

Evaluation of Morphological Characteristics of *Narcissus tazetta* L. under Different Concentration of Gibberellin Acid Spray and soil application of limestone powder

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Abstract

The effect of geographic origin (L1–L5), gibberellic acid (GA₃) 0, 75, and 150 mg l⁻¹, and limestone powder (CaCO₃: 0, 2, 4 g pot⁻¹) on growth and flowering characteristics of narcissus was evaluated. Location L1 gave consistently superior results for all vegetative growth characteristics. The highest rate of GA₃ and CaCO₃ significantly influenced all characteristics compared to controls. The triple interaction was also highly significant. The optimal combination of location × 150 mg l⁻¹ GA₃ × 4 g pot⁻¹ CaCO₃ gave maximum value for leaf number 14.641, leaf length 37.164 cm, leaf dry weight 6.056 g, flower number 6.482, root number 43.918, and root dry weight 2.111 g in comparison with other treatments. Stalk length and stalk diameter were maximized in location L1 with high rates of GA₃ and CaCO₃ 35.260 cm and 3.776 mm, respectively. However, bulb weight reached its peak 66.300 g in L5 under the same chemical treatments, while the largest bulb diameter 4.990 cm was recorded in L3 with 4 g pot⁻¹ CaCO₃. The results demonstrate that the synergistic application of GA₃ and limestone soil amendment, particularly with bulbs from favourable locations especially L1, significantly maximizes the growth, flowering, and bulb quality of narcissus.

Keyword: *Narcissus tazetta*, Gibberellic acid, Limestone powder, Soil amendment .

تقييم الخصائص المورفولوجية لنبات النرجس البري (*Narcissus tazetta* L.) تحت تأثير رش حامض الجبرلين وتطبيق مسحوق الحجر الجيري على التربة

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المستخلص

تمت دراسة تأثير المنشأ الجغرافي (L1–L5)، وحامض الجبرلين 0، 75 و 150 ملغم لتر⁻¹، ومسحوق الحجر الجيري CaCO₃ 0، 2 و 4 غم وعاء⁻¹ على معايير النمو والإزهار لنبات النرجس. أظهر الموقع L1 باستمرار نتائج أفضل فيما يتعلق بالصفات الخضريّة. وقد أدى أعلى تركيز لحمض الجبرلين 150 ملغم لتر⁻¹ وأعلى معدل لمسحوق الحجر الجيري 4 غم وعاء⁻¹ إلى تحسين معظم المعايير بشكل ملحوظ مقارنةً بمعاملة المقارنة. وكان التفاعل الثلاثي بين العوامل ذا دلالة إحصائية عالية. حققت إنبات الموقع الأول المعاملة 150 × ملغم لتر⁻¹ من حمض الجبرلين × 4 غم وعاء⁻¹ من كربونات الكالسيوم أعلى القيم لعدد الأوراق 14.641، طول الأوراق 37.164 سم، وزن الجاف للأوراق 6.056 غم، عدد الأزهار 6.482، عدد الجذور 43.918، وزن الجاف للجذور 2.111 غم. أما بالنسبة لطول الساق 35.260 سم وقطرها 3.776 مم، فقد تحققت أفضل النتائج أيضاً في الموقع الأول مع تركيزات عالية من حمض الجبرلين وكربونات الكالسيوم. مع ذلك، بلغ وزن البصلة ذروته (66.300 غرام) في المجموعة قي الموقع الخامس تحت نفس المعاملة الكيميائية، بينما سجل أكبر قطر للبصلة 4.990 سم في المجموعة الموقع الثالث مع إضافة 4 غم وعاء⁻¹ من كربونات الكالسيوم. تُظهر النتائج أن التطبيق التآزري لحامض الجبرلين (GA₃) وتعديل التربة بالحجر الجيري، وخاصةً مع البصيلات من المواقع الملائمة (خاصةً المجموعة L1)، يُحسن بشكل ملحوظ نموّ النرجس وإزهاره وجودة بصيلائه.

الكلمات المفتاحية: النرجس البري، حامض الجبرلين، مسحوق الحجر الجيري، محسنات التربة

Introduction

Narcissus (Narcissus tazetta) is an onion plant of the Amaryllidaceae family, flowering in the middle of winter and early in spring (Khalighi, 2003). This flower is one of the most important garden plants that its species grows in any part of the world, except for tropical regions (Dole and Wilkins, 1996). *Narcissus* is not only used as cut flowers and pot plants but also has very pharmaceutical value because it has some effective material such as alkaloid compounds like galantamine (Moraes-Cerdeira et al., 1997). Apart from the ornamental value, *Narcissus* has a traditional medicinal history. Different parts of the plant, such as the flowers, bulbs, and roots, are used to treat periodic fever, dysentery, abscesses, and skin diseases, among others (Gürdal and Kültür, 2013). They are also used as ornamental elements of parks, gardens, and refuges (Kebeli and Çelikel, 2013). Since the height of the plant plays a role in the compactness of the plant, the ornamental value of the plant, and the ease of transportation and sale of the plant

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without the stems breaking, the height of the plant matters (Çelikel et al., 2016). The *Narcissus* genus, commonly referred to as daffodils, jonquils, and paper whites, comprises 50 to 100 wild species and thousands of registered cultivars, making it one of the most important and diverse genera of geophytes worldwide (Santos-Gally et al., 2013). Plant hormones, such as gibberellins, are important for the regulation of major physiological processes such as cell growth, division, and differentiation. In bulbous ornamentals, such as geophytes, the application of gibberellic acid (GA₃) has been reported to significantly regulate plant growth, flowering, and the formation of storage organs. A recent study by Chandel et al. (2023) has demonstrated the efficacy of external application of GA₃ for the regulation of stem length, flowering, and bulb quality of calla lily plants.

It is a well-established growth regulator for many plants growth stages, including seed germination, stem elongation, flowering induction, and breaking dormancy (Hedden and Sponsel, 2015). Its efficacy has been proven for improving flower quality and plant type for ornamental horticultural crops. Research has proven its application to have a marked effect on improving plant growth and flower characteristics. For instance, Dhaduk et al. (2007) found that foliar application of GA₃ to anthurium resulted in an increase in the number of flowers, stalk length, and spathe size. Similarly, Parmar et al. (2009) found that for spider lily, the application of 200 mg l⁻¹ of GA₃, two applications at 15-day intervals, performed better than lower concentrations (100 and 150 mg l⁻¹) for all parameters, including vegetative growth, floral characteristics, and yield attributes. The wide-ranging effect of gibberellins is due to the regulation of gene expression and cell growth, making it a fundamental growth regulator for improving growth and vigor of a variety of horticultural crops. 150 mg l⁻¹ of GA₃ showed the earliest flower initiation, longest floral duration, and inflorescence with the largest diameter, longest shelf and vase life. Alshakhaly and Qrunfleh (2019) found that flowers of *Cyclamen persicum* develop faster with the application of GA₃ at 5, 10, 25, 50, or 100 mg l⁻¹ compared to the control, and also have a greater number of flowers simultaneously, for the first and second years. Mishra et al. (2019) found that application of 250 mg l⁻¹ of GA₃ to *Amaryllis belladonna* had a marked effect on its growth and yield characteristics.

The first and most obvious effect of the addition of CaCO₃ is the increase in pH that it causes in the soil if it is acidic to begin with. This effect is significant because the pH of the soil is the "master variable" that determines the solubility of essential nutrients and toxic elements to the plants (Kopittke et al., 2021). CaCO₃ reduces the solubility of aluminum and manganese ions that are toxic to the root at low pH, which is a major constraint to root growth and function (Goulding, 2016). At the same time, it increases the availability of phosphorus, molybdenum, and, most importantly, calcium itself. Calcium, Ca²⁺, is a secondary macronutrient that is essential to the growth process but difficult to transport in the phloem because it is immobile in the phloem itself. As a result, it is important to maintain its availability at the root to sustain growth at a steady rate. As a secondary macronutrient, it is a major component of the structural materials that make up the cell membrane and the cell wall, helping to maintain the integrity and stability of these structures (Thor, 2019). In the case of *Narcissus*, the optimization of its status is believed to affect the process of cell division and expansion in the developing leaves and scales of the bulb itself, which in turn influences the development of the leaves, including the area, the weight both fresh and dry, and the diameter of the bulb itself. In addition, it functions as a second messenger within the cells, participating in the process of signal transduction that can affect the process of development and the response to environmental stress (Thor, 2019). As a result, if the availability of calcium is sufficient in the soil and supplied by the CaCO₃, the signal transduction process can proceed normally to control the process of cell elongation and division and the response to hormones. This sets the stage for the interaction with the GA₃ that will follow.

