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RESEARCH ARTICLE

# Influence of organic fertilizer and licorice root on growth, flowering and chemical constitution of Chinese carnation (*Dianthus chinensis* L.)

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## Abstract

The experiment was implemented in the facilities of the Department of Horticulture and Landscape Engineering (greenhouse) at the College of Agriculture, University of Anbar. It aimed to investigate the effect of organic fertilizer and licorice (*Glycyrrhiza glabra*) root powder on the vegetative growth, flowering traits and chemical composition of Chinese carnation plants. The first factor consisted of four concentrations of organic fertilizer: 0, 5, 10 and 15 mL $L^{-1}$, The second factor included three levels of licorice root powder: 0, 3 and 6 g per pot. The experiment was arranged in a factorial arrangement (4 × 3) using a Randomized Complete Block Design with three replications. Each experimental unit consisted of three plants. The results Displayed that using organic fertilizer at a level of 15 mL $L^{-1}$ significantly elevated height of plant, branches number and leaves number, diameter of flower, number of flower, petals content of anthocyanin and leaves content of nitrogen, carbohydrate and chlorophyll. These values can be analyzed as strong proof that organic fertilizer stimulates plant growth and enhances its growth and flower traits. Adding 3 g of licorice root powder to each pot also aided to improved growth of branch and leaves, total leaves area, diameter of flower, number of flower and total chlorophyll, suggesting that this treatment could be an successful supplement to stimulate overall health of plants. These results can be used to advance practical agricultural strategies aimed at rising plant productivity and flower and leaf quality, whether in home gardening or commercial production, by employing organic fertilizer at an adequate rate and supplementing licorice root as an aid to enhance growth and promote the nutritional content of plants.

**Keywords:** chemical composition; *Dianthus chinensis*; floral characteristics; licorice root powder; organic fertilizer; vegetative growth

## Introduction

Carnation (*Dianthus* spp.) is a genus of ornamental plants belonging to the family Caryophyllaceae, comprising approximately 384 species (1). The optimal regions for carnation cultivation are located around 30° latitude north and south, such as southern California and the Mediterranean basin. Carnations are often used in wedding ceremonies, presented to the bride and groom and are commonly known as the "flower of love" due to their symbolism of affection and romance. In ancient times, the Romans offered carnations as a symbol of respect and appreciation, associating them with festive occasions and religious holidays to express positive feelings and social recognition (2). The Chinese carnation plant is a cultivated variety (cultivar) commercially known as "Rainbow Pink". It is not the result of hybridization or mutation but was developed for the purposes of cultivation and producing flowers with desirable characteristics such as bright colors, flower size and growth quality. Its stem is ribbed and highly branched, reaching a height of 25 to 30 cm. The leaves are strap-shaped with entire margins and their arrangement on the stem is opposite. The flowers are terminal, solitary or in clusters, with serrated edges, some single (single-petaled) and some double (double-petaled) and their colors are varied including red, violet, crimson, carnation and pink. The plant is cultivated for edging, in flower beds, in rock gardens and as pot plants (3).

Organic fertilizers play a major role in increasing the improvement of soil structure, its health, aeration and the absorption of nutrients, increasing their availability and thus increasing plant growth and productivity (4). Humic substances can be defined as complexly structured materials that are more stable in decomposition, dark in color and colloidal in nature, formed at the end of decomposition. The groups of organic matter compounds differ greatly among themselves in terms of resistance to decomposition. The rapid disappearance of easily decomposable materials can be observed first, followed by the slow decomposable materials, then the young plant tissues begin to disappear, followed by the older tissues and so the speed of decomposition gradually slows as the molecular structure of the materials becomes more complex. The compounds are arranged according to their decomposition speed as follows: glucose sugar to starch to cellulose then lignin (5).

