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Effect of Tryptophan and Nano NPK Fertilizer on The Flowring Growth of Two Cultivars of *Narcissus* Spp

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ABSTRACT

The experiment was conducted in the wooden canopy of the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul, during the period (2023-2024). The study aimed to examine the effect of spraying with different concentrations of the amino acid Tryptophan at three levels (0, 100, 200 mg L^{-1}) and the addition of NPK nano-fertilizer at three concentrations (0, 0.75, 1.25 mL L^{-1}), as well as the interaction between them, on the vegetative and floral growth, and the production of bulbs and bulblets of two types of Narcissus tazeta L., namely "Semper Avanti" with white flowers and "Red Devon" with yellow flowers. The experiment employed a randomized complete block design (RCBD) in a factorial arrangement with three replicates, resulting in 18 experimental units per replicate and 7 plants per unit. The results indicated that the yellow cultivar Red Devon *recorded the highest values in some studied traits, such as the time required for flower opening (115.454 days), flower stalk length (38.713 cm), and flower diameter (67.71 mm). Meanwhile, the white cultivar* Semper Avanti *recorded the highest values in the following traits: number of flowers (1.572 flowers $plant^{-1}$) and flower stalk diameter (6.826 mm).*

INTRODUCTION

The genus Narcissus belongs to the family Amaryllidaceae, which is a monocotyledonous family that includes 80 species of Narcissus out of a total of 850 species across 60 genera. Its original habitat is the Mediterranean region, particularly the Iberian Peninsula, southern France, North Africa, and Asia, extending eastward to Greece (Zeybekoglu et al., 2020). Narcissus is known by several names, including "lent lelis" and "chalice flower," referring to the crown shape resembling a cup or chalice. It is also known as "daffodil" (Abu Al-Dhahab, 1992). The Narcissus bulb is a true bulb that originated from hybridization and selection among wild species. The bulbs are generally oval or pear-shaped, with thick leaves that store nutrients.

In suitable conditions, the axils of these sheathing leaves grow into small bulbs (Hartmann et al., 1997).

The plant height ranges between (30-50) cm, with thick, ribbon-like leaves that, in some varieties, appear before flowering, as seen in the local cultivar, while in others, they appear alongside the flowers. The flowering stalk can reach (20-40) cm in length. Narcissus propagates vegetatively through bulbs, which are planted in October, grow in November, and bloom in December. Alternatively, bulbs can be stored until November at 17°C, then at (7-9)°C for (4-5) weeks, before being planted in greenhouses. Seeds produced from hybridization between species and strains may be used to produce new types over (3-4) years, and tissue culture technology can also be used for propagation (Sultan et al., 1992). The name Narcissus is derived from the Greek word Narkain, meaning "to numb" or "to cause dizziness," referring to the fragrant scent of its flowers (Khattab and Wasfi, 1988). Narcissus is a perennial flowering bulb that is typically grown as an annual winter plant. Its significance lies in its use as a beautiful cut flower with cluster-like blossoms, and it is also popular as a potted plant. Narcissus is grown in flower beds and as filler plants among shrubs in well lighting places areas with high humidity, as well as in garden landscaping. Additionally, Narcissus has medicinal uses; oils extracted from its flowers contain alkaloids, some of which are pharmacologically important. For example, the chemical compound galantamine in its flowers is used to treat Alzheimer's disease by inhibiting acetylcholinesterase, thereby alleviating symptoms of this disease, as well as for lung ailments and joint pain relief (Bastida et al., 2011; Al-Snafi, 2020).

With advances in the technology of producing and marketing cut flowers locally and internationally, a tangible agricultural boost can be achieved, creating job opportunities and increasing national income. To enhance flower productivity, it is essential to focus on agricultural practices, employing modern techniques to improve plant growth and increase commercial flower yield. Among these techniques are the use of amino acids and nano fertilizers. Amino acids serve as biostimulants with positive effects on plant growth, reducing stress effects (Matysiak et al., 2020). Nanotechnology, particularly in agriculture, has introduced new methods to address issues by providing innovative solutions, including the potential use of nano-particles in foliar and soil fertilization (Ali and Altaee, 2021).

Materials and Methods

The experiment was conducted in the wooden canopy of the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul, located in Nineveh Governorate at a longitude of 43°7'52″ E, a latitude of 36°20'43″ N, and an elevation of 223 meters above sea level, during the period from 15/10/2023 to 1/6/2024.

