



Effective of Deep Flow Technique Hydroponic Water Spinach Cultivation in Vietnam

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ABSTRACT

Background: The hydroponic method involved growing plants using a macro and micronutrient solution in water without soil. This has been the most intensive cultivation method, utilizing water and nutrients within a minimal space. In Vietnam, hydroponic cultivation models had been recently developed; however, the yield of hydroponic water spinach remained very low and there hasn't been much research.

Methods: The study was conducted over three crop seasons in an open greenhouse belonging to a farmer in Vinh Long Province, Vietnam, from February to December 2024. Water spinach had been selected as the planting material. In the deep flow hydroponics system, the plants were grown on foam panels. This study was arranged as a single factor experiment with three treatments, corresponding to the three cultivation crops. Each treatment was replicated three times at the same experimental location using a completely randomized design across identical experimental plots to evaluate and analyze the effects of variation crops over time.

Result: The measurement results showed that the pH values in the three crops had not fluctuated significantly, ranging from 5.45 to 7.15. Concurrently, the EC values ranged from 1.86 to 3.08 dS/m across all three crops. The measurement results indicated that the temperatures during the three crops had not fluctuated significantly, ranging from 27.9 to 34.4°C. The amount of water required to produce 1 kg of water spinach had ranged from 15.2 to 18.1 liters. The yield per 1,000 m² reached between 4,960 kg and 5,280 kg, which was twice as high as that of the model grown in soil. The deep flow technique (DFT) utilized in this research provided water and nutrients once only across all three crops. As a result, this system saved water, preserved the nutrient solution and delivered a high yield, thereby demonstrating the potential to expand the cultivation area for water spinach.

Key words: Deep flow technique, Hydroponic, Save water, Water spinach.

INTRODUCTION

Global warming-induced climate changes threaten agriculture by degrading soil and water (Arora, 2019; Champaneri and Patel, 2021). To optimize yields, irrigated agriculture must be prioritized over rain-fed systems, serving as an indispensable tool against unpredictable rainfall in arid and semi-arid climates (Dushyant *et al.*, 2026). Hydroponics was defined as a method of cultivating plants utilizing aqueous solutions enriched with essential macronutrients and micronutrients, entirely bypassing the use of soil. As an advanced agricultural approach, it has represented the most intensive cultivation method available, optimizing the delivery of water and nutrients within minimal spatial requirements. Furthermore, hydroponic technology has experienced significant growth and expansion across several developed regions, including the United States, Europe, Japan and Canada (Asao, 2012). Research and production regarding the cultivation of water spinach *via* hydroponic systems have remained highly limited. Historically, five distinct hydroponic configurations have been utilized within the field, which included: liquid hydroponics (or solution culture), the non-recirculating method (open system), the recirculating method (closed system), solid medium culture (aggregate system) and aeroponics (Anbarasu *et al.*, 2020).

The deep flow technique (DFT) was classified under solution culture, or liquid hydroponics, utilizing the

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recirculating method within a closed system. This configuration has represented one of the most widely adopted hydroponic frameworks globally, demonstrating suitability for both domestic and commercial applications. Furthermore, the inherent flexibility of the DFT design has historically permitted extensive customization during system construction, without technical constraints on structural configuration (Anbarasu *et al.*, 2020).

The nutrient solution for hydroponic systems was formulated from inorganic ions derived from dissolved salts