Gibberellins are potent promoters of cell elongation and stem growth. The presence of sufficient calcium may be a prerequisite for the effective action of GA₃, as calcium-dependent processes are involved in cell wall loosening and expansion (Cosgrove, 2016). Thus, a soil amendment of CaCO₃ could potentially synergize with foliar GA₃ applications to amplify effects on scape elongation and leaf growth. Conversely, calcium's role in cell wall rigidification may provide a balancing effect, producing sturdier, less-lodging stems. Mirzaei and Chehrizi (2024) studied the Comparisons of morphological and physiological characteristics of native Iranian narcissus in the field in different

populations of native narcissus (Shahla and Porpar) showing that native Iranian narcissus is a plant suitable for planting in green spaces. The planting of these plants in Mahalat has been successful. Planting native narcissus can be recommended for cities with a climate like Mahalat. To achieve this, we can introduce the native daffodils of Mazandaran and Ilam regions as the best genotypes. Because in terms of morphological indicators, they have the highest stem length, number of flowers, and number of leaves. Also, to use a flowerpot in the home or office environment, the native daffodils of the Khuzestan and Mazandaran regions can be introduced as the best genotypes. However, (Haghshenas et al., 2023) observed that the results of flower color, shape and scent are the most attractive factors for consumers in the floriculture industry. The most fragrant Iranian narcissi (*Narcissus tazetta* L.) grown in natural habitats are Shahla, Meskinak, and Porpar genotypes. The present study was conducted to evaluate the color, scent, and their interaction separately in corona and perianth of eleven Iranian narcissus accessions, for a better understanding of the bio-physiological differences in these tissues. This study aimed to examine how the geographic origin of *Narcissus tazetta* L. influences key morphological traits, with the aim of identifying which locations produce genotypes that exhibit superior ornamental qualities or production characteristics. This study aims to investigate the dose-dependent effects of foliar application of gibberellic acid (GA₃) on plant growth, flowering, and bulb development, and to determine the optimal concentrations that enhance commercially valuable traits while preventing excessive stem elongation. It also aims to evaluate the effects of soil-applied limestone (CaCO₃) as a fundamental soil amendment by assessing its direct influence on root and bulb morphology and examining its interaction with GA₃ in regulating plant physiological responses. Furthermore, the study seeks to elucidate the potential of integrating plant growth regulators with soil amendments to improve plant growth efficiency and production sustainability under degraded soil conditions and desertification-prone environments, thereby supporting sustainable land management and enhancing plant adaptation to environmental stresses associated with land degradation.

Materials and Methods

Plant Material and Experimental Design

The study was carried out in the lath house of the Department of Horticulture, College of Agriculture Engineering Sciences, University of Duhok, Kurdistan region, Iraq, from 15th October 2024, Before the experiment, bulbs of uniform size and health were selected where the bulbs were grown under suitable conditions in a well-drained substrate suitable for *Narcissus* cultivation. The study was arranged in a factorial test with a Randomized Complete Block Design (RCBD) with Three replicates, each consisting of 3 bulbs. *Narcissus* bulbs of a specific cultivar *Narcissus tazetta* L. were sourced from five different geographical locations (asihe, dashte, pirs mountain, girbishe and botiya). The locations were selected to represent potentially varying environmental conditions during the initial growth and development of the mother bulbs. Then cultivated in a pot 4L containing growing medium mixed with river soil: peatmoss 1:3v/v (Fig. 1).



Figure 1. different stage of Narcissus growth

The location was found in Narcissus

- (L1) Asihe Duhok government 37°11'41"N 43°21'18"E
- (L2) Grbish Duhok government 36°48'48"N 43°57'22"E
- (L3) Pirs mountain Duhok government 36°49'16"N 44°00'29"E
- (L4) Botiya Duhok government 36°56'43"N 42°59'23"E

(L5) Dashte Duhok government 36°58'32"N 42°43'48"E

Prior to the experiment, bulbs of uniform size and health were selected. The experiment was conducted using a randomized complete block design (RCBD) with a factorial arrangement of treatments.

The study was conducted in a controlled lathhouse environment. Bulbs were grown under standardized conditions in a well-drained substrate suitable for *Narcissus* cultivation. The experiment employed a factorial design to investigate the combined effects of three key factors:

- Location of Origin: Bulbs were sourced from five distinct geographical locations: Asihe, Dashte, Pirs mountain, Girbishe, and Botiya.
- Gibberellin (GA₃) Treatment: Three concentrations of the foliar spray were used: 0, 75, and 150 mg l⁻¹. The application was initiated when the plants had three leaves. The application was repeated three times with a 15-day interval between each application. The application was made with a hand sprayer to ensure that the plants were uniformly sprayed without causing runoff. The control plants were sprayed with the same volume of distilled water.
- Limestone Powder (CaCO₃) Application: The limestone powder, which is composed of calcium carbonate, was applied in three application rates: 0, 2, and 4 g/pot. The application was done in three installments at monthly intervals. The cultivation and gibberellin application were carried out with bulbs planted in a controlled environment in a lath house.

Morphological Data Collection

A wide range of morphological characteristics was evaluated for all plants after a seven-month development process. These characteristics included the number of leaves, leaf length, leaf area, leaf dry weight, number of flowers, stalk length, stalk diameter, number of roots, root dry weight, weight of bulbs, and diameter of bulbs.

Statistical Analysis

The experimental design was a Randomized Complete Block Design (RCBD). Each treatment had three replicates, with four plants per replicate. The analysis of data was done using ANOVA, and the means were compared using Duncan's test at $P \leq 0.05$, using SAS.

Results and Discussion

Number of Leaves

The data presented in Table 1 shows that location had a significant effect on the number of leaves, which was a positive significant, L1 was increased significantly in the number of leaves 8.739 leaves in comparison with other locations except L5 which showed 8.160 leaves. Also, the concentrations of GA₃ showed significant difference over control, which provided 8.403 leaves for 150 mg l⁻¹ in comparison with 75 mg l⁻¹ and control which gave 7.829 and 7.769 leaves respectively. 4 g pot⁻¹ of limestone powder added to the soil resulted in an average leaf number of 9.015 leaves, compared to 7.880 and 7.105 leaves in the 2 g pot⁻¹ and control alternative CaCO₃.

Concerning the interaction between location and GA₃ the significant result showed in L1 with spraying GA₃ at 150 mg l⁻¹ reached (10.764 leaves) compared to other treatments and the minimum number of leaves 6.574 in L2 without spraying GA₃. While the interaction between location and CaCO₃ illustrated that the maximum number of leaves 11.197 leaves was observed in L1 the addition of 4 g pot⁻¹ CaCO₃ (limestone powder) compared to all treatments, but the least number of leaves was obtained in L2 without adding 6.889 CaCO₃ (limestone powder).

From triple interaction among three factors, location, GA₃, and CaCO₃ (limestone powder), it can be shown that when the bulbs from L1 were treated with 150 mg l⁻¹ of GA₃, adding 4 g.pot⁻¹ CaCO₃ (limestone powder) provided the best number of leaves, 14.641 leaves, in comparison with 5.853 leaves in the same location, untreated GA₃ and CaCO₃.

Leaf Length

The data presented in Table 2 show that location had a significant effect on leaf length. L1 produced significantly longer leaves 32.481 cm compared to all other locations. The highest concentration of GA₃ (150 mg·L⁻¹) resulted in the greatest leaf length 20.901 cm, which was significantly different from the 75 mg·L⁻¹ treatment (18.702 cm) but both were superior to the control 16.263 cm. The addition of 4 g pot⁻¹ of limestone powder (CaCO₃) significantly resulted in the longest average leaf length 20.986 cm, compared to 19.323 cm and 15.557 cm for the 2 g pot⁻¹ and control treatments, respectively.

