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Article

Response of Carnation (*Dianthus caryophyllus*) to NPK Compound Fertilizer and Cormo Seaweed Extract: Effects on Vegetative and Flowering Growth, Volatile Oil Quality, and Active Compounds Analyzed by GC-MS

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Abstract: The experiment was conducted in the wooden shade house of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Basrah. Carnation plants with eight-month-old were used in the study. The experiment included two factors, the first factor was the application of NPK compound fertilizer at three concentrations: 0, 1.5, and 3.0 g pot-1. The second factor was the foliar application of Cormo seaweed extract at three concentrations: 0, 3, and 5 mL L-1. All measurements of the studied characteristics were taken when the plants reached the flowering stage. The results showed that there were a significant effect of the NPK fertilizer on the vegetative and floral growth characteristics of the carnation plants. The highest concentration of 3.0 g pot-1 gave the greatest values for plant height, stem diameter, leaf area, total number of flowers per plant, flowering period length, and specific weight of volatile oil (53.05 cm, 0.53 cm, 10.66 cm^2, 34.71 flowers, 7.05 cm, 80.64 days, 0.7478 g mL-1, respectively). Likewise, the seaweed extract at 5 mL L-1 had a significant positive impact on the same characteristics. The interaction between the NPK fertilizer at 3.0 g pot-1 and the seaweed extract at 5 mL L-1 further improved the vegetative and floral characteristics, with the highest recorded values for plant height (61.34 cm), stem diameter (0.56 cm), leaf area (12.26 cm^2), total number of flowers per plant (40.68 flowers), flowering period length (7.22 cm), and specific weight of volatile oil (0.7550 g mL-1). The results of GC-MS analysis showed many active compounds in the flowers which alkaloids, saponins, tannins, glycosides, resins, coumarins, cinnamic acid, lignan, and gallic acid. These compounds differed in concentration and abundance depending on the treatment applied. Also, the study highlighted that carnation flowers contain biologically active compounds, which differ based on the treatment conditions.

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1. Introduction

The carnation (*Dianthus caryophyllus* L.) is one of the world's most important picking flowers. This plant originally from the Mediterranean region, carnations began to spread across Europe in the sixteenth century and reached America by the mid-nineteenth century (Singh et al., 2005). Carnation plant is belonging to the Caryophyllaceae family, that includes plants that typically grow in the temperate zones of the northern hemisphere. This family contains 2,100 species and 89 genera, with the genus Dianthus containing nearly 300 species found in Europe, Asia, and North Africa. Carnations were introduced to the Australian continent in 1954 (Anon, 2002).

Carnations are among the most commercially valuable ornamental plants worldwide (Burich et al., 1996). In Victoria, the largest flower production center in the United States, the city produced about 140 million flowers suitable for picking from an estimated 100 hectares of cultivated land (Anon, 2002). The volatile oil extracted from carnations is used for medicinal purposes, including heart strengthening and as a strong diaphoretic. Additionally, it has industrial applications in the production of perfumes, sweets, and baby food (Abu Zaid, 2000; Al-Mayah, 2001). Global production of carnation flower oil was estimated at 2,000 tons in 1987. The decoction of the flower tops is known to relieve pain, particularly toothaches, and serves as a mouth freshener, gas expeller, memory enhancer, anti-emetic, and anti-colic agent, as well as an appetite stimulant (Abu Zaid, 2000). Also, carnations have medicinal importance in treating fever and expelling toxins. They are used to dye hair and as a flavoring agent in certain beverages (Perry, 1998).

