InJAST
Volume 6, Number 1, April 2025
Pages: 52-59

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: https://doi.org/10.33751/injast.v6i`1.29

Enhancing hydroponic vegetable productivity using environmentally friendly cow biourine fertilizer technology as nutrient solution

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Submitted 26 July 2023; Accepted 19 August 2025; Published 20 August 2025

ABSTRACT

The increasing scarcity of arable land and agricultural inputs has encouraged the adoption of innovative cultivation systems such as hydroponics, with vegetables being among the most suitable commodities. Hydroponic cultivation commonly relies on AB Mix as the primary nutrient source; however, the availability of livestock resources, particularly cow urine, presents an opportunity to develop biourine as an environmentally friendly alternative to synthetic fertilizers. This study employed a quantitative experimental approach using a Complete Randomized Factorial Design to examine the effects of different combinations of AB Mix and cow biourine on the growth and productivity of hydroponic vegetables. Treatments consisted of varying concentration ratios of AB Mix and biourine, with evaluation focused on vegetative parameters including plant height, leaf length, leaf width, number of leaves, and post-harvest yield. Results demonstrated that spinach (*Amaranthus sp.*) and water spinach (*Ipomoea aquatica*) exhibited optimal growth under treatments dominated by AB Mix, particularly at the P4 ratio (75% AB Mix + 25% biourine), which significantly improved vegetative growth and yield compared to other treatments. Conversely, bok choy (*Brassica rapa var. chinensis*) responded more favorably to biourine-dominated treatments, with the P5 ratio (25% AB Mix + 75% biourine) producing the best performance across measured parameters. These findings indicate that biourine can partially substitute for AB Mix in hydroponic systems, with crop-specific responses determining the optimal formulation. The study highlights the potential of livestock-derived biourine as an eco-friendly fertilizer alternative, reducing reliance on synthetic inputs and supporting sustainable hydroponic vegetable production.

Keywords: *AB Mix nutrition, cow biourine, hydroponics*

INTRODUCTION

The increasing demand for agricultural products must be balanced with the modernization of cultivation practices, particularly in light of limited land availability and agro-inputs such as fertilizers, water, and pesticides. To address these challenges, alternative agricultural systems that are innovative, practical, and competitive are required. Hydroponics has emerged as one such system, offering the potential to sustain agricultural production in areas where soil-based cultivation is constrained (Resh, 2013).

Hydroponics is considered an environmentally friendly and resource-efficient cultivation practice capable of producing high-quality crops over the long term. Leafy vegetables are among the most widely cultivated commodities in hydroponic systems due to their relatively short growth cycle and high consumer demand. This demand is increasing in both traditional and modern markets, reflecting promising opportunities for hydroponic vegetable farming (Roidah, 2014). Furthermore, hydroponics minimizes dependence on land quality, reduces vulnerability to climate variability, and supports agricultural intensification.

According to the Central Bureau of Statistics (Badan Pusat Statistik [BPS], 2020), production of leafy vegetable commodities in Indonesia shows a rising trend, with mustard production increasing by 2.13% and spinach by 1.88%, although water spinach experienced a decline of 0.69% (Table 1). Vegetables thus remain an economically valuable commodity with daily consumption needs, reinforcing their suitability for hydroponic cultivation.

Table 1. Vegetable commodities production.

Year	Production (tons)		
	Chinese cabbage	Cabbage	Spinach
2015	600.200	305.080	150.093
2016	601.204	297.130	160.267
2017	627.598	276.970	148.288
2018	635.990	289.563	162.277
2019	652.727	295.556	160.306

Source: BPS, 2020

Hydroponic systems typically rely on nutrient solutions such as the commercially available AB Mix. However, the high cost of AB Mix remains a key barrier for farmers, limiting profitability. At the same time, farmer-owned livestock represents a potential source of affordable and sustainable organic fertilizers. Cow manure and urine, if left untreated, can pollute the environment and release methane emissions, but when processed, they can be transformed into valuable organic inputs (Steinfeld et al., 2006).

