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IMPROVING THE GROWTH AND QUALITY OF THE VINCA PLANT USING NPK FERTILIZER AND CHELATED IRON AND ZINC

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ABSTRACT: This experiment was conducted to improve the growth and flowering quality of potted vinca plants *Catharanthus roseus* (L.) G.Don. using NPK (19:19:19), chelated iron, and zinc fertilization. Results indicated that adding NPK fertilization at 1 g/pot and 2 g/pot once monthly improved vegetative characteristics (plant height, number of branches, stem thickness, length and roots number, and fresh and dry weights of leaves and roots), as well as increasing the number of flowers and the fresh and dry weight of flowers. The leaf content of chlorophyll, total carbohydrates, and the percentage of N, P, and K in the leaves also increased compared to plants that were not fertilized, with a clear advantage for fertilizing at 2 g compared to fertilizing at 1 g. Spraying plants with iron and zinc significantly improved vegetative, flower and chemical characteristics, with Fe (100 ppm) yielding better results than Zn (100 ppm). Vegetative and floral characteristics reached their highest values when Fe and Zn were added together, compared to when iron and zinc were added alone. The application of Fe and Zn, either alone or in combination, improved the characteristics of plants fertilized with NPK (2 g/pot), both vegetative and floral characteristics, as well as leaf contents of total carbohydrates, chlorophyll, N, P, and K. The best results were achieved by plants fertilized with NPK (2 g/pot) in conjunction with a combined 100 ppm Fe and Zn fertilizer. Therefore, to achieve the best vegetative and floral features, it is advised to fertilize vinca plants with NPK fertilizer (2 g/pot) and 100 ppm chelated Fe and 100 ppm chelated Zn.

Keywords: *Catharanthus roseus,* fertilizers, NPK, chelated iron, chelated zinc

INTRODUCTION

Catharanthus roseus (L.) G. Don. is an important ornamental garden and medicinal plant belonging to the Apocynaceae family. The flower color of *Catharanthus roseus* can be used to differentiate between its two species.: pink and white (Jaleel and Panneerselvam, 2007).

Vinca plants are native to Madagascar, this plant adapts well to hot, dry weather and requires full sun and well-drained soil, it requires long periods of bright light and warm conditions to develop strong roots and it is grown as an ornamental plant in pots and containers in gardens, and it also has many medicinal uses (Jong-Goo and Sang-Uk, 2010).

In the dry weight of plants, nitrogen (N) is the second most abundant element after carbon and oxygen. Nitrogen is a major component of proteins, nucleic acids, phospholipids, chlorophyll in leaves, hormones, vitamins, and alkaloids, and it plays a role in every stage of plant development and growth. (O′Brien *et al*., 2016; Jiang *et al*., 2024).

Nitrogen has a significant impact on plant water uptake from the soil. Plant uptake of nitrogen sources (especially nitrate and ammonium nitrogen) generally depends on root uptake. The effect of inorganic nitrogen sources (nitrate and ammonium nitrogen) on water uptake varies depending on the plant species. Water and nitrogen have opposing and synergistic impacts on plant development (Luo *et al*., 2023 and Ma *et al*., 2023). Nitrogen content in plants is also related to the ability of the antioxidant system to scavenge reactive oxygen species (ROS). Shi *et al*. (2017) reported that the enhancement enzyme activities of antioxidant, including superoxide dismutase (SOD) activity and glutathione (GSH) concentration, under normal nitrogen supply conditions compared with low nitrogen treatment, effectively prevents the accumulation of ROS and thus reduces drought damage to plants.

Phosphorus (P) is a vital macronutrient that plants need for their growth and development (Vance *et al*., 2003). It makes up about 0.2% of the dry mass of plants and participates in fundamental metabolic activities like photosynthesis and respiration. It serves as the building block for vital biomolecules, including sugar phosphates, nucleotides, nucleic acids, phospholipids, and high-energy molecules, notably adenosine triphosphate (ATP) (Abel *et al*., 2002; Vance *et al*., 2003; Czarnecki *et al*., 2013; Aziz *et al*., 2014). It also contributes to cellular signaling cascades through its role as a signal transduction mediator (Ha and Tran, 2014).

Potassium (K^+) is among the most crucial macronutrients that affects biochemical and physiological functions and is vital for optimal development and metabolism in plants (Wang *et al*., 2013). Studies have indicated that external application of K^+ significantly impacts cell elongation and the growth of shoots and roots (Islam *et al*., 2004; Wang *et al*., 2013), has a meaningful effect on enhancing the total dry weight of plants (Clavijo-Sanchez *et al*., 2015), and boosts economic yield and quality (Hu *et al*., 2017; Guo *et al*., 2019). Additionally, photosynthetic pigments are significantly influenced by potassium (Arafa *et al*., 2011). It also has a big impact on photosynthesis, enzyme activation, phloem transport (Marschner, 2012), metabolism of protein and amino acids (Hu *et al*., 2016), and cation-anion equilibrium (Wakeel *et al*., 2011).

Iron typically exists in two oxidation forms: ferric (Fe^{+3}) and ferrous (Fe^{+2}). The oxidation form of ferrous (Fe^{+2}) can readily change, allowing it to participate in different cellular functions, but its management is crucial to avoid cytotoxicity. In neutral to alkaline soils, iron is not readily available, leading to iron-deficient plants even though it is present in ample quantities. Iron acts as a cofactor for redox enzymes, for example, ferredoxin, iron-sulfur proteins, catalase, peroxidase, and cytochrome c (Cyt) oxidase (Guerinot, 1994).

Iron, present in leghemoglobin and nitrogenase, is vital for nitrogen fixation in leguminous plants (Phillips, 1980). Yellowing is the most noticeable sign of iron deficiency in plants, which not only significantly affects plant growth and development but also impacts product quality and quantity (Bashir *et al*., 2016).

Zn acts as a cofactor for a significant number of enzymes that take part in DNA transcription, as well as in the metabolism of proteins, nucleic acids, carbohydrates, and lipids (Ishimaru *et al*., 2011; Hajiboland, 2012). Zn is a crucial element in plant enzymes, including carbonic anhydrase, alcohol dehydrogenase, alkaline phosphatase, Cu-Zn SOD, RNA polymerase, and phospholipase, and it also plays a role in reactions of other enzymes where Zn is not the main component (Hajiboland, 2012).

