Influence Of Calcium And Magnesium Oxide On The Properties Of Clay Soil In Babil Governorate

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Abstract

To study the effect of calcium and magnesium oxides on some physical and chemical properties of clay soil in Babil governorate, two study sites were selected: Al-Musayyib and Al-Mahawil. Soil samples were taken from each site at depths of 0-30 cm using a screw auger, with three samples collected from each site. these were then transported to the laboratory, dried, and ground with a wooden mallet, and then passed through a 2mm sieve for the required physical and chemical analyses. Water samples were also taken from the irrigation sources of each site and transported in glass containers labeled with the name of the study site to the laboratory for chemical analysis. CaO was added at a rate of 1.5%, MgO at 1%, and CaO + MgO at 2.5% the soil was irrigated every six days after 30 days, samples were taken again and analyzed chemically and physically to compare the results before and after the additions. The results showed that the addition of calcium and magnesium oxides had a positive effect on the physical and chemical properties of the soil, leading an increase in pH, a decrease in EC, and a reduction in exchangeable sodium and SAR. The addition of CaO increased exchangeable calcium, and MgO increased exchangeable magnesium, while their effect on potassium was minimal and did not negatively impact soil fertility. CaO + MgO showed the best results in improving chemical balance. physically, the additions led a decrease in bulk density and an increase in porosity and permeability.

keywords: cation exchange; chemical; irrigation; physical; water analyses

Introduction

Clay soils are among the most important natural resources upon which agricultural systems worldwide are based, due to their physical and chemical properties that make them a supportive element for plant growth and nutrient cycling. In Iraq, clay soils constitute a large part of the arable land, especially in Babil governorate, which lies within the alluvial plain of the Tigris and Euphrates rivers. these soils are characterized by their heavy clay nature and have played an important role in supporting agriculture for decades. however, they face agricultural challenges that require a deep understanding of the processes that occur within them, particularly their relationship to the basic elements that affect their physical and chemical properties. clay soils are characterized by their ability to retain water and dissolved nutrients due to their high surface area and negative charge. Careful improvement of their chemical composition can lead to improvements in their physical and chemical properties, which in turn increases their agricultural productivity [7]. Numerous international studies have examined the impact of soil amendments on various properties of clay soils. for example, [21]. Demonstrated that the addition of alkaline materials can modify soil structure and affect pore distribution. Another study, [15] Showed that cation balance plays a role in the soil's ability to support plant growth. These studies often originate from environmental contexts different from the Iraqi context, making it essential to conduct research investigating the impact of soil composition, irrigation conditions, and climate in Babil governorate. In this context, calcium and magnesium occupy a pivotal

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position among the basic cations that affect soil properties. calcium is an essential element in stabilizing the structure of clay soils through its role in reducing the dispersion of clay particles and promoting the formation of soil clumps, while magnesium contributes to regulating the ionic balance within the soil, although its excessive increase sometimes leads to adverse effects on the physical structure. calcium and magnesium oxides are used as soil amendments in many agricultural systems due to their ability to raise the pH of acidic soils and increase the proportion of basic cations, in addition to their role in reducing the toxicity of some elements and improving the availability of macro and micronutrients to plants [5]. However, the response of clay soils to these materials is not uniform in all environments, but is greatly affected by the nature of the original soil, its mineral content, the irrigation system, and the prevailing climatic conditions. In this context, calcium and magnesium occupy a pivotal position among the basic cations that affect soil properties. calcium is an essential element in stabilizing the structure of clay soils through its role in reducing the dispersion of clay particles and promoting the formation of soil clumps, while magnesium contributes to regulating the ionic balance within the soil, although its excessive increase sometimes leads to adverse effects on the physical structure. calcium and magnesium oxides are used as soil amendments in many agricultural systems due to their ability to raise the pH of acidic soils and increase the proportion of basic cations, in addition to their role in reducing the toxicity of some elements and improving the availability of macro and micronutrients to plants. however, the response of clay soils to these materials is not uniform in all environments, but is greatly affected by the nature of the original soil, its mineral content, the irrigation system, and the prevailing climatic conditions [17]. Based on the above, the study aimed to determine the effect of calcium and magnesium oxides on the physical and chemical properties of clay soil in central Iraq.