Biourine, produced through anaerobic fermentation of fresh cow urine and manure with the addition of nitrogen-fixing and decomposer microbes, contains essential nutrients including nitrogen (2.7%), phosphorus (2.4%), potassium (3.8%), and calcium (5.8%) (Mirna, Salim, & Gani, 2013). Studies have demonstrated the effectiveness of combining biourine with AB Mix. For example, Abdillah et al. (2017) reported significant improvements in kailan growth parameters, including plant height, leaf area, stem diameter, and fresh weight, under combined treatments. Similarly, Malinda et al. (2018) found that the application of AB Mix (75%) and biourine (25%) significantly increased leaf number in leafy vegetables.

In addition to nutrient contributions, biourine contains plant growth regulators such as indole-3-acetic acid (IAA), which play an important role in organogenesis, root development, and cell elongation (Gunawan, 2018; Benjamins & Scheres, 2008). The characteristic aroma of cow urine also acts as a natural pest repellent. Thus, the integration of biourine into hydroponic systems offers a sustainable, low-cost, and environmentally friendly alternative to conventional AB Mix fertilizers, while enhancing crop performance and reducing production costs.

METHODS

Place and Time of Research

This research was conducted at PT SWEN IT Ciomas, Bogor Regency, West Java Province. The company is a pioneer in designing and developing biogas digesters. This research was carried out for approximately three months, from March to May 2021.

Research Methodology and Design

This research method was conducted experimentally. Experimental research according to Arikunto (2005) is research that aims to see whether or not there is a causal effect of a subject to be investigated.

This research design uses a Factorial Complete Randomised Design. Each type of plant such as spinach, water spinach and bok choy get 5 separate treatments of nutrients. The number of repetitions can be determined by the calculation formula according to Federer's repetition formula, namely

$$(T-1)(R-1) \geq 15$$

Notes:
T = treatment (number of treatments)
R = replication (number of replications)
15 = general degree of freedom

According to the calculation results of the Federer formula, 5 repetitions of the 5 treatments were produced. This research was conducted in a conditioned environment, so as to provide a homogeneous effect. Three types of plants received 5 treatments, thus the number of treatments designed as 3 x 5 =15 treatment combinations. The number of experimental units consisting of 5 replicates was 15 x 5 =75 experimental units. Each replicate was arranged with 5 netpots so that there would be 375 netpot experiments.

P1T1	P1T2	P1T3
P2T1	P2T2	P2T3
P3T1	P3T2	P3T3
P4T1	P4T2	P4T3
P5T1	P5T2	P5T3

Notes:
P1 : 100% AB Mix Nutrients
P2 : 100% cow biourine
P3 : 50% Nutritional AB Mix + 50% cow biourine
P4 : 75% Nutritional AB Mix + 25% cow biourine
P5 : 25% Nutrient AB Mix + 75% cow biourine
T1 : Spinach Plant
T2 : Water spinach Plants
T3 : Bok choy plants

Research Procedures

The nutrient solution used is AB Mix fertiliser, which consists of solution A and solution B. AB Mix fertiliser is used in liquid form. Preparation of ready-to-use solution with 5 mL of solution A and B dissolved in 1 L of water, then stirred. The preparation of nutrient solution from biourine is made by mixing water and biourine in a ratio of 1:1 (1 litre of cow biourine: 1 litre of water).

The data obtained from the observations will be calculated using analysis of variance (ANOVA) at the level of $\alpha = 5\%$ to determine the effect of the treatment analysed. If the real effect is obtained, it is continued by using the Duncan Multiple Range Test (DMRT) test at the $\alpha = 5\%$ level.

RESULTS AND DISCUSSION

The observations of this study were growth variables at 14, 21, 28, and 35 days after sowing and yield variables carried out when the vegetable plants were 40 days after sowing accompanied by observations of crop yields according to the treatment at each repetition such as plant height; leaf length; leaf width, number of leaves; and consumptive water needs in plants.

