Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS

Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2025.60.72

Research Article

Effects of Bulb Size and Fertilizers on Growth, Yield and Color of *Polianthes tuberosa* "Pink Sapphire"

[1]Nguyen Thi My Duyen, [1]Tran Thanh Phong and [2]Bui Phuoc Tam

[1]Faculty of Agriculture and Natural Resources, An Giang University, Vietnam National University, Ho Chi Minh, Vietnam
[2]Loc Troi Agricultural Research Institute, An Giang, Vietnam

Abstract

Background and Objective: The *Polianthes tuberosa* "Pink Sapphire" is an economical and beautiful flower variety introduced in Vietnam. This research investigated the bulb size characteristics and the fertilizers influenced growth rate, yield and color of fluorescence when cultivated in the An Giang Province, Vietnam. **Materials and Methods:** In this study, two different sizes of tuberose bulbs (2 and 3 cm diameter), five treatments of root fertilizers and six treatments of foliar fertilizers were used. After that, monitoring indicators related to plant growth, flower yield and flower color were recorded. Data were collected and processed using Microsoft Excel. The One-way ANOVA and Duncan's were statistically analyzed using SPSS 20. The data in the study were statistically significant at the 95% level. **Results:** The findings revealed that 3 cm-sized bulbs exhibited better growth, higher yield, earlier flowering and superior flower quality compared to 2 cm-sized bulbs. Moreover, Dau Trau HCMK organic mineral fertilizer (6 g/plant/2 weeks) in combination with NPK 16-16-16+TE chemical fertilizer (1.8 g/plant/2 weeks) expresses the optimal fertilizer mixture. The foliar fertilizers AminoQuelan Mg and Vitazyme consistently showed the best performance in terms of growth and flower productivity indicators. The Đầu Trâu MK 901 foliar fertilizer treatment achieved the highest flower yield. The AminoQuelan Mg foliar fertilizer treatment (B3) produced the most stunning flower color, with color indices of L* = 82.3, a* = 4.0, b* = 4.3 and the highest anthocyanin content of 0.57%. **Conclusion:** These results helped to optimize the cultivation of the *Polianthes tuberosa* "Pink Sapphire" and served as a reference database for further research.

Key words: Bulb, color, fertilizer, growth, "Pink Sapphire", *Polianthes tuberosa*

Citation: Duyen, N.T.M., T.T. Phong and B.P. Tam, 2025. Effects of bulb size and fertilizers on growth, yield and color of *Polianthes tuberosa* "Pink Sapphire". Asian J. Plant Sci., 24: 60-72.

Corresponding Author: Nguyen Thi My Duyen, Faculty of Agriculture and Natural Resources, An Giang University, Vietnam National University, Ho Chi Minh, Vietnam

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The "Pink Sapphire" tuberose (*Polianthes tuberosa*) is an exotic flower variety, bred from a maternal plant (*Polianthes tuberosa* × *Polianthes howardii*) and a paternal plant (*Polianthes tuberosa* 'Double'), with pale pink, highly fragrant double-petal flowers. As a recently introduced variety, it has not yet been widely cultivated in Vietnam. Limited research has been conducted on cultivation techniques, care and biological characteristics of this flower. Particularly, fertilizers and bulb size have a direct impact on its growth and flowering[1,2]. The growth duration of tuberose typically spans one year or more[3]. Consequently, a substantial amount of both organic and inorganic fertilizers is required to sustain its long-term growth and flowering[4]. Macronutrients such as nitrogen, phosphorus and potassium significantly influence branching and flowering quality[2], while organic matters reinforce soil structure, improve nutrient metabolism and maintain soil health[5].

Furthermore, observations during cultivation in Vietnam reveal that the color of the tuberose is also affected by temperatures. Anthocyanin pigment holds an indispensable role in flower color formation[6]. Studies conducted on tuberose with reddish-purple flowers indicated that 80-100% of the anthocyanin content is cyaniding[7]. Micronutrients have been used to stabilize the color of cyaniding[8], with the most commonly applied micronutrients being Tin (Sn), Copper (Cu), Iron (Fe), Aluminum (Al) and Magnesium (Mg), which form complexes with anthocyanin, enhancing the vibrancy of the flower's color[9].

Besides, anthocyanin pigment is influenced by temperatures and certain plant growth regulators[10]. A requirement of a minor number of micronutrients and PGRs due to plant demand indicates that foliar application is the most suitable method, enabling rapid absorption, minimizing loss and proving more efficient than root application[10]. Hence, the study was conducted to investigate the effects of bulb size organic and inorganic basal fertilizers, as well as specific mineral elements and foliar-applied growth regulators, on the growth, coloration and longevity of the "Pink Sapphire" (*Polianthes tuberosa*).

MATERIALS AND METHODS

Place and time: The study was conducted from June, 2022 to May, 2024 at the Nguyen Nhu Experimental Garden, My Thoi Ward, Long Xuyen City, An Giang Province, Vietnam.

Materials: The *Polianthes tuberosa* "Pink Sapphire" bulbs were purchased from the Tra My Flower Garden (Quy Hop, Nghe An, Vietnam) originally sourced from Taiwan. The fresh and mature bulbs (bulb diameter of 2 cm or more) were selected to prepare for further experiments at the Nguyen Nhu Experimental Garden.

Methods

Experiment 1

Biological characteristics *Polianthes tuberosa* "Pink Sapphire": The biological characteristics of "Pink Sapphire" were described and recorded, including root, bulb, clump, leaf, plant height and flower.

Experiment 2

Effect of bulb size and root fertilizers on the growth and yield of *Polianthes tuberosa* "Pink Sapphire": Two different sizes of *Polianthes tuberosa* "Pink Sapphire" bulbs including medium bulbs (3 cm diameter) and small bulbs (2 cm diameter) were utilized. The fertilizers included Dau Trau HCMK organic mineral fertilizer (produced by Binh Dien Fertilizer Joint Stock Company, composition: 15% organic matter, 12% N, 3% P_2O_5, 1% K_2O, 0.05% CaO, 0.15% MgO, 300 ppm B, 500 ppm Zn, 300 ppm Cu) and inorganic fertilizers such as Dau Trau NPK 16-16-8+TE, NPK 16-16-16+TE, urea (46-0-0) and DAP (18-46-0).