Methods and Materials

This study was conducted at Al Qasim Green University on September 15, 2025 and ended on December 7, 2025. utilizing soil samples obtained from two distinct agricultural districts: Musayyib and Al-Mahawil. Soil samples were taken from the study areas, three samples from each area, to a depth of 0-30 cm. these samples were collected in nylon bags, labeled with the sample name and the study location. A water sample was also taken from the soil irrigation source for each area. The soil and water samples were then transported to the laboratory for the required physical and chemical analyses.

Table 1 chemical properties of irrigation water

trait	Al-Musayyab	Al-Mahawil
pH	7.3	7.6
EC (ds.m^{-1})	1.5	2.5
Ca^{2+} (g/kg)	0.11	0.13
Mg^{2+} (g/kg)	0.09	0.08
Na^{+} (g/kg)	0.17	0.21
K^{+} (g/kg)	0.01	0.01
SAR	7.5	8.2

physical analyses

size distribution of soil fractions

the size of the soil separators was determined using the hydrometer method mentioned in [1]

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bulk density

measured using core samples according to the method described in [1].

porosity

calculated based on apparent density and true density as stated in [1].

permeability

estimated using Copeland's method as presented in [1].

chemical analyses

electrical conductivity (EC)

the soil: water ratio was estimated1:1 using an EC-meter as reported in [12].

pH

measured in a soil: water suspension1:1 using a pH-meter as reported in [12].

calcium (Ca^{2+})

estimated by titration with ferrous edta-Na2 using ammonium berberate detector according to the method of Lanyon and Heald as reported in [12].

magnesium (Mg^{2+})

It was estimated by estimating calcium and magnesium together by titration with ferrous sulfate using Erichrome Black T reagent, then subtracting calcium from the total calcium and magnesium according to the method of Lanyon and Heald as described in [12].

sodium(Na^{+})

estimated using a flame photometer, as stated in [6].

potassium (K^{+})

estimated in soil extract: water (1:1) using a photo flame apparatus according to the Result and Discussion

The results in Tables (2, 3) show that the addition of calcium oxides led to a significant decrease in EC in study areas compared to the pre-treatment (control treatment), indicating a reduction in the concentration of soluble salts in the soil solution. this is attributed to the role of calcium in replacing sodium in the exchange complex, which cotributes to

method proposed by Knudesn et al. as cited in [12].

sodium adsorption ratio (SAR)

It was estimated according to the method described in [13].

calcium and magnesium oxides

This experiment was conducted in the autumn on clay soil. Four treatments were used, These treatment were: the control treatment, treatments with the addition of calcium oxide (CaO) 1.5%, magnesium oxide (MgO) 1% because it is less soluble than CaO and a mixture of calcium and magnesium oxides (CaO + MgO) 1.5% + 1%. The reason for using these ratios is that they improve sodium adsorption ratio and soil structure without causing an excessive increase in pH [8]. These materials were thoroughly mixed to with The soil and then irrigated once every six days for a month.

Calculating the amount of oxides added

We will rely on the average bulk density for each area, as we took three samples from each area. The average density in Musayyib and Mahawil it was 1.51g/cm^3.

Soil volume = Depth × Area

Soil weight = Bulk density × Volume

Statistical analysis

The experiment was conducted using a completely randomized block design (RCBD) with four treatments and three replicates in SPSS software to test the significance of differences between means. Comparisons were performed using the least significant difference (L.S.D) test at a probability level of 0.05.