of essential plant nutrients. This solution has sustained a well-defined physiological role within plant development, given that its deficiency has been shown to impede the entire vegetative and reproductive life cycle (Steiner, 1968). Soilless cultivation has allowed for more precise control over environmental factors. Specifically, key parameters within the nutrient solution, including temperature, pH, electrical conductivity and dissolved oxygen content, were meticulously regulated and monitored (Taiz and Zeiger, 1998). The appropriate pH value of the nutrient solution for optimal plant growth has been established to range from 5.5 to 6.5 (Libia and Fernando, 2012). It was demonstrated that the nutrient absorption capability of plants at a pH above 7 could be significantly reduced, primarily because ions such as Mg^{2+} , Fe^{2+} , Mn^{2+} , Ca^{2+} and PO_4^{3-} precipitated into insoluble and unavailable salts (Resh, 2004). The electrical conductivity (EC) values within hydroponic systems have been maintained within a standard range of 1.5 to 2.5 dS/m. It was observed that an EC exceeding 6.0 dS/m led to elevated osmotic pressure, which subsequently hindered nutrient uptake, whereas a lower EC severely suppressed plant growth and overall yield (Samarakoon *et al.*, 2006). Furthermore, previous research has established that a strong and linear correlation existed between reduced water uptake and elevated EC levels (Dalton *et al.*, 1997). According to Cooper (1988), the nutrient solution utilized has been maintained within an electrical conductivity (EC) range of 1.5 to 1.7 dS/m. Furthermore, previous investigations have demonstrated that the temperature of the nutrient solution affected plant nutrient and water uptake dynamics differently (Libia and Fernando, 2012). Temperature strongly regulates nitrogen (N) mineralization by controlling enzyme kinetics, microbial metabolism and substrate diffusion. This complex, microbially driven process transforms organic N into plant-available inorganic forms (Kamrun *et al.*, 2026). In spinach cultivation, the optimal solution temperature was recorded at 28°C (Nxawe *et al.*, 2009). The dissolved oxygen concentration within the nutrient solution has been shown to depend on specific crop demands and photosynthetic activity (Papadopoulos *et al.*, 1999). It was established that dissolved oxygen levels dropping below 3 or 4 mg/L severely affected root development and induced leaf chlorosis, which has been widely recognized as the primary symptom of oxygen deficiency (Gislerød and Kempton, 1983).

In Vietnam, the adoption of hydroponic cultivation models has been initiated only recent years. However, the total yield of hydroponically grown water spinach (*Ipomoea aquatica*) has remained significantly low. Given that consumer demand for this vegetable has historically escalated due to its culinary versatility and accessibility, optimizing its production has become essential. Therefore, this research into enhancing the water spinach of hydroponic cultivation was deemed critical to address these agricultural and market limitations.

MATERIALS AND METHODS

The study was conducted across three cultivation successive crops within an open greenhouse facility in Chau Thanh District, Vinh Long Province, Vietnam, spanning from February to December 2024. The experimental site has been geographically situated at the coordinates of 9°54'08.5"N 106°21'38.3"E, maintaining an elevation of 0.5 meters above sea level and a distance of 65 km from the coastline. The structural dimensions of the utilized greenhouse were measured at 4.0 m in width, 12.0 m in length and 2.7 m in height. The cultivation pond possessed structural dimensions of 24 m × 1.08 m × 0.5 m, corresponding to a total water capacity of 12.96 m³. This system was engineered to accommodate 36 foam panels, with each individual panel measuring 1.2 m in length and 60.0 cm in width. A density of 50 plastic planting bags per foam panel has been established, corresponding to a cumulative total of 1,800 planting bags distributed across a net surface area of 25.8 m² (Fig 1). This study was arranged as a single factor experiment with three treatments, corresponding to the three cultivation crops. Each treatment was replicated three times at the same experimental location using a completely randomized design across identical experimental plots to evaluate and analyze the effects of crop variations over time.

Water spinach (*Ipomoea aquatica*) was utilized as the primary plant material. Within the deep flow technique (DFT) hydroponic system, the plants were cultivated on floating foam panels. Historically, a density of 7 to 10 seeds has been introduced into each plastic planting bag, which was subsequently enclosed by a thin layer of substrate placed both above and beneath the seeds.

To avoid direct light exposure, the young seeds were initially maintained in a shaded environment and irrigated twice daily. The growth substrate was formulated utilizing a combination of cow manure and coconut peat in a 1:1 weight-to-weight ratio. This substrate mixture has exhibited an absence of organic toxicity and possessed a carbon-to-nitrogen (C/N) ratio of less than 20. Following a 7-day post-sowing period, the germinated seedlings were subsequently transferred and deployed onto the foam panels.

