Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq

RESEARCH ARTICLE
https://doi.org. 10.58928/ku26.17302

Efficacy of GA3 Primer and Foliar Application of Nano-NPK Fertilizer on Growth, Flowering, Bulbs and Bulblets Yield of Four *Narcissus* Cultivars

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Received10/09/2025 **Revised: 22/02/2026** **Accepted: 11/08/2026** **Published: 01/09/2026**

ABSTRACT

This study was designed to evaluate the effectiveness of gibberellin (GA3) priming and nano-NPK fertilizer application on the growth, flowering, and bulb production of four Narcissus cultivars. The experiment was conducted in Pirmam, Erbil Province, from October 15, 2024, to May 22, 2025. Treatments included four cultivars Little Princess, Golden Delicious, The Bride, and the local Aqra were used, bulb soaking with GA3 at concentrations of 0 and 100 mg L^{-1} for 24 hours, combined with foliar spraying of nano-NPK fertilizer at concentrations of 0, 50, and 100 mg L^{-1}. Plants were grown in PVC pots (20 cm diameter) filled with a 1:1 mixture of loamy soil and peat moss. The experimental design comprised 24 treatment combinations with three replicates each, and each replicate consisted of a single bulb planted per pot.

Our findings demonstrated that the cultivars had a significant effect the highest values of 48.99 cm, 5.97 g and 40.68 cm for plant height, leaves dry weight and flower stalk lenghth, respectively, were recorded for Golden delicious cultivar, and the highest average of 17.83 days and 2.06 were recorded for flower coordination date and bulbest produce, respectively, of Local Aqre cultivar. Moreover, GA_3 at 100 mg L^{-1} resulted in a significant increase in plant height, chlorophyll, flower coordination date, bulb volume and bulbest produce 48.99 cm, 64.83, 16.81 days, 45.27 cm3 and 1.69, respectively. Moreover, nano-NPK fertilizer at 100 mg L^{-1} resulted in a significant increase in leaf area, flower coordination date, bulb volume and bulbest produce 73.27 cm2, 64.83, 16.71 days, 46.81 cm3 and 1.88, respectively.

The interaction among Narcissus cultivars, GA_3 priming concentrations, and nano-NPK fertilizer levels exerted significant effects on flowering and yield-related traits, including leaf area, flowering date, flowering synchronization, flower stalk length, bulb volume, and bulblet number. For leaf area, the highest values were recorded in The Bride cultivar, reaching 88.01 cm^2 and 87.93 cm^2 under treatments of 0 and 100 $mg \cdot L^{-1}$ GA_3 combined with 100 $mg \cdot L^{-1}$ nano-fertilizer, respectively. The earliest flowering was observed in the local Aqra cultivar, particularly under 100 $mg \cdot L^{-1}$ GA_3 with 100 $mg \cdot L^{-1}$ nano-fertilizer, achieving a minimum of 137.33 days to flowering. Flowering coordination date was markedly enhanced in The Bride cultivar with higher GA_3 and nano-fertilizer doses, extending up to 20.00 days. Maximum flower stalk length (44.33 cm) was obtained in Golden Delicious when treated with 100 $mg \cdot L^{-1}$ GA_3 and 100 $mg \cdot L^{-1}$ nano-fertilizer. Similarly, bulb volume peaked at 55.00 cm^3 in Golden Delicious under the same treatment conditions. Bulblet production increased significantly with combined treatments, with the local Aqra cultivar producing up to 2.33 bulblets under 100 $mg \cdot L^{-1}$ GA_3 and 50–100 $mg \cdot L^{-1}$ nano-fertilizer.

***Keywords*:** Efficacy, GA_3 primer ,Nano,fertilizer spray , Growth ,Flowering, bulbs and bulblets yield, Narcissus cultivars.

INTRODUCTION

Narcissus, a bulbous genus within the Amaryllidaceae family, is widely recognized as the daffodil and represents a significant component of Mediterranean flora. It is one of the most important commercial bulb crops in global floriculture, cultivated extensively for cut flowers and potted plants. Over the past 150 years, breeding programs have produced more than 30,000 registered cultivars, highlighting the genus's remarkable genetic diversity [1]. Native to

