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Effect of Gypsum Content and Nitrogen Levels on Ammonium Absorption and Growth of Wheat (Triticum aestivum L.) in Gypsiferous Soils

Mohammed Obaid Mohammed[1], Mahir Essa Alsalihi[2], Aram Shahab Ahmed[1], Yaser Khorram Del[1], Mohammed Noori Saeed[2]*

[1]Department of Food Analysis and Health, Kifri Technical College, Garmian Polytechnic University, Kifri, Kurdistan Region, Iraq,
[2]Department of Medical Laboratory Techniques, Kifri Technical Institute, Garmian Polytechnic University, Kifri, Kurdistan Region, Iraq

Abstract — **Gypsiferous soils, which are widespread in arid and semi-arid regions, pose challenges for nutrient management and crop productivity due to their unique chemical properties. This study aimed to evaluate the effects of nitrogen fertilizer and gypsum content on ammonium absorption and the growth of wheat plants. A field experiment was conducted during the 2022–2023 fall growing season, using gypsum-rich soil samples with varying gypsum concentrations (i.e., 64 g.kg^{-1}, 136 g.kg^{-1} and 245 g.kg^{-1}) selected based on their ammonium generation capacity. The experiment utilized four levels of nitrogen fertilizer (0, 210, 420, and 840 kg ha^{-1}) and three levels of gypsum in pots containing 10 kg of soil, arranged in a randomized complete block design (RCBD) with three replicates, totaling 36 treatments. Results showed that both nitrogen and gypsum levels significantly affected ammonium absorption. The combination of low-gypsum soil and the highest nitrogen level (L1N3) resulted in the highest ammonium absorption (43.17 mg kg^{-1}), while high gypsum soil without nitrogen fertilizer (L3N0) produced the lowest absorption (14.49 mg kg^{-1}). Similarly, the dry weight of wheat plants was significantly affected by the levels of gypsum and nitrogen fertilizer, with the L1N3 interaction yielding the highest dry weight at 15.46 g, exceeding all other treatments. In contrast, the L3N0 treatment produced the lowest dry weight (13.13 g).**

Keywords— **Gypsiferous soils, Ammonium absorption, Gypsum content, Nitrogen fertilizer levels, Wheat growth, Nutrient use efficiency (NUE)**

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*Corresponding author's e-mail: mohammed.obaid@gpu.edu.iq.

I. INTRODUCTION

Wheat (Triticum aestivum L.) is a staple crop vital to global food security, particularly in semi-arid and arid regions. In these areas, gypsiferous soils create major agricultural problems because of their unique physical and chemical properties (Sumner and Miller, 2000). Often present in gypsiferous soils, gypsum ($CaSO_4 \cdot 2H_2O$) modifies the structure of the soil, the availability of nutrients, and the moisture retention. Successful wheat cultivation in such conditions requires increased awareness of how gypsum content interacts with nitrogen dynamics in the soil (Poch et al., 2018).

Gypsum significantly alters soil properties by increasing permeability and drainage, which in turn facilitates nutrient leaching, especially nitrogen. Ammonium (NH_4^+) promotes plant growth, yet it is poorly retained in soils with low cation exchange capacity (CEC). The relationship among soil gypsum concentrations, nitrogen retention, and plant uptake underscores the need for focused management measures in gypsiferous soils.

Nitrogen is crucial for photosynthesis, protein synthesis, and numerous other plant functions. Wheat can absorb both nitrate and ammonium. Although ammonium is less mobile than nitrate, it can be retained in the soil or lost through volatilization or transformation. Ammonium retention in gypsiferous soils is impeded by competition from high concentrations of calcium ions (Ca2+) resulting from gypsum decomposition.

Gypsum introduces calcium ions into the soil solution, facilitating competition with ammonium for adsorption sites on soil particles (Singhal et al., 2023). Gypsum comprises sulphate ions (SO_4^{2-}), which can modify the pH and ionic strength of soil, thereby influencing ammonium dynamics (Anderson et al., 2020).

