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Effects of seaweed extract and nano-NPK foliar spray on vegetative growth and flowering of Chinese carnation (*Dianthus chinensis* L.)

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Abstract

This study was conducted at one of the agricultural nurseries of the University of Kufa during the 2023-2024 growing season to evaluate the effects of seaweed extract application and Nano NPK fertilization on vegetative and flowering characteristics of Chinese carnation (*Dianthus chinensis* L.). The experiment was arranged as a two-factor factorial in a randomized complete block design (RCBD). Seaweed extract was applied at three levels (0, 1, and 2 g L⁻¹), while Nano NPK fertilizer was foliar-sprayed at three concentrations (0, 200, and 400 ppm). The experiment lasted for four months, during which 81 seedlings were transplanted into plastic pots (3 kg capacity) and grown under a wire shade structure covered with saran providing 25% shading. The results showed that both seaweed extract and Nano NPK significantly improved most vegetative and flowering traits compared with the control treatment. The interaction between the two factors was also significant for all studied traits. The combined application of the highest level of seaweed extract with foliar spraying of Nano NPK at 400 ppm produced the best results, including the highest number of leaves (40.79 leaves plant⁻¹) and flowers (75.16 flowers plant⁻¹), as well as increased chlorophyll and carbohydrate contents. These findings indicate that the integrated use of seaweed extract and Nano NPK fertilizer is an effective approach for enhancing vegetative growth and flowering performance of Chinese carnation.

Keywords: Nano fertilizers, seaweed extract, ornamental plants, Chinese carnation

1. Introduction

Chinese carnation (*Dianthus chinensis* L.) is a winter annual ornamental plant of short to medium height, native to Europe and Asia ^[1, 2]. The plant is characterized by an upright growth habit and narrow, dark green leaves. It is cultivated as an annual ornamental species whose flowering coincides with spring under cool night conditions, whereas exposure to severe cold or frost may cause plant damage. Chinese carnation requires approximately 12 weeks from sowing to reach the flowering stage; therefore, it is recommended to sow seeds in seedbeds about eight weeks before transplanting seedlings to their permanent locations. Seeds may also be directly sown in permanent sites in warm coastal regions that are not exposed to frost. Additionally, the plant is commonly grown in pots, rock gardens, and soil beds and is used as a bedding plant ^[3].

Seaweed extracts are considered important organic fertilizers due to their content of macro- and micronutrients, as well as plant growth regulators such as auxins and gibberellins, in addition to amino acids and organic acids. These components contribute to enhancing vegetative and root growth and improving the physiological performance of plants ^[4].

With the advancement of agricultural technologies, Nanotechnology has emerged as a promising modern approach, owing to its effective role in improving the efficiency of agricultural inputs, particularly fertilizers. This is achieved through the production of Nano-materials that enhance plant growth, improve yield quality, and increase agricultural productivity, while reducing reliance on conventional chemical fertilizers, thereby supporting agricultural sustainability ^[5].

Compound NPK fertilizer is regarded as one of the most important fertilizers used in plant production. Its application in balanced amounts that correspond to plant requirements and nutrient uptake rates leads to improved vegetative and flowering growth and increased productivity.

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Nitrogen plays a fundamental role in chlorophyll synthesis, as well as in the formation of proteins and enzymes, thereby promoting vegetative growth and biomass accumulation ^[6]. Phosphorus, on the other hand, effectively enhances root and flower development and cell division. It is present at high concentrations in young tissues with high metabolic activity and plays a crucial role in energy storage and transfer resulting from photosynthesis for growth and reproduction processes ^[7]. Phosphorus is a major constituent of nucleic acids, phospholipids, and ATP, accounting for approximately 0.2% of the plant dry weight ^[8]. Potassium plays an important role in numerous physiological processes, including photosynthesis, enzyme activation, regulation of osmotic and water balance, and control of stomatal opening and closure, thereby enhancing plant tolerance to environmental stresses ^[9, 10]. Studies indicate that potassium concentration in plant tissues ranges from 2-6% of dry weight ^[11]. It also contributes to activating enzymes responsible for carbon fixation, the synthesis of nitrogenous and carbohydrate compounds, facilitating sugar translocation within the plant, and increasing osmotic pressure in plant cells ^[12]. Given the economic and ornamental importance of Chinese carnation as a flowering ornamental plant, this study aimed to investigate the effect of seaweed extract application, foliar spraying with Nano-NPK fertilizer, and their interaction on the growth and flowering of Chinese carnation plants.