Experimental design: The experiment followed a Randomized Complete Block Design (RCBD) with two factors: Bulb size (A) and basal fertilizers (P), with each treatment repeated three times. Each replication was conducted in a plot of 1.2 m^2 (planting distance of 30×40 cm). The treatments were as follows:

- (A1) medium bulbs and (A2) small bulbs
- (P1) Dau Trau HCMK organic mineral fertilizer (6 g/plant/2 weeks)
- (P2) Organic fertilizer (cow manure)+Dau Trau HCMK organic mineral fertilizer (3 g/plant/2 weeks)+NPK chemical fertilizer (0.9 g/plant/2 weeks)
- (P3) Organic fertilizer (cow manure)+NPK chemical fertilizer (1.8 g/plant/2 weeks)
- (P4) Dau Trau HCMK organic mineral fertilizer (6 g/plant/2 weeks)+NPK chemical fertilizer (1.8 g/plant/2 weeks)
- (P5) NPK chemical fertilizer (1.8 g/plant/2 weeks)

Fertilization methods: Pre-planting fertilization involved applying decomposed cow manure at 1000 kg/ha (for P2, P3) and Dau Trau HCMK organic mineral fertilizer at 500 kg/ha (for P1, P2, P4). Ten days after planting, 120 kg/ha DAP and 60 kg/ha urea were applied by watering at the root zone of the plants. After 30 days, fertilization was repeated every 2 weeks using the treatments' formulas (P1, P2, P3, P4 and P5). For the chemical fertilizers:

- Dau Trau NPK 16-16-8+TE was used during the non-flowering stage
- Dau Trau NPK 16-16-16+TE was used from the flowering stage onwards

Experiment 3

Effect of foliar fertilizers on the color and growth of *Polianthes tuberosa* "Pink Sapphire": Bulbs of *Polianthes tuberosa* "Pink Sapphire" were planted in the Nguyen Nhu Experimental Garden in My Thoi Ward, Long Xuyen City, An Giang.

Foliar fertilizers: Dau Trau MK 901 (produced by Binh Dien Fertilizer Joint Stock Company, composition: 15% N, 20% P_2O_5, 25% K_2O, 0.05% CaO, 0.05% MgO, 2200 ppm micronutrients (B, Cu, Fe, Mn, Zn), 200 ppm NAA, 100 ppm GA_3).

AminoQuelan Mg (produced by Grow More Company LTD, composition: 8% N, 6% amino acids, 9.8% MgO).

The CAM Bi NHAT trace element foliar fertilizer (produced by Ngan Gia Nhat Trading Co. Ltd, composition: 350 ppm Ca, 1020 ppm Mg, 17000 ppm S, 1700 ppm Cu, 700 ppm Fe, 700 ppm Zn, 700 ppm Mn, 2000 ppm B).

Vitazyme (produced by Loc Troi Group JSC, composition: 22 ppm brassinosteroids, 30 ppm triacontanol, 700 ppm Cu, 600 ppm Zn, 2000 ppm Fe).

0.1% citric acid (w/v)+2% ferrous sulfate (w/v).

Experimental design: The experiment followed a Randomized Complete Block Design (RCBD), comprising six foliar fertilizer treatments (B), with each treatment repeated three times. Each replication covered an area of 3.64 m^2, with a planting distance of 30×40 cm. The treatments were:

- (B1) No foliar fertilizer (control)
- (B2) Dau Trau MK 901 foliar fertilizer
- (B3) AminoQuelan Mg foliar fertilizer
- (B4) CAM Bi NHAT trace element foliar fertilizer
- (B5) Vitazyme foliar fertilizer
- (B6) 0.1% citric acid (w/v)+2% ferrous sulfate (w/v)

Fertilization methods: The optimal basal fertilizer formula from experiment 1 was selected and applied to experiment 2. After the first flowering, flowers were removed and the foliar fertilizers (B1, B2, B3, B4, B5 and B6) were sprayed every 14 days.

Monitoring indicators: Growth and flower yield indicators were collected and measured based on the method of Das *et al.*[11].

Growth indicators:

- **Root:** Type and distribution of root
- **Bulb:** Shape of a bulb
- **Number of shoots per clump:** Counting newly formed shoots on the clump
- **Clump diameter (cm):** Measuring the diameter of the "Pink Sapphire" tuberose clump
- **Leaf:** Arrangement of leaves on the stem; leaf length is measured from the base to the tip of a leaf; leaf width is measured at the widest part of the leaf. These leaf lengths and widths are recorded at the main bulb
- **Plant height (cm):** Measuring the height of the tallest shoot (from the base to the top)

Flower yield indicators:

- **Flowering time:** The period from planting to the second flowering (in days)
- **Inflorescence length (cm):** Measuring from the base to the tip of the flower
- **Number of flowers per inflorescence:** Counting the number of flowers on the inflorescence
- **Number of flowers per clump:** Counting the number of flowers on the clump
- **Flower diameter (mm):** Selecting mid-branch flowers to measure their diameter
- **Flower longevity in the field (days):** The time from when the flower opens until the first flower wilts and when 2/3 of the inflorescence has wilted

Flower color measuring: Flower color measuring was carried out following the method of Gonnet[12]. Five inflorescences were selected at stage 10 (when the first flower bud begins to

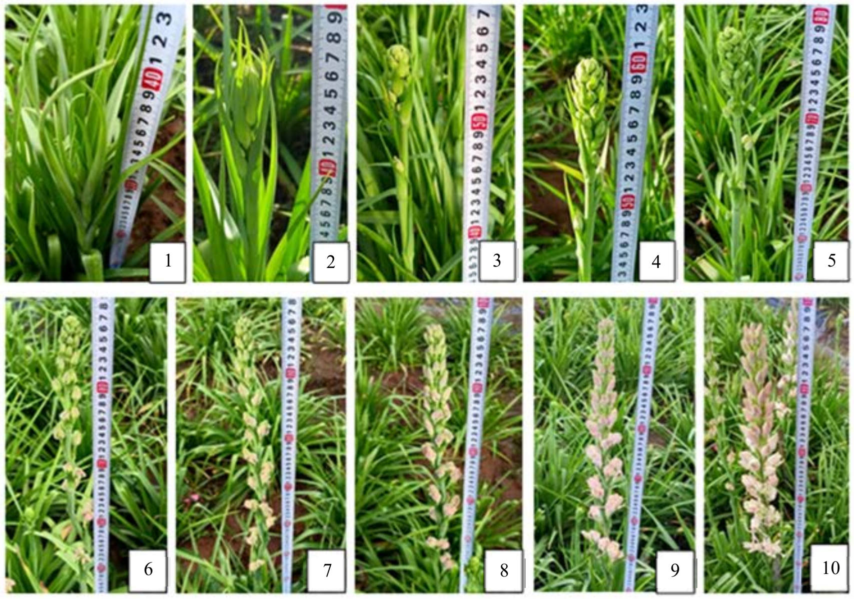

Fig. 1: Developmental stages of tuberose flowers "Pink Sapphire"
1-10: Developmental stages of tuberose flowers