Nitrogen plays a vital role in plant nutrition, not only because it is an essential element required in large quantities, but also because it is not readily available from natural sources such as rocks, unlike other essential elements like potassium, calcium, and phosphorus. Nitrogen impacts the activity of certain enzymes and is a key component of chlorophyll and many vital compounds, including nucleic acids and enzyme cofactors, which in turn impact overall plant growth. Another vital nutrient, involved in the formation of important organic compounds such as nucleic acids, amino acids, phospholipids, and enzyme cofactors is Phosphorus, all of them are critical for various biological processes. Potassium, the only ion required by all higher plants, does not integrate into organic compounds except in the formation of organic salts with organic acids. It plays an important role in activating protein synthesis enzymes and many other enzymes. Also, It is believed that potassium has a weak ability to bind to enzymes, requiring high concentrations in the plant to form potassium-protein complexes that enable enzymes to function properly. Additionally, potassium is essential for maintaining and regulating cell osmotic pressure and increasing the rate of photosynthesis (Al-Sahaf, 1989). Seaweed extracts are increasingly used as organic sources in plant production due to their effectiveness in promoting plant growth even at low concentrations. These extracts contain a range of micro- and macronutrients, amino acids, organic acids, and growth-promoting substances such as auxins, cytokinins, gibberellins, vitamins, and polysaccharides (Spinelli et al., 2009).

2. Materials and Methods

The experiment was conducted in the wooden shade house of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Basrah. Eight-month-old carnation plants were brought from a private nursery and initially planted in 15 cm diameter pots, later transplanted into 25 cm diameter pots, that had been washed and sterilized with a 4% formaldehyde solution. The pots were filled with a sterilized growing medium, treated with the same solution, consisting of a mixture of river sand and peat moss in a 1:2 ratio. The study included two factors, the first factor was the ground application of NPK compound fertilizer at three concentrations of 0, 1.5, and 3.0 g pot-1. The second factor was the foliar application of Cormo seaweed extract at concentrations of 0, 3, and 5 mL L-1. All trait measurements were taken when the plants reached the flowering stage, each experimental unit including three pots. The study evaluated the following traits:

1. Plant height (cm):
   The height of the plants in each experimental unit was measured from the soil surface in the pot to the base of the flower on the main stem using a measuring tape. The average height was recorded.

2. Stem diameter (cm):
   The diameter of the main stem was measured 10 cm above the soil surface in the pot using calipers, and the average diameter was recorded.

3. Leaf area (cm^2):
   Leaf area was measured according to the method described by Al-Najjar et al. (2021) using the following equation:

$$Leaf\ area\ (cm^2) = \frac{Average\ leaf\ weight\ (g)\ \times\ area\ of\ the\ cut\ square\ (0.25\ cm^2)}{Average\ weight\ of\ the\ cut\ square\ sample\ (g)}$$

4. Total number of flowers per plant:
   The total number of flowers produced by each plant in the experimental unit was counted, and the average number of flowers was recorded.

5. Flower diameter (cm):
   The diameter of five flowers, randomly selected from each replicate in the experimental unit, was measured when they were fully opened. The measurement was taken between the two farthest points across the diameter, using calipers, and the average diameter was recorded.

6. Length of flowering period (days):
   The length of the flowering period was measured in days, from the full opening of the first flower bud on the plant to the last flower formed. The average length of the flowering period was then calculated.

7. Specific weight of the volatile oil:
   The specific weight of the volatile oil was measured by taking 100 microliter of volatile oil using a volumetric pipette. Then the volume weighing with a sensitive balance at room temperature. Also, a 100 microliter volume of distilled water was weighed under the same conditions. Then with following equation, the specific weight of the oil was calculated:

$$Specific\ weight\ of\ the\ oil = \frac{Weight\ of\ 100\ microliters\ of\ volatile\ oil}{Weigh\ of\ 100\ microliters\ of\ distilled\ water.}$$

GC-MS Analysis

Healthy flowers were collected from all treatments, washed with tap water followed by distilled water, air-dried, and then ground using an electric grinder to obtain a fine plant powder. A 50 g sample of the dry plant powder was mixed with 500 mL of 70% ethyl alcohol in a 1000 mL glass flask, which was then sealed with cotton and aluminum foil, and placed in a shaking incubator and left for 24 hours at room temperature. The mixture was subsequently filtered through several layers of medical gauze to remove suspended particles, and then centrifuged at 3000 rpm for 10 minutes. The resulting extract was further filtered using Whitman No. 1 filter paper to obtain a clear solution, which was then used for Gas Chromatography-Mass Spectrometry (GC-MS) analysis. The active ingredients in the flowers were identified using a gas chromatography device coupled with mass spectrometry. The components were identified by comparing the resulting spectra with known compounds stored database in the National Institute of Standards and Technology (NIST).