2. Materials and Methods

The experiment was conducted at the agricultural nurseries of the Agricultural Division, University of Kufa, during the 2023-2024 growing season, inside a structure covered with a green shading net providing 25% shade. The study aimed to evaluate the effects of foliar application of Nano-NPK fertilizer and the addition of seaweed extract on the growth and flowering of Chinese carnation Seedlings were transplanted 15 days prior to the application of treatments into plastic pots with a capacity of 5 kg, filled with a growing medium composed of river soil and peat moss at a ratio of 2:1 (v/v), thoroughly mixed to ensure homogeneity. Soil analysis was conducted according to the method described by ^[13], and the results are presented in Table 1.

Table 1: Physical and chemical properties of the experimental soil

Property	Value	Unit
Soil prticles	Sand	820
	Silt	75
	Clay	105
Texture	Sand-loam	---
pH	6.5	---
EC 1: 1	2.40	dS m ⁻¹
Available N	0.08	%
Available P	0.003	%
Available K	0.07	%
Available Ca	0.012	%
Magnessium	9	mmol L ⁻¹
Fe	0.78	mg Kg ⁻¹
OM	3.22	g Kg ⁻¹

2.1 Studied Characteristics

1. **Number of leaves (leaf plant⁻¹):** The number of leaves per plant was counted, and the mean value for each experimental unit was calculated.

2. **Number of branches (branch plant⁻¹):** The number of branches per plant was recorded, and the average was calculated for each experimental unit.
3. **Leaf chlorophyll content (mg 100 g⁻¹ fresh weight):** Chlorophyll content was determined according to the method described by ^[14] using the following equation:

Total chlorophyll = [20.2 × D (645) + 8.02 × D (663)] × (V / W × 1000) × 100
4. **Total soluble carbohydrate content in leaves (mg 100 g⁻¹ dry weight):** Carbohydrate content was determined using the modified phenol-sulfuric acid colorimetric method (PSACM) as described by ^[15].
5. **Number of flowers (flower plant⁻¹):** The number of flowers was counted at seven-day intervals from the beginning of the experiment until its completion.
6. **Flower diameter (cm flower⁻¹):** Flower diameter was measured using a vernier caliper.
7. **Flower longevity (days):** Flower longevity was calculated from the time of flower opening until complete senescence.

2.2 Design and factors of the experiment: The experiment included two factors. The first factor was the application of seaweed extract at three concentrations (0, 1, and 2 g L⁻¹), while the second factor consisted of foliar spraying with Nano-NPK fertilizer at three concentrations (0, 200, and 400 ppm). The seaweed extract was applied on 7 November 2024, whereas foliar spraying with Nano-NPK was conducted seven days after the application. Both the application and spraying treatments were carried out four times per month for each factor, The experiment was arranged as a two-factor factorial experiment within a randomized complete block design (RCBD), resulting in nine treatment combinations. Each treatment was replicated three times, and the experimental units were randomly distributed within the blocks. Each experimental unit consisted of three pots, and the mean values of the pots were used as the experimental unit for statistical analysis.

3. Results and Discussion

The results indicated that the application of 2 g L⁻¹ of seaweed extract to the soil combined with foliar spraying of 400 ppm Nano-NPK significantly increased most vegetative and flowering traits. These traits included leaf number, branch number, leaf carbohydrate content, and chlorophyll content (Table 2), as well as flower number, flower diameter, and flower longevity (Table 3), compared to lower concentrations, regardless of the type of fertilization. Moreover, the interaction between soil application of seaweed extract and foliar spraying of Nano-NPK had a significant effect on all studied traits. The combined treatment of seaweed extract and Nano-NPK (2 g L⁻¹ and 400 ppm, respectively) outperformed all other interaction treatments for all measured traits, producing the highest values in leaf number (40.79 leaves plant⁻¹), branch number (5.88 branches plant⁻¹), leaf carbohydrate content (11.72 mg g⁻¹ dry weight), chlorophyll content (29.41 mg 100 g⁻¹ fresh weight), flower number (75.16 flowers plant⁻¹), flower diameter (2.8760 cm), and flower longevity (9.77 days) compared to the control treatment.

Table 2: Effect of soil application of seaweed extract and foliar spraying of Nano-NPK on vegetative growth traits of Chinese carnation.