Table 1: Some developmental stages of "Pink Sapphire" tuberose flower

Stage	Name	Time	Description
1	Tight bud (dormant stage)	Day 1	Flower buds are tightly enclosed by bracts at the tip of the shoot
2	Swollen bud	Day 4	Flowers enlarge beneath the bracts, causing the bud to swell and take on an elliptical shape
3	Cabbage head-like bud	Day 7	Buds expand further and the bracts loosen, making the tip of the bud resemble a cabbage head
4	Bud-opening	Day 10	Bracts fully open, revealing the flowers underneath
5	Elongation	Day 14	Bud begins to elongate and the first internode becomes visible
6	Coloration	Day 17	Second internode becomes more prominent and pale-pink petals begin
7	Stem elongation	Day 20	More than three internodes become visible as the stem continues to lengthen
8	Flower changing	Day 24-28	Petals grow larger and the pale pink deepens in color
9	Export harvest	Day 29-31	Flower stem becomes fully slender, with the first flower near the base swelling while the topmost buds remain closed, gradually deepening in pink color
10	Local harvest	Day 33-35	Lower flowers open 2-3 blossoms, emitting a fragrant scent

open) from each replication (Fig. 1 and Table 1). Petal samples were collected 20 g from each inflorescence and frozen at -15°C, then, crushed and soaked in 200 mL of solution (ethanol:water ratio 1:1 containing 1% HCl) for 60 min. After that, the solution mixture was filtered and the liquid was collected. The resulting liquid solution was centrifuged at 5000 rpm and the clear liquid was collected. About 5 mL of the extract solution was diluted with two buffer solutions (pH = 1 and pH = 4.5) in a 25 mL volumetric flask, then measured using the color reader CR-10 Plus (Japan).

Flower colors are represented by CIELAB color space coordinates. The instrument must be calibrated using the manufacturer's standard color samples. The CIELAB coordinate scales include: L* (lightness; black-white, 0 = black, 100 = white), a* (blue-red; negative values are more blue, positive values are more red), b* (blue-yellow; negative values are more blue, positive values are more yellow), h (hue angle; higher values are more brown) and C* (Chroma; color intensity, higher values are darker). Hue and color intensity values are calculated using the Gonnet's[12] formula:

$$C^* = (a^{*2}+b^{*2})^{0.5}$$

$$h_{ab} = \text{tang}^{-1}\left(\frac{b^*}{a^*}\right)$$

Anthocyanin content measuring: Anthocyanin content was analyzed and calculated according to the color change with the pH method of Giusti *et al.*[13]. From each replication, 25 g of Pink Sapphire petals were collected at stage 10, of which, 5 g for determining moisture content and 20 g for measuring anthocyanin content using the pH differential method. Anthocyanin content is calculated using the following formula.

Anthocyanin pigment content was calculated according to the formula of Giusti *et al.*[13]:

$$a\ (\text{mg/L}) = \frac{A \times M \times F \times V}{g \times 1}$$

Where:

- A = $\{(A_{\lambda max,pH1}-A_{\lambda 700,pH1})-(A_{\lambda max,pH4.5}-A_{\lambda 700,pH4.5})\}$
- $A_{\lambda 700}$ = Absorbance at peak wavelength and 700 nm at pH 1 and pH 4.5
- A = Anthocyanin content (mg/L)
- M = Molecular weight of anthocyanin, M = 449.2 (g/mol)
- F = Dilution factor
- V = Extract volume (liters)
- g = Molar absorptivity coefficient, g = 26.900
- l = Cuvette path length

Total percentage of anthocyanin was calculated according to the formula of Giusti *et al.*[13]:

$$\text{Anthocynin}\ (\%) = \frac{a}{m \times (100 - w) \times 10^{-2}} \times 100$$

Where:

- a = Amount of anthocyanin
- m = Initial sample weight (gr)
- w = Material moisture content (%)

Statistical analysis: Data were collected and processed using Microsoft Excel. The One-way ANOVA and Duncan's were statistically analyzed using SPSS 20. The data in the study were statistically significant at the 95% level.

RESULTS AND DISCUSSION

Experiment 1

Biological characteristics *Polianthes tuberosa* "Pink Sapphire": Pink Sapphire tuberose is a herbaceous perennial, primarily propagated through bulbs, Fig. 2a-d.

Root: Fibrous roots, which primarily grow shallowly in the surface soil layer.

Bulb: Pear-shaped, measuring about 4 cm in width, with a swollen base and a tapering top. The bulb is surrounded by multiple dormant buds and covered by leaf bases resembling fish scales (Fig. 2a). When the plant thrives, these dormant buds develop into new shoots, forming a clump.

Clump: Each clump measures 36-40 cm in diameter and can have more than 30 shoots. As a result, one clump can bear 5-6 flowering stems at the same time.

Leaves: Form a rosette at the base, growing along the flower stem (Fig. 2c). They are simple and sessile, with 9-10 leaves per plant. The leaves are 35-50 cm long and 2.6 cm wide.

Plant height: About 35 cm or more. They form clumps, with many shoots in each clump. Mature shoots produce flowers and the flower stems range in height from 75 to 94 cm.

Flowers: Double-flowered type, containing around 32 petals, standing upright and slightly outward-facing (Fig. 2b, d). The flowering period (from the time the flower stem starts to form until the first flower opens) is 28-30 days (Fig. 1, Table 1). Flowers last 7-14 days before wilting. The flower stems are 75-100 cm tall, with an inflorescence length of approximately 46 cm, bearing 40-46 individual flowers. Some flowers have deep purple highlights, creating a striking appearance. The flower clusters measure about 10 cm in diameter, with a purple-pink color (which may vary depending on the weather) and a strong, sweet fragrance.

The biological characteristics of purebred *Polianthes tuberosa* "Pink Sapphire" flowers were evaluated through the traits of roots, tubers, leaves, stems and flowers. This information helps growers select standard varieties for cultivation and is a database to support research related to breeding and farming of "Pink Sapphire" flowers further.