Plant Height

The results of the analysis of variance demonstrated that the combination of cow biourine and AB Mix nutrients had a significant effect on plant height at different growth stages (Table 2). At 14 and 21 days after planting (HSS), the P2 treatment (100% cow biourine) produced greater plant height, significantly differing from P1 (100% AB Mix), P3 (50% AB Mix + 50% cow biourine), P4 (75% AB Mix + 25% cow biourine), and P5 (25% AB Mix + 75% cow biourine). However, at later stages (28, 35, and 40 HSS), spinach plants showed the best growth under P4 (75% AB Mix + 25% cow biourine), which significantly outperformed all other treatments. A similar trend was observed in water spinach, where P4 consistently produced the tallest plants across all observed growth stages (14–40 HSS).

In contrast, bok choy plants exhibited a different response. No significant differences were observed at 21, 28, and 35 HSS across treatments. However, at 40 HSS, P5 (25% AB Mix + 75% cow biourine) resulted in significantly greater plant height compared to P2, P3, and P1. These findings indicate that crop species differ in their response to nutrient solution composition, with spinach and water spinach showing better growth under AB Mix–dominant treatments, while bok choy benefited from biourine-dominant formulations.

The observed differences can be explained by the nutrient profiles of the fertilizers. Nitrogen (N) plays a central role in vegetative growth, including stem elongation, leaf expansion, and root development (Hawkesford et al., 2012). While both AB Mix and biourine provide nitrogen, AB Mix supplies a higher concentration along with a more complete balance of macro- and micronutrients, which are essential for optimal hydroponic growth (Resh, 2013). Biourine, on the other hand, primarily contributes macronutrients such as N, P, and K, but in lower concentrations, which may explain its limited effect when applied alone (Mirna, Salim, & Gani, 2013). Nevertheless, the higher biourine concentrations in bok choy treatments (P5) appeared to stimulate growth, possibly due to the presence of growth regulators such as indole-3-acetic acid (IAA), which enhance cell elongation and organogenesis (Benjamins & Scheres, 2008).

Overall, these results suggest that partial substitution of AB Mix with biourine can maintain or even improve hydroponic vegetable productivity, depending on crop type. Such substitution could lower production costs while supporting more sustainable and environmentally friendly hydroponic systems.

Table 2. Plant height (cm) at various planting ages.

Plant	Treatment	Plant height (cm) at various planting ages				
		HSS 14	HSS 21	HSS 28	HSS 35	HSS 40
Spinach	P1	3.33b±0.45	3.49c±0.51	4.58b±1.12	5.04b±1.39	5.48b±1.69
	P2	4.26a±0.43	4.76a±0.45	4.88b±0.39	5.25b±0.43	5.48b±0.48
	P3	2.8c±0.3	3.34c±0.24	3.72c±0.34	4.17c±0.41	4.5b±0.51
	P4	2.98c±0.45	4.32b±0.83	5.55a±1.37	8.5a±2.85	10.56a±3.58
	P5	2.87c±0.23	3.26c±0.16	3.69c±0.37	4.54cb±0.53	5.07b±0.47
Water spinach	P1	8.04b±1.5	17.32b±1.93	28.64b±4.36	43.6b±10.52	51.13b±10.87
	P2	9.82a±2.08	14.12c±4.15	18.74d±2.61	23.14d±3.56	26.32c±4.1
	P3	8.14b±0.98	16.52b±2.84	25.08c±3.88	34.04c±6.13	40.72c±7.99
	P4	10.42a±0.84	19.44a±2.8	37.84a±4.44	49.14a±6.79	58.7a±8.43
	P5	8.02b±1.21	9.8d±1.53	17.56d±3.69	24.44d±5.57	33.99d±4.35
Bok choy	P1	5.12a±0.53	5.24a±0.56	5.43a±0.62	5.58b±0.7	5.68b±0.78
	P2	4.9ba±0.33	5.11a±0.26	5.58a±0.25	5.89ba±0.39	6.12b±0.52
	P3	4.77ba±0.53	5.16a±0.47	5.48a±0.39	5.73ba±0.43	5.96b±0.5
	P4	4.7b±0.71	5.3a±0.85	5.58a±0.93	5.75ba±0.94	6.09b±1.11
	P5	4.68b±0.8	5.14±0.81	5.79a±0.79	6.12a±0.67	6.55a±0.71

Note: Numbers accompanied by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level; HSS = Days After Sowing. (P1: 100% AB mix, P2: 100% cow biourine, P3: 50% AB mix + 50% cow biourine, P4: 75% AB mix + 25% cow biourine, P5: 25% AB mix + 75% cow biourine).

