Hue University Journal of Science: Natural Science
Vol. 130, No. 1D, 47–54, 2021

pISSN 1859-1388
eISSN 2615-9678

EFFECTS OF DIFFERENT NUTRIENT SOLUTIONS ON GROWTH AND FLOWER QUALITY OF GERBERA (*Gerbera jamesonii*) GROWN IN HYDROPONIC CLOSE SYSTEM

Le Thi Thuy*, Nguyen Thi Mai, Nguyen Phuong Thao, Pham Thi Van

Faculty of Biology, Hanoi National University of Education, 136 Xuan Thuy St., Ha Noi, Viet Nam

* Corresponding author: Le Thi Thuy <thuy_lt@hnue.edu.vn>

(*Received: 15 July 2021; Accepted: 23 November 2021*)

Abstract. The nutrient solution is the decisive factor for the growth and development of hydroponic plants. This study was conducted to determine the effect of five nutrient solutions, namely, Hoagland, Knop, Hydro Umat F, BKFAST, and Bio-Life, on the growth and development of gerbera (*Gerbera jamesonii*) in the hydroponic system. The results show that Hydro Umat F is the most suitable solution for planting gerbera in terms of plant height, number of leaves, leaf size, and root volume. In addition, the flower yield of the gerbera plants nourished on Hydro Umat F is also the highest, with 8.7 flowers per plant after five months in the hydroponic system. The flowers have a diameter of 9.8 cm and natural durability of 19.67 days. Meanwhile, gerbera plants stop growing after 15 days in the Bio-Life solution and 30 days in the Knop solution.

Keywords: *Gerbera jamesonii,* hydroponic system, nutrient solution

1 Introduction

Gerbera (*Gerbera jamesonii*) is a popular flower in the Asteraceae family, indigenous to South Africa and Asia. This species grows well under different climatic conditions, so it is widely cultivated in numerous countries. Gerbera is also one of the ten most popular and consumed flowers in the world [1]. This flower is durable with various petal colours such as red, orange, yellow, white, and purple. Besides, gerbera is a perennial plant suitable for home decoration, office decoration, or artistic flower arrangement [2]. Several previous studies have shown that flowering time, flower yield per plant, quality parameters, such as stalk length and flower head diameter, can change with growing seasons, cultivars, and production techniques [3, 4].

The use of nutrient solutions to replace the soil in hydroponic technology brings numerous advantages. Specifically, this technique can be applied in different farming spaces and scales, conserves water and nutrients, limits pests and diseases, and protects the environment [5]. Additionally, efficient nutrition, availability of cultivation in non-arable lands, and higher density planting lead to increased yields in hydroponically grown plants [6]. In Vietnam, hydroponic technology is used to cultivate various leafy and fruit vegetables, but it is rarely used in flower production [7, 8].

Several studies on hydroponic gerbera cultivation have been published worldwide. Khalaj et al. evaluated the effects of different types of media on gerbera growth in hydroponic systems. Fourteen substrates mixed from the main ingredients are peat, fine sand, perlite, coco peat, fired clay particles with different ratios. The

substrate formula includes perlite + peat + expanded clays (25% + 70% + 5%), giving the best results on indicators such as the number of flowers, flower height, stem neck diameter, and vase-life [9]. Uğur Şirin determined the effects of five different nutrient formulations on the yield and quality of cut flowers and gerbera growth in hydroponic systems. The best results in terms of flower yield, flower quality, and plant growth were obtained from gerbera grown in Çolakoğlu-2 nutrient solution [4].

In Vietnam, numerous hydroponic solutions, such as BKFAST, Hydro Umat, Bio-Life, and Hydro green, are commercially produced and recommended for different crops. Besides, some traditional solution formulas, for example, Hoagland and Knop, have broad usage potential, especially for vegetable production. However, an optimum formulation depends on plant species and variety, stage of plant growth, part of the plant representing the harvested crop, the season of the year, day length, and weather conditions. Therefore, it is necessary to establish a suitable nutritional formula for gerbera grown in the close net house under Vietnam's climatic conditions.

2 Materials and methods

2.1 Materials

The experiment was arranged in a net house with a roof at the Experimental Garden, Faculty of Biology, Hanoi National University of Education, from September 2020 to April 2021. The temperature, humidity, and light were maintained under natural conditions at the time of planting.