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improved soil structure and increased permeability, thus facilitating the leaching of salts. The addition of magnesium oxides resulted in a smaller decrease in EC values compared to calcium oxides. This is attributed to the slower solubility of magnesium oxides and their limited replacement of sodium compared to calcium. It should be noted that magnesium may contribute to an increase in the concentration of some salts in the short in the two study areas. the CaO + MgO treatment showed the greatest reduction in EC compared to the other treatments, indicating a complementary effect between calcium and magnesium in improving soil ionic balance and increasing salt removal efficiency. The addition of oxides led to the dissolution of salts and a temporary increase in ion concentration in the soil solution, which was reflected in the elevated EC. therefore, it is clear that calcium oxide was the most effective in reducing soil salinity, while the effect of the mixture varied according to the characteristics of each location. This demonstrates the soil's response to lime additives, which depends primarily on its initial chemical composition [4]. These additions also led to a significant increase in soil pH across study areas compared to the control treatment, indicating increased soil alkalinity after the addition. This is attributed to the decomposition of calcium and magnesium oxides in the soil and the formation hydroxides, which reduce the concentration of hydrogen ions, thus raising the pH value. The calcium oxide treatment showed a consistent increase in pH across two study areas. this can be explained by calcium's high efficiency in neutralizing acidity and its ability to replace acidic ions on the exchange complex, leading to improved soil chemical equilibrium. magnesium oxide also raised the pH, and its effect was even greater than that of calcium in some locations. this is likely due to differences in the initial soil properties, such as the initial pH level and cation exchange capacity, which influence the soil's response to magnesium. in all areas, the (CaO + MgO) mixture treatment recorded higher alkalinity values than the control treatment, suggesting a complementary effect between the two elements in modifying soil pH. This reflects an increase in the concentration of exchangeable bases and a decrease in acidic ions, which contributes to improved chemical conditions for plant growth in clay soils. A relative variation in the degree of response is also observed between regions, attributed to differences in the initial physical and chemical properties of the soils, such as clay content, organic matter, and salinity levels, which affect the soil's buffering capacity to changes in pH [20].

The addition of calcium and magnesium oxides resulted in a significant decrease in SAR values compared to the control treatment in study areas, indicating a clear improvement in sodicity and a reduced risk of clay particle dispersion. the control treatment recorded the highest SAR values in all two study areas, reflecting a higher sodium-to-calcium-magnesium ratio in the soil solution. This suggests a degree of sodicity that may negatively affect soil structural stability and permeability. The addition of calcium oxide led to a sharp decrease in SAR at sites, attributed to the high efficiency of divalent calcium ions in displacing monovalent sodium from the cation exchange complex. This displacement reduces the sodium content and an increase in the proportion of divalent positive ions, leading to clay particle stability improved physicochemical properties of the soil. magnesium oxide also reduced SAR, but to a lesser extent than calcium. this is because magnesium is less efficient at displacing sodium,. the CaO + MgO mixture treatment recorded the lowest SAR values across all regions, indicating a synergistic effect between calcium and magnesium in reducing exchangeable sodium. this reflects a significant improvement in soil ionic balance, with an increased ratio of divalent cations to sodium, leading to reduced clay particle dispersion, increased flocculation, and improved water permeability. Furthermore, the response was similar in Al-Musayyib, and

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Al-Mahawil, demonstrating that the effectiveness of the treatments was not significantly affected by locational differences. This suggests the potential for adopting these treatments in reclaiming sodic soils in various parts of the governorate [18].
The control treatment recorded the highest sodium concentration in study areas, reflecting a high exchangeable sodium content in the clay soils, which could lead to structural deterioration and an increased risk of dispersal the addition of calcium oxide resulted in a sharp and significant decrease in sodium concentration compared to the control treatment at all sites. This is attributed to the active role of divalent calcium ions in replacing monovalent sodium from the cation exchange complex. Ca^{2+} replaces Na^{+} on the surfaces of clay particles, releasing sodium into the soil solution and subsequently leaching it out of the root zone, thus reducing its concentration in the soil. the addition of magnesium oxide also reduced sodium concentration, but to a lesser extent than calcium. This is due to magnesium's relatively lower efficiency in the replacement process, as well as its different behavior in the soil colloidal system. The (CaO + MgO) mixture treatment recorded the lowest sodium concentration in most location, indicating a synergistic effect between calcium and magnesium in improving soil ionic balance. this reflects an increase in the ratio of divalent cations to sodium, which reduces the risk of sodation and improves the stability of clay particles the decrease was similar across the study areas, indicating a uniform soil response to the additives despite variations in properties between locations. This is a positive indicator of the effectiveness of these treatments under different conditions. [3].