Asia, Europe, and the Mediterranean, Narcissus is among the most prevalent winter bulbs in Iraq [2,3].
Narcissus is classified as a true bulb, originating through hybridization and selection among wild species. The bulbs are typically oval to pear-shaped and consist of fleshy, modified leaves that function as nutrient storage organs. Under favorable environmental conditions, the axils of these sheathing leaves give rise to small bulblets, contributing to the plant's capacity for vegetative propagation [4].
Within the Amaryllidaceae family, which comprises approximately 85 genera and 1,100 species worldwide, Narcissus occupies a prominent position as a winter-blooming ornamental plant of economic importance. Its fragrant, long-stemmed flowers are cultivated in beds, borders, pathways, and containers, enhancing both public and private landscapes [5,6]. Furthermore, alkaloids such as galantamine contribute to its value in pharmaceutical and cosmetic industries [7].
Most flowering bulb species require specific pre-treatments to stimulate rapid growth and successful development. Among these horticultural practices, the application of plant growth regulators has emerged as a central focus of applied research, given their essential role in enhancing flowering and overall plant productivity [8]. Gibberellic acid (GA_3), in particular, plays a critical role by promoting cell elongation and initiating floral induction through the redistribution of metabolic resources toward developing inflorescences [9].
Several approaches have been developed for the application of growth regulators to ornamental bulbs; however, the most widely adopted methods involve either foliar spraying of plants or soaking bulbs for a specified duration prior to planting. While soaking plant material in plant growth regulators (PGRs) has been shown to be effective in enhancing growth and flowering performance, its use at a commercial scale remains relatively uncommon [1].
The concentration of plant growth regulators (PGRs) and the duration of immersion are critical determinants of the effectiveness of bulb soaking treatments [10]. Lower concentrations of PGRs are particularly advantageous for large-scale and cost-effective application; however, extended soaking periods are often required to achieve comparable efficacy, as prolonged immersion enhances chemical absorption and may accelerate physiological responses. Several techniques for PGR application have been documented, with pre-planting treatments remaining the most widely employed approach in horticultural practice [11].
Gibberellins are essential plant growth regulators that influence multiple physiological and developmental processes, including seed germination, dormancy release, stem elongation, flowering induction, enzyme activation, sexual differentiation, and the senescence of leaves and fruits. Numerous studies have demonstrated their effectiveness in enhancing plant height, flower number, leaf area, chlorophyll content, productivity, and the overall quality of ornamental crops, as well as extending postharvest vase life. Gibberellic acid (GA_3), in particular, has been shown to stimulate cell division and expansion, thereby facilitating floral initiation and development [12,13]. Previous research highlights its pivotal role in improving the production potential of diverse flowering species. GA_3 also interacts with other compounds to promote the synthesis of florigen, a key hormone responsible for floral induction [14]. For example, soaking *Gladiolus* corms in GA_3 at 100 ppm significantly increased plant height (105 cm compared to 97.6 cm in the control), along with notable improvements in flowering percentage, spike length, and corm weight [15]. Similarly, subsequent studies confirmed that GA_3 treatments enhance germination rates, bud number per corm, corm size, and total corm production in *Gladiolus* [16].
To enhance flower productivity, it is essential to adopt advanced agricultural practices that utilize modern techniques aimed at improving plant growth and increasing commercial crops. Nanotechnology has introduced innovative methods in this regard, particularly through the application of Nano-fertilizers. The use of nanoparticles in foliar and soil fertilization is a promising solution to the existing challenges in crop production [17].
Nano-fertilizers, due to their nanoscale particle size, enable efficient soil and foliar absorption with minimal residue. Its properties contribute to the slow-release of substances in support of plant metabolism, making it an environmentally sustainable alternative to traditional inorganic fertilizers. It can improve growth, flowering, productivity, and product quality in both agriculture and horticulture [18]; [19]. Nanoparticles fertilizers (1 and 100 nm) with unique physical and chemical properties, such as a high surface-to-volume ratio and a particle size smaller than the pore size of plant leaves, may lead to more effective delivery of nutrients and allow them to reach the plant surfaces and transport channels [20]; [21]. Although the plant growth regulator GA3 and nano-NPK fertilizers have been proven effective, the available studies on their impact on bulbs plant growth and flowering are limited. Therefore, this study aimed to investigating the response of Narcissus cultivars to soaking bulbs with AG3 and foliar spraying with nano-NPK fertilizers in terms of the efficiency of PGRs and nutrients and their effect on growth, flowering, bulb production, and bulblet yield in four Narcissus cultivars.

Material and Methods

Site and date of the study:

This study was conducted in Pirmam, Erbil Governorate, from October 15, 2024, to May 22, 2025. The experimental site is located in the northeastern region of Iraq at an elevation of 1,180 m above sea level, within the coordinates 36.17–36.32° N latitude and 44.00–44.24° E longitude in the city center.