Experiment 2

Effect of bulb size and root fertilizers on the growth and yield of *Polianthes tuberosa* "Pink Sapphire"

Number of shoots per clump: The number of shoots is a precursor for flower yield and bulb production in tuberose. This factor is influenced by both bulb size and different nutrient regimes. After 8 months of cultivation, the average number of shoots for medium-sized bulbs (A1) was higher than for smaller bulbs (A2), at 8.69 shoots and 6.76 shoots, respectively. Larger bulbs generally contain more dormant shoots and store more nutrients, leading to a higher number of shoots. This result corresponds with the study by Zaman *et al.*[14] on white tuberose, which revealed that larger bulbs produce more shoots (bulbs) (Table 2).

Assessing the impact of fertilizer on the number of shoots for tuberose, Table 2 shows that treatment P4 (Dau Trau HCMK organic mineral fertilizer+NPK 16-16-16+TE 1.8 g/plant) yielded the highest number of shoots, at 9.42, considerably

Fig. 2(a-d): Illustrative image of parts of a *Polianthes tuberosa* "Pink Sapphire", (a) Bulbs, (b) Flower, (c) Stem and leaves and (d) Inflorescence

Table 2: Number of shoots/clumps of *Polianthes tuberosa* "Pink Sapphire" at the time of eight months after planting

	Treatment (P)					
Bulb size (A)	P1	P2	P3	P4	P5	Average (A)
A1	6.83	8.42	8.89	10.50	8.83	8.69
A2	4.28	6.33	7.94	8.33	6.89	6.76
Average (P)	5.56^{d}	7.38^{c}	8.42^{b}	9.42^{a}	7.86^{bc}	

CV main plot (%) = 6.65; CV subplot (%) = 8.63; F_A (*); F_P (*); $F_{A.P}$ (ns)

Means followed by the same letter within a column were not significantly different, ns: Not significant ($p>0.05$) and *Significant difference ($p<0.05$)

Table 3: Plant height (cm) of *Polianthes tuberosa* "Pink Sapphire" at the time of eight months after planting

	Treatment (P)					
Bulb size (A)	P1	P2	P3	P4	P5	Average (A)
A1	32.33^{ef}	34.00^{de}	37.00^{abc}	39.11^{a}	35.50^{cd}	35.59
A2	28.75^{g}	30.33^{fg}	36.92^{abc}	38.11^{ab}	35.72^{bcd}	33.97
Average (P)	30.54^{d}	32.17^{c}	36.96^{b}	38.61^{a}	35.61^{b}	

CV main plot (%) = 3.98; CV subplot (%) = 3.42; F_A (*); F_P (*); $F_{A.P}$ (*)

Means followed by the same letter within a column were not significantly different, ns: Not significant ($p>0.05$) and *Significant difference ($p<0.05$)

differing from treatments P1, P2, P3 and P5, which produced 5.56, 7.38, 8.42 and 7.86 shoots, respectively. This indicates that as the tuberose matures and flowers, its nutrient demand increases, while supplying only organic fertilizer (P1) or low amounts of NPK (P2) is inadequate for maximum shoot development. Karuppaiah[15] also suggested that the number of shoots per cluster increases with higher NPK application.

Plant height: Varieties were different in plant height, representing their unique characteristics. Therefore, plant height is a crucial indicator for assessing variety and serves as a metric for evaluating the plant's response to fertilizers, as well as the quality of the bulbs used in cultivation. Table 3 shows that the bulb size and basal fertilizers significantly affect the height of *Polianthes tuberosa* "Pink Sapphire". The experiment on bulb size impacted on plant height shows that after 8 months of growth, the average height for medium-sized bulbs (A1) was 35.59 cm, which was higher than the smaller one (A2) at 33.97 cm. According to Zaman *et al.*[14], a similar study on tuberose (*Polianthes tuberosa*) also concluded that plant height increases proportionally with bulb size.

The effect of basal fertilizers, as illustrated in Table 3, indicates that Tuberose requires more nutrients for the development of buds and flowers since the plant matures. Treatments that failed to meet the nutritional requirements displayed reduced plant height. An increase in the NPK fertilizer dosage (1.8 g/plant/2 weeks) in treatments P3, P4 and P5 had a significant effect on plant height compared to treatments P1 and P2, which involved lower NPK dosages. The highest plant height of 38.61 cm was observed in treatment P4, which involved the application of additional organic

Table 4: Clump diameter (cm) of "Pink Sapphire" at the time of eight months after planting

	Treatment (P)					
Bulb size (A)	P1	P2	P3	P4	P5	Average (A)
A1	33.22	35.08	38.67	40.50	37.56	36.37
A2	30.06	34.25	36.33	38.67	35.86	35.67
Average (P)	31.64^{d}	34.67^{c}	37.50^{b}	39.58^{a}	36.71^{b}	
CV main plot (%) = 2.86; CV subplot (%) = 4.29; F_A (*); F_P (*); $F_{A.P}$ (ns)						

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

Table 5: Effect of bulb size and root fertilizer on flower yield indicator

Treatment	Flowers/inflorescence	Flowers/clump	Inflorescence length (cm)	Flower diameter (cm)
Bulb size (A)				
A1	1.95	47.82	84.38	4.96
A2	1.43	46.63	82.48	4.77
Root fertilizer (P)				
P1	1.28^{b}	44.28^{e}	74.31^{d}	4.62^{c}
P2	1.46^{b}	46.72^{c}	81.53^{c}	4.66^{c}
P3	1.50^{b}	48.00^{b}	85.56^{b}	5.03^{ab}
P4	2.54^{a}	51.64^{a}	90.75^{a}	5.20^{a}
P5	1.67^{b}	45.50^{d}	85.00^{b}	4.83^{bc}
FA	*	*	*	*
FP	*	*	*	*
FA.P	ns	ns	ns	ns
CV main plot (%)	25.75	2.10	1.88	5.20
CV subplot (%)	23.47	1.45	1.68	3.62

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

mineral fertilizer (Dau Trau HCMK). Kabir *et al.*[5] also found that the height of tuberose (*Polianthes tuberosa* L.) peaked when a combination of chemical and organic fertilizers was employed.

The interaction between bulb size and root fertilization had a statistically significant impact on the height of *Polianthes tuberosa*. Treatment P4, combined with medium-sized bulbs (A1), produced the tallest plants, whereas treatment P1 with smaller bulbs (A2) resulted in the shortest plants, measuring 39.11 and 28.75 cm, respectively.