Concerning the interaction between location and GA₃, the most significant result was observed in L1 sprayed with 150 mg·L⁻¹ GA₃, achieving a leaf length of 34.900 cm. The minimum leaf length (8.595 cm) was recorded in L3 without

GA₃ application. The interaction between location and CaCO₃ showed that the maximum leaf length 34.793 cm was obtained in L1 with the addition of 4 g pot⁻¹ CaCO₃, while the shortest leaves 8.630 cm were found in L3 without CaCO₃ addition.

Table 1. Effect of locations, GA₃ Concentrations and its interaction on the number of leave Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of Loc. × GA ₃	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4		
L1	0	5.853 ^g	7.514 ^{c-g}	10.325 ^b	7.897 ^{abc}	8.739 ^a
	75	6.519 ^{d-g}	7.523 ^{c-g}	8.625 ^{b-f}	7.556 ^{bc}	
	150	8.527 ^{b-g}	9.126 ^{bcd}	14.641 ^a	10.764 ^a	
L2	0	5.936 ^{fg}	6.557 ^{c-g}	7.227 ^{c-g}	6.574 ^c	7.778 ^b
	75	7.083 ^{c-g}	8.417 ^{b-g}	9.250 ^{bcd}	8.250 ^{ab}	
	150	7.647 ^{b-g}	9.132 ^{bcd}	8.750 ^{b-e}	8.509 ^{ab}	
L3	0	6.102 ^{efg}	8.052 ^{b-g}	8.392 ^{b-g}	7.515 ^{bc}	7.864 ^b
	75	7.639 ^{b-g}	7.850 ^{b-g}	8.288 ^{b-g}	7.926 ^{abc}	
	150	8.783 ^{b-e}	7.476 ^{c-g}	8.194 ^{b-g}	8.151 ^{ab}	
L4	0	7.806 ^{b-g}	6.572 ^{c-g}	7.306 ^{c-g}	7.228 ^{bc}	7.459 ^b
	75	6.560 ^{c-g}	7.102 ^{c-g}	8.036 ^{b-g}	7.232 ^{bc}	
	150	6.572 ^{c-g}	8.039 ^{b-g}	9.142 ^{bcd}	7.918 ^{abc}	
L5	0	6.976 ^{c-g}	8.305 ^{b-g}	9.290 ^{bc}	8.190 ^{ab}	8.160 ^{ab}
	75	7.459 ^{c-g}	8.484 ^{b-g}	8.604 ^{b-f}	8.182 ^{ab}	
	150	7.106 ^{c-g}	8.058 ^{b-g}	9.161 ^{bcd}	8.108 ^{ab}	
Interaction of CaCO ₃ × L	L1	6.966 ^{cd}	8.054 ^{bcd}	11.197 ^a	Effect of GA ₃	
	L2	6.889 ^d	8.035 ^{bcd}	8.409 ^{bc}		
	L3	7.508 ^{cd}	7.793 ^{bcd}	8.291 ^{bcd}		
	L4	6.979 ^{cd}	7.238 ^{cd}	8.161 ^{bcd}	0	7.769 ^b
	L5	7.180 ^{cd}	8.282 ^{bcd}	9.018 ^b	75	7.829 ^b
Effect of CaCO ₃ (g)		7.105 ^c	7.880 ^b	9.015 ^a	150	8.403 ^a

Table 2. effect of location, GA₃ concentrations and its interaction on leaf length of Narcissus plant (*Narcissus tazetta* L)

Treatment		CaCO ₃ levels (g)			Interaction of	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4	GA ₃ + L	
L1	0	23.928 ^{fg}	30.992 ^d	33.092 ^{bcd}	29.337 ^b	32.481 ^a
	75	30.390 ^{de}	35.102 ^{abc}	34.123 ^{a-d}	33.205 ^a	
	150	31.452 ^{cd}	36.085 ^{ab}	37.164 ^a	34.900 ^a	
L2	0	16.003 ^{ijk}	20.400 ^{gh}	20.588 ^{gh}	18.997 ^d	22.817 ^b
	75	17.890 ^{hi}	27.043 ^f	26.615 ^f	23.849 ^c	
	150	25.980 ^f	26.242 ^f	24.589 ^f	25.603 ^c	
L3	0	8.202 ^p	8.945 ^{nop}	8.638 ^{op}	8.595 ⁱ	10.777 ^d
	75	8.910 ^{nop}	10.335 ^{m-p}	12.317 ^{k-o}	10.521 ^{hi}	
	150	8.778 ^{nop}	14.980 ^{i-l}	15.888 ^{ijk}	13.216 ^{fg}	
L4	0	8.885 ^{nop}	11.995 ^{k-p}	13.230 ^{j-m}	11.370 ^{gh}	13.940 ^c
	75	11.315 ^{j-p}	13.232 ^{j-m}	16.897 ^{hij}	13.814 ^f	
	150	10.567 ^{m-p}	14.027 ^{i-m}	25.317 ^f	16.637 ^e	
L5	0	10.170 ^{nop}	13.607 ^{j-m}	15.273 ^{i-l}	13.017 ^{fg}	13.095 ^c
	75	8.243 ^p	14.133 ^{i-m}	13.980 ^{j-m}	12.119 ^{fgh}	
	150	12.638 ^{k-o}	12.730 ^{k-m}	17.080 ^{hij}	14.149 ^f	
Interaction of CaCO ₃ × L	L1	28.590 ^b	34.059 ^a	34.793 ^a	Effect of GA ₃ Conce (mg l ⁻¹)	
	L2	19.958 ^d	24.562 ^c	23.931 ^c		
	L3	8.630 ^h	11.420 ^{fg}	12.281 ^{fg}		
	L4	10.256 ^{gh}	13.084 ^f	18.481 ^d	0	16.263 ^c
	L5	10.350 ^{gh}	13.490 ^f	15.444 ^e	75	18.702 ^b
Effect of CaCO ₃ (g)		15.557 ^c	19.323 ^b	20.986 ^a	150	20.901 ^a

From the triple interaction among the three factors location, GA_3 , and CaCO_3 , it can be shown that bulbs from L1 treated with 150 mg l^{-1} of GA_3 and 4 g pot^{-1} CaCO_3 provided the significantly best leaf length of 37.164 cm , in comparison with 8.202 cm for bulbs from L3 without GA_3 and CaCO_3 treatment.

Leaf Area

The data presented in Table 3 indicate that location significantly affected leaf area. L1 achieved the largest leaf area 42.248 cm^2 , which was significantly greater than all other locations. GA_3 concentrations significantly increased leaf area, with the 150 mg l^{-1} treatment yielding the highest value 32.743 cm^2 , followed by 75 mg l^{-1} of 28.542 cm^2 , both surpassing the control 21.863 cm^2 . Similarly, the addition of CaCO_3 at 4 g pot^{-1} produced the largest leaf area 30.533 cm^2 , which was not significantly different from the 2 g pot^{-1} treatment 29.624 cm^2 , but both were superior to the control 22.991 cm^2 .

Regarding the interaction between location and GA_3 , the significant effect was in L1 with 150 mg l^{-1} GA_3 , resulting in a leaf area of 45.273 cm^2 . The smallest leaf area 9.910 cm^2 was recorded in L4 without GA_3 . The interaction between location and CaCO_3 illustrated that the maximum leaf area (46.812 cm^2) was observed in L1 with 2 g pot^{-1} CaCO_3 , whereas the minimum 10.799 cm^2 in L4 without CaCO_3 is reiterated from the GA_3 interaction context, with the structured analysis showing L4 without CaCO_3 at 10.799 cm^2 .

Whereas the triple interaction, it is evident that bulbs from L1 treated with 150 mg l^{-1} GA_3 and 2 g pot^{-1} CaCO_3 yielded the significantly highest leaf area of 49.168 cm^2 , compared to 6.282 cm^2 for untreated narcissus plant from the L3.

