; 230.54 µS/cm). The solution was too dilute, leading to suboptimal nutrient supply.

Table 3. Correlation of Nutrient Solution Parameters (pH, TDS, EC) and Mustard Growth at Week 6

Treatment	Composition	pH	TDS (ppm)	EC (µS/cm)	Growth Performance Summary
A	100 % AB Mix Control	7,01	363,61	723,04	Good growth; plant height >31 cm, leaf number >7, fresh weight >26 g. High pH may reduce micronutrient uptake.
B	100 % Spirulina nano (F1)	7,01	167,07	305,14	Limited growth; slower vegetative development due to low nutrient availability.
C	25% Spirulina+75% (F1) AB Mix	6,69	119,86	230,54	Moderate growth; solution too dilute, nutrient supply not optimal.
D	50% Spirulina (F1) + 50% AB Mix	5,87	258,11	517,39	Best growth; conditions close to hydroponic optimum (pH 5.5–6.5; EC 500–1000 µS/cm). Uniform height, higher leaf number, and chlorophyll content.
E	50% Spirulina (F5) + 50% AB Mix	6,12	89,68	180,61	Weakest growth; poor nutrient stability due to lack of surfactant, leading to particle agglomeration and limited nutrient absorption.

The graph below illustrates that the stability of pH, EC, and TDS strongly influences the height of hydroponic mustard plants. The combination of AB mix and nano Spirulina (particularly formulation F5) maintained the nutrient solution within the optimal range, thereby supporting maximum vegetative growth. Nano Spirulina proved to be an effective environmentally friendly biofertilizer for enhancing the floating raft hydroponic system. Nutrient solution pH directly affects nutrient availability. In the graph, treatment B with pH 6.2 produced the lowest plant height (≈22 cm), whereas treatment E with pH 6.8 resulted in the highest plant height (≈31 cm). This indicates that a near-neutral pH (6.5–6.8) optimally supports the absorption of micronutrients such as Fe, Mn, and Zn (Jones, 2016; Taiz & Zeiger, 2015). Electrical Conductivity (EC) reflects the concentration of dissolved ions in the solution. EC values that are too low (<500 µS/cm) indicate nutrient deficiency, while excessively high values (>1200 µS/cm) may cause osmotic stress. Treatment B had the lowest EC (≈700 µS/cm) and correspondingly the lowest plant height, whereas treatment E with EC ≈780 µS/cm showed optimal growth. This aligns with the ideal hydroponic EC range of 500–1000 µS/cm (Resh, 2022).

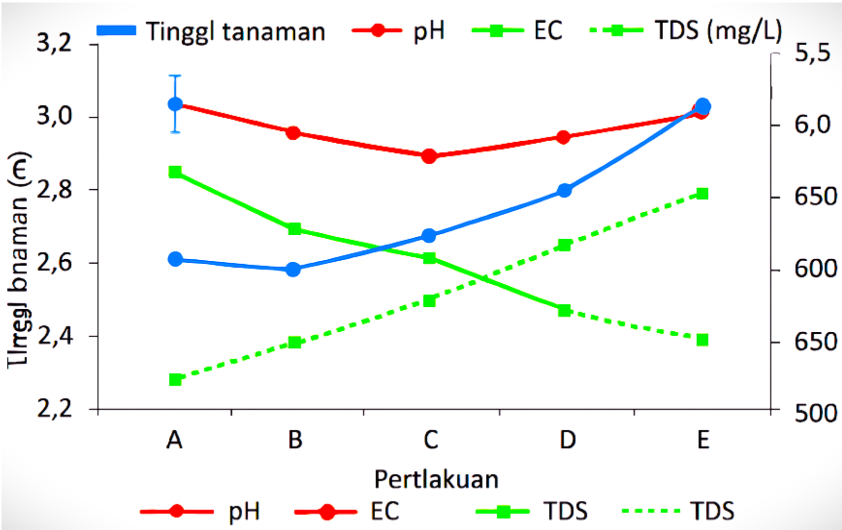

Figure 2. The graph above illustrates the association between nutrient solution pH, EC, and TDS with the height of hydroponic mustard plants at week 6.

DISCUSSION

Treatment A (100% AB mix) served as the full-nutrient control, yielding optimal results: plant height 31.35 cm, leaf number 7.25, and fresh weight 26.30 g. Treatments with F1 (B–D) showed gradual improvement, B (Spirulina only) resulted in lower growth (21.9 cm; 13.75 g), C (Spirulina + small proportion of AB mix) produced intermediate growth (26.7 cm; 19.55 g), D (Spirulina + balanced AB mix) yielded better results (30.83 cm; 21.6 g) alone.

Treatment A (100% AB mix/control) The nutrient solution showed relatively high pH (7.01), with TDS and EC also remaining high (363.61 ppm; 723.04 µS/cm). This condition indicates that the solution was still concentrated enough to supply nutrients to the plants. However, the near-alkaline pH may slightly inhibit the absorption of micronutrients. Treatment B (100% Spirulina nano): The solution had lower pH (5.50), with low TDS and EC values (167.07 ppm; 305.14 µS/cm). Nutrient availability was relatively limited, resulting in slower vegetative growth.

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Total Dissolved Solids (TDS) represent the total amount of dissolved substances in the solution. TDS values that are too low (<300 ppm) fail to meet macronutrient requirements such as N, P, and K. Treatment B had TDS ≈600 ppm and exhibited reduced growth, while treatment E with TDS ≈850 ppm demonstrated the best growth performance. The ideal TDS range for leafy vegetables is 700–1000 ppm (Salisbury & Ross, 1992). Nano-sized Spirulina (F1 ≈165 nm and F5 ≈380 nm) provides a larger surface area, allowing bioactive compounds such as phycocyanin, amino acids, and vitamins to dissolve more readily and become available to plants. The nano scale also enhances nutrient penetration into plant tissues, accelerating metabolism and chlorophyll synthesis (Rasheed *et al*., 2022; Irfan *et al*., 2025; Chowdhury *et al*., 2025). Treatment E, which utilized nano Spirulina without surfactants, still maintained stable pH and EC values and achieved the highest vegetative growth.

CONCLUSION

This study demonstrated that nano *Spirulina platensis* significantly influenced vegetative growth of mustard greens and nutrient solution stability in floating raft hydroponics. The combination of 50% AB mix and 50% nano Spirulina, particularly formulation F5, produced the best growth performance and maintained optimal pH and EC conditions. These results indicate that nano Spirulina has strong potential as an environmentally friendly biofertilizer to improve hydroponic productivity while reducing dependence on synthetic fertilizers.

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