Interactive Effects of Soil Gypsum Content and Nitrogen Fertilization on Growth, Flowering Characteristics, and Ammonium Uptake of *Chrysanthemum morifolium* L.

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Abstract

The agricultural experiment was conducted during the 2025–2026 growing season to study the effect of adding different levels of nitrogen on the growth of Chrysanthemum morifolium L. The experiment included two factors: the first was the addition of four nitrogen levels (0, 62.5, 125, 250) kg ha^{-1}, and the second factor was gypsiferous soils from different areas of Tikrit University fields containing gypsum percentages (20%, 10%, 5%), denoted as (G3, G2, G1), respectively. The experiment was designed according to a Randomized Complete Block Design (RCBD) with three replications. Both factors play important and varying roles that may positively or negatively reflect on plant growth efficiency and nutrient uptake. The study results showed that the treatment G1N3 gave the highest mean for ammonium uptake, leaf number, flower diameter, and dry weight, reaching (59.30) µg $plant^{-1}$, (61.00) leaf $plant^{-1}$, (6.93) cm, and (5.26) g $plant^{-1}$, respectively, with a significant increase compared to the control treatment. The treatment G1N2 gave the highest mean for plant height, reaching (25.66) cm, while the treatment G1N1 recorded the highest mean for leaf area, reaching (48.86) cm^2. The treatment (G3N3) gave the highest mean for flower number, reaching (4.33) flower $plant^{-1}$.

Keywords: Gypsiferous soils, Nitrogen, Ammonium, Chrysanthemum.

Introduction

Soil is considered one of the most important primary economic resources due to its direct link to agriculture, agricultural production, and ensuring food security. Iraqi soils represent a part of the soils of arid and semi-arid regions, characterized by low and erratic rainfall as well as high temperatures, which have fundamentally contributed to the accumulation of salts in the soil. Among the most prominent of these salts are (calcium carbonate and calcium sulfate). With the horizontal expansion of agricultural activity to meet the growing food demand resulting from population growth, there has been an expansion in the area of agricultural lands, including gypsiferous soils (1). The high gypsum content in the soil may lead to a decrease in its water-holding capacity and ultimately affect the infrastructure (2). The area of gypsiferous lands in Iraq is estimated at approximately 88,000 km^2, occupying about 20% of Iraq's total area (3). Gypsum ($CaSO_4 \cdot 2H_2O$) plays an important role in influencing soil properties, particularly in the dynamics of adsorption and release of ammonium ions (NH_4^+), which represent a primary source of mineral nitrogen available for plant uptake. Despite the ability of plants to rely entirely on ammonium as the sole and primary source of nitrogen, high levels of it in the root zone environment may lead to toxic effects that negatively impact

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crop growth, especially grains. High ammonium concentrations also increase the likelihood of lodging, due to weakening the mechanical strength of the stem and causing severe damage to the plant's vascular tissues (4), which will affect the transport of water and nutrients to the grains, consequently reducing grain yield and quality. When high amounts of nitrogen are present, nitrogen concentration in the biomass increases significantly (5). Chrysanthemum (Chrysanthemum morifolium L.) belongs to the Asteraceae family (6). It is considered a plant of economic and medicinal importance. China and Japan are its native origins, and it is widely cultivated in Europe and Africa (8). . Nitrogen is a crucial element for plant growth and development due to its effective role in photosynthesis. Nitrogen directly affects plant physiological processes, as it contributes to the formation of photosynthetic pigments and the enzymes that participate in carbon cycle reactions. Providing adequate amounts of nitrogen promotes vegetative and reproductive growth (9). Nitrogen fertilization is one of the fundamental factors affecting plant growth and productivity efficiency, as nitrogen deficiency leads to a reduction in leaf area, limiting the plant's ability to absorb sunlight necessary for photosynthesis.