The cultivation of wheat depends on a sufficient nitrogen supply, which affects yield, biomass, and quality (Zhang et al., 2013). The high leaching potential and poor nutrient retention of these soils make it challenging to determine appropriate nitrogen application rates (Triviño-Tarradas et al., 2020).

The uptake of ammonium by plants significantly influences agricultural yield and nitrogen use efficiency (NUE) (Naorem

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et al., 2023). NUE assesses the efficiency of nitrogen absorption by plants, which is essential for sustainable agriculture. Therefore, investigating the impact of nitrogen and gypsum concentrations on ammonium absorption may facilitate the formulation of effective nutrient management schemes (Naorem et al., 2023; Thomas, 2018).

Most contemporary research focuses on specific topics, such as the impact of nitrogen on agricultural yield and the influence of gypsum on soil structure (Mosier et al., 2021; Qader et al., 2021). However, very few studies have explored the combined effects of gypsum and nitrogen on ammonium dynamics in gypsiferous soils. Therefore, this research investigates the knowledge gap regarding nutrient dynamics in gypsiferous soils by examining the relationships among gypsum content, nitrogen levels, and ammonium absorption.

This research is significant for several reasons. Firstly, it enhances our understanding of nitrogen dynamics in gypsiferous soil, which is an essential factor for agricultural production in arid and semi-arid regions. Secondly, the results provide practical ramifications for enhancing wheat cultivation in in economically disadvantaged regions with gypsiferous soils. The research aligns with the objectives of sustainable agriculture by enhancing nitrogen efficiency, reducing environmental pollution, and promoting soil health (Zhang et al., 2024; Lal et al., 2021).

This study aims to better manage nutrients by establishing the optimal nitrogen levels for wheat development and NUE in gypsiferous soils, examining the relationships between gypsum content, nitrogen levels, and ammonium absorption, and determining how different gypsum levels affect ammonium retention and availability in soil.

II. MATERIALS AND METHODS

Soil Sample Collection and Characterization

The study was conducted under controlled conditions simulating a field environment to evaluate the interaction between gypsum and nitrogen on wheat growth and nutrient dynamics. 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 (Bremner, 1960).

Experimental Design

The experiment included three levels of gypsum soils (low, medium, high) and four levels of nitrogen fertilizer (0, 210, 420, and 840 kg ha-1). The experiment was implemented using a randomized complete block design (RCBD) with three replicates, resulting in a total of 36 treatment combinations. Soil samples with varying gypsum content were brought from the previously mentioned sites to conduct the cultivation experiment. Plastic pots capable of holding 10 kg of soil were employed to investigate the impact of ammonium absorption on wheat plants. The wheat variety "Sham 6" (Triticum aestivum L.), which is widely cultivated in semi-arid regions and is known for its sensitivity to nitrogen supply, was selected for the investigation.

Wheat Growth Parameters

Wheat growth was monitored throughout the experiment until the flag leaf stage, measuring two key parameters: plant height and dry biomass. Plant height was measured from the base of the stem to the tip of the tallest leaf intervals. Dry biomass was determined by drying the plants at 70°C for 48 hours.

The wheat was sown on 9 November 2023, and harvesting took place approximately three months later. For seeding, a circular sowing method was used: wheat seeds were manually sown starting from the edge of the plastic pot and gradually moved inwards toward the center. Each pot contained 10 kg of soil, ensuring consistent soil volume and nutrient availability across all treatments.

Data Analysis

The data obtained were analyzed using analysis of variance (ANOVA) to assess the main effects of gypsum content and nitrogen levels, as well as their interaction effects on ammonium absorption and wheat growth parameters. Means were separated using the Less Significant Difference (LSD) test at a significance level of $p \leq 0.05$. Statistical analyses were

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performed using R (version 4.4.2; R Core Team, 2024) within the RStudio integrated development environment, and Microsoft Excel.