It is well known that zinc plays a crucial role in proteins involved in RNA and DNA production, such as transcription factors (DNA-binding Zn finger motifs), RNA polymerases, and reverse transcriptase (Broadley *et al*., 2007; Suzuki *et al*., 2012; Bashir *et al*., 2016). Transcription factors that have DNA-binding Zn finger motifs not only give DNA-binding ability but also boost protein-protein interactions (Bashir *et al*., 2016).

This experiment was conducted to improve the growth and flowering of vinca plants by applying chemical fertilizers (NPK at 1 and 2 g/plant) and maximizing the benefits from these fertilizers by applying chelated forms of both iron and zinc at a rate of 100 ppm as a foliar spray.

MATERIALS AND METHODS

A pot experiment was conducted at Ornamental Plants and Landscape Gardening Res. Dept. Nursery, Hort. Res. Inst., Agric. Res. Center, Giza, Egypt during 2023 and 2024 seasons to investigate the impact of chemical NPK, zinc and iron fertilization on *Catharanthus roseus* (L.) G.Don.

Plant material:

At the beginning of March each season, well-established transplants of *Catharanthus roseus* obtained from a private nursery at Shibin El Qanater, Qalyubia governorate, Egypt, were transplanted into 20-cm-pots (1 transplant/pot) filled with about 2.5 kg of growing medium, clay an sand 1:1 volume ratio. Pots were kept for one month till the beginning of experiment treatments.

Experimental layout:

This study utilized a factorial experiment (Gomez and Gomez, 1984) in a completely randomized design (CRD) with two variables.; three NPK fertilization rates (0, 1 and 2 g/pot) represented factor A, four micronutrients of chelated zinc (Zn) and iron (Fe) (0, 100 ppm Zn, 100 ppm Fe and 100 ppm Zn + 100 ppm Fe) represented factor B, as well as their interactions. Consequently, there were 12 treatments in this experiment. Each treatment was replicated three times, and each replicate had six pots.

Chemical NPK fertilization:

After one month from transplanting (on April 1st for both seasons), plants were treated for the first time with the previously mentioned rates of NPK fertilizer, and then at 15-day intervals for an additional 5 times. Agri Gold Fert© product was used as a source of NPK 19:19:19 (19% N in amide, NH_4 and NO_3 forms, 19% P in $NH_4H_2PO_4$ form and 19% K in K_2SO_4 and KNO_3 forms). Two levels of NPK fertilization (1 and 2 g/plant) were applied as a soil addition by mixing each amount with the top portion of the growing medium surface before irrigation. Control plants were not treated with NPK fertilization (0 g/pot).

Micronutrients fertilization:

Four applications of zinc at 100 ppm, iron at 100 ppm and zink (100 ppm) + iron (100 ppm) were applied. The first one was applied a month after the transplant (on April 1st for the first and second seasons), then every two weeks. Each concentration was sprayed onto the plants until runoff. Zinc 15% and iron 13% from Agro Can Co. were used as a source of zinc and iron, respectively. Plants sprayed with tap water only refer to 0.0 ppm micronutrients (control).

Data recorded:

At the beginning of November for each season, data were recorded as follows:

1. Vegetative and root growth specifications:

Plant height (cm), stem diameter (cm), number of branches/plant, vegetative parts fresh and dry weights (g), number of leaves/plant, roots length (cm) and number, fresh and dry weights (g) of roots were measured.

2. Flowering parameters:

Flowers number and flowers fresh and dry weights (g).

3. Chemical constituents:

The method described by Herbert *et al*. (1971) was used to calculate the percentage of total carbohydrates in dry shoot samples. Leaf green degree (SPAD) in fresh leaves, as stated by Markwell *et al*. (1995) was measured at the end of the experiment by a SPAD-502 meter, and petal anthocyanin content (mg/100 g f.w.) as reported by Singh *et al*. (2004) during both seasons was determined.

At the beginning of November in the second season only, according to AOAC (1990) percentages of N, P, and K in dry leaves were determined

Statistical analysis:

By using MSTAT Computer Program (MSTAT Development Team, 1989) data were analyzed statistically. Duncan's Multiple Range Test, as outlined by Duncan (1955), was used to compare means in order to ascertain variations between the means of various treatments.

RESULTS

The average heights and stem diameters of the plants recorded in Table (1) indicate a slightly significant increase in plant height and stem diameter in both seasons when 1 and 2 g of NPK were added compared to plants that did not receive NPK fertilizer. However, there was a significant increase for plants that received a mixture of Fe and Zn compared to plants that were not fertilized at all or those that received Fe or Zn separately, as plant height reached (41.17 and 49.45 cm) in the first and second seasons, respectively, and stem diameter reached (0.87 and 0.93 cm). Regarding the interaction between NPK, Fe, and Zn, it is clear that plant height increased significantly and stem diameter too, when either Fe or Zn added to NPK. The addition of Fe and Zn together had the greatest effect with NPK (2 g), as plant height reached the highest values (48.1 and 58.30 cm) and stem diameter (0.90 and 0.97 cm) in both seasons, respectively, compared to the rest of the interactions.

The average data regarding the effect of adding Fe and Zn with NPK on the branch’s number/plant and number of leaves is shown in Table (2). The applied NPK fertilizer showed clear differences in number of branches and leaves per plant. A significant effect was observed on the number of branches and leaves due to the increased doses. In this context, it can be concluded that the highest averages were recorded after adding 2 g of NPK. These averages were (3.13 and 3.83) for the number of branches and (33.83 and 40.42) for the number of leaves in the two seasons, respectively. Also, the combined application of Zn and Fe achieved a significant advantage compared to the control or the application of either of them separately in both seasons, respectively. Meanwhile, the combined application of NPK fertilizer and Fe and Zn resulted in the highest values of (5.33 and 6.33) for the number of branches and (50.00 and 59.67) leaves/plant in both seasons.

Data presented in Table (3) indicate a slightly significant increase in root number and length, attaining the highest values for fertilized plants with 2 g of NPK.

The averages show that adding iron was superior to the control or those to which zinc was added, while adding both zinc and iron together was superior to adding either of them alone.