Statistical analysis

The GenStat software was used to analysis the data. The experiment was organized in a Randomized Complete Block Design (RCBD) with a factorial arrangement of two factors: compound fertilizer with three concentrations and seaweed extract with three concentrations. Each treatment was replicated ten times, resulting in a total of 90 experimental units. Least Significant Difference (LSD) test at a significant level of 0.05 was used to determine the differences between means (Tabiah, 2008).

3. Results and Discussions

Plant height

The results presented in Table 1 demonstrate the effects of NPK compound fertilizer and seaweed extract on carnation plant height. The compound fertilizer significantly influenced plant height, with the highest value of 53.05 cm recorded at a concentration of 3.0 g pot^{-1}, which was significantly different from the other concentrations. In contrast, the control treatment recorded the lowest height at 36.22 cm. Seaweed extract also significantly affected plant height. The concentration of 5 mL L^{-1} was notably superior to other concentrations, achieving the highest plant height of 49.48 cm, whereas the control treatment had the lowest height of 38.65 cm. Regarding the interaction effects, the combination of compound fertilizer at 3.0 g pot^{-1} and seaweed extract at 5 mL L^{-1} resulted in the tallest plants, measuring 61.34 cm, with a significant difference from other interactions.

Conversely, the control interaction treatment recorded the lowest height of 31.03 cm. Additionally, interactions involving compound fertilizer at 1.5 g pot^{-1} and seaweed extract concentrations of 3 and 5 mL L^{-1} improved plant height to 47.80 cm and 46.08 cm, respectively. This enhancement in plant height may be attributed to increased internode length, consistent with findings by Al-Abbasi (2000) on Dahlia plants and Tawajin and Al-Jalabi (2001) on Geranium plants. On the other hand, the compound fertilizer may have promoted growth by influencing auxin formation, which plays a crucial role in cell division and elongation. Additionally, higher nitrogen levels can increase gibberellin activity, and nitrogen contributes to enzyme formation and the biosynthesis of chlorophyll and plant hormones such as gibberellins (Al-Rayes, 1982). The increase in plant height might also be due to the seaweed extract's role in stimulating growth processes and activating enzymes that support cell growth and nutrient transfer. The presence of auxins, gibberellins, and cytokinins in the seaweed extract likely contributed to enhanced cell division and expansion, leading to improved vegetative growth (Saqr, 2010).

Table 1. Effect of NPK compound fertilizer and seaweed extract on carnation plant height (cm).

Compound fertilizer g pot^{-1}	seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	31.03	36.6	41.03	36.22
1.5	41.02	47.8	46.08	44.97
3	43.9	53.9	61.34	53.05
Rate of seaweed extract effect	38.65	46.10	49.48	Interaction = 3.22
L.S.D	Compound fertilizer = 2.36		Seaweed extract = 2.36	

Stem Diameter

The results of the study, presented in Table 2, illustrate the effects of NPK compound fertilizer and seaweed extract on the stem diameter of the carnation plant. The compound fertilizer had a significant impact on stem diameter, with the highest value of 0.53 cm observed at a concentration of 3.0 g pot^{-1}, which was significantly different from other concentrations. In contrast, the control treatment recorded the lowest diameter of 0.46 cm. In the same way, the seaweed extract significantly affected stem diameter. The concentration of 5 mL L^{-1} yielded the highest stem diameter of 0.54 cm, significantly outperforming other concentrations.

The control treatment had the lowest diameter at 0.48 cm. Regarding interaction effects, the combination of compound fertilizer at 3.0 g pot^{-1} and seaweed extract at 5 mL L^{-1} resulted in the highest average stem diameter of 0.56 cm, significantly different from other interactions. Conversely, the control interaction recorded the lowest average of 0.43 cm. Additionally, the interaction between compound fertilizer at 1.5 g pot^{-1} and seaweed extract at 3 and 5 mL L^{-1} improved stem diameter to 0.50 cm and 0.56 cm, respectively. These results may be attributed to the effect of increased nitrogen levels, which enhance cell membrane permeability and reduce water loss from plant tissues. This increase in membrane permeability facilitates greater water flow into cells, thereby increasing cell width and stem diameter (Cleland, 1986).