To study the effect of GA_3 soaking and nano-NPK (20:20:20) fertilizer spraying on growth, flowering, bulb and bulblets yield in four Narcissus cultivars includes: (Little princess, Golden delicious, The bride, and local Aqra), bulbs were soaked in GA_3 solutions at concentrations of (0 and 100 mg L^{-1}) for 24 hours. Different concentrations of nano-NPK fertilizer (0, 50 and 100 mg L^{-1}) treated by using foliar spray each 15 days after emergence of two real leaves. Spraying was conducted in the early morning using a hand sprayer until leaves were thoroughly wetted. Plants were grown in PVC pots (20 cm diameter) filled with a 1:1 mixture of loamy soil and peat moss.

Treatments and design:

The experimental treatments were arranged in a factorial randomized complete block design (RCBD) comprising three factors with three replicates. Each replicate was represented by a single bulb planted in a 20 cm pot, resulting in a total of 72 bulbs (24 treatments × 3 replicates × 1 pot × 1 bulb = 72 bulbs, with 24 bulbs allocated to each cultivar). Data analysis was performed using the SAS statistical software program, and treatment means were compared using Duncan's multiple range test at the 5% probability level to determine significant differences among the studied variables [22].

Parameters studied in this experiment were sprouting days, plant height(cm), leaf area (cm^2), dry weight of leaves (g), total chlorophyll content in leaves (SPAD), flowering time (days), flower decoration date (days), length of flower stalk (cm), bulbs volume (cm^3), and number of bulblets.

Table: Some of the physical and chemical characteristics of the used medium.

PH	EC ds.m^{-1}	N (%)	P (ppm)	K (ppm)	O.M (%)
7.2	0.23	0.21	14.8	126	1.41

Soil texture	Soil texture		
	Clay (%)	Silt (%)	Sand (%)
Sandy clay loam	19.3	26.4	54.3

Results and Discussion

3.1. Effect of GA_3 primer and nano-NPK fertilizer concentrations on some growth characteristics of Narcissus cultivars plant.

The results shown in Table (1) indicate that both cultivar variation and the application of GA_3 priming and nano-NPK fertilizer exerted significant effects on the growth and early flowering traits of *Narcissus* plants.

Sprouting date showed the most pronounced variation among cultivars, with Local Aqre sprouting extremely early (17.67 days) compared to Little princess (54.89 days), Golden delicious (49.11 days), and The bride (45.72 days). Early sprouting in Local Aqre likely reflects its genetic adaptation to the local environment, in agreement with [23], who noted that cultivar-specific physiological dormancy levels strongly influence sprouting time. GA_3 treatment (100 mg L^{-1}) reduced sprouting time compared to the control, consistent with the role of gibberellins in breaking bulb dormancy and stimulating cell elongation [24]. Similarly, nano-fertilizer applications maintained early sprouting, potentially due to improved nutrient uptake efficiency and enhanced metabolic activation [25].

Plant height was greatest in Golden Delicious (48.99 cm), followed by The Bride (47.69 cm), whereas Little Princess and local Aqra exhibited comparatively shorter plants. Application of GA_3 at 100 mg L^{-1} significantly increased plant height relative to the control, corroborating previous findings that gibberellins stimulate stem elongation through cell wall loosening and enhanced cell division [26]. Similarly, nano-NPK fertilizer applied at 50–100 mg L^{-1} improved plant height, suggesting a synergistic interaction between macronutrient availability and hormonal regulation.

Leaf area was significantly reduced in Local Aqre (45.36 cm^2) compared to other cultivars, which all showed larger leaf expansion (>65 cm^2). Nano-fertilizer at 100 mg L^{-1} resulted in the highest leaf area (73.27 cm^2), supporting reports by [27] that micronutrients at nano-scale improve chloroplast development and photosynthetic efficiency.

Leaves dry weight was highest in Golden delicious (5.97 g) and lowest in Local Aqre (3.54 g). The GA_3 and nano-fertilizer generally increased biomass accumulation, reflecting improved source–sink relationships and photosynthetic allocation to vegetative organs, as observed in other bulbous ornamentals [28].
Chlorophyll content (SPAD values) was relatively high across all cultivars, with Golden delicious and The bride showing the highest readings (>64 SPAD). GA_3 application increased chlorophyll content, consistent with reports that gibberellins can enhance chloroplast development and delay leaf senescence [29]. Nano-fertilizer at 100 mg L^{-1} yielded the highest chlorophyll readings (65.82 SPAD), 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 [30].
Overall, Golden delicious demonstrated superior vegetative performance in plant height, leaf area, and chlorophyll content, while Local Aqre excelled in earliness of sprouting. The synergistic effects of GA_3 and nano-fertilizer suggest that their combined application can optimize both early emergence and vegetative growth, which is consistent with findings in tulip and gladiolus cultivation [31].