Regarding the interaction between treatments, it can be noted that adding iron or zinc alone or in combination with NPK improved root number and length compared to plants that received NPK alone, reaching the highest values (9.67 and 9.67) for root number and (14.00 and 14.33 cm) for root length in both seasons when adding both iron and zinc together to plants that received 2 g of NPK.

The same trend was obtained in Table (4) when vegetative growth fresh and dry weights were determined as affected by applied Fe and Ze with NPK, both fresh and dry weights increased with increasing NPK, while the combination of iron and zinc produced the highest weights compared to adding either iron or zinc alone.

The fresh and dry weights improved more with the addition of Fe to NPK than with zinc. Adding them together brought the fresh and dry weights of the vegetative growth to the highest values (33.38 and 35.34 g/plant) for f.w. and (16.91 and 17.40 g/plant) for d.w. in the two seasons, respectively.

Fresh and dry root weights shown in Table (5) were influenced by NPK fertilization, where the fresh weight increased

Table 1. Effect of NPK, Fe, Zn fertilizers and their interactions on plant height (cm) and stem diameter (cm) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
				Plant height (cm)				
Cont.	27.67 h	28.53 gh	29.40 f-h	28.53 d	32.87 g	34.00 fg	34.50 e-g	33.79 d
Fe	30.83 d-f	31.33 de	32.67 cd	31.61 b	36.67 de	37.67 cd	39.33 c	37.89 b
Zn	29.00 f-h	29.87 e-g	30.40 e-g	29.76 c	34.33 e-g	36.40 d-f	36.33 d-f	35.69 c
Fe + Zn	33.50 c	41.90 b	48.10 a	41.17 a	39.67 c	50.67 b	58.30 a	49.54 a
Means (A)	30.25 c	32.91 b	35.14 a		35.88 c	39.68 b	42.12 a	
				Stem diameter (cm)				
Cont.	0.33 h	0.37 h	0.40 gh	0.37 d	0.43 g	0.47 g	0.50 fg	0.47 d
Fe	0.73 d	0.77 cd	0.80 b-d	0.77 b	0.83 c	0.87 bc	0.87 bc	0.86 b
Zn	0.47 fg	0.50 ef	0.57 e	0.51 c	0.57 ef	0.60 de	0.67 d	0.61 c
Fe + Zn	0.83 a-c	0.87 ab	0.90 a	0.87 a	0.90 a-c	0.93 ab	0.97 a	0.93 a
Means (A)	0.59 b	0.63 b	0.67 a		0.68 b	0.72 ab	0.75 a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

Table 2. Effect of NPK, Fe, Zn fertilizers and their interactions on number of branches and number of leaves of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
				Number of branches				
Cont.	1.00 g	1.33 fg	1.67 e-g	1.33 d	1.00 h	1.33 gh	2.00 f-h	1.44 d
Fe	2.33 de	3.00 cd	3.33 c	2.89 b	3.00 def	4.00 c-e	4.33 b-d	3.78 b
Zn	1.67 e-g	2.00 ef	2.33 de	2.00 c	2.00 f-h	2.33 f-h	2.67 e-g	2.33 c
Fe + Zn	4.33 b	4.67 ab	5.33 a	4.78 a	5.33 a-c	5.67 ab	6.33 a	5.78 a
Means (A)	2.33 b	2.75 ab	3.17 a		2.83 b	3.33 ab	3.83 a	
				Number of leaves				
Cont.	20.00 h	20.33 h	21.33 h	20.56 d	23.33 g	24.00 g	25.33 g	24.22 d
Fe	32.33 e	34.00 e	37.00 d	34.44 b	38.67 e	41.33 de	44.00 d	41.33 b
Zn	24.33 g	25.00 fg	27.00 f	25.44 c	29.33 f	30.33 f	32.67 f	30.78 c
Fe + Zn	40.33 c	46.00 b	50.00 a	45.44 a	49.33 c	55.00 b	59.67 a	54.67 a
Means (A)	29.25 c	31.33 b	33.83 a		35.17 c	37.67 b	40.42 a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

Table 3. Effect of NPK, Fe, Zn fertilizers and their interactions on number of rotos and root length (cm) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
	Number of roots							
Cont.	4.33 g	5.00 fg	5.33 f	4.89 c	4.67 f	6.00 ef	6.00 ef	5.56 c
Fe	6.33 de	6.67 d	7.00 cd	6.67 b	7.33 c-e	7.67 cd	8.00 c	7.67 b
Zn	5.00 fg	5.33 f	5.67 ef	5.33 c	6.00 ef	6.00 ef	6.33 de	6.11 c
Fe + Zn	7.67 bc	8.33 b	9.67 a	8.56 a	8.67 bc	9.67 b	11.33 a	9.89 a
Means (A)	5.83 c	6.33 b	6.92 a		6.67 b	7.33 ab	7.92 a	
	Root length (cm)							
Cont.	6.10 h	6.27 h	6.60 gh	6.32 d	7.00 h	7.00 h	7.67 gh	7.22 d
Fe	7.33 fg	8.67 de	9.07 d	8.36 b	8.33 fg	10.00 de	10.67 d	9.67 b
Zn	6.93 gh	7.33 fg	7.87 ef	7.38 c	7.67 gh	8.00 f-h	9.00 ef	8.22 c
Fe + Zn	10.97 c	12.27 b	14.00 a	12.41 a	13.00 c	14.33 b	16.33 a	14.56 a
Means (A)	7.83 c	8.63 b	9.38 a		9.00 c	9.83 b	10.92 a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

Table 4. Effect of NPK, Fe, Zn fertilizing and their interactions on vegetative parts fresh and dry weights (g) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
	Vegetative parts f.w. (g)							
Cont.	24.44i	25.54g	27.86d	25.95d	25.23i	26.64g	28.97d	26.94d
Fe	25.55g	26.73e	30.48b	27.59b	26.60g	28.00e	31.42b	28.68b
Zn	25.14h	26.08f	29.84c	26.82c	25.97h	27.00f	30.36c	27.78c
Fe + Zn	26.80e	27.67d	33.38a	29.28a	27.90e	29.14d	35.34a	30.79a
Means (A)	25.45c	26.51b	30.24a		26.42c	27.70b	31.52a	
	Vegetative parts d.w. (g)							
Cont.	12.18	13.35	13.91	13.15d	12.34g	14.27e	14.48de	13.70d
Fe	13.31	14.05	15.55	14.03b	13.50f	14.85d	15.93b	14.76b
Zn	12.98	13.57	15.37	13.97c	13.25f	14.30e	15.31	14.29c
Fe + Zn	14.40	15.24	16.91	15.52a	14.73d	15.58bc	17.40a	15.90a
Means (A)	13.22c	14.05b	15.44a		13.46c	14.75b	15.78a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