Given the ornamental, economic, and medicinal importance of Chrysanthemum, and the scarcity of studies on the plant's growth response to nitrogen in soils with varying gypsum levels, we conducted this research for the following objectives:

1. Better manage nutrients by establishing the optimal nitrogen levels for Chrysanthemum development and NUE in gypsiferous soils.
2. Examining the relationships between gypsum content, nitrogen levels, and ammonium absorption, and determining how different gypsum levels affect ammonium retention and availability in soil.

Materials and Methods

Soil Sample Collection:

Gypsiferous soils were sampled from a representative site in a semi-arid region with high gypsum content, situated in the Salahaddin Governorate, Iraq. The geographic coordinates and gypsum contents for each location were as follows:

- Location 1 (L1): 34.685542, 43.64708, gypsum contents: 64 $g.kg^{-1}$
- Location 2 (L2): 34.669703, 43.641514, gypsum contents: 136 $g.kg^{-1}$
- Location 3 (L3): 34.713859, 43.711197, gypsum contents: 245 $g.kg^{-1}$

The soil samples were obtained from the top 30 cm of the soil profile to ensure consistency in texture and structure. The soil was air-dried, sieved through a 2-mm mesh, and then characterized for several physical and chemical parameters. Total nitrogen content was quantified using the Kjeldahl method (7).

The experiment was conducted in Tikrit City during the 2025–2026 growing season. It included a pot experiment (capacity 7 kg) to determine the effect of ammonium uptake on Chrysanthemum morifolium L. in gypsiferous soils with different gypsum contents.

Experimental Design:

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The experiment included two factors: the first was the addition of nitrogen at different rates, where urea was added at four concentrations (0, 62.5, 125, 250) kg ha^{-1}, denoted as (N0, N1, N2, N3), respectively. The second factor was different gypsum levels with three percentages (20%, 10%, 5%), denoted as (G3, G2, G1), with three replications using a Randomized Complete Block Design (RCBD), resulting in a total of 36 experimental units.The recommended dose of (N) was applied to the pots in two splits: the first dose was added at the time of planting, and the second dose was added four weeks later. Plants were irrigated according to their needs and surrounding environmental conditions. When 50% of the plants flowered, the following growth measurements were taken (plant height, leaf number, leaf area, plant dry weight, plant nitrogen concentration). The following flowering traits were also recorded (number of flowers per plant, flower diameter). The results were statistically analyzed using the SAS statistical program with Analysis of Variance (ANOVA) according to the RCBD design. Differences between means were tested at significance levels using the Least Significant Difference (L.S.D) test at a probability of 5%.

Results and Discussion

It is noted from the results in Table (1) that increasing gypsum negatively affected the amount of ammonium absorbed by Chrysanthemum plants. The treatment G1 recorded the highest concentration of absorbed ammonium, reaching (36.20) µg $plant^{-1}$, with a percentage increase of 31.63% and 14.73% compared to the treatments G3 and G2, respectively, which gave means of (27.50) and (31.55) µg $plant^{-1}$, respectively. The addition of nitrogen fertilizer positively affected the amount of ammonium absorbed by the plant; increasing nitrogen application levels led to an increase in absorbed ammonium in Chrysanthemum, as the treatment N3 excelled, giving the highest concentration of absorbed ammonium at (50.51) µg $plant^{-1}$. The two-way interaction between soil gypsum content and nitrogen fertilizer addition showed clear significant differences in favor of the treatment N3G1, which recorded the highest mean for this interaction at (59.30) µg $plant^{-1}$, significantly outperforming all other interaction treatments. The treatment N0G3 recorded the lowest mean for this interaction at (18.13) µg $plant^{-1}$. The results indicated that nitrogen fertilizer significantly increased ammonium uptake, likely due to improved nutrient uptake resulting from more effective root growth (10). Increased soil gypsum content led to decreased ammonium uptake, attributed to the increased concentration of sulfate ions (SO_4^{2-}), which in turn affects ammonium uptake. The interaction results showed that high gypsum concentrations reduce the positive effect of nitrogen fertilizer on root growth and nutrient uptake by reducing ammonium availability in the root zone. These findings highlight the necessity of balanced nutrient management, combining optimal nitrogen levels with proper gypsum management, to maximize ammonium availability and support Chrysanthemum growth in gypsiferous soils (11).