Oxygen was continuously supplied to the hydroponic cultivation pond via an aquarium air pump equipped with air stones, maintaining dissolved oxygen levels within a range of 6.0 to 9.0 mg/L. The nutrient solution configuration (Table 1) has been adapted from Resh and Howard (2012) with the target pH and electrical conductivity (EC) values established at 6.5 and 3.0 dS/m, respectively. An Adwa AD14 PH/ORP meter (Serial Number: 11107130085) was utilized to measure both pH and solution temperature. Concurrently, EC values were monitored using a Hanna Groline HI98318 EC meter. The data collection period for monitoring these environmental variables within the water spinach cultivation system was strictly scheduled between 8:00 AM and 9:00 AM daily.

Growth and yield parameters of water spinach were systematically collected at harvest using consistent and reliable methodologies across all three cultivation crops.

Statistical analysis

Experimental data were systematically compiled, verified and integrated into Microsoft Excel 2019 and the SPSS version 20.0 software suited for mathematical processing and statistical evaluation. To identify statistically significant differences between the treatment means, Duncan's multiple range test was employed, with the threshold for statistical significance established at a minimum confidence level of 5% ($p < 0.05$).

RESULTS AND DISCUSSION

pH changes in three crops

The pH value, ranging from 0 to 14, measures solution acidity or alkalinity by indicating the concentration ratio of free H^+ and OH^- ions. Alterations in nutrient solution pH

affected elemental composition and speciation, including free ions, soluble complexes, chelates, ion pairs, solid or gaseous phases and varied oxidation states. As shown in Fig 2, pH values across the three crops remained relatively stable between 5.45 and 7.15, as the solution had been adjusted whenever it fell below 5.5 or exceeded 7.0. The decline in pH values toward the end of the crop is attributed to the increased release of anion radicals into the solution, driven by the preferential uptake of cationic mineral salts by plants. Libia and Fernando, (2012) that pH value of the nutrient solution for plant growth ranges from 5.5 to 6.5. Putri *et al.* (2022) conducted a study on spinach which was controlled by a pH of 6.5 for 21 days to obtain an average plant height of 35 cm. The nutrient absorption capability of plants at a pH above 7 could be reduced due to the precipitation of Mg^{2+} , Fe^{2+} , Mn^{2+} , Ca^{2+} and PO_4^{3-} into insoluble and unavailable salts (Resh, 2004).

Electric conductivity (EC) changes in three crops

Electrical conductivity (EC) varied as plants had absorbed nutrients and water from the nutrient solution. Consequently, a simultaneous decrease in some ion concentrations observed in both closed and open systems. The electrical conductivity (EC) values recorded across the three successive cultivation crops (Fig 3) ranged from 1.86 to 3.08 dS/m. It was observed that the initial EC levels at the onset of each crop were significantly higher than those recorded at harvest. This downward trend has been attributed to the progressive depletion of essential mineral ions from the nutrient solution as a function of plant uptake throughout the growth period. Especially during the third cultivation crop, the depletion of mineral ions occurred at a higher rate, added nutrients 3 times in the 3rd crop; in contrast, the second crop required only a single replenishment, whereas no additional nutrients were introduced during the first crop. Although the standard electrical conductivity (EC) values within conventional



Fig 1: Water spinach growing in deep flow technique culture in the open greenhouse.