Table 5. Effect of NPK, Fe, Zn fertilizers and their interactions on roots f.w. and d.w. (g) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	1st season				2nd season			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
				Roots f.w. (g)				
Cont.	6.10 i	6.43 h	6.87 g	6.47 d	7.49 f	7.68 f	8.47 de	7.88 d
Fe	7.30 e	7.50 d	7.57 cd	7.46 b	8.78 cd	9.10 bc	9.08 bc	8.99 b
Zn	6.90 fg	7.00 fg	7.07 f	6.99 c	8.40 e	8.66 de	8.46 de	8.50 c
Fe + Zn	7.70 bc	7.87 ab	8.00 a	7.86 a	9.32 ab	9.60 a	9.49 a	9.47 a
Means (A)	7.00 c	7.20 b	7.38 a		8.50 b	8.76 a	8.88 a	
				Roots d.w. (g)				
Cont.	3.26i	3.70g	4.09f	3.68d	3.54g	4.03f	4.37e	3.98c
Fe	3.75g	4.57d	5.07b	4.46b	4.04f	5.00c	5.48b	4.84b
Zn	3.55h	4.26e	4.78c	4.20c	3.90f	4.59d	5.34b	4.61c
Fe + Zn	4.12f	5.04b	5.58a	4.91a	4.44de	5.47b	6.02a	5.30a
Means (A)	3.67c	4.39b	4.88a		3.98c	4.77b	5.30a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

to 7.38 and 8.88 g and the dry weight attained 4.88 and 5.30 g in both seasons for those plants that received 2 g/plant. Also, the maximum for both fresh and dry weights was observed when Fe and Ze were combined, reaching 7.86 and 9.47 g for fresh weight and 4.91 and 5.30 g for dry weight across the two seasons, respectively.

Concerning the interaction, the greatest fresh and dry weights were achieved with the treatment involving NPK together with Fe + Zn.

The mean fresh and dry weights of all flowers throughout the experiment, detailed in Table (6), showed a significant increase with the addition of 2 g of NPK in comparison to the addition of 1 g or the control. The fresh and dry weights of flowers also demonstrated an increase with the combination of Fe and Ze compared to the control or the inclusion of either one alone, with Fe exerting a stronger influence than Ze.

Plants treated with 2 g of NPK in conjunction with Fe and Ze exhibited the highest weights (5.00 and 5.14 g/plant) for fresh weight and (2.67 and 2.73 g/plant) for dry weight in both seasons, respectively.

NPK has a central effect on plant activity, as it is the most important element in the formation of plant tissues, with iron and zinc interfering as co-elements in all vital processes and activities. Therefore, the values recorded in Table (7) documented the highest percentage of carbohydrates, the highest degree of greenness of leaves, and the highest content of anthocyanins in flowers at 2 g/plant.

The treatment with Fe and Zn together achieved the highest content for the previously mentioned data, while Fe alone had a clear superiority compared to Zn. Fe with NPK (2 g/plant) had the best interaction, as leaves content of chlorophyll increased by 23% and the anthocyanin content of flowers by 25%, achieving the highest value compared to the rest of the values, while the highest carbohydrate content of leaves was achieved by the interaction between NPK (2 g/plant) with iron and zinc together

The proportion of nitrogen, phosphorus, and potassium in the leaves was higher in the

Table 6. Effect of NPK, Fe, Zn fertilizers and their interactions on number of flowers/plant, flowers fresh and dry weights (g) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
				Number of flowers/plants				
Cont.	11.00h	13.67f	15.00e	13.22d	13.00j	17.00h	18.33g	16.11d
Fe	15.33e	18.67cd	22.67b	18.89b	16.67h	21.33e	26.00b	21.33b
Zn	12.33g	16.00e	19.33c	15.89c	14.33i	19.67f	22.33d	18.78c
Fe + Zn	17.67d	22.33b	28.00a	22.67a	20.67e	25.00c	30.33a	25.33a
Means (A)	14.08c	17.67b	21.25a		16.17c	20.75b	24.25a	
				Flowers f.w. (g)				
Cont.	2.30h	2.40h	2.83f	2.51d	2.44j	2.59i	3.09f	2.70c
Fe	2.83f	3.22d	3.93b	3.33b	2.96g	3.35d	4.05bc	3.45b
Zn	2.68g	3.04e	3.92b	3.22c	2.81h	3.28de	4.13b	3.41c
Fe + Zn	3.13de	3.65c	5.00a	3.93a	3.21e	3.94c	5.14a	4.09a
Means (A)	2.74c	3.08b	3.92a		2.85c	3.29b	4.10a	
				Flowers d.w. (g)				
Cont.	1.15i	1.22hi	1.27gh	1.22d	1.19i	1.27h	1.32gh	1.26d
Fe	1.52e	2.00d	2.22c	1.92b	1.58e	2.07d	2.29c	2.49b
Zn	1.42f	1.53e	1.31g	1.42c	1.47f	1.58e	1.34g	1.47c
Fe + Zn	2.23c	2.36b	2.67a	2.42a	2.32c	2.41b	2.73a	2.49a
Means (A)	1.58c	1.78b	1.87a		1.64c	1.83b	1.92a	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955).

Table 7. Effect of NPK, Fe, Zn fertilizers and their interactions on leaf total carbohydrates (%), leaf green color degree (SPAD) and petal anthocyanin content (mg/100g f.w) of *Catharanthus roseus* (L.) G.Don during the 2023 and 2024 seasons.