In vitro dwarf 3-week-old gerbera plants grown in a coco peat substrate were used as the plant material for this study. The plantlets have an average height of about 6.5 to 7 cm, with 6 to 7 leaves per plant. The gerbera plantlets were provided by the Fruit and Vegetable Research Institute.

Five different solution formulations were used to provide nutrients for the plants. Two of them were used as material according to the formula of Hoagland and Knop. The other three were commercial solutions, namely, Bio-Life (Babylon Garden Co., Ltd), Hydro Umat F (MTV Gia Vien Hydroponics Co., Ltd)), and BKFAST (Bach Khoa Creative Joint Stock Company). Table 1 presents the nutrient solutions used in this study with their contents.

Table 1. Nutrient solution formulations

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
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	420.0	326.2	910.0	1071	30.0	3.0	6.3	0.9	0.6	0.7	20	443.6	–
Knop	117.1	32,5	133.6	138.9	28.8	–	–	–	–	–	1.03	38.1	–
Bio-Life	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	600.0	1500	17.5	53.3	40	60	1.2	60	60	–	–

Note. – Do not exist; nd. Undetermined

pISSN 1859-1388
eISSN 2615-9678

2.2 Methods

Five styrofoams (foam containers) were used per experimental formulation with 25 plants, and each styrofoam contained 25 L of nutrient solution. Coco peat was used as a substrate in the study. The pH of the solution was set at 6.0–6.2 in all nutrient solution formulations and measured three times a week. This study used commercially prepared "pH up" and "pH down" products to maintain the proper pH levels. Besides, the EC (electro-conductivity) of five solutions was kept between about 1.5 and 1.8 mS/cm.

To study the effects of the nutrient solutions on the plant growth and the quality of gerbera flowers, we determined the plant height, number of leaves per plant, leaf size, root volume, flower stalk length, flower head diameter, flower stalk diameter, number of flowers per plant, and time of flower growth (days to flowering and blooming and the natural durability of flower). The growth-related parameters were measured at three stages: 15 and 30 days after planting in the hydroponic system and when the gerbera plants started flowering (flowering period). The parameters related to flower characteristics were analyzed from the time of flower appearance to five months after planting in the hydroponic system.

Microsoft Excel 2010 software and SPSS 16.0 software were used to process the statistical data via one-way ANOVA analysis (Turkey's test) when α = 0.05.

3 Results and discussion

3.1 Effect of the nutrient solutions on some parameters related to plant growth

The difference in the growth rate of gerbera plants in five nutrient solution formulations was evaluated through growth criteria: plant height, number of leaves per plant, leaf size, and root volume. Table 2, Fig. 1, and Fig. 2 show some morphological traits related to the growth performance of gerbera plants with different nutrient solutions.

The results indicate that the best growth performance of the gerbera plant was observed with the Hydro Umat F solution. This solution had the highest content of N, P, and K. Meanwhile, gerbera plants grew poorly in the Bio-Life solution with a low content of macro-elements and in the Knop solution, lacking such micro-elements as B, Mn, Zn, and Cu (Table 1). After 15 days in the Bio-Life solution, the leaves of the gerbera plants turned yellow, and the plants almost stopped growing. Similarly, in the Knop solution and after 30 days, the gerbera plants had curled leaves and brittle, fragile petioles.