Studied Traits:

Number of days until flower opening (days):

The number of days was calculated starting from the planting day until the flowers opened.

Flower stalk diameter (mm):

Measurements were taken using a Vernier caliper, averaging the diameters at the middle of the flower stalk.

Flower stalk length (cm):

Length was measured using a measuring tape from the base of the flower after full bloom to the tip of the flower stalk.

Flower diameter (mm):

The diameter was measured at full bloom using a Vernier caliper, calculating the distance between the farthest points of the petal whorls.

Number of flowers (flowers plant^{-1}):

Flowers were counted on the floral spike for each plant, and the average was calculated.

Results and Discussion

Number of Days until Flower Opening

The statistical analysis results in Table (1) showed that the yellow cultivar Red Devon required fewer days for flower opening and significantly outperformed the white cultivar Sempre Avanti, with flowers blooming after 115.454 days compared to 137.763 days for the white cultivar. Spraying with the amino acid Tryptophan at a concentration of 200 mg L^{-1} significantly reduced the days required for flower opening, recording 123.978 days compared to 129.886 days in the control treatment. The results also indicated that adding nano NPK fertilizer at a concentration of 1.25 mL L^{-1} significantly reduced the number of days required for flower opening to 124.978 days compared to 128.516 days in untreated plants.

From the interaction results between the cultivar and the amino acid Tryptophan, it was found that the yellow cultivar treated with a concentration of 200 mg L^{-1} required significantly fewer days, blooming after 112.812 days from planting, compared to 141.220 days for the control treatment of the white cultivar. Significant differences were recorded among the various interactions, with the yellow cultivar requiring the shortest duration for flower opening when treated with nano NPK fertilizer at 1.25 mL L^{-1}, recording 113.812 days compared to 139.775 days for untreated white cultivar plants. Additionally, the interaction between Tryptophan and nano NPK fertilizer revealed that spraying plants with Tryptophan at 200 mg L^{-1} combined with nano NPK fertilizer at 1.25 mL L^{-1} resulted in a significant reduction in the number of days required for flowering, reaching 121.720 days compared to 131.386 days in the control treatment.

In conclusion, it is evident that the yellow cultivar Red Devon treated with 200 mg L^{-1} of Tryptophan and nano NPK fertilizer at 1.25 mL L^{-1} recorded the lowest number of days required for flower opening, at 110.330 days compared to 143.110 days for the control treatment of the white cultivar Sempre Avanti.

Table(1): Effect of the amino acid Tryptophan, nano NPK fertilizer, and their interactions on the number of days until flower opening (days) for two Narcissus spp. Cultivars

Cultivars	Nano NPK fertilizer ML L^{-1}	Amino acid tryptophan mg L^{-1} 0	100	200	Cultivar interaction X Nano NPK fertilizer	Cultivar response
Red Devon Yellow	0	119.663 h	116.663 j	115.443 k	117.25 d	115.454 b
	0.75	118.553 i	114.663 k l	112.663 m	115.293 e-	
	1.25	117.443 j	113.663 l m	110.330 o	113.812 f	
Sempre Avanti White	0	143.110 a	138.553 d	137.663 d	139.775 a	137.763 a
	0.75	140.886 b	136.553 e-	134.663 f	137.367 b	
	1.25	139.663 c	135.663 e -f	133.110 g	136.145 c	
Cultivar interaction X Amino acid tryptophan	Yellow	118.553 d	114.996 e-	112.812 f	Effect of ano NPK fertilizer	
	White	141.220 a	136.923 b	135.145 c		
Amino acid tryptophan interaction X Nano NPK fertilizer	0	131.386 a	127.608 d	126.553 e-	128.516 a	
	0.75	129.720 b	125.608 f	123.663 h	126.330 b	
	1.25	128.553 c	124.663 g	121.720 i	124.978 c	
Effect of Amino acid tryptophan		129.886 a	125.960 b	123.978 c		

*Values with similar letters show no significant difference per Duncan's test at 5% probability.

The diameter of the floral stalk (mm):

The results of the statistical analysis in Table (2) showed that the white cultivar Sempre Avanti significantly outperformed in the floral stalk diameter trait compared to the yellow cultivar Red Devon, as the superior cultivar recorded 6.826 mm while the other cultivar recorded 6.442 mm. Treatment with spraying the amino acid tryptophan at a concentration of 200 mg L^{-1} resulted in a significant increase in this trait, reaching 7.945 mm compared to 5.035 mm in the control treatment. Additionally, the results indicate that the addition of NPK nano fertilizer at a concentration of 1.25 ml L^{-1} led to a significant increase in the floral stalk diameter, which recorded 7.596 mm compared to 5.494 mm in the control plants.

