A laboratory study of the effect of sulfur application on Ca and Mg concentration soluble in soil during incubation periods

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Abstract

The effect of sulfur application on the water soluble Ca and Mg during incubation periods was studied. Different levels of pure dry sulfur (DS) and 10% moist sulfur (MS) in the range of (200, 400, and 600 $mgKg^{-1}$) and (100, 200, 300 $mgKg^{-1}$) for Ca and Mg study respectively, were applied to study their effects on the concentrations of Ca and Mg in soil. Dry sulfur application showed a maximum content of (75 mg Kg^{-1} Ca) in the soil at a period of (60 days) and minimum content of (23 $mgKg^{-1}$ Ca) during (15 days) period. As dry sulfur level increased, Ca concentration reached a maximum value of (90 $mgKg^{-1}$) within the same incubation period, while moist sulfur application showed a maximum soluble Ca content (90 mg Kg^{-1}) at a period of (60 days) after which a continuous declined in content was noticed. Application of dry and moist sulfur of above mentioned levels on the soil samples during periods showed a fluctuated effect on the concentration of Mg in the soil, where it reached a maximum value of (35 mg Kg^{-1}) at a period of (75 days) after which a constant behavior was noticed along the addition of different sulfur levels. Calcium content showed some increment during 60 days, this means that a distinguishable effect was shown on the availability of soluble Ca and Mg upon addition of both type of sulfur (DS and MS) during incubation period.

Key words: laboratory incubation, sulfur application, Ca and Mg concentrations, wet and moist S application, calcareous soil.

Introduction

The low availability of any essential nutrient could be managed by addition of fertilizer. Generally, the problem in Iraqi soils is that it needs continuous follow up of soil status, especially due to the high content of $CaCO_3$, which compete the motion and absorption of other nutrient cations, and soil pH in addition to the effect of some atmospheric sulfur depositions near S and refinery installations. So, it is necessary to search soils of regions near petroleum refineries and other installations which release sulfur to the atmosphere. There are many similarities between the behavior of calcium and magnesium macronutrients in the soils. They are all released from minerals weathering such as calcite, gypsum, dolomite, feldspar, apatite and occur as exchangeable cations. They are the most abundant in young and minimally weathered soils and least abundant in intensively weathered and leached soil. The two elements Ca and Mg are absorbed by roots as divalent cations from the soil solutions, and exists almost in a balanced forms. Too much of any one of these elements may cause insufficiencies of the other one. There is no significant fixation of Ca or Mg into unavailable forms. The

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cations set free by weathering are exchanged on cation exchange sites and equilibrium tends to be established between the exchangeable and solution forms.

The available Ca and Mg consist of exchangeable and soluble forms of Ca and Mg (Foth, 1988). Sulfur exists in some soil minerals, including gypsum ($CuSO_4$. $2H_20$) which is on weathering release sulfur as sulfate ions ($SO^{2}_{4}{}^{-}$) which is absorbed by plant roots and microorganisms, and in many locations is added to soils via deposition and accumulates as organic sulfur (Strickland and swank 1986). Other studies found that the SO_4^{2-} desorption contributed to soluble Ca loss (Huntington and Hooper 2000). Many investigators (Johnson and vose, 1993 , Watmough and page, 2005) were studied the sulfur effect on the mobility of acidic (H and Al) elements and basic (Ca , Mg , Na , K) cations in the soil solutions. The effect of sulfur deposition on nutrient cycling and their availability in soils is studied (Katherine, 2008). The significant effect of sulfur levels related to its absorption or exchange with other anions was studied by (Galaly, 2010). AL-Salmani, (1998) showed the relation between acidity and availability of Ca and Mg in the soil. The objective of this research was to study the effect of different levels of pure dry and moist sulfur (DS and MS) application on the concentration of Ca and Mg during incubation due to their importance as macronutrients for plants.