Another study (6) explained that liquid organic fertilizer at a concentration of 2 mL $L^{-1}$ improved the growth of carnations, including vegetative parts, roots and flowers. Previously (7) found that humic acid at a concentration of 100 mL $L^{-1}$ increased all of vegetative parts, roots and flowers of gazania. The researchers (8,9) explained that a concentration of 2000 mg $L^{-1}$ of humic acid enhanced calendula growth, flower indicators, chlorophyll, carotenoid and proline content, thus increasing overall productivity.

Licorice (*Glycyrrhiza glabra* L.) is a perennial herbaceous plant in the legume family, characterized by deep roots, purple to white flowers and numerous seeds (10-12). The root is commonly used, while the leaves contain active ingredients in smaller quantities and are a source of proteins, minerals, vitamins and other active compounds (13-15). Studies have shown that licorice powder and extract promote the growth of gardenia, snowdrop and gazania plants (16, 17).

Although previous studies have focused on the effect of organic fertilizers and natural plant extracts such as licorice powder or extract on the growth, flowering and chemical content of ornamental plants, there is a lack of comparative research to assess the simultaneous effect of these organic materials on a variety of flowering plants. Most studies have focused on a single plant or specific concentrations and have not studied the detailed effects on chemical indicators of the plant such as chlorophyll, carbohydrate and nutrient content under the same experiment. Therefore, the aim of this research is to study the combined effect of organic fertilizer and licorice powder or extract on the growth, flowering and chemical composition of carnation plants in order to determine the optimal concentration of these natural substances for improving productivity and quality. The expected results will contribute to guiding the optimal use of organic materials in sustainable agriculture and increasing the productivity of flowering plants.

## Materials and Methods

The experiment was conducted in the facilities of the Department of Horticulture and Landscape Gardening (greenhouse), College of Agriculture, University of Anbar, situated in the city of Ramadi. The study was performed from 15th October 2024, to 1st April, 2025, to assess the effect of organic fertilizer and licorice root powder on the growth traits, floral development and chemical content of Chinese carnation (*Dianthus chinensis* L.). Geographically, Ramadi is positioned at 33.435° N latitude and about 43.281° E longitude.

### Service, cultivation and fertilization operations

The study used Chinese carnation seedlings derived from a trustworthy nursery in Baghdad to ensure plant quality and suitability for experiment. The seedlings were defined by their proportionally small size at planting, vitality, bright green leaves and robust roots that stimulate balanced growth of plant. One seedling was placed in each pot assessing 25 cm in diameter and 30 cm in the height and then it was loaded with a growing medium consisting of sandy soil and peat moss in a 3:1 proportion, once true leaves had advanced. A physicochemical analysis of the growing medium was conducted and results are displayed in Table 1. Plants were initially fertilized with 1 $mL^{-1}$ of equilibrated liquid NPK fertilizer. Service procedures were conducted by spreading a layer of mulch to avoid weed growth and the plants were irrigated using a drip irrigation system. A protective program was followed by standard pest control protocol. The chemical fertilizer was reintroduced after each month for a duration of three months.

**Table 1.** Soil physical and chemical properties

| Property | Value | Unit |
|---|---|---|
| Ec | 1.67 | dS $m^{-1}$ |
| pH | 7.34 | |
| O.M | 5.42 | g $kg^{-1}$ soil |
| Sand | 690 | g $kg^{-1}$ soil |
| Silt | 118 | g $kg^{-1}$ soil |
| Clay | 192 | g $kg^{-1}$ soil |
| Soil texture | Sandy loam | |
| Available N | 112.00 | M $kg^{-1}$ |
| Available P | 11.30 | M $kg^{-1}$ |
| Available K | 118.5 | M $kg^{-1}$ |
| $SO_4^{-2}$ | 7.42 | mmole $kg^{-1}$ |

Plants were initially fertilized with 1 $mL^{-1}$ of a balanced liquid NPK fertilizer. Service operations were carried out by spreading a layer of mulch to prevent weed growth and the plants were watered using a drip irrigation system. A preventive program was followed by standard pest control protocol. The chemical fertilizer was reapplied after each month for a period of three months.