SWE g.L ⁻¹	Nano - NPK ppm	No. of leaves	No. of branches	Carbohydrate in leaf mg. g ⁻¹	Chlorophyll in leaf mg.100g ⁻¹
0	0	19.75	2.20	8.21	19.30
	200	20.99	3.86	8.32	22.46
	400	23.21	3.94	8.30	22.41
1	0	27.96	4.21	9.57	23.10
	200	30.04	4.60	9.42	24.87
	400	30.45	4.84	9.70	26.64
2	0	34.55	5.10	10.25	27.61
	200	38.20	5.13	11.41	27.91
	400	40.79	5.88	11.72	29.41
L.S.D. (<i>p</i> ≤ 0.05)	SWE	0.634	0.031	0.032	0.056
	Nano - NPK	0.634	0.031	0.032	0.056
	Interaction	1.099	0.053	0.056	0.097

Values are means of three replicates.

Table 3: Effect of soil application of seaweed extract and foliar spraying of Nano-NPK on the vegetative growth traits of Chinese carnation

SWE g.L ⁻¹	Nano - NPK ppm	No. of flower (flower. plant ⁻¹)	Flower diameter (cm)	Day of flower on the plant (day)
0	0	60.22	1.2220	5.32
	200	61.32	1.4370	5.86
	400	62.55	1.6550	5.89
1	0	63.87	1.7540	6.33
	200	64.98	1.8880	6.77
	400	65.78	1.8807	7.88
2	0	66.37	2.2230	8.66
	200	67.10	2.6660	8.88
	400	75.16	2.8760	9.77
L.S.D. (<i>P</i> ≤ 0.05)	SWE	0.0329	0.027	0.0304
	Nano - NPK	0.0329	0.027	0.0304
	Interaction	0.0571	0.048	0.0527

The results presented in Tables 2 and 3 indicate that both soil application of seaweed extract and foliar spraying with nano-NPK positively influenced vegetative and flowering traits. These improvements included increases in leaf number, branch number, leaf carbohydrate and chlorophyll content, flower number, flower diameter, and flower longevity compared to the control treatment. Plants treated with 2 g L⁻¹ of seaweed extract showed the highest values for all measured traits. This superior performance can be attributed to the extract's content of macro- and micronutrients as well as plant hormones, which play a key role in stimulating vegetative growth and promoting lateral branching [16]. Seaweed extracts also enhance leaf chlorophyll content and reduce its degradation, thereby improving photosynthetic efficiency [17]. Moreover, the extract is rich in essential nutrients such as nitrogen, phosphorus, and potassium, as well as vitamins, amino acids, and organic acids, which influence a wide range of physiological processes within the plant [18]. These factors improve nutrient uptake and utilization efficiency, positively affecting vegetative growth. These results are consistent with previous studies [19, 20, 21].

Similarly, plants treated with 2 mg L⁻¹ of nano-NPK exhibited significant improvements in both vegetative and flowering traits. This enhancement is attributed to the integrated physiological role of its nutrients. Nitrogen contributes to the formation of porphyrin molecules involved in the synthesis of key metabolic compounds such as chlorophyll and cytochromes, which are essential for photosynthesis and respiration. Nitrogen, in synergy with phosphorus, also participates in the synthesis and activation of enzymes responsible for regulating metabolic activity and producing amino acids necessary for protein biosynthesis. In addition, potassium plays a fundamental role in enzyme activation and protein stabilization, thereby enhancing physiological efficiency and improving plant growth and

flowering [22]. The improvements in vegetative traits were directly reflected in flower characteristics. Increases in leaf number, leaf area, and leaf chlorophyll and carbohydrate content enhanced photosynthetic efficiency and increased the availability of assimilates for floral organs. Improved nutritional status promoted cell division and elongation in flower buds, leading to higher flower number, larger flower diameter, longer flower longevity, and better flower quality.

4. Conclusion

The study demonstrated the beneficial effects of different concentrations of seaweed extract on vegetative and flowering traits of Chinese carnation, particularly at 2 g L⁻¹, which produced significant improvements in all measured growth parameters. Foliar application of nano-NPK also had a clear positive impact, showing the highest efficiency at 400 ppm, making it an economically viable option. The interaction between soil application of seaweed extract and foliar spraying of nano-NPK (2 g L⁻¹ × 400 ppm) resulted in the highest values for all measured traits compared to individual treatments, highlighting the synergistic effect of combining these two inputs.

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