Bulgarian Journal of Agricultural Science, 30 (No 4) 2024, 615–620

Study on the effect of hydroponic nutrient solutions on the growth and development of impatiens plant (*Impatiens walleriana*)

Le Thi Thuy[1*], Nguyen Thi Hoang Lan[2], Tran Thi Giang[1] and Nguyen Duong Anh Hong[1]

[1] Hanoi National University of Education, Faculty of Biology, 136 Xuan Thuy St., Hanoi, Vietnam
[2] *Happy Kids Kindergarten, 379 Phan Ba Vanh St., Thai Binh, Vietnam*
[*]*Corresponding author:* thuy_lt@hnue.edu.vn

Abstract

Thuy, L. T., Lan, N. T. H., Giang, T. T. & Hong, N. D. A. (2024). Study on the effect of hydroponic nutrient solutions on the growth and development of impatiens plant (*Impatiens walleriana*). *Bulg. J. Agric. Sci., 30*(4), 615–620

In this study, we investigated the efficacy and suitability of five different nutrient solutions, including Biolife, BKFast, Hoagland, Hydro Umat F and Knop, on the growth and development of *Impatiens walleriana* in a hydroponic system. The investigated parameters were branch numbers, canopy diameter, leaf size, flower numbers, floral longevity, flower diameter and flowering time. The results showed that Knop and Hydro Umat F were the most suitable solutions for the growth of hydroponic *Impatiens walleriana*. The highest floral longevity (7.64 to 7.67 days) and largest flower diameter (4.68 to 4.71 cm) were obtained from Knop and Hydro Umat F solution treatment, respectively. Besides, compared to the other four solutions, using the Knop solution helped impatiens have the earliest flowers (27.14 days) and the highest number of flowers (54.86 flowers). Based on the results of our study, we recommend using the Knop nutrient solution with a TDS concentration range of 750–800 ppm and a pH level range of 5.5–6.5 for three-week-old *Impatiens walleriana* seedlings.

Keywords: Impatiens walleriana; hydroponic system; nutrient solution

Introduction

Species within the genus *Impatiens* are distributed mostly across the Old World: Africa (especially Madagascar) and tropical and subtropical montane forests of Southeastern Asia (Janssens et al., 2009; Stevens, 2019). Among the species within the *Impatiens* genus, *Impatiens walleriana* is one of the world's most widely grown ornamental plant species (Rojas-Sandova, 2018). It is characterized by its thick, fleshy leaves and a wide range of flower colors. *Impatiens walleriana*, commonly known as busy lizzie in the United Kingdom, or simply impatiens, is an evergreen plant extensively used for landscaping and is the top-selling potted plant worldwide, across both developed and developing countries (Rojas-Sandova, 2018; Brickell & Cathey, 2004). *Impatiens walleriana* prefers to grow in moist and shaded habitats. However, it is adapted to grow in a wide range of environmental conditions, tolerating mean annual temperatures ranging from 10°C to 28°C (Mandle et al., 2010; Cumo, 2013). In Vietnam, this species often grows and flowers favorably in conditions from autumn to spring, flowers fade in summer. The primary challenge encountered in the production, transportation, and sale display of *Impatiens walleriana* lies in its pronounced susceptibility to rapid wilting under conditions of drought-induced stress. Prolonged periods of water deficit in potted *Impatiens walleriana* plants have shown to significantly diminish various growth parameters, including height, shoot number, dry weight, and flower production (Blanusa et al., 2009). Furthermore, when subjected to osmotic stress in hydroponic cultivation, *Impatiens walleriana* plantlets exhibit reduced stature and width, along with compromised root length (Antonić et al., 2016). These findings highlight the detrimental impact of water-related stresses on *Impatiens* *walleriana*, emphasizing the need for effective management strategies to mitigate these impacts during cultivation, transport, and marketing processes.