Table 3. Effect of locations, GA_3 Concentrations and its interaction on the leaf area cm^2 of Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of		Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4	GA ₃ × L		
L1	0	25.178 ^{hij}	44.889 ^{a-d}	42.317 ^{b-e}	37.461 ^c		42.248 ^a
	75	41.383 ^{def}	46.379 ^{a-d}	44.265 ^{a-e}	44.009 ^{ab}		
	150	41.579 ^{c-f}	49.168 ^a	45.072 ^{a-d}	45.273 ^a		
L2	0	20.947 ^{jkl}	24.870 ^{hij}	21.927 ^{jk}	22.581 ^f		27.841 ^c
	75	25.089 ^{hij}	30.751 ^g	36.849 ^f	30.896 ^d		
	150	25.308 ^{hij}	39.676 ^{ef}	25.149 ^{hij}	30.044 ^d		
L3	0	6.997 ^o	12.129 ^{mn}	17.819 ^{kl}	12.315 ^{hi}		15.488 ^d
	75	8.144 ^{no}	16.894 ^{kl}	19.004 ^{kl}	14.681 ^h		
	150	18.955 ^{kl}	17.438 ^{kl}	22.012 ^{jk}	19.468 ^g		
L4	0	6.282 ^o	7.188 ^{no}	16.261 ^{lm}	9.910 ^{ij}		15.271 ^d
	75	8.221 ^{no}	9.012 ^{no}	10.975 ^{no}	9.403 ^j		
	150	17.893 ^{kl}	29.821 ^{gh}	31.789 ^g	26.501 ^e		
L5	0	24.014 ^{ij}	27.562 ^{ghi}	29.562 ^{gh}	27.046 ^e		37.732 ^b
	75	43.189 ^{b-e}	41.379 ^{def}	46.599 ^{abc}	43.722 ^{ab}		
	150	31.689 ^g	47.201 ^{ab}	48.394 ^a	42.428 ^b		
Interaction of CaCO ₃ × L	L1	36.047 ^d	46.812 ^a	43.885 ^b	Effect of GA ₃ Conce (mg l ⁻¹)		
	L2	23.781 ^g	31.766 ^e	27.975 ^f			
	L3	11.365 ^j	15.487 ⁱ	19.612 ^h			
	L4	10.799 ^j	15.340 ⁱ	19.675 ^h	0	21.863 ^c	
	L5	32.964 ^e	38.714 ^c	41.518 ^b	75	28.542 ^b	
Effect of CaCO ₃ (g)		22.991 ^b	29.624 ^a	30.533 ^a	150	32.743 ^a	

Leaf Dry Weight

The data presented in Table 4 demonstrate a significant effect of location on leaf dry weight. L5 produced the highest leaf dry weight 4.275 g , which was not significantly different from L1 4.151 g , while the lowest leaf dry weight was 3.515 g 150 mg l^{-1} GA_3 spraying significantly increased dry weight, with all treatments giving the best result 4.383 g , followed by 75 mg l^{-1} 3.920 g , both higher than the control 3.416 g . The addition of CaCO_3 also had a positive effect, where 4 g pot^{-1} resulted in the highest significantly of dry weight 4.457 g , compared to 4.015 g for 2 g pot^{-1} and 3.246 g for the control.

For the interaction between location and GA₃, the most significant result was found in L1 sprayed with 150 mg l⁻¹ GA₃, achieving a dry weight of 5.007 g. The minimum dry weight 3.134 g was recorded in L4 without GA₃. The interaction between location and CaCO₃ showed that the maximum significant dry weight 5.152 g was obtained in L5 with 4 g pot⁻¹ CaCO₃, while the lowest 2.715 g was in L2 without CaCO₃ addition.

However, the triple interaction among location, GA₃, and CaCO₃, it can be concluded that bulbs from L1 treated with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃ provided the significantly highest leaf dry weight of 6.056 g, in stark contrast to 2.405 g for 75mg l⁻¹ bulbs from the L2.

Table 4. Effect of locations, GA₃ Concentrations and its interaction on the leaf dry weight of Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4	GA ₃ + L	
L1	0	2.903 ^{klm}	3.499 ^{g-l}	3.096 ^{j-m}	3.166 ^{fg}	4.151 ^{ab}
	75	3.206 ^{i-m}	4.520 ^{c-f}	5.115 ^{bc}	4.280 ^{cd}	
	150	3.842 ^{e-j}	5.123 ^{bc}	6.056 ^a	5.007 ^a	
L2	0	2.739 ^{lm}	3.324 ^{h-l}	3.706 ^{f-j}	3.256 ^{fg}	3.607 ^c
	75	2.405 ^m	4.639 ^{cde}	3.807 ^{e-j}	3.617 ^{ef}	
	150	3.001 ^{j-m}	4.093 ^{d-h}	4.753 ^{cd}	3.949 ^{cde}	
L3	0	3.473 ^{g-l}	3.556 ^{g-l}	3.705 ^{f-k}	3.578 ^{efg}	3.983 ^b
	75	3.837 ^{e-j}	4.051 ^{d-i}	4.102 ^{d-h}	3.997 ^{cde}	
	150	3.696 ^{f-k}	4.296 ^{c-g}	5.129 ^{bc}	4.373 ^{bc}	
L4	0	2.779 ^{lm}	3.273 ^{h-l}	3.351 ^{h-l}	3.134 ^g	3.515 ^c
	75	3.310 ^{h-l}	3.515 ^{g-l}	3.839 ^{e-j}	3.555 ^{efg}	
	150	3.261 ^{h-l}	3.562 ^{g-l}	4.746 ^{cd}	3.856 ^{de}	
L5	0	3.349 ^{h-l}	3.870 ^{e-j}	4.616 ^{cde}	3.945 ^{cde}	4.275 ^a
	75	3.501 ^{g-l}	3.819 ^{e-j}	5.130 ^{bc}	4.150 ^{cd}	
	150	3.393 ^{h-l}	5.084 ^{bc}	5.710 ^{ab}	4.729 ^{ab}	
Interaction of CaCO ₃ × L	L1	3.317 ^{ef}	4.381 ^{bc}	4.756 ^{ab}	Effect of GA ₃ Conce (mg l ⁻¹)	
	L2	2.715 ^g	4.019 ^{cd}	4.088 ^{cd}		
	L3	3.669 ^{de}	3.967 ^{cd}	4.312 ^c		
	L4	3.117 ^{fg}	3.450 ^{ef}	3.979 ^{cd}	0	3.416 ^c
	L5	3.414 ^{ef}	4.257 ^c	5.152 ^a	75	3.920 ^b
Effect of CaCO ₃ (g)		3.246 ^c	4.015 ^b	4.457 ^a	150	4.383 ^a

Flower Number

Locations had a significant effect on flower numbers L1, L5 and L3 produced the highest average flower numbers 4.963, 4.957 and 4.931, respectively, while L4 showed the lowest 4.450. While GA₃ application significantly increased flower number compared to the control. The concentration of 150 mg l⁻¹ yielded the highest average flower number 5.045, followed by 75 mg l⁻¹ 4.822, with the control producing the lowest 4.519. Increasing CaCO₃ levels significantly enhanced flower number. The highest level of CaCO₃ 4 g pot⁻¹ resulted in the significantly greatest average flower number 5.364, compared to 2 g pot⁻¹ CaCO₃ 4.838 and control 4.183.

Whilst the combination of location and GA₃, the most significant result was found in L1 sprayed with 150 mg l⁻¹ GA₃, achieving GA₃ at 150 mg l⁻¹ produced the highest flower number 5.399, whereas in L2, the response was less pronounced reaching 4.154 without GA₃ spraying. Also, the combination of location and GA₃, show the most significant result of L1 with 4 g pot⁻¹ CaCO₃ gave the highest flower number 5.742, while L2 without CaCO₃ resulted in the lowest 3.749.

Triple Interaction between (Location × GA₃ × CaCO₃) show the highest flower number was observed in L1 treated with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃ (6.482), significantly outperforming the untreated control in the L2 3.232. This indicates that the synergistic application of GA₃ and CaCO₃ in favorable locations maximizes flower production.