Clump diameter: Clump diameter (cm) is an indicator of the lateral growth potential of *Polianthes tuberosa* "Pink Sapphire". A larger and faster-increasing clump diameter signifies robust vegetative growth, enhanced light interception and improved photosynthetic efficiency. According to Karuppaiah[15], increased photosynthetic activity and greater accumulation of organic matter within the plant contribute to higher flower yield and extended longevity. Table 4 demonstrated the influence of both bulb size and fertilizer type on clump diameter. It is evident that medium-sized bulbs consistently exhibited greater clump diameters compared to smaller ones within the same fertilizer treatments. The P4 treatment, which involved a combination of Dau Trau HCMK organic mineral fertilizer and NPK chemical fertilizer, resulted in the highest clump diameter of 39.58 cm, showing a statistically significant difference from the other treatments.

Flower yield indicators: Flower yield indicators serve as critical metrics that reflect the growth, development and overall quality of flower stems, directly impacting the economic performance of flower producers. Table 5 demonstrated that the bulb size and fertilizers significantly influence the yield parameters of *Polianthes tuberosa* "Pink Sapphire".

The assessment of the effect of bulb size showed that a larger bulb size leads to earlier flowering. Additionally, the yield indicators, such as flower/inflorescence, inflorescence length and flower diameter, demonstrated that while larger tubers (A1) generally yield higher values compared to smaller tubers (A2), the differences were not statistically significant (Table 5). These findings aligned with studies by Mane *et al.*[16] on white *Polianthes tuberosa*, which reported that larger tubers typically yield superior growth and flower yield metrics.

In contrast, the effect of root fertilizer on flower yield indicators was statistically significant. Treatment P1, which utilized only organic fertilizer, failed to provide adequate nutrients for optimal flower development, resulting in the lowest values for flower/inflorescence, flower/clump, inflorescence length and flower diameter. Specifically, this treatment yielded 1.28 flowers per inflorescence, an

Fig. 3: Inflorescence length of tuberose "Pink Sapphire"

P1-P5: Inflorescence length of tuberose from the five experiment treatments, P1: Dau Trau HCMK organic mineral fertilizer (6 g/plant/2 weeks), P2: Organic fertilizer (cow manure)+Dau Trau HCMK organic mineral fertilizer (3 g/plant/2 weeks)+NPK chemical fertilizer (0.9 g/plant/2 weeks), P3: Organic fertilizer (cow manure)+NPK chemical fertilizer (1.8 g/plant/2 weeks), P4: Dau Trau HCMK organic mineral fertilizer (6 g/plant/2 weeks)+NPK chemical fertilizer (1.8 g/plant/2 weeks) and P5: NPK chemical fertilizer (1.8 g/plant/2 weeks)

inflorescence length of 74.31 cm, 44.28 flowers per clump and a flower diameter of 4.62 cm. Conversely, the addition of NPK fertilizer (1.8 g/plant/2 weeks) in treatment P4 resulted in significantly higher values, including 2.54 flowers per inflorescence, an inflorescence length of 90.75 cm, 51.64 flowers per clump and a flower diameter of 5.20 cm. These results were notably superior compared to those observed with treatment P5, which only used NPK fertilizer (1.8 g/plant/2 weeks) (Fig. 3). This indicated that neither chemical nor organic fertilizer alone provided optimal nutrition for flower development; rather, a combination of both was necessary for optimal growth (Table 5). These findings were consistent with research by Kabir *et al.*[5], which demonstrated that a mixture of organic and chemical fertilizers enhances flower development more effectively. Furthermore, the application of Dau Trau HCMK organic mineral fertilizer was found to promote better growth compared to self-processed cow manure. This was attributed to Dau Trau HCMK's pre-commercialization research and testing, which ensures that its nutrients are nearly fully decomposed into more readily absorbable forms, with more stable nutrient composition and levels compared to self-processed fertilizers like cow manure. Hanudin *et al.*[17] also reported that cow manure's relatively low nutrient content necessitates larger quantities for effective plant growth.

Experiment 3

Effect of foliar fertilizers on the growth and color of *Polianthes tuberosa* "Pink Sapphire"

Number of shoots (shoots/clump): The number of shoots plays a crucial role in determining flower yield, as fewer shoots lead to lower flower productivity. Therefore, monitoring the number of shoots/clump is a necessity. Table 6 showed that foliar fertilizer treatments have a significant impact on the shoot quantity of "Pink Sapphire".

In the fifth and sixth months, treatment B5 exhibited the highest number of shoots, with 27.4 and 33.6 shoots per clump, respectively. There was no statistically significant difference compared to treatments B1, B3 and B4 in the fifth month or treatments B2, B3, B4 and B6 in the sixth month. The foliar fertilizer Vitazyme (P5), which contains the growth regulator brassinosteroid, has been shown to enhance shoot and branch development in plants[10]. The 7th month was recorded with the highest number of flowers. According to Ploschuk *et al.*[18] there is a reciprocal inhibitory relationship between vegetative and reproductive organs. As the plant begins to flower, the reproductive organs become the primary sink for nutrients, leading to a cessation or slowdown in the growth of vegetative organs such as stems, leaves and shoots. At this stage, the plant focuses its nutrient resources on flower development and the foliar fertilizer may not supply sufficient nutrients to generate noticeable differences among treatments B2, B3, B4, B5 and B6. However, B6, which demonstrated lower flower yield (Table 6), likely continued to direct some nutrients toward shoot development, resulting in B6 having the highest shoot count in the seventh month, with 38.2 shoots per clump. In the eighth month, as flowering decreased, the foliar fertilizer became sufficient to influence shoot production, with treatment B3 showing the highest number of shoots (35.9 shoots per clump). The nitrogen content (8%) and amino acid content (6%) in treatment B3 (AminoQuelan Mg) likely contributed to the increase in shoot

Table 6: Effect of foliar fertilizer on the number of shoots per clump

Treatment	May	June	July	August
B1	26.1^{ab}	31.4^{c}	35.1^{b}	31.3^{d}
B2	24.1^{b}	32.2^{abc}	37.7^{a}	33.7^{bc}
B3	27.1^{a}	33.4^{ab}	37.8^{a}	35.9^{a}
B4	25.4^{ab}	31.9^{bc}	36.3^{ab}	32.0^{cd}
B5	27.4^{a}	33.6^{a}	36.0^{ab}	34.2^{ab}
B6	24.2^{b}	33.2^{ab}	38.2^{a}	35.5^{ab}
Significance level	*	*	*	*
CV (%)	5.6	2.4	3.1	3.1