From observing the results of the two-factor interaction between the cultivar and the amino acid tryptophan, it was found that the plants of the white cultivar at a concentration of 200 mg L^{-1} significantly outperformed and recorded 8.201 mm, while the control treatment of the other cultivar recorded 4.845 mm. Significant differences were observed between the values of the various interactions, where the plants of the white cultivar recorded the highest value when treated with NPK nano fertilizer at a concentration of 1.25 ml L^{-1}, reaching 0.7857 cm compared to 5.210 mm for the untreated yellow cultivar plants.

The results of the interaction between the amino acid tryptophan and NPK nano fertilizer indicate that spraying plants with tryptophan at a concentration of 200 mg L^{-1} combined with the addition of NPK nano fertilizer at a concentration of 1.25 ml L^{-1} resulted in the highest value of 9.150 mm, which significantly outperformed the control treatment that reached 4.075 mm.

In conclusion, it is clear that the plants of the white cultivar Sempre Avanti, treated with a concentration of 200 mg L^{-1} of tryptophan combined with NPK nano fertilizer at a

concentration of 1.25 ml L^{-1}, achieved the highest value of 9.933 mm compared to 3.534 mm for the untreated plants of the yellow cultivar Red Devon.

Table (2): The effect of the amino acid tryptophan, nano NPK fertilizer, and their interactions on the flower stalk diameter (mm) for two varieties of Narcissus plants Narcissus spp.

Cultivars	Nano NPK fertilizer ML L-1	tryptophan Amino acid mg L^{-1} 0	100	200	Cultivar interaction X Nano NPK fertilizer	Cultivar response
Red Devon Yellow	0	o 3.534	l k j 5.416	g f 6.680	e 5.210	b 6.442
	0.75	m l 5.026	e d 7.296	c b 8.023	c 6.782	
	1.25	j i h 5.976	-e d 7.660c	b 8.366	b 7.334	
Sempre Avanti White	0	m 4.616	i h g 6.188	fgh 6.533	d 5.779	a 6.826
	0.75	l k 5.290	f e 7.096	c b 8.136	c 6.841	
	1.25	k j i 5.770	d c b 7.870	a 9.933	a 7.857	
Cultivar interaction X Amino acid tryptophan	Yellow	e 4.845	c 6.791	b 7.690		Effect of Fertilizer nano npk
	White	d 5.225	7.051 c	a 8.201		
Amino acid tryptophan interaction X Nano NPK fertilizer	0	g 4.075	e 5.802	d 6.606		c 5.494
	0.75	f 5.158	c 7.196	b 8.080		b 6.811
	1.25	e 5.873	b 7.765	a 9.150		a 7.596
Amino acid	Effect of tryptophan	5.035 c	6.921 b	a 7.945		

*Values with similar letters show no significant difference per Duncan's test at 5% probability.

Flower stalk length (cm):

The results of the statistical analysis in Table (3) showed significant differences between the two varieties in the flower stalk length trait. The yellow variety (Red Devon) recorded the highest value of 38.713 cm, while the white variety (Sempre Avanti) gave the lowest value of 28.664 cm. Spraying with the amino acid tryptophan at a concentration of 200 mg L^{-1} resulted in the highest significant increase in this trait, reaching 39.367 cm compared to 26.720 cm for the control treatment.

The same table indicates that the addition of nano NPK fertilizer at a concentration of 1.25 ml L^{-1} significantly influenced the flower stalk length, increasing it to 37.163 cm compared to 29.405 cm in the control plants.

The results of the two-factor interaction between the variety and tryptophan showed the highest significant values for flower stalk length at a concentration of 200 mg L^{-1} for the yellow variety, reaching 45.330 cm. The lowest value of 22.997 cm was recorded for the untreated white variety.

The results also revealed that the interaction between the variety and nano NPK fertilizer recorded the highest flower stalk length of 42.774 cm for the yellow variety treated with 1.25 ml L^{-1}, while it decreased to 25.072 cm for the untreated white variety.

The results of the interaction between tryptophan spraying and nano fertilizer showed the highest values of 44.383 cm when sprayed with tryptophan at 200 mg L^{-1} and nano fertilizer at 1.25 ml L^{-1}, compared to 23.941 cm for the control plants.