Nutrient Uptake Efficiency

The nitrogen use efficiency (NUE) was calculated as the ratio of wheat dry biomass to the amount of nitrogen applied, as described by Govindasamy et al. (2023). The nitrogen uptake efficiency (NUE_1) and nitrogen utilization efficiency (NUE_2) were calculated using the following equations:

NUE1 = Dry Biomass (kg) / N Applied (kg)

NUE2= Dry Biomass (kg) / N Uptake (kg)

Nitrogen uptake was determined by subtracting the initial soil nitrogen content from the final nitrogen content at harvest.

III. RESULTS

Effect of Gypsum Content and Nitrogen Fertilizer on Ammonium Absorption

Table 1 presents the effect of gypsum content, nitrogen fertilizer application, and their interaction on ammonium absorption by wheat plants. It was found that both gypsum content and nitrogen fertilizer had a significant impact on ammonium uptake. The highest ammonium absorption (38.25 mg kg^{-1}) was observed under the N3 treatment (highest nitrogen level), while the lowest value (18.34 mg kg^{-1}) was recorded under the N0 treatment (no nitrogen), reflecting a 108.7% increase in ammonium absorption. Regarding gypsum, treatment L1 (lowest gypsum level) resulted in the highest ammonium absorption (34.09 mg kg^{-1}), whereas L3 (highest gypsum level) yielded the lowest (24.73 mg kg^{-1}). The combination of treatments revealed that L1N3 and L3N0 exhibited the highest and lowest ammonium absorption values, respectively, at 43.17 mg kg^{-1} and 14.49 mg kg^{-1}, corresponding to a 197.93% increase.

Effect of Gypsum Content and Nitrogen Fertilizer on Wheat Plant Height

The treatment with the greatest nitrogen dosage (N3) resulted in the tallest plants (45.33 cm), while N0 resulted in the shortest (37.66 cm), indicating a 20.37% increase in height. Similarly, gypsum content affected plant height, with L1 producing the tallest plants (44.5 cm) and L3 the shortest (41.25 cm), a decrease of 7.3%. The combination of N3 and L1 produced the maximum plant height (51 cm), while N0 and L3 produced the minimum height (37.66 cm).

Table 1: Effect of gypsum content, nitrogen fertilizer and their interaction on the amount of ammonium absorbed by wheat plants (mg kg-1)

Gypsum Content	Nitrogen Fertilizer				Gypsum Content Mean
	N 0	N 1	N 2	N 3	
L1	21.537	36.027	35.630	43.170	34.090
L2	18.999	34.437	34.557	37.573	31.390
L3	14.496	22.943	27.493	34.011	24.730
Nitrogen fertilizer Mean	18.344	31.135	32.560	38.251	

LSD for gypsum content = 1.8558;
LSD for fertilizer level = 2.1429;
LSD for interference = 3.7116.
L_1 = Soil with 64 g.kg^{-1} gypsum content;
L_2 = Soil with 136 g.kg^{-1} gypsum content;
L_3 = Soil with 245 g.kg^{-1} gypsum content.
N0 = No fertilizer;
N1 = 210 kg ha^{-1};
N2 = 420 kg ha^{-1};
N3 = 840 kg ha^{-1}.

Table 2: Effect of gypsum content, nitrogen fertilizer and their interaction on wheat plant height (cm)

Gypsum Content	Nitrogen Fertilizer				Gypsum Content Mean
	N 0	N 1	N 2	N 3	
L1	39.66	42.66	44.44	51.00	44.50
L2	39.00	41.33	42.66	48.33	42.83
L3	37.66	39.66	42.33	45.33	41.25
Nitrogen Fertilizer Mean	38.77	41.22	43.22	48.22	

LSD for gypsum content = 0.588;
LSD for fertilizer level = 0.679;
LSD for interference = 1.176.
L_1 = Soil with 64 g.kg^{-1} gypsum content;
L_2 = Soil with 136 g.kg^{-1} gypsum content;
L_3 = Soil with 245 g.kg^{-1} gypsum content.
N0 = No fertilizer;
N1 = 210 kg ha^{-1}; N2 = 420 kg ha^{-1};
N3 = 840 kg ha^{-1}.