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Table (1) Effect of soil gypsum level on the amount of absorbed ammonium (µg plant^{-1}) in the vegetative part under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
36.20	59.30	35.23	27.76	22.50	G_1
31.55	49.13	31.70	25.53	19.83	G_2
27.50	43.10	29.93	18.83	18.13	G_3
31.75	50.51	32.28	24.04	20.15	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
1.54	0.77		0.89		

Table (2) shows the effect of gypsum content, nitrogen fertilizer application, and their interaction on the height of Chrysanthemum plants. It was found that the effect of both gypsum content and nitrogen fertilizer was significant on plant height. The treatment N2 significantly outperformed the other treatments, with a plant height value of (23.97) cm for treatment N2, while the lowest value of (21.44) cm was recorded for treatment N0. The effect of gypsum content on plant height is also shown, as treatment G3 produced the highest height value (23.62) cm, while treatment G1 gave the lowest height value (22.59) cm. The interaction between treatments produced N2G1 and N0G1, giving the highest and lowest height values, respectively, at (25.66) cm and (17.00) cm, which corresponds to an increase of 50.94%, demonstrating the beneficial and positive interaction effect between gypsum content and nitrogen fertilization. The reason for the significant increase in plant height yield with increasing nitrogen levels may be attributed to the positive effect of nitrogen on the activity of meristematic tissues and its role in cell division and stimulating cell elongation, which led to increased plant height. These results are consistent with those found by (12) and (13), and also agree with (14) . In contrast, the presence of high gypsum content negatively affected plant height due to the increase in sulfate ions, which may hinder nutrient uptake. The interaction between nitrogen and gypsum demonstrates the complexity of their combined effect on plant growth. These results support previous studies that investigated the role of nitrogen and gypsum in plant growth (15; 16).

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Table (2) Effect of soil gypsum level on Chrysanthemum plant height (cm) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
22.59	23.10	25.66	24.60	17.00	G_1
22.79	23.66	23.43	21.73	22.33	G_2
23.62	22.50	22.83	24.16	25.00	G_3
23.00	23.08	23.97	23.50	21.44	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
2.83	1.41		1.63		

Table (3) indicates that gypsum content significantly affected the number of plant leaves. It is observed that the medium gypsum content in the soil G2 gave the highest mean for the leaf number trait of Chrysanthemum plants, reaching (45.08) leaf plant^{-1}, significantly outperforming the levels G3 and G1, which gave means of (44.00) and (43.08) leaf plant^{-1}, respectively. With increasing nitrogen addition, the number of leaves significantly increased, with means of (42.33, 44.66, 51.77) leaf plant^{-1} for the addition levels N1, N2, N3, respectively, while the no-addition treatment N0 gave the lowest mean of (37.44) leaf plant^{-1}. The two-way interaction between soil gypsum content and added nitrogen levels showed significant differences among most treatments. The interaction treatment N3G1 recorded the highest mean for this interaction, reaching (61.00) leaf plant^{-1}, while the lowest mean for this interaction was recorded for treatment N0G1, reaching (30.00) leaf plant^{-1}. The reason for the decrease in leaf number may be attributed to the effect of gypsum on some physical and chemical properties of the soil and fertility, in addition to soil management, as it leads to reduced availability of essential nutrients required by the plant for various metabolic processes. The reduced uptake of these elements limits the efficiency of the fertilization process, which is negatively reflected in the number of formed leaves. The reason for the increase in leaf number upon nitrogen addition is attributed to the fact that nitrogen contributes to the formation of plant hormones that activate cells involved in leaf formation, leading to an increased number of leaves in the plant (17; 18).