The results showed that the control treatment recorded the lowest magnesium values in5 study areas, reflecting the normal level of exchangeable magnesium in the soil before any modification. the addition of calcium oxide led to a slight decrease in magnesium concentration at all sites. this is attributed to competition between calcium and magnesium ions for cation exchange sites, where Ca^{2+} partially displaces Mg^{2+} on the surface of clay particles, thus reducing the exchangeable magnesium concentration in the soil. the addition of magnesium oxide, however, resulted in a significant increase in soil magnesium concentration. this is expected given the direct supply of available Mg^{2+} ions to the soil. This reflects the direct effect of the addition on the exchangeable content of the soil, increasing its chemical strength and its ability to improve its physical and chemical properties. In the combined treatment (CaO + MgO), the highest exchangeable magnesium values were recorded in all location, indicating a complementary effect: the addition of MgO directly supplies the soil with magnesium, while CaO contributes to modifying the ionic balance, reducing negative competition and allowing for increased stability of magnesium ions at the exchange sites. this is reflected in improved soil capacity to support plant growth in terms of the availability of dietary magnesium. this pattern was also observed to be similar across the Musayyib, and Mahawil regions, indicating that the soil's response to magnesium addition is relatively stable across different locations, despite variations in initial soil properties. It is also observed that the reduction pattern was similar between Al-Musayyib, and Al-Mahawil, indicating that the soil response to the amendments was relatively uniform despite differences in initial properties between the sites. This is a positive indicator of the effectiveness of these treatments under varying conditions [23].The results indicated that the control treatment exhibited the lowest exchangeable calcium values across study areas, reflecting the natural level of calcium available in the soil before the additions. the addition of calcium oxide significantly increased the exchangeable calcium content across all areas. this is attributed to the chemical decomposition of calcium oxide, releasing Ca^{2+} ions that are directly added to the exchange sites on the surface of the clay

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particles, thus enhancing the exchange capacity and increasing calcium availability to plants. The addition of magnesium oxide, however, showed a less pronounced increase in exchangeable calcium compared to the calcium-only treatment. this is due to competition between magnesium and calcium ions for the cation exchange sites, resulting in a relatively limited effect of MgO on Ca^{2+}
The (CaO + MgO) mixture treatment recorded the highest values of exchangeable calcium in all regions, indicating a synergistic effect between calcium and magnesium: the addition of MgO does not reduce the effectiveness of CaO, but rather contributes to improving the distribution of ions and soil balance, thus maximizing the exchangeable calcium content without negatively affecting the soil's ionic balance it was also observed that the pattern of increase was similar across the study areas, indicating that the soil's response to calcium addition is relatively stable regardless of the initial properties of each soil. this is a positive indicator for adopting this treatment to improve soil properties [9]. As for potassium, the control treatment recorded the highest exchangeable potassium values in most locations, reflecting the natural potassium content of the soil before application. adding calcium oxide resulted in a slight decrease in exchangeable potassium concentration. this is attributed to competition between calcium and potassium ions for cation exchange sites in clay particles. The increase in Ca^{2+} partially reduces the soil's ability to retain exchangeable potassium, leading to a slight decrease in its concentration in the soil solution. adding magnesium oxide had a lesser effect on reducing potassium, with values remaining close to the control treatment in most areas. this is explained by the fact that Mg^{2+} ions compete for the same exchange sites but have a lesser effect on potassium than calcium. In the combined treatment (CaO + MgO), a decrease in exchangeable potassium was also observed, reflecting the effect of oxides on the soil's ionic balance. the availability of divalent ions (Ca^{2+} and Mg^{2+}) can lead to partial displacement of potassium from exchange sites, especially in soils with limited exchange capacity It is noted that the pattern of change was similar across the study areas, indicating that the effect of oxides on potassium was relatively consistent across different locations. [22].