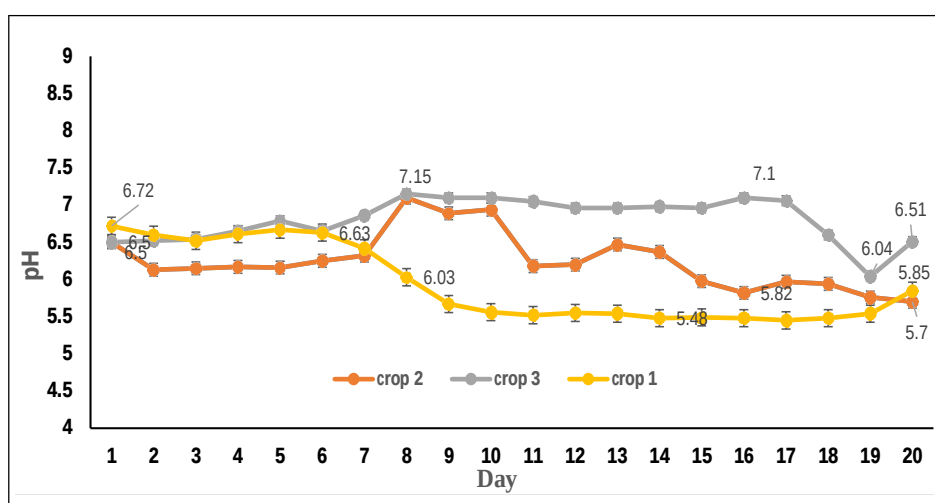


Fig 2: pH values changed in three crops of water spinach cultivation.

hydroponic systems have been established to range from 1.5 to 2.5 dS/m, previous literature has demonstrated that an EC exceeding 6.0 dS/m led to elevated osmotic pressure, which subsequently hindered nutrient uptake. Conversely, a lower EC threshold has been shown to severely suppress plant growth and overall yield (Samarakoon *et al.*, 2006).

Cooper (1988) reported that the EC of the hydroponic nutrient solution was maintained within a range of 1.5 to 1.7 dS/m. Concurrently, Sonneveld and Voogt (2009) established that the optimal EC value is highly crop-specific and inherently dependent on ambient environmental conditions. Despite these specific variations, general EC values for standard hydroponic systems have been demonstrated to range more broadly from 1.5 to 2.5 dS/m.

Temperature changes in three crops

The Mekong Delta has been characterized as a region strictly influenced by a sub-equatorial humid tropical climate. Historical meteorological data indicated that the average annual temperature ranged from 24°C to 27°C, while the diurnal temperature variation remained low, fluctuating between 7°C and 8°C. Furthermore, the

maximum thermal amplitude between the hottest and coldest months was recorded at merely 3°C to 4°C (Ngoc and Khoi, 2016). The temperature measurements recorded across the three successive cultivation crops exhibited minimal fluctuations, ranging strictly from 27.9°C to 34.4°C (Fig 4). Libia *et al.* (2012) reported that the temperature of a nutrient solution directly influences the differential uptake of water and essential nutrients by the crop. Notably, the thermal conditions observed in the current study were consistently higher than those reported by Nxawe *et al.* (2009) for spinach seedlings, where the optimum growth temperature was established at 28.0°C.

Water level changed in the hydroponic pond

The amount of water consumed did not differ significantly between crops (Table 2), ranging from 2,000 to 2,250 L per crop. Correspondingly, water spinach yields ranged from 124.5 to 131.9 kg/25 m², indicating a water footprint of 15.16 to 18.07 L per kilogram of biomass produced. Notably, the water consumption observed in this study was substantially lower than that typically reported for conventional open-field cultivation. The reduced water consumption was

Table 1: Hydroponic solution.

Fertilizer type	Grouping	Weigh (g/1.000 lit solution)
H ₃ BO ₃	B	0.286
Ca (NO ₃) ₂ .4H ₂ O	A	101
CuSO ₄ .5H ₂ O	B	0.039
Na ₂ EDTA.2H ₂ O	A	3.119
Fe ₂ (SO ₄) ₃	A	1.677
MgSO ₄ .7H ₂ O	B	45.64
MnSO ₄ .H ₂ O	B	0.154
H ₃ PO ₄	B	52.73
KNO ₃	A	51.84
Na ₂ MoO ₄ .2H ₂ O	B	0.013
ZnSO ₄ .2H ₂ O	B	0.03

Resh and Howard (2012).