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Effect of Gypsum Content and Nitrogen Fertilizer on Wheat Dry Weight

Table 3 illustrates that nitrogen fertilizer significantly affected wheat plant dry weight. Treatment N3 yielded the highest dry weight (14.72 g), while N0 resulted in the lowest (13.8 g), indicating a 6.6% increase. Gypsum concentration influenced dry weight, with L1 producing the highest dry weight (14.76 g); however, increasing gypsum levels (L2 and L3) led to reductions. The combination of L1N3 yielded the highest dry weight (15.46 g), while L3N0 produced the lowest (13.13 g).

Table 3: Effect of gypsum and nitrogen fertilizer content on dry weight of wheat plant (g)

Gypsum content	Nitrogen Fertilizer				Gypsum Content Mean
	N 0	N 1	N 2	N 3	
L1	14.26	14.50	14.83	15.46	14.46
L2	14.00	14.36	14.46	14.80	14.40
L3	13.13	13.40	13.50	13.90	13.48
Nitrogen Fertilizer Mean	13.80	14.08	14.26	14.72	

LSD for gypsum content = 0.125;
LSD for fertilizer level = 0.145;
LSD for interference = 0.251.
L_1 = Soil with 64 g.kg^{-1} gypsum content;
L_2 = Soil with 136 g.kg^{-1} gypsum content;
L_3 = Soil with 245 g.kg^{-1} gypsum content.
NO = No fertilizer;
N1 = 210 kg ha^{-1};
N2 = 420 kg ha^{-1};
N3 = 840 kg ha^{-1}.

Table 4: ANOVA for Ammonium Absorbed (mg/plant)

Source Of Variation	df	S.S	M.S	F calculate	P value
Rep Stratum	2	0.18598	0.09299	1.12	
Location (L)	2	556.412	278.206	3363.86	<.001
N Level (N)	3	1905.974	635.3246	7681.88	<.001
L*N	6	70.8811	11.81352	142.84	<.001
Residual	22	1.8195	0.0827		
Total	35	2535.272			

*df = degrees of freedom; S.S.= sum of squares; M.S.= mean square.

Table 5: ANOVA for Ammonium Absorbed (mg/plant)

Source of variation	df	S.S	M.S	F calculate	P value
Rep stratum	2	1.195	0.5975	1.96	
Location (L)	2	64.4057	32.2028	105.47	<.001
N Level (N)	3	434.4895	144.8298	474.35	<.001
L*N	6	14.0923	2.3487	7.69	<.001
Residual	22	6.7171	0.3053		
Total	35	520.8997			

*df = degrees of freedom; S.S.= sum of squares; M.S.= mean square.

Table 6: ANOVA for Dry Weight (g)

Source of variation	df	S.S	M.S	F calculate	P value
Rep stratum	2	0.91045	0.45522	5.51	
Location (L)	2	10.4696	5.2348	63.38	<.001
N Level (N)	3	4.03989	1.34663	16.3	<.001
L*N	6	0.29074	0.04846	0.59	0.737
Residual	22	1.8171	0.0826		
Total	35	17.52778			

*df = degrees of freedom; S.S.= sum of squares; M.S.= mean square.

IV. DISCUSSION

Ammonium Absorption

The present study explored the interactive effects of gypsum content and nitrogen fertilizer on ammonium absorption, plant height, and dry weight of wheat grown in gypsiferous soils. The results indicated that nitrogen fertilizer significantly increased ammonium absorption, likely due to enhanced nutrient absorption resulting from a more effective root development (Abebe and Abebe, 2016). In contrast, high gypsum content likely decreased ammonium uptake due to the increased concentration of sulfate ions (SO_4^{2-}), which interfere with ammonium absorption. The interaction results showed that elevated gypsum concentrations diminish the positive impacts of nitrogen fertilizer on root growth and nutrient uptake by decreasing ammonium availability in the rhizosphere. The findings highlight the necessity of balanced nutrient management, combining optimal nitrogen levels with controlled gypsum application, to maximize ammonium availability and support wheat growth in gypsiferous soils (Eswaran and Zi-Tong, 1991).