Table (1): Effect of GA_3 primer and nano-NPK fertilizer concentrations on some growth and flowering characteristics of Narcissus cultivars plant.

Characteristics	Cultivars				GA_3 mg L^{-1}		Nano fertilizer mg L^{-1}		
	Little princess	Golden delicious	The bride	Local Aqre	0	100	0	50	100
Sprouting date (days)	54.89 a	49.11 b	45.72 c	17.67 d	44.28 a	39.42 b	41.42 a	41.42 a	42.71 a
Plant height (cm)	45.43 b	48.99a	47.69 ab	45.07b	45.36 b	48.23 a	44.84 b	48.13 a	47.43 a
Leaf area (cm^2)	68.05 a	65.40 a	68.44 a	45.36 b	59.73 a	63.90 a	49.78 c	62.38 b	73.27 a
Leaves dry weight (g)	4.96 b	5.97 a	5.29 b	3.54 c	4.76 a	5.12 a	3.25 b	6.02 a	5.55 a
Chlorophyll (SPAD)	61.27 b	64.26 a	64.14 a	64.26 a	62.13 b	64.83 a	59.93 b	64.69 a	65.82 a

Means with same letter for each factor and interaction are not significantly different at 5% level based on Duncan's Multiple Range test.

3.2 Effect of GA3 primer and nano-NPK fertilizer concentrations on some flowering and bulbs yield characteristics of Narcissus cultivars plants.

The results in Table (2) indicate that both cultivar type and the application of GA_3 primer and Nano-fertilizer significantly influenced the flowering and bulb yield characteristics of Narcissus plants.
Flowering date varied considerably among cultivars, with Local Aqre recording the earliest flowering (150.22 days), followed by The Bride (167.83 days) and Golden delicious (168.17 days), while Little princess had the latest flowering (169.33 days). Early flowering in Local Aqre could be attributed to its inherent genetic potential and adaptability, as reported in similar studies where cultivar differences largely determined phonological responses [23]. The use of GA_3 and nano-fertilizer slightly reduced flowering time compared to the control.
Flowering coordination date (flowering uniformity period) was longest in Local Aqre (17.83 days) and shortest in

Little princess (13.22 days). Treatments with 50–100 mg L^{-1} Nano-fertilizer and 100 mg L^{-1} GA_3 increased flowering coordination, possibly by synchronizing bud development. This effect is consistent with the findings of [27], who reported that growth regulators and micronutrients improved uniform flowering in bulbous plants.

Flower stalk length was significantly affected, with Golden delicious producing the tallest stalks (40.68 cm) and Local Aqre the shortest (30.74 cm). GA_3 application (100 mg L^{-1}) markedly increased stalk length, likely due to enhanced cell elongation, a well-documented physiological role of gibberellins [24]. Nano-fertilizer at 100 mg L^{-1} also improved stalk length, suggesting that nano-sized nutrients may enhance nutrient uptake efficiency [25].

Bulb volume was highest in Golden delicious and The Bride (44.72 – 44.41 cm^3) and lowest in Little princess (38.89 cm^3). The application of GA_3 at 100 mg L^{-1} and nano-fertilizer at 100 mg L^{-1} significantly increased bulb volume compared to control. This could be due to improved assimilate translocation into storage organs, as reported by [28] in bulbous ornamentals.

Bulblet production was highest in Local Aqre (2.06 bulblets) and lowest in Little princess and Golden delicious (1.22 bulblets). Nano-fertilizer at 100 mg L^{-1} produced the highest number of bulblets, supporting earlier findings that micronutrient availability stimulates vegetative propagation [32]. GA_3 also promoted bulblet formation, possibly due to its role in stimulating meristematic activity.

In general, Local Aqre displayed superiority in earliness and bulblet production, while Golden delicious excelled in stalk length and bulb volume. The combination of GA_3 and nano-fertilizers demonstrated a synergistic effect on enhancing yield and quality traits, in agreement with studies on other ornamental bulbs such as gladiolus and tulip [31].

Table (2): Effect of GA_3 primer and nano-NPK fertilizer concentrations on some flowering and bulbs yield characteristics of Narcissus cultivars plants.