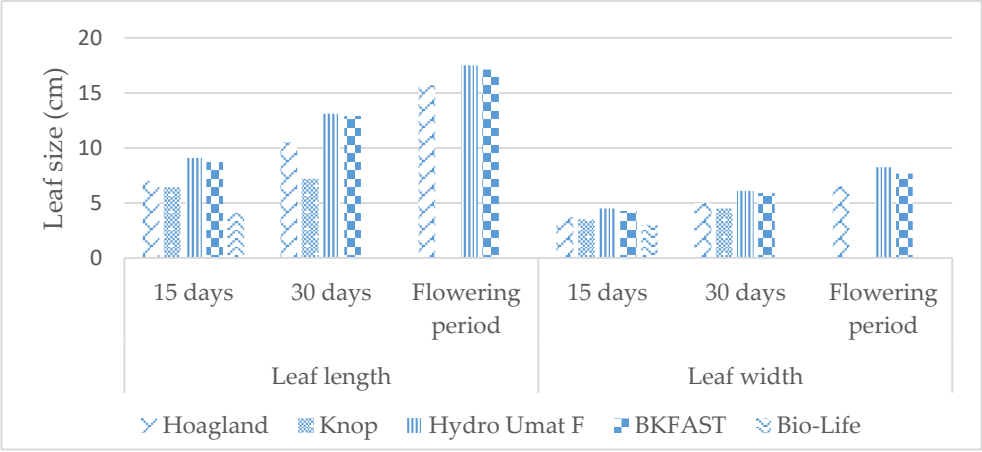

Fig. 1. Effect of nutrient solution formulations on leaf size

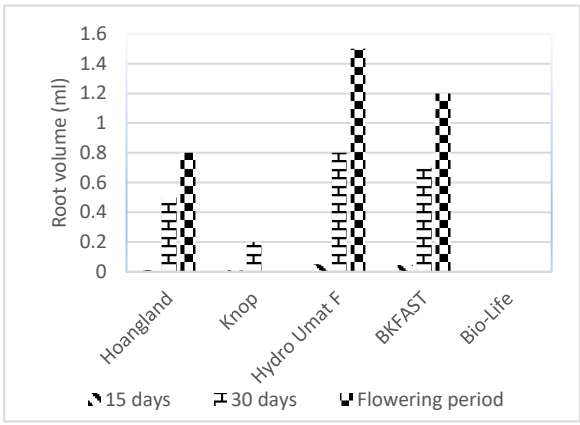

Fig. 2. Effect of nutrient solution formulations on root volume

Plant height and number of leaves

Before transporting to the hydroponic system, gerbera plantlets of similar sizes were chosen as the material for different experimental treatments. During the first 30 days, the plant height was not statistically different, ranging from 12.60 to 12.66 cm on the 15th day and 15.82 to 15.92 cm on the 30th day when cultured in the Hydro Umat F and BKFAST solutions (Table 2). These plants were about 3.8 to 4.3 cm higher than those grown in the Hoagland solution under the same conditions. The difference was not observed until the flowering stage. The plant grew the highest in the Hydro Umat F formulation (21.15 cm), 1.1 to 1.2 times higher than those grown in the BKFAST and Hoagland solutions.

Regarding the number of leaves, the Hydro Umat F solution enabled the plants to have the most leaves with 5.8 and 11.1 new leaves on the 30th day and at flowering. BKFAST was similar to Hydro Umat F with just approximately 0.75 fewer leaves. Hoagland was very different from the first two solutions, giving about half of the leaves. The last two formulations exhibited inferior performance: Knop solution resulted in only 2.66 leaves on the 30th day, while Bio-Life created one new leaf on the 15th day and killed the plants afterwards.

Leaf size and root volume

The leaf is the main photosynthetic organ of plants. Therefore, bigger leaves increase photosynthesis intensity, enhancing accumulation of organic matter in plants, thereby increasing crop yield [10]. The results in Fig. 1 show that the leaves of gerbera plants grown in the Hydro Umat F, BKFAST, and Hoagland solutions are significantly larger at the flowering stage. The Knop solution moderately increased the leaf size, while Bio-Life provided no leaf size change.

Table 2. Effect of nutrient solutions on plant height and number of leaves per plant

Plant height (cm)					
Time in system (day)	**Hoagland**	**Knop**	**Bio-Life**	**Hydro Umat F**	**BKFAST**
0	$6.34^{a} \pm 0.40$	$6.40^{a} \pm 0.32$	$6.38^{a} \pm 0.38$	$6.40^{a} \pm 0.36$	$6.35^{a} \pm 0.42$
15	$8.34^{b} \pm 0.28$	$8.44^{b} \pm 0.28$	$6.82^{a} \pm 0.44$	$12.60^{c} \pm 0.44$	$12.60^{c} \pm 0.37$
30	$12.07^{b} \pm 0.25$	$8.45^{a} \pm 0.39$	_	$15.92^{c} \pm 0.31$	$15.8^{c} \pm 0.31$
Flowering	$16.97^{a} \pm 0.47$	_	_	$21.15^{c} \pm 0.43$	$18.87^{b} \pm 0.50$
Number of leaves per plant					
0	$6.78^{a} \pm 0.35$	$6.84^{a} \pm 0.43$	$6.80^{a} \pm 0.32$	$6.74^{a} \pm 0.41$	$6.81^{a} \pm 0.30$
15	$8.60^{a} \pm 0.30$	$8.60^{a} \pm 0.30$	$7.80^{a} \pm 0.20$	$9.80^{b} \pm 0.20$	$9.40^{b} \pm 0.30$
30	$11.50^{b} \pm 0.33$	$9.50^{a} \pm 0.43$	_	$12.50^{c} \pm 0.52$	$11.75^{b} \pm 0.25$
Flowering	$13.50^{a} \pm 0.53$	_	_	$17.25^{c} \pm 0.25$	$16.50^{b} \pm 0.47$