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Table (3) Effect of soil gypsum level on the number of leaves of Chrysanthemum plants (leaf plant^{-1}) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
44.00	61.00	44.66	41.33	30.00	G_1
45.08	49.00	41.66	47.66	42.00	G_2
43.08	45.33	47.66	39.00	40.33	G_3
44.05	51.77	44.66	42.33	37.44	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
3.57	1.78		2.06		

It is evident from the results in Table (4) that increasing nitrogen addition significantly affected leaf area. The treatment N3 gave the highest mean of (45.07) cm² leaf^{-1}, significantly outperforming the other treatments N2, N1, and N0, which had means of (40.25, 44.68, and 39.84) cm² leaf^{-1}, respectively. Soil gypsum content significantly affected leaf area, as treatment G2 gave the highest mean of (42.98) cm² leaf^{-1}, significantly outperforming treatments G3 and G1, which gave means of (41.74 and 42.97) cm² leaf^{-1}, respectively. The interaction between nitrogen fertilizer and gypsum content showed significant differences among most treatments, with superiority for treatment N1G1, which recorded the highest mean of (48.86) cm² leaf^{-1}, while treatment N0G1 gave the lowest mean for the interaction at (35.14) cm² leaf^{-1}. The significant effect of nitrogen addition is attributed to the role of nitrogen in plant activation and its importance in the vital activities of the plant, which is positively reflected in increasing leaf number and surface area. This agrees with (19) and (20). The reason may also be due to nitrogen's contribution to extending the period during which the plant can carry out photosynthesis to increase leaf chlorophyll content, thereby causing an increase in leaf area, in addition to the effect of nitrogen on cell division and expansion, which is positively reflected in vigorous growth, leading to increased leaf area. These results are consistent with those of (21). The results also showed that soil with medium gypsum content (10%) gave a significant superiority in leaf area, while increasing the gypsum percentage to 20% negatively affected leaf area. This may be attributed to gypsum leading to deterioration of soil physical properties such as porosity and aeration, which reduces root growth and spread, as its negative effect began to appear. However, productive gypsiferous soils can be fertile if their nutrient content is improved through fertilizer addition (22).

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Table (4) Effect of soil gypsum level on the total leaf area of Chrysanthemum plants (cm^2) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
41.74	46.50	36.46	48.86	35.13	G_1
42.98	41.80	37.60	45.26	47.26	G_2
42.67	46.93	45.46	39.93	38.36	G_3
42.46	45.07	39.84	44.68	40.25	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
3.79	1.89		2.19		

It is clear from the results in Table (5) the positive effect of soil gypsum content, nitrogen fertilizer addition, and their interaction on flower number. The number of flowers per plant increased significantly with increasing nitrogen addition, with means of (3.11, 3.55, 3.77) flower $plant^{-1}$ for treatments N1, N2, N3, respectively, while the control treatment gave a mean of (2.55) flower $plant^{-1}$. Increasing gypsum content led to an increase in flower number per plant, with treatment G3 giving a mean of (3.58) flower $plant^{-1}$, significantly outperforming treatments G2 and G1, which gave means of (3.00 and 3.16) flower $plant^{-1}$, respectively. The interaction between the two factors showed clear significant differences in favor of treatment N3G3, which recorded the highest mean for this interaction at (4.33) flower $plant^{-1}$, significantly outperforming all other interaction treatments, while treatment N0G1 recorded the lowest mean at (2.00) flower $plant^{-1}$. The reason for the increase in flower number with increasing gypsum content may be because gypsum acts as a soil conditioner and positively affects flower yield by providing essential nutrients and improving soil properties. It also helps remove harmful salts from the root zone and neutralizes ammonium toxicity in acidic soils, thereby stimulating plants to flower. The superiority of the nitrogen addition factor is attributed to nitrogen encouraging photosynthesis and respiration processes, regulating plant hormone activity, and promoting cell division (23).