Characteristics	Cultivars				GA_3 mg L^{-1}		Nano fertilizer mg L^{-1}		
	Little princess	Golden delicious	The bride	Local Aqre	0	100	0	50	100
Flowering date (days)	169.33 a	168.17 b	167.83 b	150.22 c	164,78 a	163.00 b	165.83 a	163.08 b	162.75 b
Flowering coordination date (days)	13.22 d	14.39 c	16.72 b	17.83 a	14.28 b	16.81 a	14.08 c	15.83 b	16.71 a
Length of flowers stalk (cm)	36.86 b	40.68 a	39.53 a	30.74 c	35.80 b	38.10 a	34.81 c	37.15 b	38.90 a
Bulb volume(cm^3)	38.89 b	44.72 a	44.41 a	41.88 ab	39.68 b	45.27 a	37.22 c	43.39 b	46.81 a
Bulblets produce	1.22 b	1.22 b	1.44 b	2.06 a	1.28 b	1.69 a	1.00 c	1.58 b	1.88 a

Means with same letter for each factor and interaction are not significantly different at 5% level based on Duncan‘s Multiple Range test.

3.3 Effect of triple interactions among cultivars, GA3 primer and nano-NPK fertilizer concentrations on some growth characteristics of Narcissus plants.

The data in Table (3) demonstrate that the triple interaction among *Narcissus* cultivars, GA_3 primer levels, and nano-NPK fertilizer concentrations exerted a significant influence on growth parameters including sprouting date, plant height, leaf area, leaf dry weight, and chlorophyll content (SPAD).

Regarding **sprouting date**, the shortest emergence period was recorded in the Local Aqre cultivar, particularly at higher Nano-fertilizer concentrations and GA_3 levels, with values as low as 14-20 days. This suggests a strong stimulatory effect of GA_3 and nano-fertilizers on breaking dormancy and accelerating sprouting, consistent with the role of GA_3 in promoting cell elongation and enzyme activation during germination [33] ; [34]. In contrast, Little princess and Golden delicious tended to have longer sprouting durations, indicating cultivar-specific physiological responses.

Plant height was markedly increased by the combined application of GA_3 (100 $mg{\cdot}L^{-1}$) and moderate to high Nano-fertilizer levels, with the highest values (53.67 cm) observed in Golden delicious under GA_3 at 100 $mg{\cdot}L^{-1}$ and 50 $mg{\cdot}L^{-1}$ nano-fertilizer. This enhancement can be attributed to GA_3-induced stem elongation via stimulation of cell wall loosening and division [35], as well as improved nutrient uptake efficiency through nano-fertilizers [36].

For **leaf area**, the maximum values were (88.01 cm² and 87.93 cm² in The bride with GA_3 0 and 100 $mg{\cdot}L^{-1}$ + 100 $mg{\cdot}L^{-1}$ Nano-fertilizer) highlight a synergistic effect between hormonal stimulation and Nano-nutrient availability. The increased photosynthetic surface area enhances light interception and biomass accumulation [37].

Leaf dry weight was highest in Golden delicious (7.83 g) when treated with 100 $mg{\cdot}L^{-1}$ GA_3 and 50 $mg{\cdot}L^{-1}$ Nano-fertilizer, reflecting both structural biomass accumulation and improved metabolic activity. Such results align with previous findings that GA_3 enhances assimilate translocation and nutrient utilization efficiency [38].

Chlorophyll content (SPAD) generally increased under GA_3 and nano-NPK fertilizer treatments, with maximum values exceeding 68.12 SPAD units in Golden Delicious. This enhancement may be attributed to the positive influence of nano-NPK fertilizer, which improves nutrient availability and uptake, thereby supporting photosynthetic activity and carbohydrate synthesis. Such processes facilitate the optimal translocation of assimilates from source to sink [30]. In addition, GA_3 contributes to this effect through its role in promoting chloroplast development and enhancing photosynthetic efficiency [40].

Overall, the results indicate that the growth response is strongly dependent on genotype, and optimal combinations of GA_3 and nano-fertilizer can substantially improve *Narcissus* vegetative performance. The synergy between GA_3 and nano-nutrient treatments enhances both morphological and physiological traits, in agreement with previous studies on ornamental bulbous plants [41].

Table (3): Effect of triple interactions among cultivars, GA_3 primer and nano-NPK fertilizer concentrations on some growth characteristics of Narcissus plants.