Table 5. Effect of locations, GA₃ Concentrations and its interaction on the flower number Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of GA ₃ + L		Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4			
L1	0	3.653 ^{j-l}	4.649 ^{b-l}	5.137 ^{a-h}	4.480 ^{c-f}		4.963 ^a
	75	4.357 ^{d-l}	5.065 ^{a-i}	5.607 ^{a-f}	5.010 ^{a-d}		
	150	4.190 ^{f-l}	5.524 ^{a-g}	6.482 ^a	5.399 ^a		
L2	0	3.232 ^l	4.399 ^{c-l}	4.832 ^{b-i}	4.154 ^f		4.675 ^{ab}
	75	3.365 ^{k-l}	4.649 ^{b-l}	5.899 ^{ab}	4.638 ^{a-f}		
	150	4.649 ^{b-l}	5.149 ^{a-h}	5.899 ^{ab}	5.232 ^{abc}		
L3	0	4.107 ^{g-l}	4.315 ^{d-l}	4.149 ^{g-l}	4.190 ^{ef}		4.931 ^a
	75	4.690 ^{b-k}	5.274 ^{a-h}	5.815 ^{abc}	5.260 ^{ab}		
	150	5.232 ^{a-h}	5.149 ^{a-h}	5.649 ^{a-e}	5.343 ^{ab}		
L4	0	4.232 ^{e-l}	4.274 ^{d-l}	5.274 ^{a-h}	4.593 ^{b-f}		4.450 ^b
	75	4.315 ^{d-l}	4.565 ^{b-l}	4.515 ^{b-l}	4.465 ^{c-f}		
	150	3.515 ^{j-l}	4.182 ^{f-l}	5.182 ^{a-h}	4.293 ^{def}		
L5	0	4.848 ^{b-i}	5.182 ^{a-h}	5.498 ^{a-g}	5.176 ^{abc}		4.957 ^a
	75	4.515 ^{b-l}	4.515 ^{b-l}	5.182 ^{a-h}	4.737 ^{a-f}		
	150	3.848 ^{h-l}	5.682 ^{a-d}	5.348 ^{a-g}	4.959 ^{a-e}		
Interaction of CaCO ₃ × L	L1	4.067 ^{fg}	5.079 ^{a-e}	5.742 ^a	Effect of GA ₃ Conce (mg l ⁻¹)		
	L2	3.749 ^g	4.732 ^{c-f}	5.543 ^{ab}			
	L3	4.677 ^{c-f}	4.913 ^{b-e}	5.204 ^{abc}			
	L4	4.021 ^{fg}	4.340 ^{efg}	4.990 ^{a-e}	0	4.519 ^b	
	L5	4.404 ^{d-g}	5.126 ^{a-d}	5.343 ^{abc}	75	4.822 ^a	
Effect of CaCO ₃ (g)		4.183 ^c	4.838 ^b	5.364 ^a	150	5.045 ^a	

Stalk Length

The data presented in Table 6 show that location significantly affected stalk length, with L1 producing the longest stalks 31.610 cm compared to all other locations, while L3 showed the lowest 9.757 cm. Of all the GA₃ concentrations used in this experiment, 150 mg l⁻¹ recorded the highest stalk lengths of 19.525 cm, significantly outperforming the 75 mg l⁻¹ and control treatments that recorded 17.707 cm. The application of 4 g pot⁻¹ of CaCO₃ yielded the longest stalks 19.806 cm, compared to 2 g pot⁻¹ 18.405 cm and the control 14.525 cm.

Concerning the interaction between location and GA₃, the highest stalk length 33.046 cm was recorded in L1 with 150 mg l⁻¹ GA₃, while the lowest 7.553 cm was observed in L3 without GA₃ spraying. The interaction between location and CaCO₃ showed that L1 with 2, 4 g pot⁻¹ CaCO₃ produced the longest stalk length (33.234 and 32.438 cm respectively, compared to the minimum 7.416 cm in L3 without CaCO₃).

From the triple interaction among location, GA₃, and CaCO₃, it can be concluded that narcissus bulbs from L1 treated with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃ produced the significant longest of stalks 35.260 cm, compared to all treatments excepted some treatments in L1, while the shortest 6.877 cm in L3 without GA₃ or CaCO₃.

Stalk Diameter

The results in Table 7 indicate a significant effect of location on stalk diameter, with L1 and L2 showing the largest diameters 2.878 mm and 2.782 mm, respectively. GA₃ at 150 mg l⁻¹ and 75 mg l⁻¹ both significantly increased stalk diameter 2.287 mm and 2.148 mm compared to the control 1.793 mm. Similarly, the highest level of CaCO₃ 4 g pot⁻¹ resulted in the largest diameter (2.376 mm), compared to 2 g pot⁻¹ 2.174 mm and the control 1.678 mm.

The combination of the location of plant growth and the GA₃ concentration was remarkable in L1 with 75 mg l⁻¹ GA₃, resulting in a stalk diameter of 3.107 mm. Conversely, the lowest diameter of 1.120 mm was recorded in L3 without GA₃. Considering the interaction of the location and CaCO₃, the stalk diameter was 3.153 mm in L1 with 4 g pot⁻¹ CaCO₃. The lowest of 1.133 mm was recorded in L3 without CaCO₃. For the three-way interaction, the largest stalk diameter was 3.776 mm in L1 with 75 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃. The smallest was 1.000 mm in L5 with 75 mg l⁻¹ GA₃ but without CaCO₃.

Table 6. Effect of locations, GA₃ Concentrations and its interaction on the Stalk length Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of		Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4	GA ₃ + L		
L1	0	28.037 ^{efg}	30.167 ^{cde}	30.342 ^{b-e}	29.515 ^b		31.610 ^a
	75	29.565 ^{def}	34.277 ^{ab}	32.965 ^{a-d}	32.269 ^a		
	150	29.872 ^{def}	35.260 ^a	34.006 ^{abc}	33.046 ^a		
L2	0	14.511 ^{k-n}	19.575 ^{ij}	19.763 ^{ij}	17.950 ^d		21.648 ^b
	75	17.065 ^{jk}	26.218 ^{e-h}	25.790 ^{fgh}	23.024 ^c		
	150	22.822 ^{hi}	25.417 ^{gh}	23.672 ^h	23.970 ^c		
L3	0	6.877 ^u	7.970 ^{stu}	7.813 ^{tu}	7.553 ^h		9.757 ^d
	75	7.418 ^{tu}	9.075 ^{p-u}	11.492 ^{m-t}	9.328 ^{gh}		
	150	7.953 ^{stu}	14.155 ^{k-o}	15.063 ^{k-n}	12.391 ^f		
L4	0	8.060 ^{r-u}	10.837 ^{n-u}	12.405 ^{l-r}	10.434 ^{fg}		12.912 ^c
	75	9.823 ^{o-u}	12.357 ^{l-s}	16.180 ^{kl}	12.787 ^f		
	150	9.350 ^{p-u}	12.927 ^{k-q}	24.267 ^{gh}	15.514 ^e		
L5	0	8.753 ^{q-u}	12.890 ^{k-q}	14.557 ^{k-n}	12.067 ^f		11.966 ^c
	75	6.847 ^u	13.267 ^{k-p}	13.263 ^{k-p}	11.126 ^{fg}		
	150	10.921 ^{n-u}	11.680 ^{m-t}	15.513 ^{klm}	12.705 ^f		
Interaction of CaCO ₃ × L	L1	29.158 ^b	33.234 ^a	32.438 ^a	Effect of GA ₃ Conce (mg l ⁻¹)		
	L2	18.133 ^d	23.737 ^c	23.075 ^c			
	L3	7.416 ^h	10.400 ^{fg}	11.456 ^f			
	L4	9.078 ^{gh}	12.040 ^f	17.617 ^d			
	L5	8.840 ^g	12.612 ^{ef}	14.444 ^e	0	15.504 ^c	
Effect of CaCO ₃ (g)		14.525 ^c	18.405 ^b	19.806 ^a	75	17.707 ^b	
					150	19.525 ^a	