### Study factors

#### The first factor

Involved the addition of organic fertilizer produced by the Libro Company at four levels:

- $F_0$: No application (control)

- $F_1$: Organic fertilizer at 5 ml $L^{-1}$

- $F_2$: Organic fertilizer at 10 ml $L^{-1}$ (manufacturer's recommended rate)

- $F_3$: Organic fertilizer at 15 ml $L^{-1}$

The organic fertilizer composition is: Nitrogen 15 %, Calcium 5 %, Fulvic acid 5 %, Seaweed extract 2 % and Organic matter 50 %.

#### The second factor

Licorice plant roots were ground using a precise method and then added at three levels: 0, 3 and 6 g, added directly to the cultivation medium (sand + peat moss). Below is a chemical analysis of the licorice root powder. The following Table 2 shows the components of licorice root, according to previous studies (18).

**Table 2.** Composition of licorice (*Glycyrrhiza glabra*) roots

| Macro & Microelements | | | Amino Acids | | |
|---|---|---|---|---|---|
| **Element** | **Value** | **Unit** | **Amino Acid** | **Value** | **Unit** |
| N | 1.81 | % | Threonine | 0.144 | mg $g^{-1}$ |
| P | 1.12 | % | Arginine | 0.286 | mg $g^{-1}$ |
| K | 2.01 | % | Alanine | 0.463 | mg $g^{-1}$ |
| Mg | 0.56 | % | Valine | 0.513 | mg $g^{-1}$ |
| Ca | 2.11 | % | Leucine | 0.426 | mg $g^{-1}$ |
| Na | 0.20 | % | Isoleucine | 0.713 | mg $g^{-1}$ |
| Mn | 7.536 | µg $g^{-1}$ | Tyrosine | 0.026 | mg $g^{-1}$ |
| Fe | 52.132 | µg $g^{-1}$ | Serine | 0.627 | mg $g^{-1}$ |
| Zn | 23.684 | µg $g^{-1}$ | Proline | 0.548 | mg $g^{-1}$ |
| Cu | 10.170 | µg $g^{-1}$ | Tryptophan | 0.235 | mg $g^{-1}$ |
| **Other Compounds** | | | **Vitamins** | | |
| **Compound** | **Value** | **Unit** | **Vitamin** | **Value** | **Unit** |
| Glycyrrhizin | 4.093 | g 100 $g^{-1}$ | Vitamin B1 | 0.127 | mg $g^{-1}$ |
| Sucrose | 1.47 | g 100 $g^{-1}$ | Vitamin B2 | 0.026 | mg $g^{-1}$ |
| Glucose | 2.08 | g 100 $g^{-1}$ | Vitamin B6 | 0.038 | mg $g^{-1}$ |
| Gibberellin | 1.374 | g 100 $g^{-1}$ | Pantothenic acid | 0.081 | mg $g^{-1}$ |
| | | | Biotin | 0.067 | mg $g^{-1}$ |
| | | | Niacin | 0.097 | mg $g^{-1}$ |
| | | | Inositol | 0.103 | mg $g^{-1}$ |

### Study parameters

The following characteristics were measured during the study:

1. Plant height (cm).
2. Total number of branches (branch plant$^{1}$).
3. Number of leaves (leaf plant$^{1}$).
4. Total leaf area (cm$^{2}$).
5. Flower diameter (cm).
6. Number of flowers (flowers plant$^{1}$).
7. Petal anthocyanin content (mg 100 g$^{1}$ fresh weight): This characteristic was measured as per method described previously (19).
8. Leaf Nitrogen Percentage: The nitrogen content (%) was estimated according to the method described by previous researchers (20).
9. Total Carbohydrates (mg g$^{1}$): The carbohydrate content in the leaves was calculated according to the method described earlier (21).
10. Total Chlorophyll Content (mg100 g$^{1}$ fresh weight ): The total chlorophyll content in the leaves was calculated according to the method indicated in previous studies (22).