Leaf Length

The analysis of variance indicated that the combination of cow biourine and AB Mix nutrients significantly influenced leaf length across different plant ages (Table 3). In spinach (*Amaranthus sp.*) and water spinach (*Ipomoea aquatica*), treatments P4 (75% AB Mix + 25% cow biourine) and P1 (100% AB Mix) consistently produced longer leaves at 14, 21, 28, 35, and 40 HSS, significantly outperforming P3 (50% AB Mix + 50% cow biourine), P2 (100% cow biourine), and P5 (25% AB Mix + 75% cow biourine). These results suggest that leaf elongation in these crops is highly dependent on nutrient solutions dominated by AB Mix, likely due to its more complete balance of macro- and micronutrients essential for leaf development.

By contrast, bok choy (*Brassica rapa var. chinensis*) exhibited a different growth response. At 14, 28, 35, and 40 HSS, the P5 treatment (25% AB Mix + 75% cow biourine) resulted in significantly longer leaves compared to P4, P3, and P2. This finding highlights that bok choy performs better under biourine-dominant treatments, indicating species-specific differences in nutrient uptake and utilization.

The variation in crop responses can be explained by the role of nitrogen (N) and other essential nutrients. Nitrogen is central to leaf expansion, as it promotes chlorophyll synthesis, photosynthetic activity, and cell elongation (Hawkesford et al., 2012). AB Mix, which contains higher and more balanced concentrations of both macro- and micronutrients, supports robust leaf growth in spinach and water spinach. Conversely, the effectiveness of biourine in bok choy may be linked not only to its macronutrient contribution (N, P, K) but also to the presence of natural plant growth regulators such as indole-3-acetic acid (IAA), which are known to stimulate leaf expansion and organogenesis (Gunawan, 2018; Benjamins & Scheres, 2008). Similar findings have been reported by Abdillah et al. (2017), who observed improved vegetative growth in leafy vegetables under treatments combining AB Mix and organic liquid fertilizers.

Overall, these findings underscore the potential of integrating biourine into hydroponic nutrient solutions. While AB Mix remains essential for crops like spinach and water spinach, bok choy demonstrates the capacity to utilize biourine more effectively. This crop-specific response suggests that partial substitution of AB Mix with biourine could reduce production costs while maintaining or enhancing yield, thereby supporting more sustainable hydroponic vegetable cultivation.

Table 3. Length of leaf (cm) at various ages of planting.