Finally, the three-way interaction of the study factors revealed that spraying the yellow variety (Red Devon) with tryptophan at 200 mg L^{-1} combined with nano fertilizer at 1.25 ml L^{-1} gave the highest significant value of 50.883 cm, while this value decreased to 21.220 cm for the untreated white variety

(Sempre Avanti).

Table (3): The effect of the amino acid tryptophan, nano NPK fertilizer, and their interactions on the flower stalk length (cm) for two varieties of Narcissus plants Narcissus spp.

Cultivars	Nano NPK fertilizer ML L^{-1}	Amino acid tryptophan mg L^{-1} 0	100	200	Cultivar interaction X Nano NPK fertilizer	Cultivar response
Red Devon Yellow	0	26.663 k	36.110 f	38.443 e-	33.738 c	
	0.75	31.220 0 i	40.996 d	46.663 b	39.626 b	38.713 a
	1.25	33.443 g	43.996 c	50.883 a	42.774 a	
Sempre Avanti White	0	21.220 o	26.110 k	27.886j	25.072 f	
	0.75	23.330 m	30.330 i	34.443 g	29.367 e	28.664 b
	1.25	24.443 l	32.330 h	37.883 e	31.552 d	
Cultivar interaction X Amino acid tryptophan	Yellow	30.442 d	40.367 b	45.330 a	Effect of Nano NPK fertilizer	
	White	22.997 f	29.590 e	33.404 c		
Amino acid tryptophan interaction	0	23.941 i	31.110 f	33.165 e	29.405 c	
	0.75	27.275 h	35.663 d	40.553 b	34.497 b	

*Values with similar letters show no significant difference per Duncan's test at 5% probability.

Flower Diameter (mm):

The statistical analysis results in Table (4) indicate significant differences in flower diameter between the yellow and white varieties. The yellow variety (Red Devon) outperformed with a value of 67.718 mm, while the white variety (Sempre Avanti) recorded 60.760 mm. Spraying with the amino acid tryptophan at a concentration of 200 mg L^{-1} caused significant differences in flower diameter, reaching 72.388 mm for the yellow variety compared to 54.280 mm for the control plants.

The same table shows that adding nano NPK fertilizer at a concentration of 1.25 ml L^{-1} resulted in a significant increase in flower diameter, recording 68.920 mm compared to 58.168 mm for the control plants.

Regarding the two-factor interaction between the variety and amino acid at a concentration of 200 mg L^{-1}, significant differences were observed in flower diameter for the yellow variety,

which recorded 75.856 mm compared to 51.495 mm for the control treatment of the white variety.

A significant difference in flower diameter was also noted between the interaction of the variety and nano NPK fertilizer, where the yellow variety treated with 1.25 ml L^{-1} recorded 72.611 mm, while the untreated white variety recorded 54.587 mm.

The interaction between the amino acid tryptophan and nano NPK fertilizer showed significant superiority at concentrations of 200 mg L^{-1} and 1.25 ml L^{-1}, with the highest value being 78.910 mm compared to 50.278 mm for the control treatment.

Overall, the three-way interaction of the study factors revealed that treating the yellow variety with tryptophan at a concentration of 200 mg L^{-1} combined with nano NPK fertilizer at 1.25 ml L^{-1} recorded the highest significant value in flower diameter for the yellow variety, reaching 81.696 mm, while it decreased to the lowest level of 47.933 mm for untreated white variety (Sempre Avanti) plants.

Table (4): The effect of the amino acid tryptophan, nano NPK fertilizer, and their interactions on the flower diameter (mm) for two varieties of Narcissus plants Narcissus spp.

Cultivars	Nano NPK fertilizer ML L-1	Amino acid tryptophan mg L^{-1}			Cultivar interaction X Nano NPK fertilizer	Cultivar response
		0	100	200		
Red Devon Yellow	0	52.623 l	64.616 g	68.010e-	61.750 d	67.718A
	0.75	57.576 k	70.946 d	77.863 b	68.795 b	
	1.25	60.996 i	75.139 c	81.696 a	72.611 a	
Sempre Avanti White	0	47.933 m	56.366 k	59.463 j	54.587 e-	60.760 B
	0.75	53.360 l	62.853h	71.173 d	62.462 d	
	1.25	53.193 l	66.373 f	76.123 c	65.230 c	
Cultivar interaction X Amino acid tryptophan	Yellow	57.065 e-	70.234 b	75.856 a	Effect of Nano NPK fertilizer	
	White	51.495 f	61.864 d	68.920 c		
Amino acid tryptophan interaction X Nano NPK fertilizer	0	50.278 i	60.491 f	63.736 e-	58.168 c	
	0.75	55.468 h	66.900 d	74.518 b	65.628 b	
	1.25	57.095 g	70.756 c	78.910 a	68.920 a	
Effect of Amino acid tryptophan		54.280 c	66.049 b	72.388 a		

*Values with similar letters show no significant difference per Duncan's test at 5% probability.