### Statistical analysis

The experiment comprised the addition of organic fertilizer at four levels and the addition of licorice root powder at three levels. It was a factorial experiment with two factors (4 x 3) within RCBD with three replications. Each treatment in each replication was represented by three seedlings. Analysis of the data was carried out using the GenStat statistical program and the arithmetic means were compared using the Least Significant Difference (L.S.D.) test at a significance level of 0.05 (23).

## Results

### Plant height (cm)

The results in Table 3 showed that using organic fertilizer at a concentration of 15 ml L$^{-1}$ (F3) led to a significant increase in the average height of Chinese carnation plants, reaching 39.878 cm compared to the lowest average height of 31.674 cm in the control treatment (F0), indicating a clear practical effect of organic fertilizer on promoting plant elongation. On the other hand, no statistically significant differences were observed when using licorice root. The interaction between the organic fertilizer and the licorice root did not produce any significant effect, indicating that the increase in plant height was mainly related to the effect of the organic fertilizer alone.

**Table 3.** Influence of organic fertilizer, powder of licorice root and their relationship on plant height (cm) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 30.490 | 32.187 | 32.345 | **31.674** |
| **F1** | 35.013 | 36.560 | 37.143 | **36.239** |
| **F2** | 35.700 | 37.160 | 38.830 | **37.230** |
| **F3** | 38.870 | 39.260 | 41.503 | **39.878** |
| **Mean G** | **35.018** | **36.292** | **37.455** | |
| **L.S.D $_{0.05}$** | F = 5.375 | G= N.S | F×G = N.S | |

### Total number of branches (branch plant$^{-1}$)

The results revealed that the application of organic fertilizer at a level of 15 mLL$^{-1}$ (F3) significantly elevated the average number of branches per plant, achieving 9.629 branch plant$^{1}$ compared to the F3 treatment, which noted 7.448 branch plant$^{1}$. This indicates a clear practical effect of the fertilizer on number of branches. G2 treatment with 6 g of licorice roots powder also demonstrated a further significant rise in the branches number, recording 8.971 branch plant$^{1}$. The results underlined the importance of the interaction between two factors study, with the F3G1 treatment being the highly efficient, as the mean number of branches noted 10.833 branches plant$^{1}$, compared to the control treatment F0G0, demonstrating enhanced branching when the two treatments were combined (Table 4).

**Table 4.** Influence of organic fertilizer, powder of licorice root and their relationship on the total number of branches (branch plant$^{1}$) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 7.163 | 7.310 | 7.870 | **7.448** |
| **F1** | 8.240 | 8.520 | 9.210 | **8.657** |
| **F2** | 8.627 | 8.803 | 9.593 | **9.008** |
| **F3** | 8.843 | 10.833 | 9.210 | **9.629** |
| **Mean G** | **8.218** | **8.867** | **8.971** | |
| **L.S.D $_{0.05}$** | F = 0.209 | G= 181 | F×G = 363 | |

### Total number of leaves (leaf plant$^{-1}$)

The results demonstrated that the treatment with organic fertilizer at a level of 15 mL L$^{-1}$ (F3) resulted in a significant rise in the total number of leaves in the plant, attaining 60.950 leaf plant$^{1}$ in relation to the treatment (F0), which registered 47.111 leaf plant$^{1}$, showing a clear practical effect of organic fertilizer in stimulating vegetative growth. The treatment with powder of licorice root at a concentration of 3 g (G1) also excelled in this trait, attaining 58.992 leaf plant$^{1}$, demonstrating a positive role for plant extracts in encouraging formation of leaves. The results of the interrelation between two factors demonstrated significant differences, with the F3G1 combined treatment documenting the highest value of 72.827 leaf plant$^{1}$, while the minimal values were in the treatment F0G0,