Plant	Treatment	Leaf length (cm) at various ages of planting				
		HSS 14	HSS 21	HSS 28	HSS 35	HSS 40
Spinach	P1	1.12a±0.19	1.33b±0.27	1.6b±0.39	1.82b±0.53	1.99b±0.67
	P2	0.83c±0.07	1.01c±0.06	1.02d±0.07	1.14d±0.09	1.22c±0.11
	P3	1.01b±0.06	1.16c±0.07	1.28c±0.12	1.44dc±0.07	1.55c±0.09
	P4	1.1a±0.17	2a±0.54	2.37a±0.61	3.6a±1.11	4.3a±1.31
	P5	0.72d±0.12	1.04c±0.18	1.3c±0.2	1.54cb±0.14	2.05b±0.25
Water spinach	P1	6.12a±1.03	11.02a±1.43	13.66a±1.28	15.08b±1.41	17.62a±1.87
	P2	3.05c±0.4	4.69d±0.49	5.06d±0.3	6.28e±0.45	7d±0.57
	P3	5.86a±0.8	9.36b±0.94	11.78b±1.07	12.92c±1.55	14.88b±1.8
	P4	6.17a±0.92	9.24b±1.52	13.2a±1.83	16.14a±2.53	18.62a±3.04
	P5	5.12b±0.62	5.94c±0.82	8.32c±1.44	9.96d±1.85	11.2c±2.25
Bok choy	P1	1.95cb±0.17	3.6b±0.63	6.48a±0.99	8.52a±1.4	9.97a±1.9
	P2	0.54d±0.08	1.3d±0.25	3.11d±0.12	4.22d±0.2	5.14c±0.22
	P3	1.88c±0.14	3.24c±0.56	4.63c±1.23	4.94c±1.4	5.95c±1.65
	P4	2.03b±0.24	4.06a±0.74	5.59b±1.41	6.2b±1.64	7.5b±2.11
	P5	2.6a±0.35	3.65b±0.55	7.02a±0.87	8.46a±0.78	10.04a±0.97

Note: Numbers accompanied by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level; HSS = Days After Sowing. (P1: 100% AB mix, P2: 100% cow biourine, P3: 50% AB mix + 50% cow biourine, P4: 75% AB mix + 25% cow biourine, P5: 25% AB mix + 75% cow biourine).

Leaf Width

Leaf width was significantly affected by the combination of cow biourine and AB Mix across different crop types (Table 4). In spinach (Amaranthus sp.), treatment P4 (75% AB Mix + 25% cow biourine) consistently produced the widest leaves at 14, 21, 28, 35, and 40 HSS, significantly outperforming P1 (100% AB Mix), P5 (25% AB Mix + 75% cow biourine), P3 (50% AB Mix + 50% cow biourine), and P2 (100% cow biourine).

A similar trend was observed in water spinach (*Ipomoea aquatica*), where P4 treatment at 21, 28, 35, and 40 HSS yielded significantly wider leaves than all other treatments. These results highlight the importance of a nutrient balance dominated by AB Mix, which provides complete macro- and micronutrients required for optimal leaf expansion.

In contrast, bok choy (*Brassica rapa var. chinensis*) responded more favorably to biourine-dominant formulations. At 14, 28, 35, and 40 HSS, P5 (25% AB Mix + 75% cow biourine) produced the widest leaves, significantly differing from P1, P4, P3, and P2. This finding indicates that bok choy may utilize organic nutrient sources such as biourine more effectively, possibly due to the presence of natural growth regulators and beneficial microbial metabolites in the fermented solution (Gunawan, 2018).

These results are consistent with previous findings. Sitorus and Santoso (2019) reported that lettuce plants treated with 85% AB Mix + 15% cow biourine produced the widest leaf area. Similarly, Abdillah et al. (2017) demonstrated that integrating organic liquid fertilizers with AB Mix improved vegetative growth parameters in kailan. The presence of indole-3-acetic acid (IAA) and other bioactive compounds in biourine further enhances cell division and elongation, contributing to increased leaf area (Benjamins & Scheres, 2008).

Overall, the findings suggest that spinach and water spinach require AB Mix–dominant nutrient solutions for optimal leaf development, while bok choy performs better with biourine-dominant treatments. This species-specific response underscores the potential of partial AB Mix substitution with biourine to reduce costs and promote sustainable hydroponic production.

Table 4. Leaf width (cm) at different ages of planting.