Fe-Ze (B)	Season (2023)				Season (2024)			
	NPK (g/plant) (A)							
	0	1	2	Means (B)	1	2	0	Means (B)
				Leaf content total carbohydrates (%)				
Cont.	5.925ai	6.052g	6.112f	6.030d	5.896j	5.999i	6.046g	5.980d
Fe	6.025h	6.145e	6.223d	6.131c	6.012e	6.087f	6.154d	6.084c
Zn	6.155e	6.149e	6.224d	6.176b	6.053g	6.052g	6.165c	6.090b
Fe + Zn	6.239c	6.332b	6.423a	6.332a	6.128e	6.254b	6.362a	6.248a
Means (A)	6.086c	6.170b	6.246a		6.022c	6.098d	6.181a	
				Leaf green color degree (SPAD)				
Cont.	30.25i	32.42g	34.28e	32.32d	31.45g	32.97f	34.99e	33.14c
Fe	36.42d	38.49b	42.32a	39.08a	37.17cd	39.11b	42.82a	39.70a
Zn	31.59h	33.31f	36.51d	33.81c	31.76g	34.95e	37.07d	34.59b
Fe + Zn	36.21d	37.50c	42.16a	38.62b	37.08d	38.01c	42.60a	39.23a
Means (A)	33.62c	35.43b	38.82a		34.37c	36.26b	39.37a	
				Petal anthocyanin content (mg/100g f.w)				
Cont.	87.88i	92.37g	101.57f	93.94c	91.28k	93.37j	104.55	96.40c
Fe	105.9e	110.28d	126.93a	114.37a	105.59g	112.59d	129.62a	115.94a
Zn	91.35h	101.31f	110.29	100.98b	93.40j	103.34i	111.45e	102.73b
Fe + Zn	106.31e	115.70c	120.30b	114.10a	105.20g	120.20c	122.30b	115.90a
Means (A)	97.86c	104.92b	114.77a		98.87c	107.18	116.98	

At a 0.05 level of probability, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

NPK-fertilized plants (2 g/plant) than in the control, as shown in Figs. (1-3). Also, spraying the plants with iron and zinc produced the highest values. The interaction between NPK, iron, and zinc together had the highest significant values compared to the other treatments.

DISCUSSION

The obtained results of this study regarding NPK performance were in agreement with previous documented research. In the same context, the stem diameter, leaf count, root length, and fresh root weight of *Tagetes erecta* L. were all increased by fertilizing it with 2 g/pot of NPK fertilizer at a concentration of (19:19:19), as well as a slight increase in the number of flowers and their fresh and dry weight compared to control plant (Nofal *et al*, 2021). With different levels of NPK, each element had a positive effect on basic growth parameters of Chinese carnation, including shoot height, number of leaves, number of flowers, and chlorophyll in leaves (Owain, 2024). Also, in a pot experiment, a compound fertilizer containing NPK was applied to *Aeschynanthus longicaulis*. However, nitrogen had a more significant effect on shoot growth and root-to-shoot ratio than phosphorus and potassium. Overall, all aerial parts and root characteristics improved as the concentration of the compound fertilizer increased (Deng and Li, 2022). The height, leaf width, and number of branches of *Cattleya* orchids plants increased when a compound fertilizer containing NPK (28:10:10) was applied at levels of 1, 2, 3, and 4 g/plant. The best plant characteristics were achieved at 2 g/plant, while the highest chlorophyll index (CCI) was represented by the SPAD value in leaves at a concentration of 3 g/plant (Mubarok *et al*., 2024). Finally, Ali (2021) suggested that spraying *Chrysanthemum hortorum* Hort plants with 0.50 g/l of nano-NPK fertilizer resulted in a significant increase in leaf area, leaf chlorophyll content, flower diameter, petal number, and leaf nutrient content (N, P, K). N, P, and K substances play a key role in stimulating several enzymes and aiding in the creation of proteins, which in turn benefits the signs of vegetative growth. This finding aligns with the research of Abdollahi *et al*. (2016) on coriander (*Coriandrum sativum* L.), who found that N, P, and K substances greatly enhanced the vegetative growth traits of the plant.

Higher levels of nutrients in leaves, including nitrogen, phosphorus, and potassium, can result in enhanced cell growth and expansion. This process, in turn, contributes to greater production and storage of nutrients and carbohydrates within the flowers (Shaheen *et al*., 2007).

Satari *et al*. (2022) conducted an experiment on *Phalaenopsis* orchid, which resulted in an increase in plant length, number of leaves, dry weight, and chlorophyll content of the leaves. There was also a significant improvement in number of flowers when the plants were treated with NPK fertilizer at a concentration of 19:6:20, as it had a better effect than the other concentrations.

The highest plant length and the highest values of plants per unit area were obtained when fertilizing the plant *Salidago canadensis* with 75:120:90 kg/hectare (NPK) (Bharath *et al.,* 2020).

The study conducted by Sari *et al*. (2023) aimed to assess how sunflower (*Helianthus annuus* L.) responded to different doses of NPK fertilizer (16:16:16) (9 g/plant, 10 g/plant, 11 g/plant) in terms of growth, yield, and quality. The results demonstrated that the NPK fertilizer dosage of 9 g/plant produced the greatest plant height, stem diameter, and flower count.

A pot experiment was conducted on the effect of three (NPK) fertilization rates and five zinc and Mn levels on vegetative growth, photosynthetic pigment content, and leaf nitrogen, phosphorus, and potassium % of *Delonix Regia* seedlings. It was found that increasing NPK levels led to an increase in plant height, stems dry weight, leaves, and roots, and chlorophyll content of leaves. The NPK percentage in leaves also increased.