Cultivars	GA_3 mg.L^{-1}	Nano-fertilizer mg L-1	Characteristics				
			Sprouting date (days)	Plant height (cm)	Leaf area (cm^2)	Leaves dry weight (g)	Chlorophyll (SPAD)
Little princess	0	0	58.33 ab	40.93 c	48.51 e-h	2.80 gh	51.43 f
		50	57.00 a-c	44.83 bc	67.09 a-f	6.27 a-d	62.36 a-e
		100	59.33 a	45.13 bc	75.06 a-c	5.03 c-f	63.29 a-e
	100	0	51.00 c-f	44.67 bc	64.84 a-f	3.17 f-h	59.25 de
		50	52.00 b-e	47.87 a-c	68.93 a-f	6.33 a-d	65.78 a-c
		100	51.67 c-f	49.17 ab	83.86 ab	6.13 a-d	65.50 a-c
Golden delicious	0	0	51.00 c-f	44.00 bc	51.42 d-h	3.37 f-h	61.81 b-e
		50	53.33 a-d	49.30 ab	65.82 a-f	5.70 b-e	61.74 b-e
		100	50..00 d-f	49.10 ab	73.43 a-d	6.80 a-c	65.68 a-c
	100	0	45.33 fg	48.30 a-c	53.26 c-h	4.83 d-f	62.39 a-e
		50	46.67 d-g	53.67 a	65.11 a-f	7.83 a	65.80 a-c
		100	48.33 d-g	49.57 ab	83.39 ab	7.30 ab	68.12 a
The bride	0	0	46.00 e-g	46.30 a-c	49.54 e-h	3.70 f-h	58.89 e
		50	46.33 e-g	49.07 ab	62.34 b-g	7.00 ab	64.57 a-e
		100	52.00 b-e	44.76 bc	88.01 a	4.83 d-f	64.91 a-d
		0	42.33 g	48.70 a-c	52.40 c-h	2.80 gh	61.60 c-e

	100	50	42.67 g	47.67 a-c	70.44 a-e	6.67 a-d	67.13a-c
		100	45.00 ef	49.67 ab	87.93 a	6.73 a-c	67.75 ab
Local Aqre	0	0	20.00 h	41.93 bc	37.96 h	2.80 gh	61.90 b-e
		50	18.67 h	45.93 a-c	49.39 d-h	4.07 e-g	64.40 a-e
		100	19.33 h	43.07 bc	48.15 e-h	4.27 e-g	64.58 a-e
	100	0	17.33 h	43.87 bc	40.34 gh	2.07 h	62.18 a-e
		50	16.00 h	46.67 a-c	49.94 d-h	4.30 e-g	65.72 a-c
		100	14.67 h	48.93 a-c	46.38 f-h	3.27 f-h	66.76 a-c

Means with same letter for each factor and interaction are not significantly different at 5% level based on Duncan‘s Multiple Range test.

3.4. Effect of triple interactions among cultivars, GA_3 and nano-NPK fertilizer concentrations on some flowering and bulbs yield characteristics of Narcissus plants.

The results in Table (4) show that the triple interaction between *Narcissus* cultivars, GA_3 primer concentrations, and Nano-fertilizer levels had significant effects on flowering and yield related traits, including flowering date, flowering coordination date, flower stalk length, bulb volume, and bulblet number.

Flowering date was notably earlier in the Local Aqre cultivar, particularly under 100 mg·L⁻¹ GA_3 combined with 50–100 mg·L⁻¹ Nano-fertilizer, with the earliest flowering at 137.33 days. This acceleration may be attributed to GA_3's ability to promote floral initiation by enhancing the expression of flowering-related genes and breaking physiological dormancy [42]. Nano-fertilizers likely enhanced nutrient availability and improved plant vigor, further contributing to earlier flowering [39]. Conversely, Little princess and Golden delicious generally had later flowering dates, indicating genetic differences in flowering responses.

Flowering coordination date increased markedly in The bride with higher GA_3 and Nano-fertilizer doses, reaching up to 20.00 days. Greater coordination may improve marketability by producing a more uniform flowering period, which is important for ornamental production scheduling [41].

Flower stalk length was maximized in Golden delicious at 100 mg·L⁻¹ GA_3 with 100 mg·L⁻¹ nano-fertilizer, reaching 44.33 cm. GA_3 is well-known to stimulate stem elongation by promoting cell division and elongation in the sub-apical meristem [35]. Enhanced nutrient delivery from Nano-fertilizers, particularly potassium likely contributed to structural growth and turgor maintenance [36].

Bulb volume was greatest (55.00 cm³) in Golden delicious under high GA_3 and Nano-fertilizer levels, suggesting improved assimilate translocation to storage organs. GA_3 enhances sink strength by mobilizing carbohydrates, while Nano-fertilizers support optimal nutrient status for bulb development [43].

Bulblet number increased notably with combined treatments, with Local Aqre producing up to 2.33 bulblets under 100 mg·L⁻¹ GA_3 and 50–100 mg·L⁻¹ nano-fertilizer. The multiplication of bulblets is vital for commercial propagation and reflects both enhanced vegetative vigor and resource allocation [38].