Hydroponic culture is the technique that uses nutrient solutions and substrate instead of soil, and so is not affected by soil-borne diseases or soil nutrient deficiencies. It also requires less water and pesticides compared with cultivation in soil (Garibi et al., 2019; Ai et al., 2021). As a result, hydroponic products are generally considered safe for consumption and carry a lower risk of bacterial transmission (Lopez-Galvez et al., 2014). Although hydroponic technology is used for some flowers such as gerbera (Şirin, 2011), chrysanthemum (Barbosa et al., 2015; Ai et al., 2021), there is no specific study that directly applies this technique to growing impatiens flowers. In a study conducted by Burnett et al., hydroponics was merely used as a supplementary technique to investigate the impact of factors like PEG-8000 permeability on the nutrient absorption capacity of *Impatiens walleriana* plants (Burnett et al., 2005). Similarly, the study by Lai et al. solely utilized a hydroponic system combined with cd supplementation to assess the viability of flower propagation for *Impatiens walleriana* through stem cutting on cd-polluted soil (Lai et al., 2017).

In the hydroponic method, the nutrient solution is an important factor that clearly affects the yield and quality of plants. The optimal nutrient solution depends on the species, growth stage, harvesting organ of the plant or its susceptibility to nutritional disturbances as well as on the season and other climatic factors (Şirin, 2011). In Vietnam, hydroponic technology has been primarily employed for cultivating leafy vegetables and fruits, with limited use in flower production (Thuy et al., 2020; Nguyen et al., 2022). Therefore, further research and experimentation in this field hold significant potential in expanding cultivation methods for flowers and ornamental plants. Additionally, exploring the application of hydroponic techniques to flowers and ornamental plants in the unique climate conditions of Vietnam will contribute to diversifying agricultural practices and creating new opportunities in this sector.

Materials and Methods

The plant material was 3-week-old Impatiens walleriana seedlings obtained from the Fruit and Vegetable Research Institute, Vietnam Academy of Agricultural Sciences. The seedlings have unbranched stems, an average height of 10 to 11 cm. The nutrient contents of the five nutrient solutions used in this study are presented in Table 1. Two out of the five solutions, namely Knop and Hoagland, were prepared based on the formulation proposed by Nguyen et al. (2013). The remaining three solutions, including Biolife (Babylon Garden Co., Ltd), BKFast (Bach Khoa Creative Joint Stock Company) and Hydro Umat F (MTV Gia Vien Hydroponics Co., Ltd), were commercial and prepared following the manufacturer's instructions. The closed hydroponic system employed for the experiment consisted of 14 × 12 cm plastic pots, and each pot held 0.75 l of nutrient solution.

During the experiment, the seedlings were transplanted into net pots with coco peat and placed within a closed hydroponic system. Each plastic pot accommodated 1 impatiens seedlings. Ten plastic pots contained the same type of nutrient solution, and the experiment was repeated 3 times for each solution formula. The pH level of the nutrient solutions was carefully monitored and maintained at a range of 6.0–6.5 in all formulations (Except for the experiment to study the effect of the pH level of the nutrient solution on the flowering stage of plants).

To evaluate the effect of 5 nutrient solutions on the growth and development of impatiens, 3 growth parameters, including the number of branches/plant, canopy diameter and leaf size, were determined by normal measuring methods at 15 and 30 days after planting in the hydroponic system. Four parameters related to impatiens flowers were all monitored for a period of 2 months, including day to 50% flowering (calculated from the time of transferring the plants into the nutrient solution until 50% of the plants appear the first flower buds), the number of flowers/plant, flower diameter and floral longevity. In which, floral longevity was defined as the time between when a flower was completely open to

Table 1. The nutrient contents of five hydroponic solutions

Nutrient solutions	Contents of basic elements in 5 nutrient solution formulations, ppm												
	N	P	K	Ca	Mg	B	Mn	Zn	Mo	Cu	Fe	S	Na–EDTA
Biolife	3.7	0.002	8.5	2.6	2.50	0.3	3.6	4.3	0.1	4.6	3.6	0.4	nd
BKFast	266.6	133.3	300.0	150.0	17.5	53.3	40	60	1.2	60	60	–	–
Hoagland	99.4	15.5	117.2	92.1	24.2	2.5	2.5	0.2	0.2	0.1	5.6	35.4	37.3
Hydro Umat F	171.3	33.9	273.8	160.7	50	0.5	1.0	0.9	0.6	0.7	3.0	66.5	-
Knop	117.1	32.5	133.6	138.9	28.8	–	–	–	–	–	1.03	38.1	–

Note: – Do not exist; nd. Undetermined when all of the petals abscised from the pedicle (Howard et al., 2012).