Table 2. Effect of NPK compound fertilizer and seaweed extract on carnation plant stem diameter (cm).

Compound fertilizer g pot^{-1}	seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	0.43	0.46	0.5	0.46
1.5	0.5	0.5	0.56	0.52
3	0.5	0.53	0.56	0.53
Rate of seaweed extract effect	0.48	0.5	0.5	Interaction = 0.098
L.S.D	Compound fertilizer = 0.77		Seaweed extract = 0.77	

Leaf Area

The results of the study, presented in Table 3, demonstrate the effects of NPK compound fertilizer and seaweed extract on carnation leaf area. Compound fertilizer significantly affected leaf area, with the highest value of 10.66 cm^2 recorded at a concentration of 3.0 g pot^{-1}, showing a significant difference from other concentrations. The control treatment had the lowest value of 7.38 cm^2. Also, eaweed extract significantly influenced leaf area. The 5 mL L^{-1} concentration achieved the highest leaf area of 10.10 cm^2, significantly surpassing other concentrations.

The control treatment recorded the lowest rate of 7.61 cm^2. Regarding interaction effects, the combination of compound fertilizer at 3.0 g pot^{-1} and seaweed extract at 5 mL L^{-1} resulted in the largest average leaf area of 12.26 cm^2, significantly different from other interactions. In contrast, the control interaction had the lowest average of 6.35 cm^2. Additionally, the interaction between compound fertilizer at 1.5 g pot^{-1} and seaweed extract at concentrations of 3 and 5 mL L^{-1} improved leaf area to 10.11 cm^2 and 9.48 cm^2, respectively. The increase in leaf area may be attributed to the compound fertilizer's role in promoting growth through its impact on auxin formation, which is crucial for cell division and elongation. Additionally, higher nitrogen levels enhance the formation and activity of gibberellins and contribute to the synthesis of chlorophyll and plant hormones such as auxins and gibberellins (Hassan, 2002; Al-Mukhtar, 2003).

Table 3. Effect of NPK compound fertilizer and seaweed extract on carnation leaf area (cm).

Compound fertilizer g pot^{-1}	seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	6.35	7.23	8.56	7.38
1.5	8.11	10.11	9.48	9.23
3	8.37	11.34	12.26	10.66
Rate of seaweed extract effect	7.61	9.56	10.1	Interaction = 1.11
L.S.D	Compound fertilizer = 0.88		Seaweed extract = 0.88	

Total number of flowers

The results of the study, presented in Table 4, illustrate the effects of NPK compound fertilizer and seaweed extract on the total number of flowers in carnation plants. Compound fertilizer significantly influenced the total flower amount, with the highest number of 34.71 flowers recorded at a concentration of 3.0 g pot-1, significantly differing from other concentrations. The control treatment had the lowest flower count of 24.60 flowers. Also, seaweed extract had a notable effect on the total number of flowers. The concentration of 5 mL L-1 achieved the highest count of 35.08 flowers, significantly surpassing other concentrations.

The control treatment recorded the lowest count of 23.41 flowers. Regarding interaction effects, the combination of compound fertilizer at 3.0 g pot-1 and seaweed extract at 5 mL L-1 resulted in the highest flower count of 40.68 flowers, showing a significant difference from other interactions. In contrast, the control interaction had the lowest flower count of 19.23 flowers. Additionally, the interaction between compound fertilizer at 1.5 g pot-1 and seaweed extract at 3 and 5 mL L-1 improved flower count to 27.45 and 35.33 flowers, respectively. These results may be attributed to the impact of fertilizer treatment on vegetative characteristics, such as leaf area and carbohydrate and chlorophyll content, which positively influenced flower production (Al-Jalabi, 2001). Also, the increase in flower number may be due to the seaweed extract's role in stimulating growth processes, activating enzymes that promote cell growth and elongation, and enhancing nutrient transfer. Growth regulators that presence in the seaweed extract such as auxins, gibberellins, and cytokinins likely contributed to increased cell division and expansion, improving floral growth indicators.