As for bulk density, the control treatment recorded the highest values in study areas, reflecting the soil in its natural state before any modification. the addition of calcium oxide led to a significant decrease in bulk density at all locations. this is attributed to calcium's effect in promoting flocculation among clay particles, increasing pore size and allowing for more uniform particle dispersion, thus reducing the soil's bulk density. the addition of magnesium oxide also contributed to a decrease in bulk density, but to a lesser extent than calcium. This is because magnesium ions are relatively less efficient at promoting flocculation compared to calcium, although they did contribute to improving the arrangement of clay particles. The combined treatment (CaO + MgO) recorded the lowest bulk density values in all locations, indicating a synergistic effect between calcium and magnesium in improving the soil's structure. Both Ca^{2+} and Mg^{2+} promote flocculation and improve the distribution of pore spaces among clay particles, which is reflected in the decrease in bulk density, increased soil aeration, and improved water permeability
The similarity in soil structure across the study areas indicates that the effect of the additives on soil structure was relatively stable across different locations despite variations in the initial physical properties of the soil. [2].

Control treatment recorded the lowest porosity values in all study locations, reflecting the soil in its natural state before any additions, where clay soils tend to be compacted with reduced air spaces. Adding calcium oxide significantly increased porosity at all locations. this is attributed to Ca^{2+} 's effect in promoting flocculation among clay

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particles and improving particle arrangement, thus creating larger air spaces and contributing to improved soil permeability and aeration. adding magnesium oxide also contributed to increased porosity, but to a lesser extent than calcium. This is because Mg^{2+} improves soil structure but is less effective than calcium in promoting flocculation and increasing air spaces. In the combined treatment (CaO + MgO), the highest porosity values were recorded in study areas, indicating a synergistic effect between calcium and magnesium. Together, they improve clay particle arrangement, increase air spaces, and enhance the structural balance of clay soil, resulting in the maximum increase in porosity compared to the individual additions we observe that the increase was similar across the study areas, indicating that the effect of the additives on porosity was stable across the different sites. [2].

The control treatment recorded the lowest permeability values in study areas all locations, reflecting the compaction of clay particles in the clay soil and the limited interconnected spaces that allow water to pass through. Adding calcium oxide increased soil permeability in all areas. this is attributed to Ca^{2+} 's effect in promoting flocculation among clay particles, which reduces agglomeration and opens pathways for water within the soil, thus improving water flow. Adding magnesium oxide also contributed to increased permeability, but to a lesser extent than calcium in most locations. this is because Mg^{2+} partially improves the arrangement of clay particles but is less effective at increasing water pathways compared to calcium. the combined treatment (CaO + MgO) recorded the highest permeability values in the different locations, indicating a synergistic effect between calcium and magnesium. calcium promotes flocculation and improves particle arrangement, while magnesium contributes to structural stability, creating a more consistent network of interconnected spaces that allows for better water flow we observe that the increase was similar the study areas, indicating that the effect of the additives on porosity was stable across the different sites [14].

Table 2 physical and chemical properties of the Musayyib after and befor addition

trait	refined	control	befor adding		befor adding CaO + MgO	uint
			CaO	MgO		
EC	r1	1.58	1.49	1.51	1.45	$ds.m^{-1}$
	r2	1.55	1.44	1.52	1.42	
	r3	1.57	1.47	1.51	1.41	
pH	r1	7.7	8.2	8	8.3	
	r2	7.7	8.1	7.9	8.2	
	r3	7.5	8	7.9	8.1	
SAR	r1	6.1	2	4.2	1.6	
	r2	5.9	1.9	3.7	1.4	
	r3	6.2	2.1	4.3	1.5	
Na^{+}	r1	4.33	1.07	2.17	1.02	
	r2	4.28	1.13	2.27	0.99	
	r3	4.38	1.04	2.25	1.04	
Mg^{2+}	r1	2.81	2.63	9.82	10.3	
	r2	2.76	2.65	9.72	10.1	
	r3	2.86	2.67	9.75	11.2	g/kg
Ca^{2+}	r1	1.97	2.30	2	2.41	
	r2	1.95	2.35	2.02	2.45	