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Wheat Plant Height

Nitrogen was responsible for the increased cell elongation and vegetative development that led to the increase in plant height. Conversely, the presence of a high gypsum content may negatively affect plant height due to an excess of sulfate ions that potentially hinder nutrient absorption. The interaction between nitrogen and gypsum demonstrated the complexity of their combined influence on plant growth. These results support earlier studies investigating the roles of nitrogen and gypsum in plant development (Arya et al., 2005; Jain et al., 2018).

Dry Weight

The application of nitrogen contributed to increased dry weight by promoting cell elongation and vegetative growth (Ahmad et al., 2014). However, higher gypsum concentration was linked to decreased dry weight due to restricted vegetative development. This reduction may be caused by chemical interactions in the soil, such as ammonium precipitation, which limits nitrogen availability to plants (Larney and Angers, 2012; Murtaza et al., 2016). The interaction effects further suggest that while nitrogen improves biomass production, excessive gypsum can counteract this benefit by diminishing ammonium uptake (Bello et al., 2021; Abate et al., 2021).

CONCLUSION

This study evaluated the individual and combined effects of gypsum content and nitrogen fertilizer on wheat growth and ammonium absorption in gypsiferous soils. The results demonstrate that both inputs play significant but contrasting roles in plant development and nutrient uptake. It was found that plants with a moderate level of gypsum have improved plant height, dry weight, and absorbed a greater amount of ammonium. However, excessive gypsum had a detrimental effect, likely due to sulfate ion interference. Similarly, increasing nitrogen levels consistently enhanced plant height, biomass accumulation, and ammonium uptake by stimulating root development and overall vegetative growth.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCE

Abate, S., Belayneh, M. and Ahmed, F. (2021) ‘Reclamation and amelioration of saline-sodic soil using gypsum and halophytic grasses: Case of Golina-Addisalem irrigation scheme, Raya Kobo Valley, Ethiopia’, *Cogent Food & Agriculture, 7*(1), 1859847.

Abebe, B. and Abebe, A. (2016) ‘Effect of the time and rate of N-fertilizer application on growth and yield of wheat (Triticum aestivum L.) at Gamo-gofa Zone, Southern Ethiopia’, *Journal of Natural Sciences Research, 6*(11), pp. 111-122.

Ahmad, R. et al. (2014) ‘Does nitrogen fertilization enhance drought tolerance in sunflower?’ A review, *Journal of Plant Nutrition, 37*(6), pp. 942-963.

Anderson, G.C. et al. (2020) ‘Short- and long-term effects of lime and gypsum applications on acid soils in a water-limited environment: 1. Grain yield response and nutrient concentration’, *Agronomy, 10*(8), 1213.

Arya, R., Chaudhary, K.R. and Lohara, R.R. (2005) ‘Effect of nitrogen and gypsum on the establishment and early growth of Salvadora persica (L.) on salt affected soils under hot arid conditions in India’, *Forests, Trees and Livelihoods, 15*(3), pp. 291-306.

Bello, S.K. et al. (2021) ‘Mitigating soil salinity stress with gypsum and bio-organic amendments: A review’, *Agronomy, 11*(9), 1735.

Bremner, J.M. (1960) ‘Determination of nitrogen in soil by the Kjeldahl method’, *The Journal of Agricultural Science, 55*(1), pp. 11-33.

Eswaran, H. and Zi-Tong, G. (1991) ‘Properties, genesis, classification, and distribution of soils with gypsum’, in Occurrence, Characteristics, and Genesis of Carbonate, Gypsum, and Silica Accumulations in Soils. SSSA Special Publication 26, pp. 89-119.