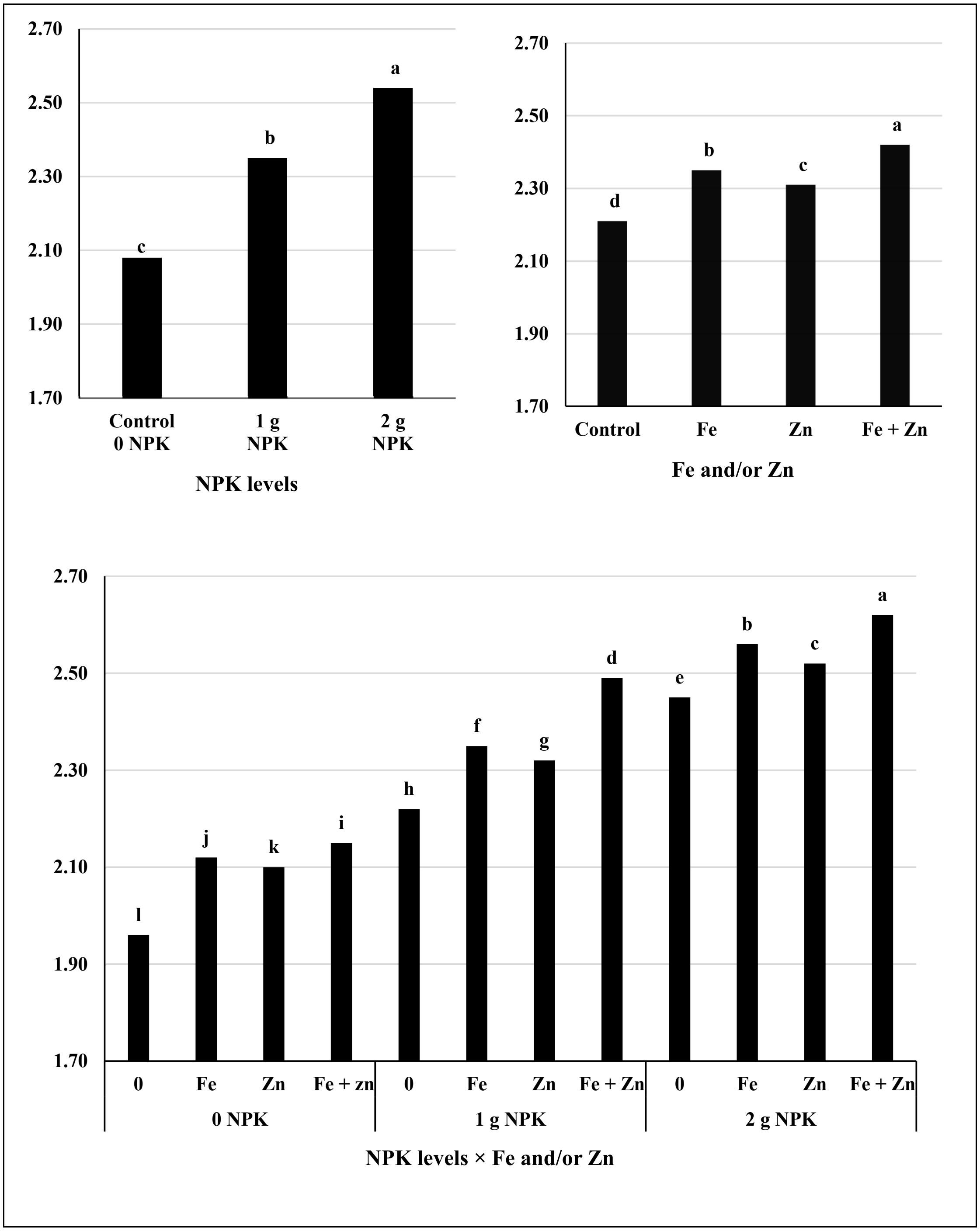

Fig. 1. Effect of NPK, Fe and Ze fertilizers and their interaction on leaves nitrogen content (%) in the second season.

At a 0.05 level of likelihood, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