The experiment was carried out in a net house with a roof at the Experimental Garden, Faculty of Biology, Hanoi National University of Education, from October 2020 to March 2021 and from October 2021 to March 2022. The experimental plants grew under natural conditions. To analyze and process the statistical data obtained from the experiment, Microsoft Excel 2010 and SPSS 16.0 software were employed. A one-way ANOVA analysis, specifically Turkey's test, using a significance level of α = 0.05 was conducted.

Results and Discussion

Effect of nutrient solutions on some parameters related to plant growth

Number of branches per plant: The stems can branch vigorously. The number of branches per plant reflects not only the growth capacity of the impatiens but also the number of flowers per plant. Table 2 presents the influence of different nutrient solutions on the number of branches per plant in a scientific manner. It was observed that impatiens plants cultivated in Hydro Umat F and Knop solutions had the highest number of branches, with 10.78 and 11.13 branches, respectively, at 30 days. These results are not much higher than that obtained from impatiens grown in BKFast and Hoagland solutions. Compared to the five nutrient solutions studied, the plants cultivated in the Biolife solution displayed the slowest growth rate and minimal branching. Specifically, after approximately 30 days in the hydroponic system, most plants had a small and weak branch system. This outcome can be explained by the inadequate mineral content in the Biolife solution, as depicted in Table 1.

Canopy diameter: The number of branches/plant is directly proportional to the increase in canopy diameter, as evidenced by the research findings in Table 2. Specifically, the Knop and Hydro Umat F solutions still exhibited the most significant positive effects on canopy diameter, similar to branch numbers. When comparing the data for the 15th and 30th days after planting in the hydroponic system, it was observed that the canopy diameter of impatiens plants on the 30th day in the Knop and Hydro Umat F solutions showed a 1.84–1.85 times increase compared to those measured on the 15th day. In contrast, the plants treated with the Biolife solution only exhibited a 1.09 – fold increase.

Leaf size: The result presented in Table 3 showed that similar to branch numbers and canopy diameter, measured data of on the size of impatiens leaves also divided into 3 groups. Specifically, plants grown in Knop and Hydro Umat F solutions had the largest leaf size, followed by plants grown in Hoagland and BK-Fast solutions, and the leaves of plants grown in the Biolife solution were still the smallest.

Table 3. Effect of nutrient solution on the size of impatiens leaves, cm

Nutrient solutions	Days after planting on hydroponic system			
	15 days		30 days	
	Leaf length	Leaf width	Leaf length	Leaf width
Biolife	$2.53^{c} \pm 0.16$	$1.97^{b} \pm 0.20$	$2.84^{c} \pm 0.21$	$2.01^{c} \pm 0.35$
BKFast	$3.04^{b} \pm 0.20$	$2.09^{a} \pm 0.31$	$4.75^{b} \pm 0.32$	$3.88^{b} \pm 0.37$
Hoagland	$3.10^{b} \pm 0.32$	$2.13^{a} \pm 0.36$	$4.64^{b} \pm 0.39$	$3.81^{b} \pm 0.26$
Hydro Umat F	$3.20^{a} \pm 0.21$	$2.11^{a} \pm 0.28$	$5.24^{a} \pm 0.25$	$4.11^{ab} \pm 0.21$
Knop	$3.38^{a} \pm 0.24$	$2.17^{a} \pm 0.21$	$5.37^{a} \pm 0.36$	$4.25^{a} \pm 0.24$

Note: Different letters in each row indicate a significant difference among varieties when α ≤ 0.05

According to the manufacturer's recommendations, Biolife solution can be used to hydroponically grow many different crops, including leafy vegetables and ornamental plants. However, the results of this study indicated that the impatiens plants grown in Biolife solution grew very slowly, and the plants were almost unbranched and had stunted leaves. Although some plants flowered, the flower buds later fell off and tended to fade 35 to 40 days after planting in the hydroponic system. The excessive low mineral elements concentration in the Biolife solution may be responsible for this result.