Table 4. Effect of NPK compound fertilizer and seaweed extract on total number of flowers.

Compound fertilizer g pot^{-1}	seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	19.23	25.32	29.24	24.6
1.5	24.76	27.45	35.33	29.18
3	26.23	37.22	40.68	34.71

Rate of seaweed extract effect	23.41	30	35.08	Interaction = 2.35
L.S.D	Compound fertilizer = 2.11		Seaweed extract = 2.11	

Flower diameter

The results that presented in Table 5 exhibit the effects of NPK compound fertilizer and seaweed extract on the flower diameter of carnation plants. The NPK fertilizer had a significant impact on flower diameter, with the highest value of 7.05 cm recorded at a concentration of 3.0 g pot-1, showing a significant difference from other concentrations. The control treatment recorded the lowest value of 6.60 cm. Likewise , seaweed extract significantly influenced flower diameter. The concentration of 5 mL L-1 resulted in the highest flower diameter of 7.05 cm, significantly outperforming other concentrations.

The control treatment showed the lowest diameter of 6.74 cm. Regarding the interaction effects, the combination of NPK fertilizer at 3.0 g pot-1 and seaweed extract at 5 mL L-1 yielded the largest flower diameter of 7.22 cm, with a significant difference from other interactions. Conversely, the control interaction recorded the smallest diameter of 6.34 cm. Additionally, the interaction between NPK fertilizer at 1.5 g L-1 and seaweed extract at concentrations of 3 and 5 mL L-1 also enhanced flower diameter, with values of 7.21 and 7.11 cm, respectively. This increase in flower diameter may be attributed to the plants receiving a sufficient amount of nutrients essential for vegetative growth, which positively influenced floral characteristics, including flower diameter.

Table 5. Effect of NPK compound fertilizer and seaweed extract on total number of flowers.

Compound fertilizer g pot^{-1}	Seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	6.34	6.64	6.82	6.6
1.5	7.12	7.21	7.11	7.15
3	6.77	7.15	7.22	7.05
Rate of seaweed extract effect	6.74	7	7.05	Interaction = 1.11
L.S.D	Compound fertilizer = 0.78		Seaweed extract = 0.78	

Length of flowering period

The effects of NPK compound fertilizer and seaweed extract on the flowering period of carnation plants are presented in Table 6. The NPK fertilizer significantly influenced the flowering period, with the longest duration of 80.64 days recorded at a concentration of 3.0 g pot-1, showing a significant difference from other concentrations. In contrast, the control treatment recorded the shortest duration of 54.26 days. Likewise, seaweed extract had a significant effect on the flowering period. The concentration of 5 mL L-1 resulted in the longest flowering period of 74.63 days, significantly outperforming other concentrations.

The control treatment showed the shortest period of 62.91 days. Regarding the interaction effects, the combination of NPK fertilizer at 3.0 g pot-1 and seaweed extract at 5 mL L-1 resulted in the longest flowering period of 86.00 days, with a significant difference from other interactions. Conversely, the control interaction recorded the shortest duration of 47.88 days. Additionally, the interaction between NPK fertilizer at 1.5 g L-1 and seaweed extract at concentrations of 3 and 5 mL L-1 also enhanced the flowering period, with durations of 62.01 and 73.45 days, respectively. The explanation of prolonged flowering period may be that the fertilizer treatments increasing potassium absorption, which plays a crucial role in promoting photosynthesis. That leads to increase production of carbohydrate and protein and accelerates their transport to consumption sites, thereby accelerating the appearance of flower buds.

Table 6. Effect of NPK compound fertilizer and seaweed extract on Length of flowering period (day).