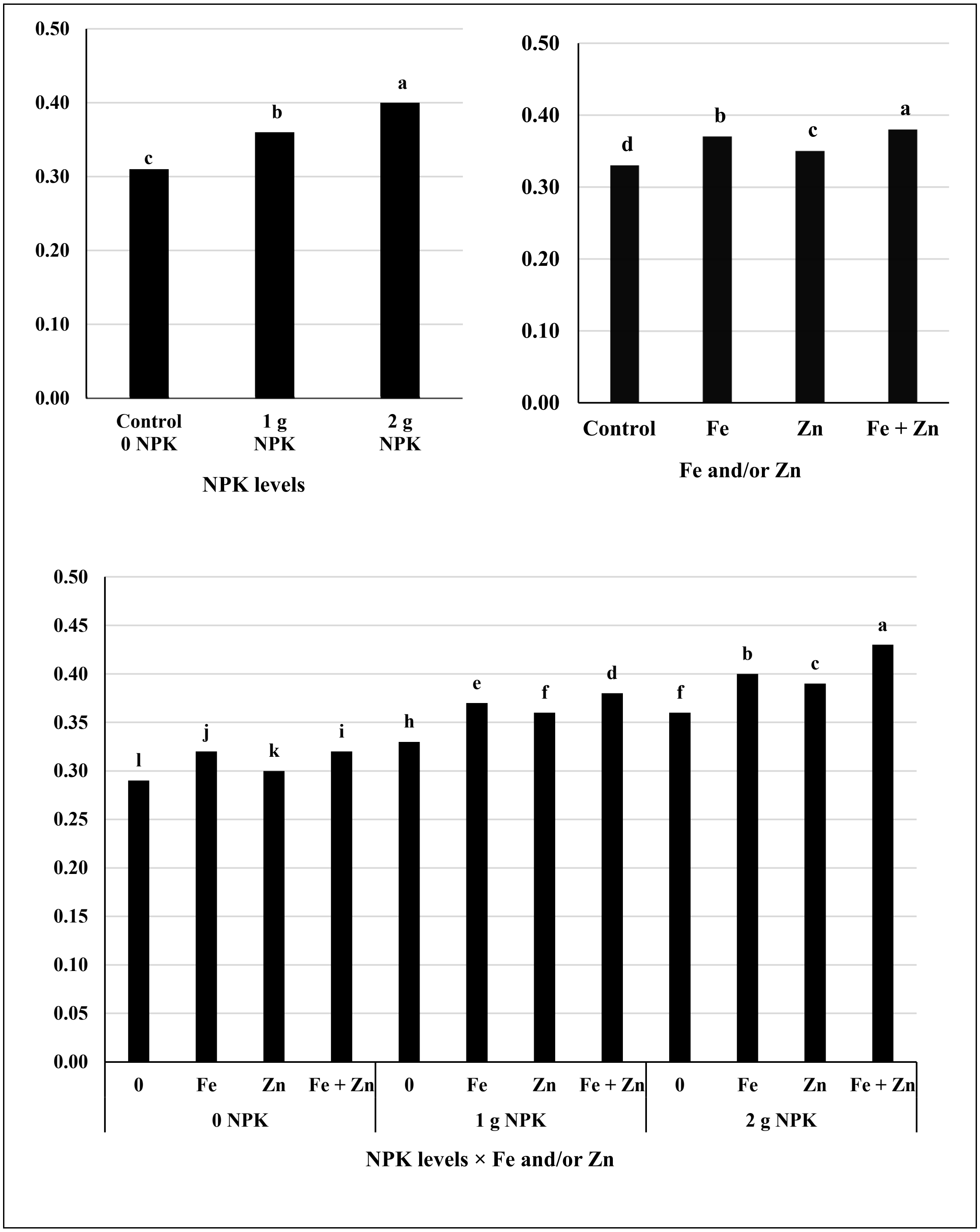

Fig. 2. Effect of NPK, Fe and Ze fertilizers and their interaction on leaves phosphorus content (%) in the second season.

At a 0.05 level of likelihood, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

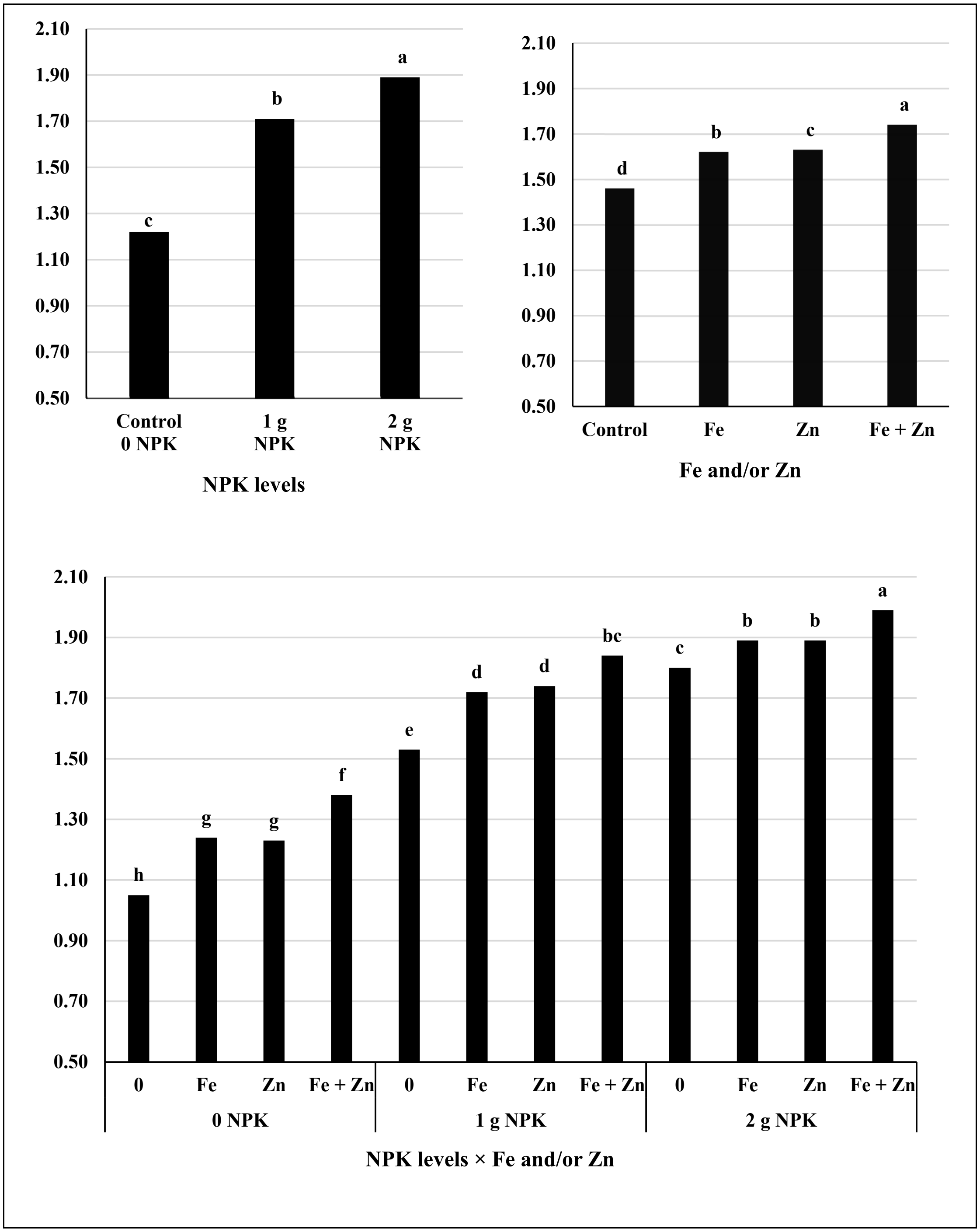

Fig. 3. Effect of NPK, Fe and Ze fertilizers and their interaction on leaves potassium content (%) in the second season.

At a 0.05 level of likelihood, it indicates that the same letter does not differ significantly, according to Duncan's Multiple Range Test (Duncan, 1955)

It was also observed that the addition of zinc and Mn improved the utilization of NPK fertilizers at all levels (Abdou and Badran, 2018).

For the growth of crop plants, nitrogen (N) is necessary. It contributes to several vital functions, including development, expansion of leaf area, and production of biomass yields. Numerous plant compounds, such as amino acids, chlorophyll, nucleic acids, ATP, and phytohormones, incorporate nitrogen as a key element and are crucial for carrying out biological functions related to carbon and nitrogen metabolism, photosynthesis, and protein synthesis (Frink *et al.*, 1999). A lack of nitrogen accessible to plants can impede their growth and progression. Additionally, nitrogen aids in enhancing root development, boosting volume, surface area, diameter, the total length of roots, primary root length, and dry weight, which in turn improve nutrient absorption and balances nutrient levels as well as boosts dry mass production according to Ding *et al.* (2005) and Diaz *et al.* (2006).