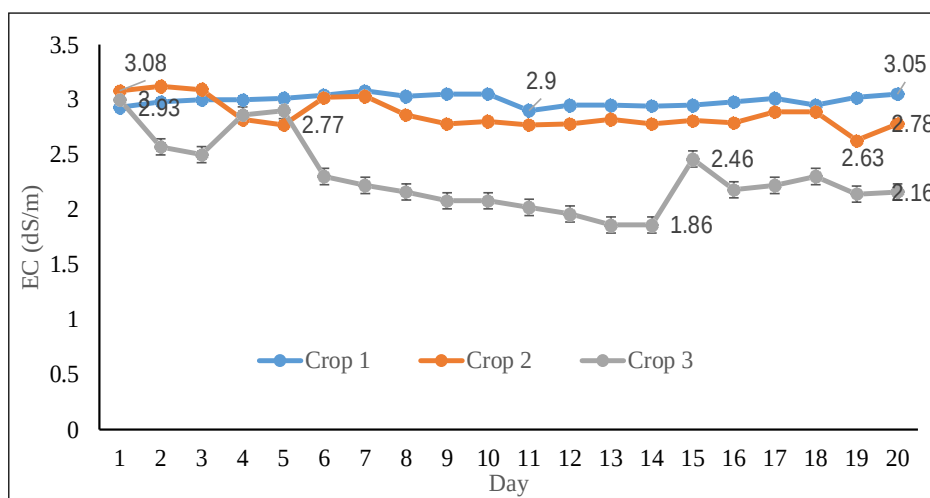


Fig 3: Electric conductivity (EC) in three crops of water spinach cultivation.

attributed to minimized evaporation losses. This was achieved because the dense canopy cover of water spinach effectively shielded the water surface, significantly limiting direct evaporation to the atmosphere. According to a study by Kutluk and Salih (2022) on a greenhouse hydroponic system (0.6 m²), the water requirement for producing 1 kg of Matador spinach (*Spinacia oleracea* var. *Matador*) was 55.2 L. In contrast, conventional soil-based cultivation typically required 200 to 400 L of water per kilogram of harvested vegetable product.

Comparison of growth and yield of water spinach in three crops

The average number of leaves, plant density per basket and total yield per 0.72 m² decreased slightly from crop

1 (3.67 kg) to crop 3 (3.34 kg), corresponding to an estimated yield of 4,960 to 5,280 kg per 1,000 m². However, these variations were not statistically significant ($P>0.05$, Table 3). Although a marginal decrease in yield was observed in crop 3 compared to crop 1, this difference was not statistically significant across crops. The slight variation was likely driven by the low pH in the nutrient solution, which affected elemental composition and chemical speciation (including free ions, soluble complexes, chelates, ion pairs, solid or gaseous phases and varied oxidation states). Nevertheless, overall yield stability was maintained because the nutrient concentrations in the hydroponic solution were sufficient to support optimal water spinach growth, complemented by consistent seed quality and microclimatic conditions throughout the sequential