Compound fertilizer g pot^{-1}	Seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	47.88	50.44	64.45	54.26
1.5	66.8	62.01	73.45	67.42
3	74.04	81.88	86	80.64
Rate of seaweed extract effect	62.91	64.78	74.63	Interaction = 3.12
L.S.D	Compound fertilizer = 2.22		Seaweed extract = 2.22	

Specific weight of the oil

The results presented in Table 7 show the effects of NPK compound fertilizer and seaweed extract on specific weight of the volatile oil in carnation plant. The NPK fertilizer showed important effect, with the highest specific weight value recorded at 0.7478 for 3.0 g pot^{-1} concentration, which was significantly different from the other concentrations. In contrast, the lowest value of specific weight was 0.6757 recorded in the control treatment. Likewise, seaweed extract significantly affected the specific weight of the carnation's volatile oil.

The concentration of 5 mL L^{-1} outperformed the other concentrations, yielding the highest specific weight of 0.7447, while the control treatment had the lowest value of 0.7098. Regarding the interaction effects, the combination of NPK fertilizer at 3.0 g L^{-1} and seaweed extract at 5 mL L^{-1} resulted in the highest specific weight of the volatile oil, reaching 0.7550, with a significant difference from other interactions. The control interaction recorded the lowest value of 0.6600. Additionally, the combination of NPK fertilizer at 1.5 g L^{-1} and seaweed extract at concentrations of 3 and 5 mL L^{-1} also improved the specific weight of the volatile oil, with values of 0.6913 and 0.7510, respectively. This increase in specific weight may be attributed to the retention of slow-evaporating oil components and oxygenated compounds, which contribute to a higher specific weight. It could also be due to an increase in the unsaturation of volatile oil bonds or a higher proportion of high molecular weight fatty acids.

Table 7. Effect of NPK compound fertilizer and seaweed extract on Specific weight of the oil of carnations flowers.

Compound fertilizer g pot^{-1}	Seaweed extract mL L^{-1}			Rate of compound fertilizer effect
	0	3	5	
0	0.6600	0.639	0.7280	0.6757
1.5	0.6999	0.6913	0.7510	0.7141
3	0.7694	0.719	0.7550	0.7478

Rate of seaweed extract effect	0.7098	0.6831	0.7447	Interaction = 0.067
L.S.D	Compound fertilizer = 0.033		Seaweed extract = 0.033	

GC-MS Analysis

The results of the GC-MS analysis of carnation flowers, as presented in Table 8 and Figure 1, reveal the chemical components present in the flowers of the ornamental plant Dianthus caryophyllus (carnation). The analysis included the interaction treatment between NPK compound fertilizer at a concentration of 3.0 g pot-1 and seaweed extract at a concentration of 5 mL L-1, as this combination gave the best vegetative and floral effects, with time, area, and concentration of each compound in the sample. The results showed there are several active compounds, the most significant and abundant which alkaloids, saponins, tannins, glycosides, resins, coumarins, cinnamic acid, lignan, and gallic acid.

These compounds were differed in their concentration and abundant depending on treatment applied. Also, the data in this study was shown that carnation plants contain biologically active compounds that differ according the treatment. that suggested their potential as a valuable medicinal resource. These findings imply that carnation flowers could be a significant source of compounds beneficial for health maintenance. The presence of these compounds also suggests potential applications in cosmetics, as well as antibacterial and antiviral properties. The detection of various coumarins and alkaloids, which are important sources of flavonoids and coumarins, further indicates the potential of these flowers in treating skin diseases. The presence of coumarin compounds similar to those found in medicinal drugs used for skin treatments supports the traditional use of carnation flowers in folk medicine for skin disease treatment. These results open new avenues for the pharmacological exploitation of carnation plants, highlighting their chemical and preventive importance.

Table 8. Chemical components identified by GC-MS in carnation flowers.