Table 7. Effect of locations, GA₃ Concentrations and its interaction on the stalk diameter Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of GA ₃ + L	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4		
L1	0	2.130 ^{f-k}	2.931 ^{b-e}	2.756 ^{b-f}	2.606 ^{bc}	2.878 ^a
	75	2.495 ^{d-i}	3.049 ^{b-e}	3.776 ^a	3.107 ^a	
	150	2.756 ^{b-f}	3.085 ^{a-d}	2.925 ^{b-e}	2.922 ^{ab}	
L2	0	1.933 ^{h-n}	2.619 ^{c-h}	2.499 ^{d-i}	2.350 ^c	2.782 ^a
	75	2.408 ^{e-j}	3.363 ^{ab}	3.318 ^{abc}	3.030 ^a	
	150	2.718 ^{b-g}	3.188 ^{a-d}	2.996 ^{b-e}	2.967 ^{ab}	
L3	0	1.019 ^p	1.134 ^{op}	1.205 ^{nop}	1.120 ^g	1.458 ^b
	75	1.093 ^{op}	1.411 ^{k-p}	1.619 ^{k-p}	1.374 ^{fg}	
	150	1.287 ^{l-p}	1.997 ^{g-l}	2.360 ^{e-j}	1.881 ^d	
L4	0	1.167 ^{op}	1.521 ^{k-p}	1.605 ^{k-p}	1.431 ^{efg}	1.644 ^b
	75	1.310 ^{l-p}	1.768 ^{i-o}	2.000 ^{g-l}	1.692 ^{def}	
	150	1.250 ^{m-p}	1.712 ^{j-p}	2.469 ^{d-i}	1.810 ^{de}	
L5	0	1.155 ^{op}	1.255 ^{l-p}	1.963 ^{h-m}	1.458 ^{efg}	1.616 ^b
	75	1.000 ^p	1.802 ^{i-o}	1.802 ^{i-o}	1.534 ^{def}	
	150	1.446 ^{k-p}	1.770 ^{i-o}	2.354 ^{e-j}	1.857 ^d	
Interaction of CaCO ₃ × L	L1	2.460 ^b	3.022 ^a	3.153 ^a	Effect of GA ₃ Conce (mg l ⁻¹)	
	L2	2.353 ^{bc}	3.057 ^a	2.938 ^a		
	L3	1.133 ^g	1.514 ^{efg}	1.728 ^{de}		
	L4	1.242 ^{fg}	1.667 ^{de}	2.024 ^{cd}	0	1.793 ^b
	L5	1.200 ^g	1.609 ^{ef}	2.040 ^{cd}	75	2.148 ^a
Effect of CaCO ₃ (g)		1.678 ^c	2.174 ^b	2.376 ^a	150	2.287 ^a

Root number

Is highly influenced by location, as shown in Table 8. Both L5 and L1 have the highest significant root numbers of 32.607 and 30.233 roots, respectively. GA₃ at 150 mg l⁻¹ and 75 mg l⁻¹ significantly increased root number (28.083 and 26.296 roots, respectively compared to the control 20.609 roots. The application of 4 g pot⁻¹ CaCO₃ yielded the highest significant root number 29.946 roots, surpassing both 2 g pot⁻¹ 26.683 roots and the control 18.359 roots. For the location × GA₃ interaction, the best significant value of root number 34.029 roots was recorded in L1 with 150 mg l⁻¹ GA₃, while the minimum 12.881 roots was in L4 without GA₃. The location × CaCO₃ interaction showed the highest significant root number 37.035 roots in L5 with 4 g pot⁻¹ CaCO₃, and the lowest 11.917 roots in L3 without CaCO₃.

The triple interaction indicated that the greatest root number 43.918 roots was obtained in L1 with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃, this treatment was recorded significant value compared to the most treatment including control which was recorded the lowest 9.972 roots in L4 without GA₃ or CaCO₃.

Table 8. Effect of locations, GA₃ Concentrations and its interaction on the Root number of Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of		Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4	GA ₃ + L		
L1	0	18.748 ^{k-s}	22.918 ^{g-p}	29.751 ^{b-j}	23.806 ^{cd}		30.233 ^a
	75	25.918 ^{e-n}	37.252 ^{a-d}	35.418 ^{a-f}	32.863 ^{ab}		
	150	24.585 ^{f-o}	33.585 ^{a-g}	43.918 ^a	34.029 ^a		
L2	0	20.085 ^{i-s}	18.252 ^{i-s}	16.752 ^{m-s}	18.363 ^{def}		24.400 ^b
	75	16.418 ^{n-s}	33.585 ^{a-g}	32.585 ^{b-h}	27.529 ^{bc}		
	150	20.752 ^{j-s}	31.752 ^{b-i}	29.418 ^{b-k}	27.307 ^{bc}		
L3	0	13.397 ^{p-s}	17.085 ^{m-s}	20.918 ^{i-r}	17.133 ^{ef}		18.603 ^c
	75	10.178 ^{r-s}	14.085 ^{o-s}	21.418 ^{i-q}	15.227 ^f		
	150	12.175 ^{p-s}	30.085 ^{b-j}	28.085 ^{c-l}	23.448 ^{cd}		
L4	0	9.972 ^s	12.585 ^{p-s}	16.085 ^{n-s}	12.881 ^f		19.137 ^c
	75	14.193 ^{o-s}	21.252 ^{i-q}	29.368 ^{b-k}	21.604 ^{de}		
	150	11.710 ^{qrs}	22.702 ^{h-p}	34.368 ^{a-f}	22.927 ^{cd}		
L5	0	27.518 ^{d-m}	31.702 ^{b-i}	33.368 ^{a-h}	30.863 ^{ab}		32.607 ^a
	75	28.368 ^{b-l}	35.702 ^{a-e}	38.702 ^{abc}	34.257 ^a		
	150	21.368 ^{i-q}	37.702 ^{a-d}	39.035 ^{ab}	32.702 ^{ab}		
Interaction of CaCO ₃ × L	L1	23.084 ^{def}	31.252 ^{bc}	36.363 ^{ab}	Effect of GA ₃ Conce (mg l ⁻¹)		
	L2	19.085 ^f	27.863 ^{cd}	26.252 ^{cd}			
	L3	11.917 ^g	20.418 ^{ef}	23.474 ^{def}			
	L4	11.958 ^g	18.846 ^f	26.607 ^{cd}	0	20.609 ^b	
	L5	25.752 ^{cde}	35.035 ^{ab}	37.035 ^a	75	26.296 ^a	
Effect of CaCO ₃ (g)		18.359 ^c	26.683 ^b	29.946 ^a	150	28.083 ^a	

Root Dry Weight

Results in Table 9 show a significant effect of location on root dry weight, with L1 and L5 yielding the highest significant root dry weight 1.259 and 1.236 g respectively. GA₃ at 150 mg l⁻¹ produced the greatest root dry weight 1.309 g, significantly higher than 75 mg l⁻¹ 1.133 g and the control (0.964 g). Similarly, 4 g pot⁻¹ CaCO₃ resulted in the highest root dry weight 1.318 g, compared to 2 g pot⁻¹ 1.167 g and the control 0.919 g.

The location × GA₃ interaction was observed significantly results in L1 with 150 mg l⁻¹ GA₃, giving 1.692 g, while the lowest 0.856 g was in L1 without GA₃ treated. While the location × CaCO₃ interaction showed the maximum significantly root dry weight 1.583 g in L5 with 4 g pot⁻¹ CaCO₃, and the minimum 0.790 g in L2 without CaCO₃. About the triple interaction, the highest root dry weight 2.111 g was achieved in L1 with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃ and it was significantly compared to all treatment, also, compared to the lowest (0.700 g) in L2 with 75 mg l⁻¹ GA₃ but without CaCO₃.

Bulb Weight

Table 10 indicates that location had a significant effect on bulb weight, with L5 producing the heaviest bulbs 43.655 g compared to all treatments, while the lightly bulbs weight was found in L4 reaching 23.343g. However, GA₃ at 150 mg l⁻¹ resulted in the highest bulb weight 40.640 g, significantly greater than 75 mg l⁻¹ 31.951 g and the control

28.023 g. The soil application of 4 g pot⁻¹ CaCO₃ yielded the highest significantly bulb weight 39.522 g, compared to 2 g pot⁻¹ 33.237 g and the control 27.855 g.

Also, interaction between the location × GA₃, shown the maximum bulb weight 50.544 g was recorded in L5 with 150 mg l⁻¹ GA₃ which was the significantly compared to all treatment, while the minimum 14.984 g was in L4 without GA₃. The location × CaCO₃ interaction showed the highest weight 49.619 g in L5 with 4 g pot⁻¹ CaCO₃ which was the significantly compared to all treatment except the L2 in the same level of CaCO₃ 45.520 g, and the lowest 18.658 g in L3 without CaCO₃. While the triple interaction revealed that the greatest bulb weight (66.300 g) was obtained in L5 with 150 mg l⁻¹ GA₃ and 4 g pot⁻¹ CaCO₃, it was significantly compared to all treatment and compared to the lowest (10.988 g) in L4 without GA₃ or CaCO₃.

Bulb Diameter: Data in Table 11 show that location significantly influenced bulb diameter, with L1, L2, and L5 showing the largest diameters 3.758 cm, 3.850 cm, and 4.068 cm, respectively. GA₃ at 150 mg·L⁻¹ produced the largest bulb diameter 3.893 cm, significantly greater than 75 mg l⁻¹ 3.385 cm and the control 3.348 cm. Similarly, 4 g pot⁻¹ CaCO₃ significantly resulted in the largest diameter 3.948 cm, compared to 2 g.pot⁻¹ 3.574 cm and the control 3.104 cm.