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

Table 7: Effect of foliar fertilizer on plant height (cm)

Treatment	May	June	July	August
B1	47.7^{ab}	52.7^{bc}	63.3	65.6
B2	47.5^{ab}	55.5^{ab}	62.6	63.3
B3	50.6^{ab}	55.0^{ab}	64.0	67.9
B4	50.7^{ab}	55.7^{ab}	63.9	64.4
B5	54.2^{a}	57.1^{a}	64.3	67.8
B6	45.9^{b}	51.3^{c}	62.5	62.7
Significance level	*	*	ns	ns
CV (%)	8.0	3.6	5.5	6.1

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

production. This finding is consistent with research by Baqir and Al-Naqeeb[19], who reported that foliar application of amino acids enhanced shoot production and yield in wheat. In contrast, treatment B1, which did not receive additional nutrient supplementation, consistently recorded the lowest number of shoots across all months.

Plant height (cm): Plant height reflects its development through its response to different fertilizer treatments and light regimes. The results from Table 7 showed that foliar fertilizers and shading nets have an impact on the plant height of "Pink Sapphire".

In the 5th and 6th months, treatment B5 resulted in the tallest plants, with heights of 54.2 and 57.1 cm, respectively, showing no significant difference compared to treatments B1, B2, B3 and B4 (5th month) and treatments B2, B3 and B4 (6th month). This result can be explained that Vitazyme contains vital components required for plant growth such as triacontanol, B-vitamins (thiamine, riboflavin, pyridoxine and cobalamine), biotin, folic acid, niacin and other as yet unquantified growth regulators such as certain glycosides and porphyrins[20]. Treatment B6 had the shortest height at the 5th and 6th month, at 45.9 and 51.3 cm, respectively, possibly due to the leaf scorch from frequent application of 2% iron sulfate. In the 7th and 8th months, as the plants produced more flowers and allocated more nutrients to flower development, there were no significant differences in height across the treatments.

Flower parameters: Key flower characteristics, such as flowering time, the number of flowers per inflorescence, inflorescence length and flower diameter, directly affect the quality of the flower stalks. Therefore, monitoring the impact of fertilizers on these parameters is crucial. Table 8 shows the following.

Flowering time: Treatment B2 (Dau Trau 901 foliar fertilizer with 15% nitrogen, 20% phosphorus pentoxide and 25% potassium oxide) had the shortest flowering time of 153.3 days, which was statistically different from the other treatments. This result was consistent with Abd El-Kafie *et al.*[21], who found that increasing potassium and phosphorus fertilizer levels shortened the flowering period of *Polianthes tuberosa*.

Number of flowers per inflorescence: Treatment B5 (Vitazyme) demonstrated the highest flowers of 57.5, showing no significant difference compared to treatments B2 and B3. A related study by Selim *et al.*[23] also concluded that the spraying of Vitazyme in soybeans resulted in an increase of approximately 10 pods per plant compared to the control group.

Inflorescence length: The foliar fertilizer treatments B3 (AminoQuelan Mg) and B5 (Vitazyme) exhibited the longest inflorescence lengths, measuring 103.4 and 103.6 cm, respectively, with no significant difference compared to treatment B4.

Table 8: Effect of foliar fertilizer on flower parameters

Treatment	Flowering time (days)	Flowers/inflorescence	Inflorescence length (cm)	Flower diameter (mm)
B1	169.3^{b}	49.7^{c}	97.4^{b}	52.9
B2	153.3^{a}	54.2^{abc}	97.7^{b}	53.7
B3	167.0^{b}	56.0^{ab}	103.4^{a}	55.5
B4	166.7^{b}	51.7^{bc}	99.0^{ab}	52.7
B5	167.3^{b}	57.5^{a}	103.6^{a}	53.5
B6	168.0^{b}	51.7^{bc}	96.4^{b}	52.2
Significance level	*	*	*	ns
CV (%)	3.6	5.2	2.7	4.4

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

Table 9: Effect of foliar fertilizer on flower yield and longevity

Treatment	Flower yield (flowers per inflorescence)	First flower wilting (days)	2/3 flower wilting (days)
B1	3.2^{b}	5.4^{bc}	9.8
B2	3.9^{a}	6.7^{a}	12.1
B3	3.9^{a}	6.0^{abc}	11.2
B4	3.4^{b}	5.5^{abc}	10.6
B5	3.9^{a}	6.6^{ab}	11.3
B6	2.6^{c}	5.3^{c}	10.1
Significance level	*	*	ns
CV (%)	5.5	10.3	10.9

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

Flower diameter: The diameter of *Polianthes tuberosa* "Pink Sapphire" flowers ranged from 52.2 to 55.5 mm. Treatment B5 showed the largest flower diameter at 55.5 mm, with no statistically significant difference from the other treatments.

Flower yield: Table 9 shows the average number of flowers per inflorescence after eight months of cultivation, indicating that foliar fertilizer treatments influenced the flower yield of *Polianthes tuberosa* "Pink Sapphire". Treatments B2, B3 and B5 produced the highest yield with 3.9 flowers per inflorescence, followed by treatment B1 with 3.2 flowers per inflorescence. The lowest yield was recorded in treatment B6 at 2.6 flowers per inflorescence, likely due to the detrimental effects of frequent leaf scorching caused by the application of 2% iron sulfate, which reduced flower yield.

Flower longevity: Treatment B2 exhibited the highest flower longevity at both stages of flower inflorescence when the first flower wilted and when two-thirds of the inflorescence wilted, with durations of 6.7 days and 12.1 days, respectively. The longevity of flowers in treatment B2 can be attributed to the high phosphorus and potassium content in the Đâu Trâu MK 901 fertilizer (N: 15%, P_2O_5: 20%, K_2O: 25%, CaO: 0.05%, MgO: 0.05%, TE [B, Cu, Fe, Mn, Zn]: 2200 ppm, NAA: 200 ppm, GA3: 100 ppm), which includes essential micronutrients and growth regulators. According to Jiang *et al.*[22], the application of high-potassium fertilizer during the flowering stage can enhance the beauty and longevity of flowers. Similarly, the study of Selim *et al.*[23] found that the use of phosphorus and GA3 increased the flower longevity of white *Polianthes tuberosa*. However, at the first flower senescence stage, treatment B2 shows no statistically significant difference with treatments B3, B4 and B5. At the two-thirds senescence stage, no statistical differences were observed across all treatments, with flower longevity ranging from 9.8 to 12.1 days.