**Table 5.** Influence of organic fertilizer, powder of licorice root and their relationship on the total number of leaves (leaf plant$^{1}$) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 45.270 | 49.883 | 46.180 | **47.111** |
| **F1** | 51.003 | 55.620 | 53.203 | **53.276** |
| **F2** | 52.587 | 57.637 | 54.173 | **54.799** |
| **F3** | 54.950 | 72.827 | 55.073 | **60.950** |
| **Mean G** | **50.953** | **58.992** | **52.158** | |
| **L.S.D $_{0.05}$** | F = 1.235 | G= 1.069 | F×G = 2.138 | |

demonstrating that combining organic fertilizer and powder of licorice root promotes vegetative development more than using individual factor (Table 5).

### Total leaf area (cm$^{2}$ plant$^{-1}$)

The results in Table 6 shown that the F2 treatment of organic fertilizer led to a significant rise in the mean of the total leaf area of plants, noting 510.358 (cm$^{2}$ plant$^{1}$compared to the F0 treatment of 474.756 cm$^{2}$ plant$^{1}$, demonstrating a positive role for organic fertilizer in enhancing vegetative growth. The use of licorice root powder also revealed superiority at level G1, which recorded the maximum average of 513.013 cm$^{2}$ plant$^{1}$, indicating a practical effect in improving growth of leaf efficiency. The correlation between the two factors had a clear statistical effect, as the F3G1 combination treatment achieved the maximum value (544.940 cm$^{2}$

**Table 6.** Influence of organic fertilizer, powder of licorice root and their relationship on the total leaf area (cm$^{2}$plant$^{-1}$) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 466.453 | 481.180 | 476.633 | **474.756** |
| **F1** | 471.277 | 492.990 | 518.200 | **494.156** |
| **F2** | 479.187 | 532.943 | 512.943 | **510.358** |
| **F3** | 489.183 | 544.940 | 483.950 | **506.024** |
| **Mean G** | **476.525** | **513.013** | **497.932** | |
| **L.S.D $_{0.05}$** | F = 16.949 | G= 14.679 | F×G = 29.356 | |

plant$^{1}$), significantly exceeding the F0G0 control treatment, demonstrating that combining two study factors promotes the total leaf area more successfully than using each agent alone.

### Flower diameter (cm)

Table 7 results revealed that the treatment with organic fertilizer at a level of 15 mL L$^{-1}$ (F3) caused a significant increase in the mean diameter of the flower, as it clearly exceeded the treatment F0, which recorded the least value (5.792 cm), thus illustrating the effective role of organic fertilizer in flower traits. The treatment with licorice root powder also revealed a significant advantage over the other values, reaching 5.643 cm compared to the G0 treatment which noted 4.768 cm, indicating beneficial effect of the plant extract in promoting growth of flowers. The correlation between the two study factors verified these effects, as the F3G1 combination treatment

**Table 7.** Influence of organic fertilizer, powder of licorice root and their relationship on the flower diameter (cm) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 4.483 | 4.780 | 4.633 | **4.632** |
| **F1** | 4.633 | 5.263 | 4.947 | **4.948** |
| **F2** | 4.817 | 5.710 | 5.263 | **5.263** |
| **F3** | 5.137 | 6.820 | 5.420 | **5.792** |
| **Mean G** | **4.768** | **5.643** | **5.066** | |
| **L.S.D $_{0.05}$** | F = 0.125 | G= 0.108 | F×G = 0.217 | |

documented the highest value flower diameter of 6.820 cm, while the least value was in the F0G0 treatment, indicating that the combination of two study factors enhances the flowering trait more than the effect of individual factor.