Table 2. Number of branches/plant and canopy diameter of *Impatiens walleriana* grown in different nutrient solutions

Number of branches/plant					
Days after planting on hydroponic system	Biolife	BKFast	Hoagland	Hydro Umat F	Knop
15	$1.38^{c} \pm 0.27$	$3.95^{b} \pm 0.36$	$3.81^{b} \pm 0.28$	$4.19^{a} \pm 0.43$	$4.24^{a} \pm 0.36$
30	$1.44^{c} \pm 0.30$	$9.86^{b} \pm 0.82$	$10.01^{b} \pm 0.43$	$10.78^{a} \pm 0.44$	$11.13^{a} \pm 0.65$
Canopy diameter, cm					
15	$12.06^{d} \pm 0.84$	$16.07^{b} \pm 1.03$	$16.23^{b} \pm 1.15$	$17.34^{a} \pm 1.28$	$17.62^{a} \pm 1.02$
30	$13.18^{d} \pm 0.67$	$28.96^{b} \pm 2.04$	$29.03^{b} \pm 1.35$	$32.13^{a} \pm 2.78$	$32.43^{a} \pm 2.65$

Note: Different letters in each row indicate a significant difference among varieties when α ≤ 0.05

Thus, among the 5 studied nutrient solutions, Knop and Hydro Umat F solutions were the most suitable for the growth stage of *Impatiens walleriana*, followed by Hoagland and BK-Fast solutions. Therefore, plants were grown continuously in all these four solutions, and parameters related to the yield and quality of impatiens flowers are monitored and evaluated. Unlike the results obtained on gerbera plants, in another study, Hydro Umat F solution was the most suitable solution for gerbera growth, but the use of Knop solution in hydroponic systems caused this plant to stop growing after 30 days (Le et al., 2021). This result showed that it is necessary to determine the suitable nutrient solution for hydroponic cultivation of each type of plant.

Days to 50% flowering: The results in Table 4 showed that plants began to appear flower buds quite early, about 27.14 days to 33.34 days after cultivating in the hydroponic system, and 50% of the plants had flowers. Among them, plants grown in Knop solution had the earliest flowers. The time to appear flowers of plants in the remaining 3 solutions was later than that of plants in Knop solution, from 5.04 to 9.2 days, and the latest was for plants grown in BK-Fast solution (33.34 days).

Number of flowers/plant: The experimental results (Table 4) also clearly demonstrated the effect of the nutrient solution on the number of flowers on plants. After two months, plants grown in Knop solution had the highest number of flowers/plant, reaching 54.86. Statistics showed that at the first flowering, the plant appeared about 7 to 10 flowers (This flower number is similar to the results obtained in the study of Esringü et al. (2015) when growing Impatiens walleriana in a mixture of 2 soil+1 peat+1 sand and applying fulvic acid and humic acid), then on average one week, plants grown in Knop solution had 5 to 6 new flowers. Therefore, impatiens flowers bloomed continuously and maintained their flower numbers throughout the 2 months of the study. Similar to the Knop solution, the number of flowers/plant of plants grown in the Hydro Umat F solution was also quite high, with 50.34 flowers/plant. This value of plants grown in BKFast and Hoagland solutions was 43.65 and 39.17 flowers, respectively. The number of flowers/plant in this study was higher than that of those obtained by Nguyen & Vo (2006). Specifically, using three nutrient solutions, namely MS, Knudson C and Alan Cooper, the number of flowers/plant obtained was 24, 17 and 13, respectively. This result is only about 33.2% to 62.3% if compared with the yield of flowers obtained when growing impatiens plants in Hoagland solution in this study.

Floral longevity: Floral longevity plays an important role in the reproductive ecology of plants (Abdala-Roberts et al., 2007; Howard et al., 2012). The results in Table 5 below indicated that the impatiens flower had relatively high durability, and the period of time from full bloom until the petals fell ranged from 7.59 to 7.70 days. Statistical data showed that, unlike other parameters, floral longevity did not show much difference between the nutrient solutions. In their study, Howard et al. (2012) also showed that the floral longevity of impatiens flowers depends on species. Among 259 commercially inbred lines of impatiens grown in a greenhouse, mean floral longevity ranged from 3.3 ± 0.4 to 15.8 ± 2.5 days. Besides, the mean floral longevity of hybrids ranged from 2.8 ± 0.4 to 14.1 ± 2.8 days.

Flower diameter: The flower diameter was found to be influenced by the type of nutrient solution used (Table 5). Specifically, impatiens cultivated using the Knop and Hydro Umat F solutions displayed flower diameters ranging from 4.68 to 4.71 cm, approximately 0.48 to 0.55 cm larger than plants grown in the Hoagland solution and BK-Fast solutions, respectively. This result is also higher than the data on the diameter of impatiens flowers published by Nguyen & Vo (2006), in which the largest flower diameter was 4.0 cm, measured in plants grown in MS solution.