Flower color: Table 10 indicates that foliar fertilizer treatments had a significant impact on flower color indices, although the differences in color between treatments were minimal.

The B3 treatment demonstrated the lowest lightness (L*) value of 82.3, indicating the darkest and most saturated hue, although the variation was not statistically significant compared to other treatments. The a* values across all foliar fertilizer treatments were positive, signifying a red hue in the flowers. Consequently, a* value serves as the most critical index for evaluating the color intensity of pink tuberose flowers. The B3 treatment exhibited the deepest red coloration, with an a* value of 4.0. In contrast, treatment B1 recorded the lowest red intensity, with an a* value of 2.8, with no statistically significant difference from treatments B2, B4, B5 and B6. The b* value among all treatments was also positive, reflecting a yellow hue. Among these, treatment B1 showed the highest yellow intensity, with a b* value of 6.4, though the difference was not statistically significant when compared to treatments B2, B4, B5 and B6.

Based on the CIE LAB color space values (Table 10), the B3 foliar fertilizer treatment (AminoQuelan Mg) resulted in the most vivid and aesthetically pleasing flower color, although the difference was not significantly pronounced compared to

Fig. 4: Color of "Pink Sapphire"

Table 10: Effect of basal fertilizer on flower color

Treatment	L*	a*	b*
B1	84.9	2.8^{b}	5.8^{a}
B2	82.9	3.4^{ab}	5.3^{ab}
B3	82.3	4.0^{a}	4.3^{b}
B4	83.7	3.0^{b}	5.6^{a}
B5	82.6	3.4^{ab}	5.1^{ab}
B6	84.4	3.1^{ab}	6.0^{a}
Significance level	ns	*	*
CV (%)	1.6	15.8	11.5

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05), *Significant difference (p<0.05), L*: Represents the lightness of color, where L* = 0 is black and L* = 100 is white, a*: Represents the green-red spectrum; negative values indicate more green and positive values indicate more red and b*: Represents the blue-yellow spectrum; negative values indicate more blue and positive values indicate more yellow

Table 11: Effect of foliar fertilizer on anthocyanin pigment (%)

Treatment	B1	B2	B3	B4	B5	B6
Anthocyanin pigment (%)	0.31^{b}	0.43^{b}	0.57^{a}	0.37^{b}	0.39^{b}	0.32^{b}
Significance level	*					
CV (%)	15.9					

Means followed by the same letter within a column were not significantly different, ns: Not significant (p>0.05) and *Significant difference (p<0.05)

other treatments. According to a study of Abd El-Kafie *et al.*[21], spraying 2.4 nM $Mg(NO_3)_2$ on *Polianthes tuberosa* L. at 19°C enhanced the red-pink hue of the flowers compared to the control. However, at 25°C, the red color diminished with no significant variation in color and at 32°C, the flowers were predominantly white. This suggests that the magnesium component in the B3 treatment contributes to enhancing the pink tuberose flower's color, though the effect is moderated by high temperatures during the flowering period, resulting in no substantial color difference Fig. 4.

Anthocyanin pigment (%): According to Zhao and Tao[6] anthocyanin plays an indispensable role in the development of color in plants, particularly in flowers. Hence, determining the anthocyanin content is crucial for evaluating the impact of foliar fertilizers on the coloration of pink tuberose flowers.

The optical density A (Abs) is measured at wavelengths of 700 and 500 nm (where maximum absorbance occurs). Table 11 signifies that the foliar treatment B3 (AminoQuelan Mg) has the highest anthocyanin content at 0.57%, which is statistically different from the other treatments. Several studies have indicated that magnesium (Mg) can form complexes with anthocyanins, assisting in stabilizing the color of flowers[24]. The Mg application treatment does not influence the activity of the two key enzymes, phenylalanine ammonia-lyase (PAL) and chalcone isomerase (CHI), involved in the anthocyanin synthesis pathway. Thus, Mg does not enhance the synthesis of anthocyanins but rather forms complexes with them, which helps to increase their stability and slows down their degradation at elevated temperatures. Consequently, treating chrysanthemums with $Mg(NO_3)_2$ at high temperatures resulted in higher anthocyanin levels compared to untreated controls[25]. Therefore, spraying Mg solutions during high-temperature conditions enhances anthocyanin accumulation. Following this, treatment B2 exhibited an anthocyanin content of 0.43%, with no significant difference from treatments B1, B4, B5 and B6, which had anthocyanin levels of 0.31, 0.37, 0.39 and 0.32%, respectively.

CONCLUSION

The medium-sized bulbs (3 cm diameter) demonstrated superior performance in terms of growth parameters and flower yield. The application of NPK 16-16-8+TE in combination with Dau Trau HCMK organic mineral fertilizer (P4) had the highest efficiency. The foliar fertilizers AminoQuelan Mg and Vitazyme consistently exhibited the highest efficacy in promoting growth and flower yield, particularly in plant height, shoot number, flower number per inflorescence, inflorescence length and flower diameter. These data were useful for studies in breeding and selecting the *Polianthes tuberosa* "Pink Sapphire" flower. A further study is necessary to investigate the effects of minerals on the color of "Pink Sapphire" tuberose under different temperature conditions in Vietnam.

SIGNIFICANCE STATEMENT

The *Polianthes tuberosa* "Pink Sapphire" is a highly valuable flower that has just been introduced to Vietnam. Thus, its characteristics and cultivation methods in the conditions of Vietnam have not been well understood. This study provided information on the effects of bulb size and fertilizers, the two most influential factors on yield and quality of *Polianthes tuberosa*. This helps growers in the Mekong Delta of Vietnam practice good farming and improve their income. The result of the study also contributed to the basic background for further research related to breeding and selection.

ACKNOWLEDGMENT

The research fund of 1500 USD was provided by An Giang University, Vietnam National University, Ho Chi Minh City, Vietnam.