Overall, the findings highlight that the combined use of GA_3 and nano-fertilizers can significantly improve both flowering earliness and quality traits in *Narcissus*, with cultivar specific responses. Local Aqre showed superior earliness and bulblet production, while Golden delicious excelled in stalk length and bulb volume. This suggests that selecting the appropriate cultivar-treatment combination can optimize ornamental yield and market value.

Table (4): Effect of triple interactions among cultivars, GA_3 primer and nano-NPK fertilizer concentrations on some growth and flowering characteristics of Narcissus plants.

Cultivars	GA_3 mg.L^{-1}	Nano-fertilizer mg L^{-1}	Characteristics				
			Flowering date (days)	Flowering coordination date (days)	Length of flower stalk (cm)	Bulbs volume (cm^3)	Bulblets number
Little princess	0	0	170.67 a	11.00 k	33.00 d-g	30.00 f	0.33 e
		50	169.67 a-c	11.67 jk	35.93 c-f	35.00 ef	1.00 c-e
		100	168.67 a-e	13.00 ij	36.90 b-e	35.00 ef	1.33 b-d
	100	0	169 67 a-c	13.33 h-j	36.43 c-f	45.00 b-d	1.33 b-d
		50	167.33 de	15.00 f-i	37.83 b-d	43.33 b-e	1.67a-c
		100	170.00 ab	15.33 f-h	41.03 a-c	45.00 b-d	1.67a-c
	0	0	168.67 a-e	11.67 jk	37.07 b-e	36.00 d-f	0.33 e
		50	168.33 b-e	13.33 h-j	42.03 ab	45.00 b-d	1.00 c-e

Golden delicious		100	168.00 b-e	14.67 g-i	40.80 a-c	50.00 ab	1.67 a-c
	100	0	168.67 a-e	13.33 h-j	39.53 a-c	35.00 ef	0.67 de
		50	167.33 de	16.00 e-g	40.30 a-c	47.33 a-c	1.67 a-c
		100	168.00 b-e	17.33 c-e	44.33 a	55.00 a	2.00 ab
The bride	0	0	167.33 de	14.00 g-i	36.07 c-f	35.10 ef	0.67 de
		50	167.33 de	15.00 f-i	38.00 b-d	41.67 b-e	1.33 b-d
		100	169.33 a-d	15.33 f-h	39.90 a-c	48.00 a-c	2.00 ab
	100	0	168.67 a-d	17.00 d-f	39.10 a-c	41.67 b-e	1.00 c-e
		50	166.67 e	19.00 a-c	41.93 ab	50.00 ab	1.67 a-c
		100	167.67 c-e	20.00 a	42.17 ab	50.00 ab	2.00 ab
Local Aqre	0	0	155.00 g	15.33 f-h	25.27 h	35.00 ef	1.67 a-c
		50	151.33 h	18.00 b-d	31.33 fg	40.07 c-e	2.00 ab
		100	153.00 h	18.33 a-d	33.30 d-g	45.33 bc	2.00 ab
	100	0	158.00 f	17.00 d-f	32.03 e-g	40.00 c-e	2.00 ab
		50	146.67 i	18.67 a-d	29.80 gh	44.73 b-d	2.33 a
		100	137.33 j	19.67 ab	32.73 d-g	46.17 a-c	2.33 a

Means with same letter for each factor and interaction are not significantly different at 5% level based on Duncan‘s Multiple Range test.

Conclusion

This study concluded that the growth, flowering, and bulbs productivity of Narcissusare greatly affected by genotype. The local Aqra cultivar demonstrated superiority in early sprouting and bulblet yield, whereas the Golden delicious cultivar excelled in vegetative growth vigor, stalk length, and bulb size. The distinct cultivar-specific responses to GA_3 priming and nano-NPK fertilization. The combined application of GA_3 and nano fertilizers significantly enhanced vegetative traits such as plant height, leaf area, and chlorophyll content, while also improving reproductive parameters including flowering earliness, stalk length, bulb volume, and bulblet production. The synergistic interaction between GA_3 and nano-fertilizers underscores their potential as integrated horticultural practices for improving both productivity and quality in ornamental bulb crops. These results provide valuable insights for improving commercial Narcissus cultivation and highlight the importance of selecting appropriate cultivar-treatment combinations to maximize ornamental yield and market value.