Except for some micronutrients (B, Mn, Zn, Mo and Cu) with very low content, the composition and content of remaining macronutrients in the Hydro Umat F solution are quite similar to those of the Knop solution. Compared to the composition of the Knop solution, the BK-Fast solution contains a higher content of elements, including both ma-

Table 4. Effect of nutrient solutions on flowering time and number of flowers per plant

Parameters	BKFast	Hoagland	Hydro Umat F	Knop
Days to 50% flowering	33.34^{a} ±1.81	32.28^{ab} ±2.01	32.18^{ab} ±1.54	27.14^{c} ±1.12
Number of flowers/plant	43.65^{c} ±3.28	39.17^{d} ±3.21	48.34^{b} ±3.01	54.86^{a} ±2.12

Note: Different letters in each row indicate a significant difference among varieties when $\alpha \leq 0.05$

Table 5. Effect of nutrient solutions on floral longevity (day) and flower diameter, cm

Parameters	BKFast	Hoagland	Hydro Umat F	Knop
Floral longevity	7.70^{a} ±0.63	7.59^{a} ±0.42	7.67^{a} ±0.50	7.64^{a} ±0.44
Flower diameter	4.20^{b} ±0.21	4.13^{b} ±0.26	4.71^{a} ±0.15	4.68^{a} ±0.19

Note: Different letters in each row indicate a significant difference among varieties when $\alpha \leq 0.05$

cronutrients and micronutrients; however, it lacks S, while the content of all elements in the Biolife solution is very low (Table 1). The results in the study show that the impatiens plant does not have a high demand for micronutrients, the balance of elements in the nutrient solution ensures its good growth and favorable flowering. These findings emphasize the significant role of nutrient solutions in influencing flower characteristics, and they can be of utmost importance in optimizing flower production within hydroponic systems.

Effect of pH level and TDS concentration in Knop solution on the number of flowers per plant, floral longevity and flower diameter

Based on the analysis of parameters related to the growth and flower quality of impatiens, the Knop solution is the most suitable nutrient solution for the growth and flowering of impatiens plants among 5 research solutions. Furthermore, in order to select a nutrient solution with suitable technical parameters for the hydroponic cultivation of impatiens, we continued to evaluate the influence of pH level and TDS concentration of Knop solution on the yield and quality of impatiens flowers. The experiment focused on determining 3 parameters: number of flowers/plant, floral longevity and flower diameter for 2 months (Table 6).

The nutrient solutions used in the above experiments had pH ranges between 6.0–6.5. In this experiment, we used Knop solution with 3 different pH ranges: 4.5–5.0, 5.5–6.0 and 6.5–7.0. The data in Table 6 shows that the number of flowers/plant, flower diameter and flower durability in plants grown in a solution with a pH of 5.5–6.0 are equivalent to the results obtained in the standard experiment with a pH of 6.0–6.5. While, pH 4.5–5.0 markedly reduced all three parameters, pH 6.5–7.0 did not greatly affect the study results except for the data on floral longevity. Specifically, the number of flowers/plants in the Knop solution with pH 4.5–5.0 decreased by about 50% compared to its value in the solution with pH 5.5–6.0, which was only 28.25 flowers/plant. Besides, these flowers had a small flower size (3.62 cm), and their durability decreased, and flowers faded and fell after about 4.12 days. In the Knop solution with a pH of 6.5–7.0, although floral longevity decreased from 7.69 days to 6.8 days, the number of flowers/plant and flower diameter were not significantly different from those grown in Knop solution with a pH of 5.5–6.0.

Regarding the effect of TDS concentration, it was observed that both low and high TDS values had adverse effects on the flowering stage. At a TDS concentration of 400-450 ppm, the number of flowers/plant significantly decreased to 30.17 flowers, accounting for only 55.95% compared to the results obtained from plants cultivated in solution with a TDS of 750–800 ppm. Furthermore, flower size also diminished (3.18 cm in diameter), and flowers fell off after around 4.07 days.

Regarding flower diameter, there was no statistical difference between plants grown in Knop solution with TDS 1150–1200 ppm and plants grown in Knop solution with TDS 750–800 ppm, with results ranging from 4.67 to 4.74 cm. However, the number of flowers and floral longevity of impatiens plants cultivated in Knop solution with 1150–1200 ppm TDS were lower, with approximately 47.13 flowers/plant falling off, about 2.49 days earlier than the stock solution.