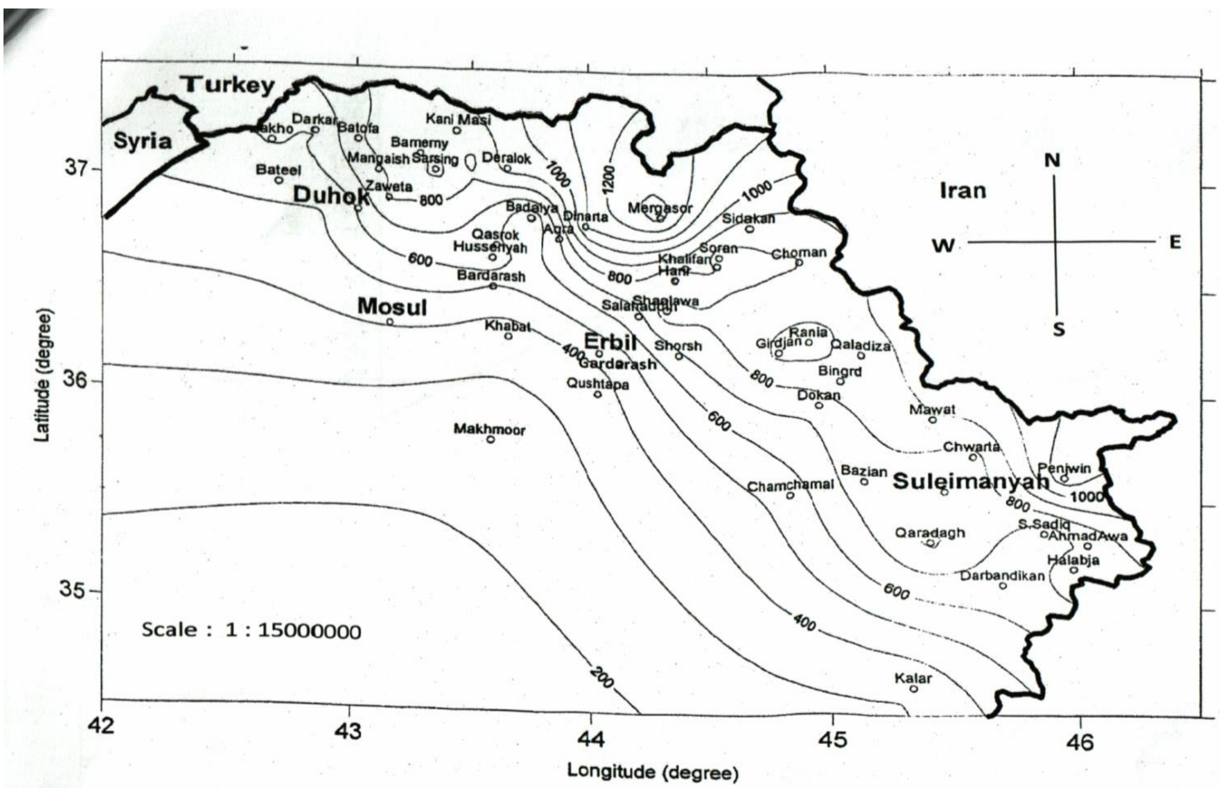

Fig. (1): The location of the studied soil.

Materials and Methods

A representative soil samples of depth (0-30 cm) were taken on winter season from Gardarash farm - Erbil governorate - Iraqi Kurdistan region (Fig.1) which is classified as (see table 1). Soil samples were transferred in clean containers to the laboratories where they dried, crashed and sieved through 2 mm openings. Three levels of pure dry sulfur and (10%) moist sulfur were applied to soil samples 200 , 400 , 600 and 100 , 200 , 300 $mgKg^{-1}$ for dry and moist respectively, according to the Ca and Mg initial content present in the soil, and incubated for a period of three months in order to study the effect of sulfur on the soluble forms of Ca and Mg in the soil. 14 soil samples (three with added DS and MS and two without S for each Ca and Mg) were placed in plastic bags and kept in laboratory with daily recorded temperature. The use of both type of sulfur is to simulate soils far from water sources and contains sulfur depositions released from near installation, and those soils with some of moisture in order to follow up during such periods. Test for soluble Ca and Mg in the soil were accomplished using optical method (Baruh and Barthakur, 1999) every 15 days incubation. Some of the chemical and physical properties of the soil were shown in (table 1) and their contents determined as follows:

pH

Measured using pH-meter, model (332 Jenway) according to (Jackson, 1973).