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فعالية نقع البرايمر GA3 والسماد النانوي على نمو وإزهار وإنتاج الأبصال والبصيلات لأربعة أصناف من النرجس

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الخلاصة

هدفت الدراسة إلى تقييم فعالية النقع في ***GA_3*** والرش بالسماد النانوي كسماد حيوي في تحسين النمو والإزهار وإنتاج الأبصال والبصيلات لأصناف النرجس المدروسة **.**

أجريت هذه الدراسة في منطقة بيرمام / محافظة أربيل خلال الفترة من 15 تشرين الأول 2024 ولغاية 22 أيار 2025، بهدف دراسة تأثير النقع في منظم النمو ***GA_3*** والرش بالسماد النانوي على النمو والإزهار وإنتاج الأبصال والبصيلات في أربعة أصناف من النرجس وهي ***(Little princess*** ،***Golden delicious*** ، ***The bride*** ، ***Local Aqre).***تم نقع الأبصال بتركيزين مختلفين من 0 ***GA_3 (***و100 ملغم لتر⁻¹) لمدة 24 ساعة، كما استُخدمت تراكيز مختلفة من السماد النانوي (0، 50، 100 ملغم لتر⁻¹) بالرش الورقي كل 15 يوماً بعد ظهور ورقتين حقيقتين وحتى ظهور البراعم الزهرية. وفي ساعات الصباح الباكر، رُشت الأوراق بواسطة مرش يدوي حتى مرحلة البلل. زُرعت الأبصال في أوعية بلاستيكية ***(PVC)*** بقطر 20 سم، مملوءة بخليط من التربة الطينية والدبال النباتي بنسبة (1:1 حجماً). شملت الدراسة (24) معاملة (4 × 2 × 3 = 24 معاملة) بثلاث مكررات، مثل كل مكرر بوعاء (20 سم) يحتوي على وسط النمو (تربة طينية + دبال نباتي 1:1) مزروع ببصلة واحدة، ليكون مجموع الأبصال المستخدمة 72 بصلة (24 معاملة × 3 مكررات × 1 وعاء × 1 بصلة = 72 بصلة، أي 24 بصلة لكل صنف

أوضحت النتائج أن معاملة النقع في ***GA_3*** والرش بالسماد النانوي حسّنت بشكل ملحوظ موعد الإنبات (17.67 يوم) مما أثر بقوة على وقت الإنبات. كما أدى النقع في ***GA_3***بتركيز (100 ملغم لتر⁻¹) إلى زيادة ارتفاع النبات (48.99 سم). وحقق ***Local Aqre*** أعلى إنتاج للبصيلات (2.06 بصيلة). أما بالنسبة لمساحة الأوراق، فقد سُجلت أعلى القيم (88.01 سم² في صنف***The Bride*** ، و87.93 سم² في نفس الصنف عند معاملة ***GA_3*** بتركيز 100 ملغم لتر⁻¹ مع 100 ملغم لتر⁻¹ سماد نانوي). في حين بلغت أطول سوق زهرية في صنف ***Golden Delicious*** عند معاملة 100 ملغم لتر⁻¹ ***GA_3*** مع 100 ملغم لتر⁻¹ سماد نانوي مسجلة 44.33 سم**.**

أظهرت التداخلات الثلاثية بين أصناف النرجس وتراكيز ***GA_3*** ومستويات السماد النانوي تأثيرات معنوية في الصفات المتعلقة بالإزهار والإنتاج مثل: موعد التزهير، موعد تزامن الإزهار، طول الساق الزهرية، حجم البصلة، وعدد البصيلات. تميز ***Local Aqre*** بتبكير التزهير خاصة عند معاملة 100 ملغم لتر⁻¹ ***GA_3*** مع 50–100 ملغم لتر⁻¹ سماد نانوي حيث بلغ أبكر موعد للتزهير 137.33 يوم. أما موعد تزامن الإزهار (مؤشر التناسق في التزهير) فقد ارتفع بشكل ملحوظ في صنفي ***The Bride*** و ***Local Aqre*** مع زيادة تراكيز ***GA_3*** والسماد النانوي ليصل إلى 20.00 يوم. وسجل صنف ***Golden Delicious*** أطول سوق زهرية (44.33 سم) عند نفس التوليفة (100 ملغم لتر⁻¹ ***GA_3*** و 100 ملغم لتر⁻¹ سماد نانوي). كما بلغ أكبر حجم للبصلة (55.00 سم³) في ***Golden Delicious*** عند المستويات العالية من ***GA_3*** والسماد النانوي. أما عدد البصيلات فقد ازداد بشكل واضح في المعاملات المشتركة، حيث أعطى ***Local Aqre*** حتى 2.33 بصيلة عند معاملة 100 ملغم لتر⁻¹ ***GA_3*** مع 50–100 ملغم لتر⁻¹ سماد نانوي.

الكلمات المفتاحية: الفعالية نقع ، GA_3 الرش بالسماد النانوي ، النمو ، الإزهار ، إنتاج الأبصال والبصيلات ، أصناف النرجس.