Thus, it can be seen that, like most other hydroponic plants, *Impatiens walleriana* grows well in solutions with a pH ranging from 5.5 to 6.5. The pH value lower than 5.5–6.5 can affect the flowering of plants, it reduces the number of flowers/plant, flower diameter and floral longevity. Impatiens walleriana has the ability to flower in nutrient solutions with a wide range of TDS concentrations, from 450–1200 ppm. However, the solution with low TDS reduces the quantity and quality of flowers, causes small flower buds, and fades flower color. In high TDS solutions, plants tended to develop extra leaves and shoots, reducing flower number and floral longevity. The overabundance of nutrients may have promoted the development of the stem and leaf systems, reducing the differentiation of flower buds in *Impatiens walleriana.*

Conclusion

The results of the evaluation of the parameters related to growth, yield and quality of impatiens showed that among the five studied nutrient solutions, including Biolife, BKFast, Hoagland, Hydro Umat F and Knop: Knop and Hydro Umat F are two solutions that ensure good growth and favorable

Table 6. Effect of pH level and TDS concentration of Knop solution on flowering stage of *Impatiens walleriana*

Parameters	pH level			TDS level (ppm)		
	4.5–5.0	5.5–6.0	6.5–7.0	400–450	750–800	1150–1200
Number of flowers/plant	28.25^{d} ±1.56	55.01^{a} ±2.25	54.25^{a}±3.02	30.17^{c} ±1.21	54.90^{a} ±2.65	47.13^{b} ±3.54
Flower diameter, cm	3.62^{b} ±0.39	4.65^{a} ±0.38	4.59^{a}±0.43	3.18^{c} ±0.21	4.67^{a} ±0.36	4.74^{a} ±0.41
Floral longevity, day	4.12^{d} ±0.67	7.69^{a} ±0.50	6.8^{b}± 0.34	4.07 ±0.53	7.65^{a} ±0.41	5.16^{c} ±0.63

Note: Different letters in each row of each experimental factor indicate a significant difference among varieties when $\alpha \leq 0.05$

flowering. Meanwhile, Biolife solution is not suitable for hydroponic cultivation of this plant; Using Knop solution with pH 5.5–6.5 and TDS concentration 750–800 ppm (parts per million) ensures early flowering (plant had flower buds after 27.14 days in hydroponic system), a large number of flowers (54.86 to 55.01 flowers/plant for 2 months), long durability (floral longevity is 7.65 to 7.69 days), a large flower diameter (4.65 to 4.68 cm).

References

Abdala-Roberts, L., Parra-Tabla, V. & Navarro, J. (2007). Is floral longevity influenced by reproductive costs and pollination success in *Cohniella ascendens* (Orchidaceae)? *Ann. Bot., 100*(6), 1367-1371.

Ai, P., Liu, X., Li, Z., Kang, D., Khan, M. A., Li, H., Shi, M. & Wang, Z. (2021). Comparison of chrysanthemum flowers grown under hydroponic and soil-based systems: yield and transcriptome analysis. *BMC Plant Biol., 21(*517). https://doi.org/10.1186/s12870-021-03255-4.

Antonić, D., Milošević, S., Cingel, A., Lojić, M., Trifunović-Momčilov, M., Petrić, M. & Simonović, A. (2016). Effects of exogenous salicylic acid on *Impatiens walleriana* L. grown *in vitro* under polyethylene glycol-imposed drought. *South African Journal of Botany, 105,* 226-233.

Barbosa, J. G., Barbosa, M. S., Almeida, D. B., Sá, P. G., Finger, F. L., Martinez, H. E. P., Grossi, J.A.S., (2015). Production and postharvest quality of chrysanthemum flowers grown in hydroponic system under different N: K ratios. *Acta Hortic., 1060*(42), 281–287.

Blanusa, T., Vysini, E. & Cameron, R. W. (2009). Growth and flowering of *Petunia* and *Impatiens:* Effects of competition and reduced water content within a container. *HortScience*, *44*(5), 1302-1307.

Brickell, C. & Cathey, H. M. (2004). The American Horticultural Society A-Z Encyclopedia of Garden Plants. United States: DK Pub.