Compound Name	Reten.tim (min)	Area (mV.s)	Height (mV)	Area (%)	Height (%)	Height (%)
Alkaloids	**12.866**	**249.199**	**200.111**	**0.2**	**0.4**	**0.4**
Saponins	**16.888**	**193.389**	**290.123**	**0.1**	**1.5**	**1.5**
Tannins	**15.986**	**234.387**	**388.311**	**0.3**	**0.2**	**0.2**
Glycosides	**10.723**	**271.623**	**198.300**	**0.2**	**2.3**	**2.3**
Resins	**7.853**	**437.698**	**265.150**	**0.3**	**2.6**	**2.6**
Coumarins	**11.435**	**287.899**	**399.389**	**0.2**	**0.2**	**0.2**
Cinnamic	**6.765**	**528.788**	**173.445**	**0.4**	**0.3**	**0.3**
Lignan	**5.789**	**228.311**	**230.334**	**0.4**	**1.4**	**1.4**
Callic acid	**9.932**	**327.899**	**363.376**	**0.2**	**1.2**	**1.2**

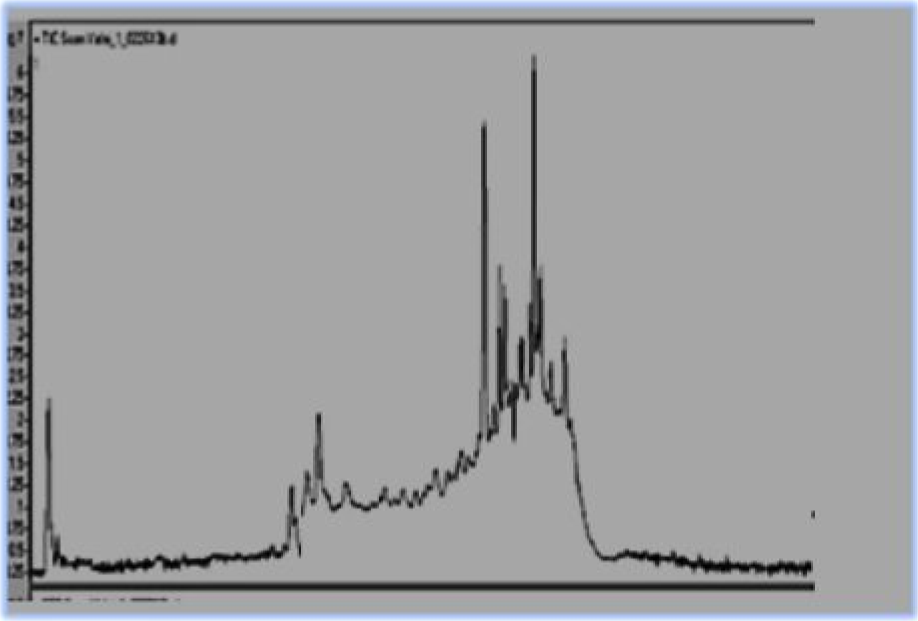

Figure 1. Chemical components identified by GC-MS in carnation flowers.

4. Conclusion

Addresses the role of essential nutrients, particularly nitrogen, phosphorus, and potassium (NPK), in plant growth. Nitrogen is crucial for chlorophyll and enzyme activity, but is unavailable from natural sources like potassium and phosphorus, making its supplementation necessary for optimal growth. The research also highlights the importance of potassium in enzyme activation and cell osmotic pressure regulation, and phosphorus in forming critical organic compounds (Al-Karimjassim, 2019).

Theories from this study, conducted in a controlled wooden shade house, revolve around the effects of different NPK concentrations and seaweed extracts on plant development. The experiment involved testing three NPK fertilizer levels and seaweed extract concentrations on eight-month-old carnation plants. Vegetative and flowering characteristics were measured, and GC-MS analysis identified active compounds.

The results demonstrate that higher concentrations of NPK fertilizer and seaweed extract significantly improved vegetative growth (plant height, stem diameter, leaf area), flower production, and volatile oil quality. The combination of 3.0 g pot-1 of NPK fertilizer and 5 mL L-1 seaweed extract yielded the best outcomes, enhancing plant height, number of flowers, and specific weight of volatile oil. The GC-MS analysis revealed the presence of biologically active compounds, such as alkaloids, saponins, and tannins, with potential medicinal applications.

In conclusion, the study provides strong evidence that the interaction between NPK fertilizer and seaweed extract enhances both the growth and biochemical properties of carnation plants. This opens new possibilities for improving flower quality and exploring their use in medicinal and cosmetic products.

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