REFERENCES

1. Khairul Mazed, H.E.M., M.A.I. Pulok, M. Hafizur Rahman, N. Monalesa and S.G. Partho, 2015. Growth and yield of tuberose as influenced by different levels of manures and fertilizers. Int. J. Multidiscip. Res. Dev., 2: 555-558.
2. Abdalghani, S., Z. Fadhil, M. Rizq and F. Muhammed, 2024. Influence of nitrogen, potassium and phosphorus fertilizers with foliar application of micronutrient of iron, zinc and manganese on bulb characteristics of single flower tuberose plants (*Polianthes tuberosa*, L.). AlQalam J. Med. Appl. Sci., 7: 656-663.
3. Amin, M.R., M. Faridujjaman, H. Mehraj, A.F. Ona and A.F.M. Jamal Uddin, 2013. Influence of potash levels on growth and flowering of tuberose. J. Exp. Biosci., 4: 15-18.
4. Castañeda-Saucedo, M.C., E. Tapia-Campos, J. del Pilar Ramirez-Anaya, R. Barba-Gonzalez and M.L. Pita-Lopez, 2023. Effect of fertilization and planting date on the production and shelf life of tuberose. Agronomy, Vol. 13. 10.3390/agronomy13020422.
5. Kabir, A.K.M.R., M.H. Iman, M.M.A. Mondal and S. Chowdhury, 2011. Response of tuberose to integrated nutrient management. J. Environ. Sci. Nat. Resour., 4: 55-59.
6. Zhao, D. and J. Tao, 2015. Recent advances on the development and regulation of flower color in ornamental plants. Front. Plant Sci., Vol. 6. 10.3389/fpls.2015.00261.
7. Huang, K.L., I. Miyajima and H. Okubo, 2001. Anthocyanin constitution of flowers in newly established colored tuberose (Polianthes). J. Fac. Agric. Kagoshima Univ., 45: 381-386.
8. Castaneda-Ovando, A., M. de Lourdes Pacheco-Hernandez, M.E. Paez-Hernandez, J.A. Rodriguez and C.A. Galan-Vidal, 2009. Chemical studies of anthocyanins: A review. Food Chem., 113: 859-871.
9. Cavalcanti, R.N., D.T. Santos and M.A.A. Meireles, 2011. Non-thermal stabilization mechanisms of anthocyanins in model and food systems-an overview. Food Res. Int., 44: 499-509.
10. Castañeda-Murillo, C.C., J.G. Rojas-Ortiz, A.D. Sánchez-Reinoso, C.C. Chávez-Arias and H. Restrepo-Díaz, 2022. Foliar brassinosteroid analogue (DI-31) sprays increase drought tolerance by improving plant growth and photosynthetic efficiency in lulo plants. Heliyon, Vol. 8. 10.1016/j.heliyon.2022.e08977.
11. Das, S.C., K. Das, M.M. Rahman, F.N. Khan and G. Rasul, 2022. Genetic diversity and performance of tuberose (*Polianthes tuberosa* L.) genotypes at Gazipur, Bangladesh. Open Access J. Agric. Res., Vol. 7. 10.23880/oajar-16000294.
12. Gonnet, J.F., 1998. Colour effects of co-pigmentation of anthocyanins revisited-1. A colorimetric definition using the CIELAB scale. Food Chem., 63: 409-415.
13. Giusti, M.M., L.E. Rodriguez-Saona and R.E. Wrolstad, 1999. Molar absorptivity and color characteristics of acylated and non-acylated pelargonidin-based anthocyanins. J. Agric. Food Chem., 47: 4631-4637.
14. Zaman, R., A.N.F. Ahmmed and R. Ferdous, 2024. Investigating the incidence and severity of field diseases impacting tuberose (*Polianthes tuberosa* L.) cultivation: A case study in the Jashore District, Bangladesh. Heliyon, Vol. 10. 10.1016/j.heliyon.2024.e39876.
15. Karuppaiah, P., 2019. Effect of zinc and boron on growth, yield and quality of tuberose (*Polianthes tuberosa* L.) cv. Prajwal. Hortic. Int. J., 3: 7-11.
16. Mane, P.K., G.J. Bankar and S.S. Makne, 2024. Influence of spacing, bulb size and depth of planting on flower yield and quality of tuberose (*Polianthes tuberosa* L.) cv. 'single'. Indian J. Agric. Res., 41: 71-74.
17. Hanudin, E., W. Iskyati and N.W. Yuwono, 2021. Improving nutritional value of cow manure with biomass ash and its response to the growth and K-Ca absorption of mustard on inceptisols. IOP Conf. Ser.: Earth Environ. Sci., Vol. 752. 10.1088/1755-1315/752/1/012015.

18. Ploschuk, E.L., G.A. Slafer and D.A. Ravetta, 2005. Reproductive allocation of biomass and nitrogen in annual and perennial *Lesquerella* crops. Ann. Bot., 96: 127-135.
19. Baqir, H.A. and M.A.S. Al-Naqeeb, 2019. Effect of some amino acids on tillering and yield of three bread wheat cultivars. Iraqi J. Agric. Sci., 50: 20-30.
20. Nardi, S., M. Schiavon and O. Francioso, 2021. Chemical structure and biological activity of humic substances define their role as plant growth promoters. Molecules, Vol. 26. 10.3390/molecules26082256.
21. Abd El-Kafie, O.M., A.M Hamza, K.H. El-Hindi and M.M. Abd El-Baset, 2010. Influence of phosphorus, potassium and yeast nutrition on growth, flowering and chemical composition of tuberose. J. Plant Prod., 1: 431-449.
22. Jiang, K., S. Peng, Z. Yin, X. Li and L. Xie *et al*., 2024. Effects of N, P, K nutrition levels on the growth, flowering attributes and functional components in *Chrysanthemum morifolium*. Horticulturae, Vol. 10. 10.3390/horticulturae10030226.
23. Selim, S.M., F.M. Matter, M.A. Hassanain and S.M. Youssef, 2017. Response of growth, flowering, concrete oil and its component of *Polianthes tuberosa* L. cv. double to phosphorus fertilizer and gibberellic acid. Int. J. Curr. Microbiol. Appl. Sci., 6: 1639-1652.
24. Goto, T. and T. Kondo, 1991. Structure and molecular stacking of anthocyanins-flower color variation. Angew. Chem. Int. Ed. Engl., 30: 17-33.
25. Shaked-Sachray, L., D. Weiss, M. Reuveni, A. Nissim-Levi and M. Oren-Shamir, 2002. Increased anthocyanin accumulation in aster flowers at elevated temperatures due to magnesium treatment. Physiol. Plant., 114: 559-565.