Burnett, S., Van Iersel, M. & Thomas P. (2005). PEG-8000 alters morphology and nutrient concentration of hydroponic impatiens. *HortScience, 40*(6), 1768-1772.

Cumo, C. (2013). *Encyclopedia of Cultivated Plants: From Acacia to Zinnia.* California, USA: ABC-CLIO.

Esringü, A., Sezen, İ., Aytatlı, B. & Ercişli, S. (2015). Effect of humic and fulvic acid application on growth parameters in *Impatiens walleriana* L. *Akademik Ziraat Dergisi, 4*(1), 37-42.

Gharibi, S., Tabatabaei, B. E., Saeidi, G., Talebi, M. & Matkowski, A. (2019). The effect of drought stress on polyphenolic compounds and expression of flavonoid biosynthesis related genes in *Achillea pachycephala* Rech. *Phytochemistry, 162*, 90-98.

Howard, N. P., Stimart, D., de Leon, N., Havey, M. J. & Martin, W. (2012). Diallel Analysis of Floral Longevity in *Impatiens walleriana*. *J. Amer. Soc. Hort. Sci., 137*(1), 47-50.

Janssens, S. B., Knox, E. B., Huysmans, S., Smets, E. F. & Merckx, V. S. F. T. (2009). Rapid radiation of Impatiens (Balsaminaceae) during Pliocene and Pleistocene: result of a global climate change. *Molecular Phylogenetics and Evolution, 52*(3), 806-824.

Lai, H. Y., Lam, C. M., Wang, W. Z. & Ji, Y. J. (2017). Cadmium uptake by cuttings of *Impatiens walleriana* in response to different cadmium concentrations and growth periods. *Bulletin of Environmental Contamination and Toxicology, 98*, 317-322.

Le, T. T., Nguyen, T. M., Nguyen, P. T. & Pham, T. V. (2021). Effects odd different nutrient solutions in growths and flower quality of gerbera (*Gerbera jamesonii*) grown in hydroponic close system. *Hue University Journal of Science: Natural Science, 130*(1D), 47–54.

Lopez-Galvez, F., Allende, A., Pedrero-Salcedo, F., Alarcon, J. J. & Gil, M. I. (2014). Safety assessment of greenhouse hydroponic tomatoes irrigated with reclaimed and surface water. *International Journal of Food Microbiology, 191,* 97-102.

Mandle, L., Warren, D. L., Hoffmann, M. H., Peterson, A. T., Schmitt, J. & Wettberg, E. J. (2010). Conclusions about niche expansion in introduced *Impatiens walleriana* populations depend on method of analysis. *PLoS ONE, 5*(12), e15297.

Nguyen, T. V. & Vo, T. B. M. (2006). Culture of Impatiens wallerana by hydroponics methods. *Science and Technology Development, 9*(1), 41-46 (in Vietnamese).

Nguyen, V. M., La, V. H. & Ong, X. P. (2013). Methods of Research in Plant Physiology. *Vietnam National University Publishing House* (in Vietnamese).

Nguyen, T. P. D., Vu, N. T., Nguyen, Q. T., Tran, T. T. H., Cao, P. B., Il-Seop, K. & Dong, C. J. (2022). Growth and Quality of Hydroponic Cultivated Spinach (*Spinacia oleracea* L.) Affected by the Light Intensity of Red and Blue LEDs. *Sains Malaysiana, 51*(2), 473-483

Rojas-Sandova, J. (2018). *Impatiens walleriana* (busy lizzy). *CABI Compendium Publisher.*

Şirin, U. (2011). Flower longevity and quality attributes of gerbera cut floweraffected by different nutrient solutions. *African Journal of Agricultural Research, 6*(21), 4910-4919.

Stevens, P. F. (2019). Angiosperm Phylogeny Website. Version 14. St. Louis, Missouri, USA: Missouri Botanical Garden.

Thuy, L. T., Huong, K. M. & Sen, D. T. (2020). Effect of three nutrient solutions including Hoagland, Hydro bee, and TC Mobi on some parameters related yield of hydroponic bitter gourd (*Momordica charantia*). Conference on Biology research and teaching in Vietnam, *Publishing House for Science and Technology*, 454-553 (in Vietnamese).

Received: **September, 15, 2023**; *Approved*: **March, 06, 2024;** *Published:* **August, 2024**