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

pISSN 1859-1388
eISSN 2615-9678

The gerbera plants grown in Hydro Umat F solution had the largest leaf size just on the 15th day, with a length and width of 9.1 and 4.5 cm. These values were 2.2- and 1.5-fold higher than those obtained from the plants grown in the Bio-Life solution (4.1 and 3 cm). This increase remained until the 30th day. Meanwhile, these values for the plants cultured in BKFAST and Hoagland were 1.3- and 1.48-fold and those of Knop are 1.2 and 1.1-fold. At flowering, the leaf length and width of the plants grown in the Hydro Umat F solution were 17.5 and 8.25, BKFAST 17.1 and 7.65, and Hoagland 15.7 and 6.5 cm. The growth and development of the root system, especially in hydroponic cultivation, plays an essential role in helping plants absorb nutrients optimally. A suitable nutrient solution often creates an extensive root system, and when the root system is robust, it promotes plant growth. The size of the gerbera root system grown in different nutrient solutions is presented in Fig. 2.

As with other growth parameters, the root volume was different among the plants grown in the five nutrient solution formulations. Particularly, Hydro Umat F provided a large number of branched roots and rootlets with a volume of 1.5 mL at the flowering stage. BKFAST also gave a significant root volume (1.2 mL), 1.5-fold the Hoagland solution. Meanwhile, gerbera roots from the Bio-Life solution almost stopped growing, new roots formed very slowly. The plants grown in the Knop solution exhibited a better root growth than those grown in the Bio-Life solution, with fewer new roots and a low elongation rate. As a result, the root volume on the 30th day was ¼-fold smaller than the root volume of the plants grown in Hydro Umat F. The root characteristics were consistent with those for the plant height, the number of leaves/plants, and the leaf size.

Thus, the analysis above reveals that Hydro Umat F, BKFAST, and Hoagland provided better growth parameters than the other formulations. Therefore, they were used in the subsequent experimental phase.

3.2 Effect of the nutrient solutions on some parameters related to flower quality

The data in Table 3 show that, after 37 days of growth in the hydroponic system, the gerbera plants nourished with Hydro Umat F and Hoagland solution provided flower buds, five days faster than those grown in BKFAST. Compared with the results for the *in vitro* gerbera plants grown in soil reported by Gantait et al., the hydroponic gerbera plants in this study experienced delayed flowering of approximately five days [1].

Table 3. Effect of nutrient solutions on the time-lapse of flower growth (day)

Traits	Hoagland	Hydro Umat F	BKFAST
Day to flowering	$37.20^{a} \pm 2.20$	$37.50^{a} \pm 1.70$	$42.04^{b} \pm 2.30$
Bloom period	$30.67^{b} \pm 2.10$	$27.20^{a} \pm 2.00$	$34.04^{c} \pm 2.38$
Natural durability of flower	$16.33^{b} \pm 1.46$	$19.67^{c} \pm 1.26$	$14.16^{a} \pm 1.10$

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

This study also indicates that gerbera plants in the Hydro Umat F solution bloomed earliest (27.20 days after flower bud appearance) and latest in the BKFAST solution (34.04 days). As a result, flowers grown in the Hydro Umat F solution had the most extended natural durability, up to 19.67 days from blooming until the wilted petals and the droopy flower stalks. This value in the plants grown in Hoagland and BKFAST was 16.33 and 14.16 days. A study reported that the cut flower durability (vase-life) of the red, orange, pink, and purple gerbera varieties, cultivated on soil and treated with different foliar fertilizer formulations, ranges from 10.9 to 15.6 days [11]. This indicator of the *in vitro* gerbera grown hydroponically is 10.18–14.20 days [12]. Therefore, we can see that using hydroponic gerbera pots in this study could significantly prolong flowers' durability for decorative purposes.

Besides, to determine the effects of the nutrient solutions on the quality of gerbera flowers, we conducted measurements and observations on the flowers for a period of 5 months, starting in September 2020, when the plants were grown in the hydroponic system. For this purpose, the number of flowers per plant, the flower head diameter, the flower stalk length, and the flower stalk diameter were analyzed to seek whether there is a difference in the qualities of the flowers in terms of the nutrient solution formulations applied. The results are shown in Table 4.