Plant	Treatment	Leaf width (cm) at different ages of planting				
		HSS 14	HSS 21	HSS 28	HSS 35	HSS 40
Spinach	P1	0.6b±0.23	0.93b±0.33	1.12b±0.42	1.4c±0.58	1.58c±0.69
	P2	0.24d±0.06	0.53c±0.07	0.6d±0.1	0.81d±0.15	0.95d±0.19
	P3	0.43c±0.12	0.78b±0.2	0.88c±0.2	1.03d±0.24	1.2d±0.32
	P4	0.82a±0.27	1.57a±0.5	1.78a±0.55	2.67a±0.71	3.22a±0.77
	P5	0.38c±0.11	0.62c±0.11	0.81c±0.16	1.8b±0.09	1.93b±0.08
Water spinach	P1	1.16a±0.19	1.83b±0.46	3.35a±0.54	4.19b±0.78	4.94b±0.96
	P2	0.59d±0.18	1c±0.15	1.23d±0.14	1.59d±0.27	1.82d±0.35
	P3	1.03b±0.16	1.7b±0.24	2.65b±0.4	2.93c±0.47	3.47c±0.58
	P4	1cb±0.2	2.17a±0.48	3.52a±0.67	4.94a±1.21	5.82a±1.27
	P5	0.9c±0.25	1.07c±0.31	1.53c±0.6	1.95d±0.67	2.2d±0.85
Bok choy	P1	1.03b±0.11	2.12b±0.31	3.3b±0.56	4.36a±0.85	5.16a±1.06
	P2	0.88c±0.15	0.96d±0.31	1.81d±0.22	2.12d±0.3	2.49d±0.39
	P3	0.96cb±0.22	1.93c±0.27	2.39c±0.43	2.52c±0.54	3.08c±0.63
	P4	1.02b±0.15	2.43a±0.45	3.2b±0.83	3.53b±0.97	4.39b±1.25
	P5	1.45a±0.17	2.04cb±0.23	3.8a±0.43	4.66a±0.41	5.52a±0.48

Note: Numbers accompanied by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level; HSS = Days After Sowing. (P1: 100% AB mix, P2: 100% cow biourine, P3: 50% AB mix + 50% cow biourine, P4: 75% AB mix + 25% cow biourine, P5: 25% AB mix + 75% cow biourine).

Number of Leaves

The number of leaves was significantly influenced by the combination of AB Mix and cow biourine treatments (Table 5). In spinach (*Amaranthus sp.*), treatment P4 (75% AB Mix + 25% cow biourine) consistently produced the highest leaf numbers at 21, 28, 35, and 40 HSS, significantly outperforming P1 (100% AB Mix), P2 (100% cow biourine), P5 (25% AB Mix + 75% cow biourine), and P3 (50% AB Mix + 50% cow biourine). This indicates that a nutrient balance dominated by AB Mix with partial supplementation of biourine creates an optimal environment for leaf initiation and expansion.

A similar response was observed in water spinach (*Ipomoea aquatica*), where P4 treatment also resulted in significantly more leaves at 21, 28, 35, and 40 HSS compared to other treatments. This suggests that water spinach, like spinach, benefits from a nutrient solution where mineral nutrients are predominant, but enhanced with organic components from biourine.

By contrast, bok choy (*Brassica rapa var. chinensis*) exhibited a different trend. At 28, 35, and 40 HSS, treatment P5 (25% AB Mix + 75% cow biourine) produced the highest number of leaves, significantly differing from P1, P4, and P3. This finding suggests that bok choy utilizes organic nutrient inputs more efficiently, possibly due to its greater responsiveness to bioactive compounds and microbial metabolites present in biourine.

Nutrients such as nitrogen (N) and phosphorus (P) play a central role in leaf development. Nitrogen enhances protein synthesis and chlorophyll formation, while phosphorus supports energy transfer and carbohydrate metabolism, thereby influencing leaf initiation and expansion (Taiz et al., 2015). The availability of these nutrients in both AB Mix and biourine ensures that carbohydrates produced during photosynthesis are effectively converted into proteins, which in turn stimulates the growth of new leaves. According to Gardner, et al. (1991), photosynthetic efficiency increases with greater leaf area, as wider leaves capture more light, enhancing biomass accumulation.

These results are consistent with previous studies. Sitorus & Santoso (2019) found that lettuce plants treated with a combination of AB Mix and biourine showed significantly higher vegetative growth. Similarly, Abdillah et al. (2017) demonstrated that integrating organic liquid fertilizers with AB Mix improved leaf production in kailan. This highlights the potential of combining AB Mix with biourine not only to reduce dependency on synthetic nutrient solutions but also to enhance sustainable hydroponic production.