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Table (5) Effect of soil gypsum level on flower number of Chrysanthemum plants (flower plant^{-1}) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
3.00	3.66	3.66	2.66	2.00	G_1
3.16	3.33	3.66	3.00	2.66	G_2
3.58	4.33	3.33	3.66	3.00	G_3
3.24	3.77	3.55	3.11	2.55	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
0.83	0.41		0.48		

The results in Table (6) indicate that soil gypsum content significantly affected flower diameter. Treatment G2 gave the highest mean of (5.88) cm, significantly outperforming treatments G3 and G1, which gave means of (5.63 and 5.44) cm, respectively. It is also evident that increasing nitrogen fertilizer addition led to a significant increase in flower diameter, as treatments N1, N2, and N3 gave means of (5.32, 6.03, and 6.54) cm, with increases of 12.47%, 27.48%, and 38.26%, respectively, compared to the no-addition treatment, which gave the lowest mean of (4.73) cm. It is clear from the same table that the interaction between soil gypsum content and nitrogen level was significant, with the interaction treatment N3G1 giving the highest mean of (6.93) cm, significantly outperforming all other interaction treatments, while the interaction treatment N0G2 gave the lowest mean of (4.66) cm. The reason for the increase in flower diameter with increasing nitrogen addition may be attributed to nitrogen encouraging photosynthesis and respiration processes, regulating plant hormone activity, and promoting cell division (23). The soil with medium gypsum content (10%) gave the highest mean for flower diameter trait, which may be due to the medium gypsum percentage improving the physical properties of the soil, allowing roots to spread easily in the soil. Gypsum also plays a significant role in aeration, which improves plant growth and is consequently positively reflected in yield.

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Table (6) Effect of soil gypsum level on flower diameter of Chrysanthemum plants (cm) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
5.63	6.93	5.83	5.06	4.70	G_1
5.88	6.86	6.43	5.56	4.66	G_2
5.45	5.83	5.83	5.33	4.83	G_3
5.65	6.54	6.03	5.32	4.73	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
0.56	0.28		0.32		

It is clear from Table (7) that nitrogen fertilizer significantly affected the dry weight of Chrysanthemum plants. Treatment N3 achieved the highest plant dry weight (4.04) g plant^{-1}, while treatment N0 achieved the lowest plant dry weight (1.87) g plant^{-1}, indicating an increase of 116.04%. Increasing gypsum content negatively affected dry weight, as treatment G1 achieved the highest dry weight (3.12) g plant^{-1}, while increasing gypsum contents G2 and G3 led to a 20% decrease in dry weight, with the lowest value recorded for treatment G3 at (2.60) g plant^{-1}. The interaction N3G1 achieved the highest dry weight (5.26) g plant^{-1}, while treatment N0G1 achieved the lowest dry weight (1.56) g plant^{-1}. This is attributed to the essential role of nitrogen in forming proteins and enzymes necessary for stimulating cell division and elongation and enhancing vegetative growth (24). Increased gypsum concentration was associated with decreased dry weight and restricted vegetative growth. The reason for this decrease may be due to chemical reactions in the soil, such as ammonium precipitation, which limits the availability of nitrogen to the plant (25; 26). The two-way interaction effect indicates that while nitrogen improves plant biomass production, high gypsum content negatively affects this benefit by reducing ammonium uptake (27; 28).

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Table (7) Effect of soil gypsum level on the dry weight of Chrysanthemum plants (g plant^{-1}) under different nitrogen levels.

Mean	Nitrogen Concentration (kg ha^{-1})				Gypsum Level (%)
	N_3	N_2	N_1	N_0	
3.12	5.26	3.40	2.26	1.56	G_1
2.77	3.36	3.03	2.50	2.20	G_2
2.60	3.50	2.96	2.10	1.86	G_3
2.83	4.04	3.13	2.28	1.87	Mean
Interaction	Gypsum Percentage		N Concentration		L.S.D 0.05
0.71	0.35		0.41		

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