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	r3	2.01	2.42	2.06	2.48	
K^+	r1	1.12	0.48	0.51	0.25	
	r2	1.08	0.25	1.27	0.21	
	r3	0.91	0.39	1.94	0.18	
bulk density	r1	1.49	1.31	1.38	1.28	g/cm^3
	r2	1.50	1.31	1.40	1.29	
	r3	1.52	1.36	1.43	1.34	
porosity	r1	42	47	43	49	%
	r2	41	44	41	46	
	r3	39	43	41	47	
permeability	r1	0.18	0.31	0.24	0.33	cm/hr
	r2	0.17	0.29	0.22	0.31	
	r3	0.19	0.33	0.25	0.35	
texture	clay					

Table 3 physical and chemical properties of the Mahawil after and befor addition

trait	refined	control	befor adding		befor adding CaO + MgO	uint
			CaO	MgO		
EC	r1	1.57	1.48	1.52	1.43	$ds.m^{-1}$
	r2	1.54	1.46	1.51	1.40	
	r3	1.59	1.52	1.54	1.42	
pH	r1	7.4	7.9	7.7	8	
	r2	7.5	7.9	7.8	8.1	
	r3	7.6	8.1	7.9	8.2	
SAR	r1	6.6	2	4.6	1.8	
	r2	6.4	2	4.2	1.6	
	r3	6.6	2.1	4.7	1.8	
Na^+	r1	4.73	1.14	2.44	1.10	g/kg
	r2	4.68	1.11	2.41	1.09	
	r3	4.79	1.19	2.51	1.13	
Mg^{2+}	r1	3.07	2.85	10.24	11.5	
	r2	3.01	2.01	10.93	12	
	r3	2.92	2.76	11.88	12.2	
Ca^{2+}	r1	1.12	2.03	2.01	2.13	
	r2	1.94	2.39	2	2.43	
	r3	2.01	2.48	2.05	2.52	
K^+	r1	1.17	0.62	0.65	0.23	
	r2	1.14	0.32	0.33	0.17	
	r3	0.89	0.61	0.64	0.21	
bulk density	r1	1.52	1.34	1.42	1.31	g/cm^3
	r2	1.52	1.34	1.41	1.31	
	r3	1.51	1.33	1.40	1.29	
porosity	r1	40	45	42	48	%
	r2	42	43	41	47	

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	r3	38	41	40	45	
permeability	r1	0.18	0.27	0.21	0.33	cm/hr
	r2	0.17	0.25	0.19	0.31	
	r3	0.19	0.30	0.25	0.35	
texture	clay					

Statistical analysis

The results tables (4, 5) according to the design of the completely randomized blocks, showed that clay soils differ in their response to the addition of Ca^{2+} and Mg^{2+} oxides depending on their location and the characteristic studied. This reflects the role of the primary characteristics of the soil in the extent of its response. In the Al-Mahawil area, There is little difference between the processors with respect to porosity because porosity is a slow-changing property in the short term. Therefore, the change in microclusters is greater than the change in total porosity. Permeability, however, was superior to treatments T2 and T4 because Ca^{2+} promotes flocculation, which increases porosity and thus increases permeability compared to magnesium. The presence of Mg^{2+} may weaken the effect of Ca^{2+} in some cases [21]. EC values ranged between significant and insignificant, attributed to the limited solubility of the added oxides. The increased EC value in T4 is attributed to the increased divalent cations in the soil solution. pH differences were significant between treatments except for T1 and T2 because the soil is already alkaline, and the added oxides form hydroxides, limiting the difference between the addition of Ca^{2+} oxide and the addition of calcium oxide [21].

Significant differences were also observed between treatments in SAR values for sodium, except for T2-T4, because calcium displaces Na^{+} at exchange sites, and Mg^{2+} is less efficient at doing so. Significant differences were also observed for magnesium, except for T1-T2, due to its absence, and for Ca^{2+}, except for T2-T3 and T2-T4. This is attributed to two reasons: either the similarity of effective concentrations or the effect of ionic balance in the presence of Mg^{2+}. K^{+} (T1) was significant with the other treatments but not significant between T2-T3 and T2-T4, because increasing Ca^{2+} and Mg^{2+} leads to the displacement of K^{+} from exchange sites to similar degrees across the treatments [10].