### Number of flowers (flower plant$^{-1}$)

The results revealed that the organic fertilizer treatment with a level of 15 mL L$^{-1}$(F3) caused a significant increase in the mean of flowers number of plants, noting 27.924 flower plant$^{1}$compared to the treatment (F0), which reached 21.620 flower plant$^{1}$, thus illustrating the effective role of organic fertilizer in strengthening the flowering ability of the plant. The powder of licorice root also showed a clear beneficial effect, with the G1 treatment recording the top mean of 26.511 flower plant$^{1}$, outperforming the G0 treatment which documented 22.053 flower plant$^{1}$, indicating its role in encouraging

**Table 8.** Influence of organic fertilizer, powder of licorice root and their relationship on the number of flowers (flower plant$^{1}$) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 19.677 | 23.683 | 21.500 | **21.620** |
| **F1** | 22.150 | 24.367 | 24.167 | **23.561** |
| **F2** | 22.373 | 25.953 | 24.530 | **24.286** |
| **F3** | 24.010 | 32.040 | 27.723 | **27.924** |
| **Mean G** | **22.053** | **26.511** | **24.480** | |
| **L.S.D $_{0.05}$** | F = 0.763 | G= 0.661 | F×G = 1.322 | |

flowering. The interaction between the two study factors authenticated this superiority, as the F3G1 combined treatment attained the highest number of flowers at 32.040 plant$^{1}$, while the control treatment F0G0 recorded the bottom number at 19.677 plant$^{1}$, demonstrating that the combination of organic fertilizer and powder of licorice root promotes flowering to a superior degree than the effect of factor independently (Table 8).

### Petal anthocyanin content (mg 100 g$^{-1}$ fresh weight)

The results displayed that all organic fertilizer treatments caused an increase in the anthocyanin content of Chinese carnation petals compared to the non-addition treatment, despite the fact that the differences between them were not statistically meaningful, which demonstrates a general effect of organic fertilizers in encouraging the accumulation of floral pigments. Treatment F3 noted the highest value at (31.032 mg 100 g$^{1}$ fresh weight) soluble weight, compared to the lowest value in treatment F0 (24.996 mg 100 g$^{1}$ fresh weight), reflecting a clear practical improvement of using organic fertilizers. on the other hand, the powder of licorice root did not show a

**Table 9.** Influence of organic fertilizer, powder of licorice root and their relationship on Petal anthocyanin content (mg 100 g$^{1}$ F.W) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| **F0** | 21.330 | 23.997 | 29.660 | **24.996** |
| **F1** | 31.217 | 34.993 | 24.330 | **30.180** |
| **F2** | 26.107 | 29.327 | 37.663 | **31.032** |
| **F3** | 32.107 | 29.440 | 32.440 | **31.329** |
| **Mean G** | **27.690** | **29.439** | **31.023** | |
| **L.S.D $_{0.05}$** | F = 3.357 | G= N.S | F×G = 5.814 | |

significant effect on this traits, signaling its limited role in stimulating anthocyanin production. The two-way reaction parameters highlighted important results, with treatment F2G2 documenting the highest value of (37.663 mg 100 g$^{1}$ fresh weight), while the least values were in treatment F0G0, signaling that combining organic fertilizer and an appropriate level of the powder of licorice root can improve the pigmentation to increased level than using each separately (Table 9).

### Leaf nitrogen concentration (%)

Table 10 results revealed that organic fertilizer with a level of 15 mL $L^{-1}$ (F3) had a significant and clear effect in elevating the nitrogen concentration in leaves of plants, reaching 1.788 % compared to the treatment F0, which recorded the least value at 0.933 %. This indicates the importance of organic fertilizer in boosting nutrient absorption and enhancing plant nutritional status. The powder of licorice root also showed a significant effect in rising nitrogen content, with treatments G2 and G1 documenting the highest values (1.525 and 1.506 %), respectively, relative to treatment G0, indicating its role in boosting plant metabolism. As for the results of the interaction between organic fertilizer and licorice root, they showed that the F3G1 combination treatment was the most efficient, recording the maximum nitrogen concentration of 2.103 %, while the least values were at F0G0 treatment, denoting that the combination of two study factors improves plant feeding more than the effect of single factor.