The location × GA₃ interaction was most significantly in L1 with 150 mg l⁻¹ GA₃, giving 4.508 cm it is significantly compared to all treatment except 4.276 and 4.217 in L5 with spraying 75 and 150 mg l⁻¹ GA₃ respectively, and 4.381 and 4.073 in L2 with 150 mg l⁻¹ GA₃ and L3 without GA₃, while the smallest 2.412 cm was in L4 without GA₃. The location × CaCO₃ interaction showed the maximum diameter of bulbs 4.378 cm in L5 with 4 g pot⁻¹ CaCO₃ which was significantly compared to all treatment except (4.256 cm in L1 with 4 g.pot⁻¹ CaCO₃ and 4.122 in L5 with 2 g pot⁻¹ CaCO₃ and 4.063 cm in L2 with 2 g pot⁻¹, and the minimum 2.209 cm in L4 without CaCO₃. From the triple interaction, the largest bulb diameter 4.990 cm was significantly achieved in L3 with 4 g.pot⁻¹ CaCO₃, compared to the smallest 1.973 cm in L4 with 75 mg l⁻¹ GA₃ but without CaCO₃.

Table 9. Effect of locations, GA₃ Concentrations and its interaction on the Root dry weight of Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of GA ₃ X L	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4		
L1	0	0.793 ^{nop}	0.873 ^{m-p}	0.902 ^{l-p}	0.856 ^h	1.259 ^a
	75	0.934 ^{l-p}	1.318 ^{d-i}	1.438 ^{cde}	1.230 ^{cd}	
	150	1.188 ^{e-l}	1.777 ^b	2.111 ^a	1.692 ^a	
L2	0	0.797 ^{nop}	1.000 ^{j-o}	1.141 ^{f-m}	0.979 ^{fgh}	1.063 ^c
	75	0.700 ^p	1.355 ^{d-h}	1.108 ^{g-m}	1.054 ^{ef}	
	150	0.874 ^{m-p}	1.191 ^{e-l}	1.404 ^{c-f}	1.156 ^{cde}	
L3	0	1.010 ^{j-o}	0.937 ^{l-p}	1.080 ^{h-n}	1.009 ^{e-h}	1.145 ^b
	75	1.118 ^{f-m}	1.179 ^{e-l}	1.146 ^{f-m}	1.148 ^{cde}	
	150	1.076 ^{h-n}	1.249 ^{d-j}	1.514 ^{cd}	1.279 ^{bc}	
L4	0	0.730 ^{op}	0.949 ^{k-p}	0.975 ^{j-p}	0.884 ^{gh}	0.971 ^d
	75	0.964 ^{j-p}	1.024 ^{i-o}	1.068 ^{h-n}	1.019 ^{efg}	
	150	0.852 ^{m-p}	1.038 ⁱ⁻ⁿ	1.140 ^{f-m}	1.010 ^{e-h}	
L5	0	0.895 ^{l-p}	1.128 ^{f-m}	1.245 ^{d-k}	1.090 ^{def}	1.236 ^a
	75	0.873 ^{m-p}	1.110 ^{g-m}	1.654 ^{bc}	1.212 ^{cd}	
	150	0.989 ^{j-p}	1.381 ^{d-g}	1.848 ^b	1.406 ^b	
Interaction of CaCO ₃ × L	L1	0.972 ^{efg}	1.322 ^b	1.484 ^a	Effect of GA ₃ Conce (mg l ⁻¹)	
	L2	0.790 ^h	1.182 ^{bcd}	1.218 ^{bcd}		
	L3	1.068 ^{def}	1.122 ^{cde}	1.246 ^{bc}		
	L4	0.849 ^{gh}	1.003 ^{ef}	1.061 ^{def}	0	0.964 ^c
	L5	0.919 ^{fgh}	1.206 ^{bcd}	1.583 ^a	75	1.133 ^b
Effect of CaCO ₃ (g)		0.919 ^c	1.167 ^b	1.318 ^a	150	1.309 ^a

Table 10. Effect of locations, GA₃ Concentrations and its interaction on the Bulb weight of Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of GA ₃ + L		Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4			
L1	0	22.439 ^{klm}	27.041 ^{h-l}	39.641 ^{b-g}	29.707 ^{fg}	38.379 ^b	
	75	35.258 ^{d-j}	46.774 ^{bcd}	40.701 ^{b-f}	40.911 ^{bcd}		
	150	36.374 ^{c-i}	46.641 ^{bcd}	50.541 ^b	44.519 ^b		
L2	0	28.874 ^{g-k}	29.918 ^{f-k}	42.128 ^{b-e}	33.640 ^{ef}	35.503 ^b	
	75	21.208 ^{k-n}	37.058 ^{c-i}	47.041 ^{bcd}	35.102 ^{def}		
	150	24.574 ^{j-m}	41.341 ^{b-f}	47.391 ^{bc}	37.769 ^{cde}		
L3	0	16.141 ^{lmn}	28.691 ^{g-k}	26.324 ^{i-l}	23.719 ^h	26.809 ^c	
	75	16.674 ^{lmn}	30.658 ^{e-k}	28.974 ^{g-k}	25.435 ^{gh}		
	150	23.158 ^{klm}	28.806 ^{g-k}	41.856 ^{b-e}	31.273 ^{fg}		
L4	0	10.988 ⁿ	16.874 ^{lmn}	17.091 ^{lmn}	14.984 ⁱ	23.343 ^d	
	75	16.874 ^{lmn}	16.559 ^{lmn}	14.417 ^{mn}	15.950 ⁱ		
	150	46.250 ^{bcd}	23.167 ^{klm}	47.867 ^{bc}	39.094 ^{b-e}		
L5	0	38.000 ^{c-h}	38.333 ^{c-h}	37.857 ^{c-h}	38.063 ^{cde}	43.655 ^a	
	75	40.175 ^{b-g}	42.200 ^{b-e}	44.700 ^{bcd}	42.358 ^{bc}		
	150	40.833 ^{b-f}	44.500 ^{bcd}	66.300 ^a	50.544 ^a		
Interaction of CaCO ₃ × L	L1	31.357 ^{de}	40.152 ^{bc}	43.628 ^b	Effect of GA ₃ Conce (mg l ⁻¹)		
	L2	24.885 ^f	36.105 ^{cd}	45.520 ^{ab}			
	L3	18.658 ^g	29.385 ^{ef}	32.385 ^{de}			
	L4	24.704 ^f	18.867 ^g	26.458 ^{ef}	0	28.023 ^c	
	L5	39.669 ^{bc}	41.678 ^{bc}	49.619 ^a	75	31.951 ^b	
Effect of CaCO ₃ (g)		27.855 ^c	33.237 ^b	39.522 ^a	150	40.640 ^a	

Table 11. Effect of locations, GA₃ Concentrations and its interaction on the Bulb diameter Narcissus plant (*Narcissus tazetta* L).