Chlorophyll is an essential biochemical element in photosynthesis, playing a vital role in capturing, moving, and transforming light energy. Chlorophyll can be categorized into Chl a, Chl b, carotenoids, among others. The majority of Chl a and all of Chl b are engaged in the processes of light absorption and transportation, while only a small fraction of Chl a takes part in the conversion of light. Numerous studies have demonstrated that an increase in chlorophyll content leads to enhanced photosynthesis (Pons and Westbeek, 2004; Mu *et al*., 2016), The amounts of chlorophyll and nitrogen are positively correlated (Mu and Chen, 2021).

Nitrogen is essential in a variety of ways. It's a part of the molecular architecture of biomolecules like porphyrin, which is present in vital metabolic molecules including chlorophyll pigments and cytochromes, which are necessary for respiration and photosynthesis, as well as phosphorus-activated coenzymes, which are essential for the activity of several enzymes and acids production (Al-Akabi, 2016). By regulating the osmotic pressure of guard cells, potassium regulates the mechanism of stomata opening and closing, which boosts enzyme activity and stabilizes protein structure, which in turn promotes the transport of nutrients through the vessels and Tracheids or increases the efficiency of sugar transport from the leaves to storage sites (Hansch and Mendel, 2009).

Compounds of nitrogen, phosphorus, and potassium help to activate a variety of enzymes and protein production, which has a beneficial impact on the vegetative growth characteristics of the vinca. These findings corroborate Abdollahi *et al*. (2016) study on *Coriandrum sativum* L.

Between 40 and 50% of a plant's dry weight is made up of nitrogen Potassium is essential for regulating photosynthesis and respiration rates and boosting protein synthesis, while phosphorus is crucial for both processes. (Csizinszky, 2000). This may explain the previous results obtained from increased shoot and root growth. This is consistent with the results of Hindawi (2008) on *Plantago arenarea* and Sakr *et al*., (2018) on *Pelargonium graveolens*.

The results obtained indicate that the addition of NPK to the vinca significantly improved the dry and fresh vegetative and root characteristics, and these results are consistent with Vembu *et al.* (2010) on *Catharanthus roseus*.

Iron application was found to enhance plant uptake of zinc, copper, and Mn and increase leaf chlorophyll content, which is reflected in plant productivity. It is recommended to apply chelated iron multiple times to vinca plant. Adding chelated iron, chelated zinc, and urea to the soil was more effective than spraying them on the leaves (Abo-Rady, 1988).

Because iron plays a vital role in photosynthesis, *Catharanthus roseus* plants were treated with various nanoparticles (Fe_2O_3) in different concentrations for 70 days, which led to improved growth parameters, photosynthetic pigments, and enhanced absorption of potassium and phosphorus Askary *et al*. (2016).

Far *et al*. (2015) documented that adding chelated zinc to *Calendula officinalis* L. plants increased plant height and leaf chlorophyll content.

In terms of the interaction between iron and zinc, the treatment of *Brassica oleracea* var. *italica* with 200 mg Fe/l plus 100 mg Zn/l of both chelated and nano-iron and zinc performed better than the other interactions, yielding the highest levels of plant height, leaf area, dry matter, and total chlorophyll in the leaves (Al-Tameemi *et al*., 2019).

CONCLUSION

Based on the results obtained, it can be recommended to spray the Vinca plant once a month with chelated iron (100 ppm) and chelated zinc (100 ppm) alternately with adding NPK fertilizer (19:1919) at a rate of 2 g/pot per month to improve the vegetative specifications (plant height, stem diameter, number of leaves, fresh and dry weight of the vegetative and root system) and improve the floral specifications (number of flowers and fresh and dry weight of flowers).

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تحسين نمو وجودة نبات الونكا بإستخدام التسميد NPK والحديد والزنك المخلبي

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أجريت هذه التجربة لتحسين نمو وجودة الإزهار لنباتات الونكا *Catharanthus roseus* (L.) G.Don. المزروعة في أصص باستخدام التسميد المركب NPK (١٩:١٩:١٩) وعناصر الحديد والزنك المخلبية. أشارت النتائج إلى أن إضافة التسميد NPK بمعدل ١ و٢ جم/أصيص مرة واحدة شهريًا أدى إلى تحسين الخصائص الخضرية (ارتفاع النبات وعدد الفروع وسمك الساق وطول وعدد الجذور والوزن الطازج والجاف للأوراق والجذور) بالإضافة إلى زيادة عدد الأزهار ووزنها الطازج والجاف. كما زاد محتوى الأوراق من الكلوروفيل والكربوهيدرات الكلية والنسب المئوية للنيتروجين والفوسفور والبوتاسيوم في الأوراق مقارنةً بالنباتات التي لم يتم تسميدها (الكنترول)، مع وجود تفوق واضح للتسميد بمعدل ٢ جم/أصيص مقارنة بالتسميد بمعدل ١ جم/أصيص. أدى رش النباتات بالحديد و الزنك إلى تحسين الخصائص الخضرية والزهرية والكيميائية بشكل كبير، حيث أعطى الحديد (١٠٠ جزء في المليون) نتائج أفضل من الزنك (١٠٠ جزء في المليون). بلغت الصفات الخضرية والزهرية أعلى قيمها عند إضافة الحديد و الزنك معًا، مقارنةً بإضافة الحديد و الزنك كلٍّ على حدة. أدى استخدام الحديد و الزنك، سواءً بمفردهما أو معًا، إلى تحسين خصائص النباتات المسمدة بـ NPK (٢ جم/أصيص)، وخصائصها الخضرية والزهرية، بالإضافة إلى محتوى الأوراق من الكربوهيدرات الكلية، والكلوروفيل، والنيتروجين، والفوسفور، والبوتاسيوم. وقد حققت النباتات المسمدة بـ NPK (٢ جم/أصيص) مع الحديد + الزنك بتركيز ١٠٠ جزء في المليون لكل منهما أفضل النتائج. لذلك، يُنصح بتسميد نباتات الونكا *Catharanthus roseus* (L.) G.Don بـ ٢جرام NPK/اصيص شهرياً مع الرش بالحديد + الزنك المخلبي معاً بتركيز ١٠٠ جزء في المليون لكل منهما لتحقيق أعلى الصفات الخضرية والزهرية.