**Table 10.** Influence of organic fertilizer, powder of licorice root and their relationship on the leaf nitrogen concentration (%) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| F0 | 0.843 | 0.947 | 1.010 | **0.933** |
| F1 | 1.183 | 1.373 | 1.737 | **1.431** |
| F2 | 1.450 | 1.600 | 1.493 | **1.514** |
| F3 | 1.400 | 2.103 | 1.860 | **1.788** |
| Mean G | **1.219** | **1.506** | **1.525** | |
| L.S.D $_{0.05}$ | F = 0.047 | G= 0.041 | F×G = 0.082 | |

### Carbohydrate percentage in branches (%)

Table 11 results demonstrated that the treatment with organic fertilizer at a level of 15 mL $L^{-1}$ (F3) brought about a significant increase in the percentage of carbohydrates in leaves of plants, as it documented 11.608 % compared to the bottom percentage of 9.521 % in the F0 treatment, which demonstrates the role of organic fertilizer in stimulating vital processes and rising the accumulation of carbohydrate compounds in the leaves of plants. The powder of licorice root also showed a significant effect, with treatment G1 documenting the maximum carbohydrate content of 11.237 %, demonstrating the role of this plant extract in enhancing photosynthetic efficiency and carbohydrate storage. With respect to the interaction between organic fertilizer and licorice root, the results demonstrated a clear statistical significance, as the F3G1 compound treatment documented the highest carbohydrate percentage, achieving 13.907 %, while the F0G0 treatment registered the lowest values, signaling that combining organic fertilizer with an appropriate level of root powder attains a greater cumulative effect in stimulating carbohydrate accumulation within the plant.

**Table 11.** Influence of organic fertilizer, powder of licorice root and their relationship on carbohydrate percentage in branches (%) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| F0 | 9.330 | 9.853 | 9.380 | **9.521** |
| F1 | 10.003 | 10.453 | 10.653 | **10.370** |
| F2 | 10.350 | 10.733 | 10.353 | **10.479** |
| F3 | 10.203 | 13.907 | 10.713 | **11.608** |
| Mean G | **9.972** | **11.237** | **10.275** | |
| L.S.D $_{0.05}$ | F = 0.522 | G= 0.452 | F×G = 0.904 | |

### Leaf chlorophyll content (mg 100 $g^{-1}$ fresh weight)

Table 12 results demonstrated that the treatment with organic fertilizer at a level of 15 mL $L^{-1}$ (F3) led to a significant rise in the chlorophyll content of plant leaves, documenting 31.586 mg 100 $g^{1}$ fresh weight, compared to the bottom value of 25.642 mg 100 $g^{1}$ fresh weight in the treatment F0. This mirrors the vital role of organic fertilizer in stimulating photosynthesis and improving vegetative effectiveness. The powder of licorice root also revealed a similarly significant effect, with treatments G1 and G2 recording high values (29.884 and 29.674 mg 100 $g^{1}$ fresh weight), respectively, indicating its role in facilitating green pigment formation. The interaction between the two factors showed a clear cumulative effect, as the F3G1 compound treatment recorded the highest chlorophyll content of 34.210 mg 100 $g^{1}$ fresh weight, while the F0G0 treatment recorded the lowest value, indicating that the combination of organic fertilizer and root powder enhances the photosynthesis process to a greater degree than the effect of each individual treatment, which is reflected positively on the plant's vitality and physiological activity.

**Table 12.** Influence of organic fertilizer, powder of licorice root and their relationship on leaf chlorophyll content (mg 100 $g^{-1}$ F.W.) of Chinese carnation

| Organic fertilizer (F) | Licorice root powder (G) | | | |
|---|---|---|---|---|
| | G0 | G1 | G2 | Mean F |
| F0 | 23.607 | 25.640 | 27.680 | **25.642** |
| F1 | 26.913 | 28.740 | 29.647 | **28.433** |
| F2 | 28.950 | 30.947 | 30.507 | **30.134** |
| F3 | 29.683 | 34.210 | 30.863 | **31.586** |
| Mean G | **27.288** | **29.884** | **29.674** | |
| L.S.D $_{0.05}$ | F = 0.395 | G= 0.342 | F×G = 0.685 | |