Table 5. Number of Leaves at various ages planted.

Plant	Treatment	Number of leaves at different ages planting				
		HSS 14	HSS 21	HSS 28	HSS 35	HSS 40
Spinach	P1	4a±0.29	4.64b±0.7	5.48b±0.96	6.12cb±1.42	6.8cb±1.66
	P2	3.32c±0.48	4.12dc±0.44	4.88c±0.83	5.72c±0.98	6.2dc±1.26
	P3	3.64b±0.49	4.08d±0.28	5.44b±0.77	6.52b±0.71	7.12b±0.88
	P4	3.64b±0.49	5.56a±1.04	6.16a±0.9	7.32a±1.14	8.24a±1.67
	P5	4.24a±0.66	4.48cb±0.65	4.6c±0.65	5.08d±0.4	5.96d±0.2
Water spinach	P1	6.52cb±0.65	10.16b±0.94	16b±4.07	20b±5.72	23.44b±6.75
	P2	6.4c±0.91	8.4c±1.35	11.48c±1.73	13.84c±2.48	15.6c±3.21
	P3	6.92b±0.76	10.56b±0.87	15.72b±2.57	18.56b±4.49	21.88b±4.28
	P4	6.76cb±0.93	15.64a±2.61	20.76a±4.73	33.64a±8.55	38.48a±8.83
	P5	7.6a±0.65	9.08c±0.91	12.6c±1.61	14.88c±1.83	16.64c±2
Bok choy	P1	4.12b±0.33	5.96a±0.2	6.08b±0.28	7.04b±0.68	8b±0.71
	P2	4.64a±0.49	5.44b±0.51	5.56c±0.58	5.68dc±0.56	5.72d±0.61
	P3	4b±0	5.36b±0.57	5.36c±0.57	5.44d±0.51	5.84d±0.99
	P4	4b±0	5.76a±0.6	5.92b±0.7	6.08c±0.64	6.52c±1
	P5	3.28c±0.46	4.2c±0.41	6.44a±0.65	7.84a±1.14	8.8a±1.32

Note: Numbers accompanied by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level; HSS = Days After Sowing. (P1: 100% AB mix, P2: 100% cow biourine, P3: 50% AB mix + 50% cow biourine, P4: 75% AB mix + 25% cow biourine, P5: 25% AB mix + 75% cow biourine).

Post-Harvest Observations

The analysis of variance showed that the combination of cow biourine and AB Mix nutrition significantly affected post-harvest parameters observed at 40 HSS (Table 6). For spinach (*Amaranthus sp.*) and water spinach (*Ipomoea aquatica*), treatment P4 (75% AB Mix + 25% cow biourine) produced the best results, with significantly higher root length, root weight, and fresh consumption weight compared to P1 (100% AB Mix), P2 (100% cow biourine), P3 (50% AB Mix + 50% cow biourine), and P5 (25% AB Mix + 75% cow biourine). This suggests that a mineral-dominant nutrient solution supplemented with organic inputs optimizes root development and biomass accumulation in these leafy vegetables.

By contrast, bok choy (*Brassica rapa var. chinensis*) showed a different pattern. At 40 HSS, treatment P5 (25% AB Mix + 75% cow biourine) resulted in significantly greater root length, root weight, and fresh consumption weight compared to all other treatments, including P4. This indicates that bok choy responds more positively to higher proportions of organic inputs, likely due to its ability to utilize bioactive compounds and growth-promoting microorganisms present in cow biourine.

These findings are in line with previous research. Hanum et al. (2021) reported that liquid organic fertilizer derived from cow urine significantly increased plant height, number of leaves, and fresh weight in mustard greens (*Brassica juncea L.*). However, when used as a sole nutrient source, liquid organic fertilizers often fail to meet plant nutrient requirements due to the slower release and lower availability of essential elements. Integrating AB Mix with biourine balances rapid nutrient availability from inorganic sources with the long-term benefits of organic inputs, thus enhancing overall plant growth and productivity.