Number of flowers (flowers plant^{-1})

The results of the statistical analysis in Table (5) showed that the white variety *Sempre Avanti* significantly outperformed in the number of flowers (flowers per plant) compared to the yellow variety *Red Devon*. The white variety recorded a higher number of flowers, reaching 1.572 flowers per plant, compared to the yellow variety, which recorded 1.381 flowers per plant. The treatment with the amino acid tryptophan at a concentration of 200 mg L^{-1} had a significant effect in increasing the number of flowers, with treated plants recording 1.750 flowers per plant compared to the control treatment, which recorded 1.226 flowers per plant. The results also showed that the addition of NPK nano-fertilizer at a concentration of 1.25 mL L^{-1} significantly

increased the number of flowers, as plants treated with nano-fertilizer recorded 1.706 flowers per plant compared to the control treatment, which recorded 1.246 flowers per plant.

Regarding the interaction between variety and tryptophan, the results demonstrated a significant superiority of the white variety at a concentration of 200 mg L^{-1} of tryptophan, where treated plants recorded 1.937 flowers per plant compared to the yellow variety, which recorded 1.182 flowers per plant. Additionally, the interaction between variety and NPK nano-fertilizer showed significant superiority for the white variety treated with fertilizer at a concentration of 1.25 mL L^{-1}, where the number of flowers reached 1.861 flowers per plant compared to the yellow variety, which recorded 1.167 flowers per plant. Furthermore, the interaction between tryptophan and nano-fertilizer resulted in a significant increase in the number of flowers when plants were sprayed with tryptophan at a concentration of 200 mg L^{-1} combined with the addition of NPK nano-fertilizer at a concentration of 1.25 mL L^{-1}, reaching 2.207 flowers per plant compared to the control treatment, which recorded 1.109 flowers per plant.

In general, it is evident that the plants of the white variety *Sempre Avanti* treated with the combination of tryptophan at a concentration of 200 mg L^{-1} and NPK nano-fertilizer at a concentration of 1.25 mL L^{-1} recorded the highest number of flowers, reaching 2.598 flowers per plant, compared to the yellow variety *Red Devon*, which recorded 1.000 flowers per plant in untreated plants.

Table (5): The effect of the amino acid tryptophan, NPK nano-fertilizer, and their interactions on the number of flowers (flowers $plant^{-1}$) for two varieties of Narcissus spp. plants.

Cultivars	Nano NPK fertilizer ML L^{-1}	tryptophan Amino acid mg L^{-1} 0	100	200	Cultivar interaction X Nano NPK fertilizer	Cultivar response
Red Devon Yellow	0	1.000 h	1.228 g	1.275 g	1.167 d	1.381 B
	0.75	1.254 g	1.425 e f g	1.597 c d e	1.425 b c	
	1.25	1.292 g	1.544 d e f	1.817 b	1.551 b	
Sempre Avanti White	0	1.218 g	1.337 f g	1.422 e f g	1.325 c	1.572 A
	0.75	1.265 g	1.536 d e f	1.792 b c	1.531 b	
	1.25	1.330 f g	1.655 b c d	2.598 a	1.861 a	
Cultivar interaction X Amino acid tryptophan	Yellow	1.182 d	1.399 c	1.563 b	Effect of fertilizer Nano NPK	
	White	1.271 d	1.509 b c	1.937 a		
Amino acid tryptophan interaction X Nano NPK fertilizer	0	1.109 f	1.282 e	1.348 d e	1.246 c	
	0.75	1.259 e	1.480 c d	1.694 b	1.478 b	
	1.25	1.311 e	1.599 b c	2.207a	1.706 a	
Effect of Amino acid tryptophan		1.226 c	1.454 b	1.750a		