We can see that the number of flowers per plant changes between 5.1 and 8.7, and the highest flower yield is observed with the Hydro Umat F solution. This yield is related to the superior plant height, the number of leaves, and the root volume of the gerbera plants grown in the Hydro Umat F solution, as described above.

The data show that Hydro Umat F gives 2.9 flowers/plant more than Hoagland. The BKFAST solution provides the lowest flower yield at 5.1 flowers per plant. This application includes 266.6 ppm N, 133 ppm P, and 600 ppm K. The content of micro-elements Mn, Zn, Cu, Fe is higher than that of the other two solution formulations. On average, the number of flowers/plant/month is 1.74 from the Hydro Umat F solution, 1.16 from the Hoagland solution, and 1.02 from the BKFAST solution. Sirin's study on Skyline variety (sown from seed) reported a value from 1.14 to 3.22 flowers/plant/month. The study showed that the gerbera plant from the Hoagland–Arnon solution produced an average of 1.8 flowers/plant/month. Gerbera plants with good care can flower continuously for 4–5 years [2]. Our study recorded the number of flowers per plant in the early growing stage when the plant began to adapt to the environment and nutrition regime. Therefore, compared with the results of Sirin's study, which was conducted over 18 months, the number of flowers/plant/month in this study is smaller.

Table 4. Effect of nutrient solutions on flower quality parameters

Traits	Hoagland	Hydro Umat F	BKFAST
Number of flowers per plant	$5.80^{a} \pm 0.50$	$8.70^{b} \pm 0.70$	$5.10^{a} \pm 0.30$
Flower head diameter (cm)	$8.00^{a} \pm 0.08$	$9.80^{b} \pm 0.08$	$7.72^{a} \pm 0.04$
Flower stalk length (cm)	$16.57^{b} \pm 0.38$	$24.23^{c} \pm 0.51$	$14.47^{a} \pm 0.26$
Flower stalk diameter (mm)	$5.81^{a} \pm 0.04$	$6.02^{c} \pm 0.07$	$5.90^{b} \pm 0.05$

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

pISSN 1859-1388
eISSN 2615-9678

While the number of flowers per plant is a direct indicator of the gerbera yield, the flower head diameter is one of the most important criteria for evaluating the quality of gerbera. Like other parameters in the study, the flower diameter is the largest when grown in the Hydro Umat F solution (9.80 cm), 0.9 cm wider than that of Gantait et al., but 1.1 cm narrower than what was reported by Khalaj on the golden gerbera variety [1, 12]. The flower diameters are not statistically different between the flowers grown with BKFAST and Hoagland (8 and 7.72 cm).

As for the flower stalk length, the gerbera plants used in this study were a dwarf variety, so the flower stalk was relatively short, ranging from 14.47 to 24.23 cm, 15.06 to 21.9 cm shorter than the results reported by Şirin [4]. The most extended flower stalk length was observed in the plants nourished with the Hydro Umat F solution, followed by the Hoagland and BKFAST solutions. In other tall gerbera varieties, the flower stalk could be 2–4 times longer, depending on the nutrient solution used. For example, in Şirin's study, the flower stalk length ranged from 36.6 to 39.2 cm, or 47.9 to 52.2 cm, as reported by Khalaj and Kanani [4, 13]. Besides the nutritional factor, the flower stalk length depends on the cultivar. With hydroponic gerbera, an appropriate flower stalk length can make the flower pot beautiful and, at the same time, prevents the flower from breaking or tilting during planting.

The results in Table 4 show a statistical difference between the flowers in terms of the flower stalk diameter. This parameter is an essential quality criterion affecting the endurance period of the flowers following the harvest and increases the natural durability of flowers on the plant. The largest flower stalk diameter is 6.02 mm in Hydro Umat F, followed by BKFAST and Hoagland (5.90 and 5.81 mm).

4 Conclusion

In this paper, we evaluate the plant growth indicators at the vegetative stage and the criteria related to the quality of gerbera flowers grown in five nutrient solution formulations. The formulation with a high content of N, P, K and appropriate micro-element composition (Hydro Umat F) provides the most satisfactory characteristics.

Funding statement

This research was financially supported by the SPHN 20-01 project of Hanoi National University of Education. The authors would like to thank you for this meritorious assistance and valuable contribution.

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