## Discussion

The results of the study showed that adding manufactured organic fertilizers to Chinese carnation plants led to a significant improvement in all studied vegetative, floral and chemical characteristics, including plant height, number of branches, number of leaves and leaf area. This is attributed to the fact that the humic substances in organic fertilizers increase the permeability of leaf cell membranes, which facilitates the absorption and transport of nutrients within the plant and increases the movement of energy and materials necessary for biosynthesis processes, which is reflected positively on the growth of the vegetative mass of plants (24). Studies have also demonstrated that these substances improve the effectiveness of many essential enzymes, including catalytic enzymes and respiratory enzymes like phosphatases, transaminases, invertases and $H^+$-ATPase, hence promoting the level of protein metabolism and DNA generation and contributing to the enhancement of the vegetative traits of plants (25-27). As for the floral traits, organic fertilizers have caused an increase in the number and diameter of flowers, as humic substances are considered to act in the same way to plant hormones, like cytokinins, gibberellins and auxins, encouraging the growth of floral tissues and rising flowering effectiveness and yield (28, 29). Moreover, the use of these materials increases the level of indoleacetic acid (IAA), which plays an significant role in promoting flower growth and stimulating the aggregation of anthocyanin and chlorophyll pigments, thus improving the plant's physiological activity (30). Fulvic acid, found in organic fertilizers, also contributes to an increase in carbohydrates, which are a direct source of energy and essential elements for plant growth (31, 32). Regarding the effect of licorice root powder, a tangible improvement in vegetative, floral and chemical characteristics was observed, including the number of branches, number of leaves, leaf area, diameter and number of flowers, nitrogen content, carbohydrates and the amount of chlorophyll in the leaves. This is attributed to the content of the root's aqueous extract of amino acids, sugars, vitamins, nutrients and gibberellins, which promote the production of secondary compounds and activate enzyme systems within the plant, including oxidation-reduction systems, thereby increasing the cells' ability to divide and elongate and stimulating the accumulation of carbohydrates and proteins (33-35). Amino acids also play a vital role as biological stimulants that reduce the impact of environmental stresses, especially during the hot months and are precursors to the synthesis of plant hormones such as tryptophan, which is a major precursor to auxin, thus inhibiting enzymes such as cellulase and pectinase, improving nutrient absorption and activating many enzymes within the plant, this encourages cell division, limits the harmful effects of free radicals resulting from metabolic processes, prevents the oxidation of proteins and fats and reduces damage to plant tissues (36-38). Accordingly, it is clearly shown that combining organic fertilizer and licorice root powder achieves a cumulative and enhancing effect on the vegetative, floral and chemical characteristics of Chinese carnation plants, promoting growth, increasing metabolic efficiency and stimulating flowering and confirming the importance of the interaction between the two factors in improving overall productivity and plant health.

## Conclusion

The present research demonstrates that organic fertilizer and powder of licorice root application significantly improve Chinese carnation vegetative, floral and biochemical traits. The best performance was observed in the carnation fertilized with 15 mL $L^{-1}$ organic fertilizer and 3 g powder of licorice root per plant due to the advancement of plant growth, flower yield and biochemical content. Overall, the study observations highlight that combining organic fertilizers with natural plant extracts -based biostimulants is an efficient approach to enhancing plant efficiency. This combined strategy decreases reliance on chemical inputs and, facilitate to the sustainable production of ornamental crops.

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## Authors' contributions

MSA and MHI played a key role in formulating the core research idea and compiling a comprehensive literature review to arrive at the final research conclusion, as well as statistically analyzing the data obtained from this study. AKA and AFZA conducted the experiment, collected the experimental data, and interpreted the results. All Authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors have stated that there are no conflicts of interest.

**Ethical issues:** None

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