In the Musayyib area, there were significant differences between treatments for porosity, except for T1-T3. This is attributed to the difference in the initial soil condition, as Ca^{2+} increases large pores and improves clay flocculation, while Mg^{2+} effectiveness is lower compared to Ca^{2+} [11]. Permeability was significant between all treatments except T2-T24, which proves that Ca^{2+} is the decisive factor and that adding Mg^{2+} to Ca^{2+} (the mixture treatment) did not produce any additional improvement compared to Ca^{2+} alone. While all EC differences between treatments were significant, attributable to soil sensitivity to ionic change, variations in initial salinity, solubility and leaching, and pH, all differences were significant due to the effect of alkaline addition. The mixed treatment yielded the greatest increase due to the combined effect of Ca^{2+} and Mg^{2+}. SAR and Na^{+} were significant except for T2-T4, further confirming the dominance of Ca^{2+} over Na^{+} behavior in this soil. The studied exchangeable cations, such as Ca^{2+}, showed significant differences except for T1-T2 and T3-T4 due to the proximity of the source. Mg^{2+} was significant except for T1-T3, indicating varying soil responses to addition depending on the initial soil condition. K^{+} differences were significant except for T1-T3 and T2-tT4, attributed to the similarity of the effects of these treatments.

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The chemical properties responded faster than the physical properties in the studied soils, which is attributed to the change in ionic balance. Ca^{2+} is the most influential factor in improving soil structure and permeability, as well as in reducing SAR and Na^{+}. The effect of Mg^{2+} in the mixture treatment was weaker or equal to the effect of Ca^{2+}. This shows the difference in response in the two study areas and the importance of their primary properties in determining the efficiency of the treatments.

Table 4 Average Values and L.S.D in the Musayyib Area

trait	control (T1)	CaO (T2)	MgO (T3)	CaO + MgO (T4)	L.S.D
porosity	40.66	44.66	41.66	47.33	1.73
bulk density	1.50	1.32	1.40	1.30	0.05
permeability	0.17	0.31	0.23	0.33	0.04
EC	1.56	1.46	1.51	1.42	0.01
pH	7.63	8.1	7.93	8.2	0.17
SAR	6.53	2.03	4.5	1.73	0.41
Na^{+}	4.33	1.08	2.23	1.01	0.10
Mg^{2+}	2.81	2.65	9.76	10.53	0.78
Ca^{2+}	1.97	2.35	2.02	2.44	0.07
K^{+}	1.03	0.37	1.24	0.21	0.49

Table 5 Average Values and L.S.D in the Al-Mahawil Area

trait	control (T1)	CaO (T2)	MgO (T3)	CaO + MgO (T4)	L.S.D
porosity	40	43	41	46.66	3.53
bulk density	1.51	1.33	1.41	1.3	6.62
permeability	0.18	0.27	0.21	0.33	0.06
EC	1.56	1.48	1.52	1.41	0.06
pH	7.5	7.6	7.8	8.1	0.1
SAR	6.53	2.03	4.5	1.73	0.41
Na^{+}	4.73	1.14	2.45	1.11	0.12
Mg^{2+}	3	2.54	11	11.9	0.86
Ca^{2+}	1.69	2.3	2.02	2.36	0.32
K^{+}	1.06	0.51	0.54	0.2	0.34

Conclusions

The addition of calcium and magnesium oxides raised soil pH and improved chemical balance. These treatments also reduced EC, Na^{+} and the SAR value, uptake, thereby decreasing soil stiffness and improving soil stability. Both CaO and MgO increased the exchangeable calcium and magnesium content, while the decrease in K^{+} was slight and harmless. The physical properties of the soil improved after the additions, with a decrease in bulk density and an increase in porosity and permeability, thus improving aeration and water flow. the combined CaO + MgO treatment achieved the best results, demonstrating a synergistic effect in improving both the chemical and physical properties of the soil.

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