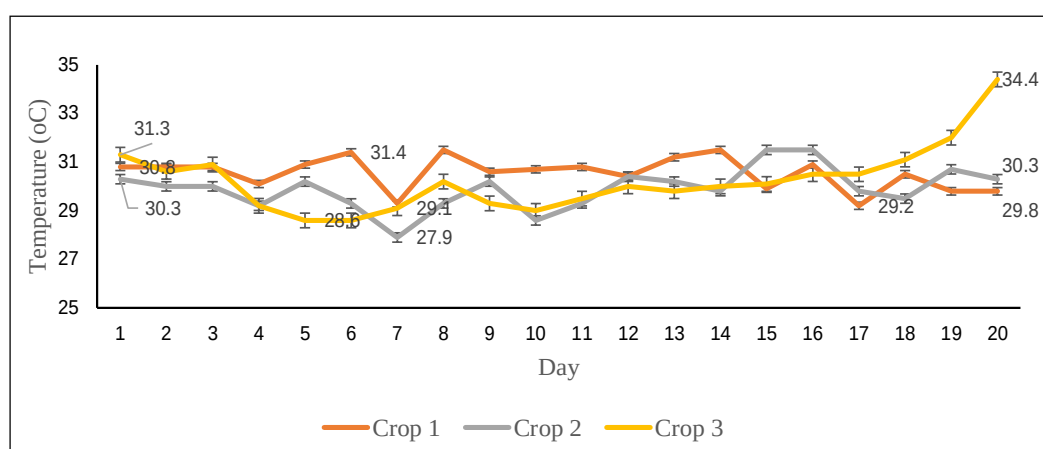


Fig 4: Temperature in three crops of water spinach cultivation.

Table 2: Water level changed in the hydroponic tank of water spinach cultivation.

Day	Crop 1		Crop 2		Crop 3	
	Water level in the tank (cm)	Volume of water in the tank (liter)	Water level in the tank (cm)	Volume of water in the tank (liter)	Water level in the tank (cm)	Volume of water in the tank (liter)
1	40	10,000	32	8,000	23.5	5,875
5	39	9,750	30.5	7,625	22.5	5,625
10	35	8,750	28	7,000	20.5	5,125
15	33.5	8,375	25.5	6,375	18	4,500
20	32	8,000	23.5	5,875	14.5	3,625
Total	8	2,000	8.5	2,125	9.0	2,250

Table 3: Growth and yield components of water spinach in three crops cultivation.

Season	Leaf/tree	Tall (cm)	Weight average of tree	Total tree/bag	Weight of bag (gam)	Yield (kg/foam panel = 0.72 m ²)	Yield of pond, area: 25 m ² (kg)
Crop1	8,3±0,33	52,5 ^c ±0,28	8,8 ^{ab} ±0,11	8,3±0,33	73,3±3,07	3,67±0,15	132
Crop2	8,0±0,57	56,7 ^b ±0,33	9,0 ^a ±0,14	8,0±0,00	72,3±1,16	3,61±0,05	130
Crop3	7,6±0,33	59,0 ^a ±0,57	8,63 ^b ±0,08	8,0±0,00	69,1±0,7	3,34±0,35	124
F	ns	*	**	ns	ns	ns	
CV (%)	9,3	1,32	7,31	4,10	4,70	14,79	

Note: ns (no difference), * and ** difference at 5% and 1% through T-test (Unit: million).

crops. In a study by Dinh *et al.* (2020), hydroponic water spinach cultivation yielded 2,080 kg per 1,000 m² over a 45-day harvest period in the summer crop and 4,940 kg per 1,000 m² over 67 days in the summer-autumn crop. In comparison, conventional soil cultivation utilizing an NPK fertilizer formula (100-80-40) achieved a lower yield, ranging from 1,889 to 2,068 kg per 1,000 m² (Ba *et al.*, 2009).

CONCLUSION

The pH levels monitored across the three crops showed minimal fluctuation, ranging from 5.45 to 7.15, while the electrical conductivity (EC) values ranged from 1.86 to 3.08 dS/m. Similarly, the solution temperature remained relatively stable, spanning a range of 27.9 to 34.4°C. The amount of water consumed did not differ significantly between crops, ranging from 2,000 to 2,250 L per crop. Correspondingly, producing 1 kg of water spinach required 15.16 to 18.07 L of water. Total yield decreased slightly from crop 1 to crop 3 equivalents to an estimated 5,280 kg to 4,960 kg per 1,000 m². These variations were not statistically significant. This overall yield stability suggested that the system maintained consistent productivity across the sequential cultivation crops. The deep flow technique (DFT) utilized in this study simultaneously delivered water and nutrients across three consecutive crops. This system conserved both water and nutrient resources, promoted high yields and demonstrated strong scalability for expanding water spinach cultivation.

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Disclaimers

Two authors contributed to the conceptualization, draft preparation of this manuscript, data collection and analysis. Both authors have read and agreed to the published version of the manuscript.

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Conflict of interest

Two authors declare no conflicts of interest.

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