*Values with similar letters show no significant difference per Duncan's test at 5% probability. The varieties differed in flowering growth traits. The yellow variety, Red Devon, outperformed in the traits of the number of days required for flower opening, flower stalk length, and flower diameter, as shown in Tables (1, 2, 3, 4). Meanwhile, the white variety, Sempre Avanti, excelled in traits like flower stalk diameter and number of flowers, as indicated in Tables (2, 5). The results also showed that the yellow variety significantly outperformed in all studied traits. This may be due to genetic differences between the varieties, which in turn control their

performance. These genetic differences might exhibit further genetic variation due to the surrounding environmental conditions. This has been mentioned in several studies (Khan et al., 2012), and it aligns with the findings of Zeybekoglu (2020) and Abdulazeez et al. (2020). Moreover, the flowering growth traits shown in Tables (1, 5), represented by the number of days to flower opening and the number of flowers, could be attributed to the environmental conditions, such as temperature and relative humidity, which were sufficient to enhance the efficiency of photosynthesis. This, in turn, increased the activity of vital processes and the accumulation of dry matter, which stimulated the formation of good vegetative growth in the plant, reflected in plant height, leaf length, number of leaves, dry weight, and leaf area. This positively affected the improvement of flowering growth traits, as found by Terry et al. (2021) regarding the effect of day temperatures (10 - 15 °C) and night temperatures (3 - 10 °C) required for flowering of Narcissus plants.

The results of flowering growth traits showed that treatment with the amino acid tryptophan at a concentration of 200 mg L^{-1} advanced and outperformed the number of days to flower opening (Table 1). This could be due to the positive role of tryptophan in synthesizing IAA and other essential organic compounds like DNN, RNA (Goss, 1973), which stimulates early flowering and development. Tryptophan at a concentration of 200 mg L^{-1} also had a significant effect on flower stalk diameter, length, and the number of flowers, which can be explained by the increase in the number of leaves, leaf area, and total chlorophyll content, as well as carbohydrates, which provided the necessary nutrients for flower growth and improved its traits. Furthermore, tryptophan encourages the growth of Narcissus plants by stimulating cell division and increasing enzyme activity, thereby increasing flower stalk length and diameter. This is consistent with the findings of Abd-Elkader et al. (2020), Mustafa and Al-Saad (2020). Based on this, the vegetative growth of Narcissus also encouraged better flower quality because tryptophan increases the plant's resistance to environmental stresses, such as temperature fluctuations, balancing hormone levels, and physiological processes (Rao et al., 2012). Amino acids help protect cells and tissues from damage and delay flower senescence (Naglaa et al., 2001).

Observing the flowering growth results, the data in Table (1) show that the treatment with nano NPK fertilizer accelerated the number of days required for flower opening. This is attributed to the crucial role of nitrogen in creating a balance between synthesized carbohydrates and absorbed nitrogen, which stimulates the emergence and development of flower buds (Abd-El-wahed, 2004). Additionally, potassium plays a role in transporting photosynthetic products from the leaves to the flower buds. Nano fertilizers, due to their small particle size, interact with plant parts, causing various morphological and physiological changes (Khodakovskaya et al., 2012). These results align with those of Asgari et al. (2014). The data in Tables (5, 4, 3, 2, 1) regarding flower stalk diameter, length, flower diameter, and number of flowers indicate a significant effect of nano NPK fertilizer. This is due to the presence of nitrogen and phosphorus in the fertilizer, which stimulates the production of auxin, increases gibberellin activity in plant tissues, and enhances cell division and elongation (Biram, 2013). Nitrogen and phosphorus also help provide better nutrients synthesized inside the leaves, like carbohydrates, through their effective role in photosynthesis, and they are important in activating enzymes and building proteins (Al-Maadi et al., 2013). These findings align with what Ai-hashemi and Zohoor (2024) mentioned. Additionally, the increase in the number of flowers (Table 5) can be attributed to the role of nitrogen in the synthesis of tryptophan, a precursor to auxin (IAA), which stimulates the growth of flower buds and increases the number of flowers (Gamal, 2004). Furthermore, the role of nitrogen and phosphorus in producing energy-rich compounds increases the amount of nutrients in the plant, which, in turn, encourages growth and increases the number of flowers

(Adams and Winsor, 1979). Additionally, the role of potassium, when applied properly, improves water and nutrient transport throughout the plant, enhancing floral inflorescences (Singh et al., 2013).

Overall, the superiority of flowering growth traits is attributed to the fact that fertilization treatments provided an adequate amount of essential nutrients necessary for the development of high-quality vegetative growth. Nano NPK fertilizer improved nutrient levels, leading to better photosynthesis and carbohydrate production, which helps in optimal partitioning of nutrients from the source to the sink. These results are consistent with Al-Taher (2016).

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