Govindasamy, P. et al. (2023) ‘Nitrogen use efficiency—a key to enhance crop productivity under a changing climate’, *Frontiers in Plant Science*, 14, 1121073.

Jain, D., Asthir, B. and Verma, D.K. (2018) ‘Practices in nitrogen fertilization of wheat (Triticum aestivum L.): Effects on the distribution of protein sub-fractions, amino acids, and starch characteristics’, in Technological Interventions in Management of Irrigated Agriculture. Oakville, ON: Apple Academic Press, pp. 213-243.

Lal, R. et al. (2021) ‘Soils and sustainable development goals of the United Nations: An International Union of Soil Sciences perspective’, *Geoderma Regional,* 25, e00398.

Larney, F.J. and Angers, D.A. (2012) ‘The role of organic amendments in soil reclamation: A review’, *Canadian Journal of Soil Science, 92*(1), pp. 19-38.

Liu, Y.L., Yao, S.H., Han, X.Z., Zhang, B. and Banwart, S.A. (2017) ‘Soil mineralogy changes with different agricultural practices during 8-year soil development from the parent material of a Mollisol’, *Advances in Agronomy*, 142, pp. 143-179.

Mosier, S., Córdova, S.C. and Robertson, G.P. (2021) ‘Restoring soil fertility on degraded lands to meet food, fuel, and climate security

https://doi.org/10.54809/ga11a.2025.002

needs via perennialization', *Frontiers in Sustainable Food Systems*, 5, 706142.

Murtaza, B. et al. (2016) 'Nitrogen management in rice-wheat cropping system in salt-affected soils', Soil Science: Agricultural and Environmental Perspectives, pp. 67-89.

Naorem, A. et al. (2023) 'Soil constraints in an arid environment—challenges, prospects, and implications', *Agronomy, 13*(1), 220.

Poch, R.M., Artieda, O. and Lebedeva, M. (2018) 'Gypsic features', in Interpretation of Micromorphological Features of Soils and Regoliths. 1st edn. Amsterdam: Elsevier, pp. 259-287.

Qader, S.H. et al. (2021) 'The role of earth observation in achieving sustainable agricultural production in arid and semi-arid regions of the world', *Remote Sensing, 13*(17), 3382.

Singhal, R.K. et al. (2023) 'Beneficial elements: New players in improving nutrient use efficiency and abiotic stress tolerance', *Plant Growth Regulation, 100*(2), pp. 237-265.

Sumner, M.E. and Miller, R.W. (2000) Handbook of Soil Science. Boca Raton, FL: CRC Press.

Thomas, G.W. (2018) Soil Chemistry and Nutrient Dynamics. London: Academic Press.

Triviño-Tarradas, P. et al. (2020) 'Evaluation of agricultural sustainability on a mixed vineyard and olive-grove farm in Southern Spain through the INSPIA model', *Sustainability, 12*(3), 1090.

Wang, Z.-H., Miao, Y.-F. and Li, S.-X. (2015) 'Effect of ammonium and nitrate nitrogen fertilizers on wheat yield in relation to accumulated nitrate at different depths of soil in drylands of China', *Field Crops Research*, 183, pp. 211-224.

Zhang, C. et al. (2024) 'The role of nitrogen management in achieving global sustainable development goals', *Resources, Conservation and Recycling*, 201, 107304.

Zhang, J. et al. (2013) 'Agricultural land use affects nitrate production and conservation in humid subtropical soils in China', *Soil Biology and Biochemistry*, 62, pp. 107-114.

Zhu, H. et al. (2020) 'Interactive effects of soil amendments (biochar and gypsum) and salinity on ammonia volatilization in coastal saline soil', *Catena*, 190, 104527.

Zia, R. et al. (2021) 'Seed inoculation of desert-plant growth-promoting rhizobacteria induces biochemical alterations and develops resistance against water stress in wheat', *Physiologia Plantarum, 172*(2), pp. 990-1006.