Table 6. Post-harvest crop observation.

Plants	Treatment	Number of leaves at different ages planting		
		Root length	Root fresh weight	Consumption fresh weight
Spinach	P1	6.02d±1.21	1.52c±0.41	4.51c±1.11
	P2	2.9e±0.27	5.28b±0.55	2.57d±0.1
	P3	8.44b±0.61	5.24b±0.54	6.74b±0.8
	P4	12.73a±1.27	7.42a±1.28	18.94a±3.71
	P5	6.64c±0.24	1.9c±0.06	5.92b±0.4
Water spinach	P1	12.27b±1.89	6.77d±1.68	19.75b±2.64
	P2	8.56c±1.43	2.58e±0.19	15.44c±1.79
	P3	13.15b±2.67	13.39b±3.67	22.53b±4.11
	P4	12.96b±1.89	37.72a±0.69	49.72a±11.6
	P5	14.84a±1.24	11.73c±2.63	14.45c±1.83
Bok choy	P1	5.26b±1.81	2.99c±0.43	3.66c±0.49
	P2	2.84d±0.18	1.12d±0.04	2.52d±0.32
	P3	2.94d±0.23	1.12d±0.04	2.9d±0.27
	P4	4.23c±0.15	3.83b±0.81	8.78b±1.96
	P5	6.49a±3.06	5.1a±2.17	9.59a±0.72

Note: Numbers accompanied by the same letter in the same column indicate no significant difference based on the DMRT test at the 5% level; HSS = Days After Sowing. (P1: 100% AB mix, P2: 100% cow biourine, P3: 50% AB mix + 50% cow biourine, P4: 75% AB mix + 25% cow biourine, P5: 25% AB mix + 75% cow biourine).

The findings demonstrate that tailoring hydroponic nutrient solutions with biourine can improve productivity while advancing more sustainable input use. A 75% AB mix + 25% cow biourine formulation (P4) consistently maximized vegetative growth and post-harvest traits in spinach and water spinach, whereas bok choy responded best to 25% AB mix + 75% biourine (P5). These crop-specific optima suggest that integrating biourine can partially substitute synthetic nutrients without compromising yield, provided electrical conductivity and pH remain within crop-appropriate ranges. Strategically, such substitutions align with broader environmental and food-security agendas that call for resilient water–food systems and reduced dependence on fully synthetic inputs (Pambudi, 2021). They also reflect interdisciplinary perspectives linking agriculture, environmental quality, and human health—where diversifying nutrient sources and boosting vegetable production contribute to healthier diets and cleaner production cycles (Waage, 2022). At a systems level, adopting biourine within hydroponics fits DPSIR-style integrated management, helping translate environmental pressures (waste effluents) into positive responses (resource recovery and circular nutrient flows) (Widiyono, 2022).

CONCLUSION

This study demonstrates that the combination of AB Mix and cow biourine has a significant effect on the vegetative growth and post-harvest performance of hydroponic vegetables. A higher proportion of AB Mix (P4: 75% AB Mix + 25% biourine) resulted in the best growth of spinach and water spinach, as indicated by plant height, leaf length, leaf width, number of leaves, and fresh weight at harvest, while a higher proportion of biourine (P5: 25% AB Mix + 75% biourine) produced superior growth in bok choy. These results indicate that crop response depends on the balance of nutrient availability, particularly nitrogen and phosphorus, as well as the suitability of electrical conductivity (EC) and pH values, which influence nutrient absorption efficiency. The integration of AB Mix with biourine ensures a complementary supply of essential nutrients, where AB Mix provides sufficient macronutrients and biourine contributes organic matter and micronutrients, thereby enhancing plant growth according to species-specific requirements. Overall, the study highlights that optimizing the ratio of AB Mix and biourine is crucial for maximizing hydroponic vegetable productivity, with the 75:25 ratio most effective for spinach and water spinach, and the 25:75 ratio more suitable for bok choy cultivation.

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