Electrical conductivity

Measured using EC-meter, model (Molitine P4 /Set-2) according to (Rowell, 1996).

Cation exchange capacity

Measured using 1N sodium acetate solution of pH 8.2 according to (Carter, 1993).

Soil organic matter

Determined by oxidation with 1 M potassium dichromate solution and concentrated sulfuric acid, and then calibrated with ferrous ammonium sulfate using diphenylamine indicator according to (Rowell, 1996).

Calcium carbonate

Determined titrimetrically by shaking with 0.2 N ammonium oxalate solution precipitate calcium oxalate,and the excess of ammonium oxalate determined by potassium permanganate according to (Allen, 1974).

calcium

Determined by using atomic absorption instrument (Perkin – Elmer model) by exposing group of un-exited atoms to the radiations emitted from excited atoms of same element, each element absorbed at certain wave length according to (Galen, 1985)

Sodium

Determined using (corning 400 flame photometer) according to (Tandon, 1999).

magnesium

Determined as described in case of determination of initial Ca^{2+}.

Nitrate

Determined by evaporating the soil extract to dryness,then addition of phenol disulfonic acid and 6N ammonium hydroxide solution to form yellow color which is measured at 415 nm using spectral colorimeter according to (Baruah and Barthakur 1999).

Sulfate

Determined indirectly from combined Ca and Mg by titration with 0.01N EDTA according to (Jackson, 1973)

Chloride

Determined by titration with silver nitrate and potassium dichromate as indicator according to More method (Tandon, 1999).

Potassium

Determined by addition of N ammonium acetate solution to the soil samples, shaking and filter, measure the amount of K using corning 400 flame photometer (Baruah and Barthakur, 1999).

Texture

By using hydrometer which measures, 4 minute after sedimentation, particle size that refers to the texture of soil (Baruah and Barthakur, 1999)

Table (1): Some of the chemical and physical properties of the soil.

Soil properties	Values	Units
pH	7.4	--------
EC at 25 °C	0.65	Ds m^{-1}
CEC	22	C mole(+) Kg^{-1} soil
S.0.M	2.4 or 24	% or gmKg^{-1}soil
$CaCO_3$	170	gmKg^{-1}soil
Ca^{2+} initial	50	mg Kg^{-1} soil
Na^{+}	20	gmKg^{-1} soil
Mg^{2+} initial	10	mg Kg^{-1} soil
NO_3^{-}	5	mg Kg^{-1} soil
SO_4^{2-}	15	mg Kg^{-1} soil
CL^{-}	0.6	mg Kg^{-1} soil
K^{+}	120	mg Kg^{-1} soil
Texture	Silty clay loam	-------

Soil solutions of different pH values were prepared and their effect on Ca and Mg solubility in the soil were studied.

Results and discussion

Results of effect of different pH values on Ca and Mg are presented on table 2. Values of soluble Ca and Mg showed fluctuation in the contents where it reached (80 $mgKg^{-1}$ Ca) at pH range of (6 – 6.4) and (15 $mgKg^{-1}$ Ca) at pH range of (8 – 10), while for Mg it reached (35 and 3 $mgKg^{-1}$) respectively at the same pH range (Table 2) due to reduce with rising of soil pH. The effect of sulfur application during incubation period on initial and after incubation on Ca and Mg concentrations (max. and min.) in the soil was shown in (Table 3).

Table (2): Maximum and minimum soluble Ca and Mg at different soil solution pH during incubation period.

pH range	Ca-content (mg kg^{-1})		Mg-content (mg kg^{-1})	
	max.	min.	max.	Min.
4 – 5.2	50	30	10	6
6.0 – 6.4	80	40	35	3
6.8 – 8.0	35	30	23	15
8.0 – 10	20	15	13	10

Table(3): Maximum and minimum concentrations of Ca and Mg during incubation period (a) with out sulfur (b) with three levels dry sulfur (c) with three levels moist sulfur.