Treatment		CaCO ₃ levels (g)			Interaction of GA ₃ + L	Effect of Locations
Location	GA ₃ (mg l ⁻¹)	0	2	4		
L1	0	2.343 ^{mno}	2.957 ^{i-o}	3.741 ^{c-k}	3.014 ^{fgh}	3.758 ^a
	75	3.507 ^{e-m}	3.553 ^{d-l}	4.200 ^{a-h}	3.753 ^{b-d}	
	150	3.990 ^{a-j}	4.707 ^{a-d}	4.827 ^{abc}	4.508 ^a	
L2	0	3.157 ^{g-n}	3.607 ^{d-l}	3.823 ^{a-k}	3.529 ^{def}	3.850 ^a
	75	3.423 ^{e-m}	4.057 ^{a-i}	3.440 ^{e-m}	3.640 ^{cde}	
	150	3.923 ^{a-j}	4.292 ^{a-g}	4.927 ^{ab}	4.381 ^a	
L3	0	2.340 ^{mno}	4.890 ^{abc}	4.990 ^a	4.073 ^{a-d}	3.282 ^b
	75	2.857 ^{i-o}	2.690 ^{k-o}	2.890 ^{i-o}	2.812 ^{gh}	
	150	3.273 ^{f-n}	2.383 ^{mno}	3.223 ^{f-n}	2.960 ^{fgh}	
L4	0	2.523 ^{l-o}	2.557 ^{l-o}	2.157 ^{no}	2.412 ^h	2.751 ^c
	75	1.973 ^o	2.357 ^{mno}	2.998 ^{i-o}	2.443 ^h	
	150	2.132 ^{no}	3.198 ^{f-n}	4.868 ^{abc}	3.399 ^{efg}	
L5	0	3.065 ^{h-o}	3.768 ^{b-k}	4.298 ^{a-g}	3.711 ^{b-d}	4.068 ^a
	75	3.998 ^{a-j}	4.332 ^{a-g}	4.498 ^{a-e}	4.276 ^{ab}	
	150	4.048 ^{a-i}	4.265 ^{a-g}	4.337 ^{a-f}	4.217 ^{abc}	
Interaction of CaCO ₃ × L	L1	3.280 ^{def}	3.739 ^{bcd}	4.256 ^{ab}	Effect of GA ₃ Conce (mg l ⁻¹)	
	L2	3.501 ^{cd}	3.985 ^{abc}	4.063 ^{abc}		
	L3	2.823 ^{ef}	3.321 ^{de}	3.701 ^{bcd}		
	L4	2.209 ^g	2.704 ^{fg}	3.341 ^{de}	0	3.348 ^b
	L5	3.704 ^{bcd}	4.122 ^{abc}	4.378 ^a	75	3.385 ^b
Effect of CaCO ₃ (g)		3.104 ^c	3.574 ^b	3.948 ^a	150	3.893 ^a

According to Singh (1996), it was observed that increasing the size of bulbs results in a higher number of leaves, which in turn promotes greater vegetative growth. This enhanced growth boosts the production of photosynthetic

products, such as carbohydrates, which are formed by converting light energy into chemical energy. A concentration of 50 mg l⁻¹ of gibberellic acid was found to produce superior growth characteristics. The maximum length and number of leaves 20.903 cm and 8.403 leaves per plant was recorded with GA3 at 150 mg l⁻¹. Similarly, the tallest plant was obtained by Patel et al., (2010), Singh et al., (2018) and Sharifuzzaman et al., (2011) from GA3 150 mg l⁻¹ in chrysanthemum. Contrary to this, Farag et al., (2018) and Sahu et al., (2021) obtained the tallest plant from GA3 at 200 mg l⁻¹ in chrysanthemum. Sahu et al., (2021), El-Ghait et al., (2018) and Sajid et al., (2018) also found that the maximum number of leaves per plant was recorded from the plants sprayed with treatment containing GA3 at 200 mg l⁻¹, GA3 at 300 mg l⁻¹ and GA3 at 100 mg l⁻¹, respectively. Alhajhoj (2017) also found that the application of GA3 at 300 mg l⁻¹ resulted in the maximum number of flowers per plant which was equal to that of GA3 at 200 mg l⁻¹. Sharifuzzaman et al., (2011) and Singh et al., (2018) obtained the maximum number of flowers per plant from the spraying of GA3 at 150 mg l⁻¹ which was significantly higher than GA3 at 150 mg l⁻¹. Sahu et al., (2021) found that the maximum number of flowers per plant was from GA3 at 200 mg l⁻¹ and GA3 at 250 mg l⁻¹, respectively. The increased stalk length with GA3 at 100 mg l⁻¹. treatment might be due to rapid internodal elongation, rapid cell division and cell elongation in the intercalary meristem. Singh et al., (2018) opined that the reason for the increased stalk might be that the length of the flower stalk is due to redirecting the movement of organic metabolism and in establishing sink compounds. The increase in length with GA3 at 100 mg l⁻¹. might be due to increased activity of growth promoting enzymes by synthesizing more nucleic acid and other. This response may be due to the role of gibberellic acid in increasing the size and expansion of plant cells through its effect in increasing the flexibility and plasticity of the cell walls and increasing their expansion. Adaws et al., (2011). The reason may be due to the action of oxy induced by spraying gibberellin. Because it has a role in cell growth and stimulates and modifies the processes of gene duplication and translation, which then stimulate the construction of DNA, RNA, and protein. On the other hand, the auxins induced by gibberellin play a role of great importance in stimulating the plasticity of cell walls, by breaking the bonds of the cell walls and are arranged in new sites under the influence of swelling pressure therefore contribute to increasing cell size and expansion as well as the formation of enzymes. Its components, such as the cellulose enzyme, which in turn weakens the fiber systems and the construction and decomposition of components of the cell walls, which comes through stimulating the pumping of hydrogen ions (protons) and reducing the cell pH, which causes an increase in the acidity of the cell walls, thus changing the water relations of the plant, especially the turbidity and osmotic pressure of the cell, which causes water flow (Castro-Camba et al., 2022) stated that gibberellin works to elongate the stem and the height of plants by two different physiological processes, the first represented in cell division and the second in the cellular elongation of plant tissue cells.

Based on the physiological principle that bulb weight in geophytes is a function of carbohydrate accumulation, more recent studies affirm that assimilating production directly governs bulb yield. For instance, research in *Lilium* has demonstrated that a greater leaf area, which enhances photosynthetic capacity, is positively correlated with increased final bulb weight (Karagüzel, 2020). (Xia et al., 2004) and more leaves per plant are usually produced by larger bulbs than by smaller ones (e.g., in *Lachenalia*) (Kapczyńska, 2014). In our study, an increase in leaf DW was observed along with an increase in the size of planted bulbs. However, this tendency was not of a model nature. The most pronounced effect of CaCO₃ application was observed in below ground and vegetative growth parameters. Plants receiving the 2 g pot⁻¹ treatment consistently exhibited the highest values for bulb weight, bulb diameter, and number of daughter bulbs. This is in line with the well-established role of calcium as a major structural component in cell walls and membranes, playing a crucial role in cell division and growth during organ development (White & Broadley, 2003). The better bulb formation is also likely due to better root health; the number of roots and root dry weight was significantly increased with moderate CaCO₃ soil treatment. This can be ascribed to two processes: first, the mitigation of possible low-pH toxicity (such as aluminium), which favors primary root growth (Kopittke et al., 2021), and second, the involvement of calcium ions in root cell signaling and tip growth, which is vital for lateral root emergence and development (Edel & Kudla, 2016). The subsequent increased ability to explore roots and uptake nutrients/water provided the needed stimulus for better bulb filling and daughter bulb formation. It is also interesting to note that the highest treatment rate (4 g pot⁻¹) often caused a reduction in these measures compared to the 2 g treatment, possibly due to a threshold effect where too much CaCO₃ could have caused a nutrient imbalance, perhaps due to decreased availability of other cations such as potassium and magnesium.

Conclusion

In summary, this research has made it clear that the growth and flowering factors of narcissus are significantly affected by the combined effects of geographical location, the application of gibberellic acid (GA₃), and the addition of limestone (CaCO₃) to the soil. Among the different geographical locations, L1 was found to be the best in giving the highest values for most of the vegetative and floral characters. The application of the highest concentration of GA₃ significantly improved all the measured factors compared to the lower concentrations and the control. Similarly, the addition of the highest rate of limestone powder significantly improved all the measured factors compared to the lower rates and the control.

The interaction effects of the above factors were very significant. The best combination of factors universally included the selection of bulbs from the most favorable location (L1), the application of the highest concentration of GA₃, and the addition of the highest rate of limestone powder. This combination of factors significantly outperformed all other factors for most of the measured characters, including leaf growth, flower production, stalk length, root growth, and bulb characteristics.

Sustainability Statement

This study contributes to sustainable ornamental horticulture by evaluating the integrated use of gibberellic acid and limestone powder to improve the morphological performance of *Narcissus tazetta* L. Optimizing plant growth through appropriate plant growth regulator application and soil amendment practices can reduce unnecessary agricultural inputs, enhance resource-use efficiency, improve bulb productivity and ornamental quality, and support environmentally sustainable floricultural production systems.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. All data generated or analyzed during this study are included in the published article and its supplementary materials, where applicable.

Author Contributions (CRediT)

First author: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft. Second author: Methodology, Validation, Supervision, Writing – review & editing. Third author: Investigation, Resources, Visualization, Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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