Sulfur application ($mgKg^{-1}$)	max. Ca($mgKg^{-1}$)	min. Ca($mgKg^{1}$)	max. Mg($mgKg^{-1}$)	min. Mg($mgKg^{-1}$)
a - In the absence of sulfur before incubation.	50 (initial content)		10 (initial content)	
b - application of three(DS) levels (200 , 400 and 600) at three periods.	75	23	35	10
	80	18	35	3
	90	25	35	2
C - application of three(MS) levels (100 , 200 and 300) at three periods.	90	24	33	3
	90	22	33	2
	80	25	33	2

The effect of incubation period on the Ca and Mg concentrations in soils without sulfur application was shown in (Table 4) where Ca content showed a minimum value of (15 $mgKg^{-1}$) during a period of (60 days) and a maximum value of (55 $mgKg^{-1}$) during (75 days). While soluble Mg showed slightly increase in its content during early period and then reached its maximum content (45$mgKg^{-1}$) during a period of (60 days) after which an appreciable decrease was noticed. The difference in the maximum values between Ca and Mg contents within different periods is due to physio-chemical reactions in soil (Bohn and McNeal, 1985), which affect the concentration of Ca and Mg ions and their mobility in the soil solution.

Table (4): Effect of incubation on the concentration of Ca in soil without sulfur application.

Incubation time (days)	Ca content (mgKg^{-1})	Mg content (mgKg^{-1})
0	50	10
15	49	37
30	30	36
45	28	40
60	15	45
75	55	28
90	5	26

Table(5) showed a noticeable effect of dry sulfur (200 mgKg^{-1}) on Ca concentration in the soil where it reached a minimum content of (30 mgKg^{-1}) during a period of (15 days) and maximum content of (73 mgKg^{-1}) during a period of (60 - 75 days) after which a decreased in content was seen, this is may be due to high contribution of sulfate ion with Ca and Mg in soil solution (Ismail, 1992). The same behavior of soluble Ca was seen with addition of dry sulfur (400 mgKg^{-1}). While the application of (600 mgKg^{-1}) DS showed a maximum Ca content of (90 mgKg^{-1}) at a period of (60 days). This means that high level of sulfur addition can increases soil acidity and more exchangeable Ca released to the soil solution (Sullivan and Sutherland, 2006).

Behavior of Ca in the presence of different levels of moist sulfur (200 , 400 and 600 mgKg^{-1}) had similar treal to dry sulfur. Calcium reached a maximum content of (90 mgKg^{-1}) with the two levels at a period of 60 days (Table 5). Using a high levels of moist sulfur (600 mgKg^{-1}) causes a decrease in Ca content (77 mgKg^{-1}) during same period of incubation.

Table (5): Effect of incubation period on the concentration of Ca in soil treated with (DS) and (MS).

Incubation period (days)	With 200 mgKg-1 DS	with 400 mgKg-1 DS	With 600 mgKg-1 DS	with 200 mgKg-1 MS	With 400 mgKg-1 MS	With 600 mgKg-1 MS
0	50	50	50	50	50	50
15	30	18	26	25	20	26
30	40	28	28	28	28	48
45	45	40	49	40	40	48
60	73	63	90	90	90	77
75	68	65	50	50	35	57
90	37	34	36	35	35	30

Available Mg showed different behavior relative to calcium during period of incubation as shown in (Table 6), where a decrease in magnesium content was seen during a period of (60 days) incubation in the presence of different levels of dry sulfur

(100 , 200 and 300 $mgKg^{-1}$), while it reached its maximum content of (35 $mgKg^{-1}$) at (75 days) incubation. Generally, there is no significant effect on magnesium behavior during early incubation period as in dry sulfur application because of retarded release of Mg ions to the soil solution and their affinity to form more magnesium sulfate relative to calcium sulfate (Watmough and Page, 2005).

Moist sulfur application on the soil samples showed similar behavior for Mg as in case of dry sulfur addition along different period. Periods of Mg decline can be used as indicator for management of fertilizer.

Table (6): Effect of incubation periods on Mg concentration in soils treated with (DS) and (Ms).

Incubation period (days)	with 100 $mgkg^{-1}$ DS	With200 $mgkg^{-1}$ DS	with 300 $mgkg^{-1}$ DS	with 100 $mgkg^{-1}$ MS	with 200 $mgkg^{-1}$ MS	with 300 $mgkg^{-1}$ MS
0	10	10	10	10	10	10
15	12	7	7	5	5	6
30	17	8	8	7	7	7
45	10	5	4	5	5	5
60	13	4	3	4	3	3
75	35	35	32	32	35	33
90	28	27	32	32	34	31

Conclusion and Recommendation

From illustrated tables and, it can be concluded that the addition of sulfur to the soil showed an important effect on the behavior of soluble Ca and Mg relative to that with no sulfur addition. Soluble Ca behaved nearly similarly in soils applied with DS and WS with some fluctuations in content when using different sulfur levels. While soluble Mg showed a gradual decrease during a period of (60 days) after which a sharp elevation was seen after (15 days). Also it is concluded that the soils treated with MS released more Ca than Mg and causes early appearance of maximum contents of Ca or Mg during different periods of incubation. It can be said that it is necessary to follow up the Ca and Mg status in the soil for a best management for these two important plant nutrients. Soils near atmospheric sulfur depositions should be thoroughly investigated locally for precise management (agriculturally and environmentally).

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دراسة مختبرية حول تأثير اضافة الكبريت في تراكيز الكالسيوم و المغنسيوم الذائبة في تربة كلسية خلال مدد مختلفة من الحضن

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الخلاصة

تم في هذا البحث دراسة تأثير الكبريت المضاف في تراكيز الكالسيوم والمغنسيوم الذائبة خلال مدد حضن مختبري مختلفة. تم اضافة مستويات مختلفة من الكبريت الجاف و 10% رطب (200 و 400 و 600 ملغمS كغم$^{-1}$) لدراسة تاثيره على جاهزية الكالسيوم و المسويات (100 و 200 و 300 ملغم Sكغم$^{-1}$) لدراسة تاثيره في جاهزية المغنيسوم الى نماذج التربة بعمق (0 – 30سم). تم حفض نماذج التربة في المختبر(8 – 20م°) لمدة (90يوم) و ذلك لدراسة تراكيز الكالسيوم و المغنسيوم في التربة. اضهرت النتائج اقصى محتوى للكالسيوم الجاهز (75 ملغم Sكغم$^{-1}$) عند حفض عينات التربة لمدة (60يوم) و اقل محتوى (23 ملغم Sكغم$^{-1}$) خلال (15يوم) وذلك باضافة الكبريت الجاف في حين تشير النتائج الى اعلى مستوى للكالسيوم الجاهز عند حفظ التربة في الفترة نفسها عند اضافة كبريت رطب فيه 10% ماء الى نماذج التربة في حين محتوى الكالسيوم الذائب بلغت ذروتها (90 ملغم Sكغم$^{-1}$) خلال المدة (60يوم) و التي بعدها اظهر الكالسيوم انخفاظا في المحتوى. كذلك استعملت في هذا البحث الكبريت الجاف و الرطب و المستويات المذكورة اعلاه لمتابعة تاثيره في تركيز المغنيسيوم الذائب في التربة حيث اوضحت النتائج عدم استقرار في محتوى المغنيسيوم خلال مدد حفظ النماذج حيث بلغت اعلى محتوى (35 ملغم Sكغم$^{-1}$) خلال مدة (75يوم) و التي بعدها كان محتوى المغنسيوم ثابتا وبخلاف محتوى الكالسيوم الجاهز الذي اظهر ارتفاعا ملموسا خلال (60يوم) و ذلك يشير على تاثير الكبريت بنوعيه في جاهزية المغتسيوم في التربة خلال مدة الحضن.