Journal of Libyan Academy Bani Walid 2026
مجلة الأكاديمية الليبية بني وليد
e-ISSN: 3104-3860
Volume 2, Issue 1, 2026, Pages: 11-17
Website: https://journals.labjournal.ly/index.php/Jlabw/index

Soil pH Dynamics in a Calcareous Soil as Influenced by Organic and Sulfur Amendments under Different Irrigation Water Qualities

Jamal. S. M. Taher [1*], **Awad M. Mohamad** [2], **Shukri. M. Elsbia** [3]
[1,3] Department of ecology science, Omar Elmukhtar University, Libya .
[2] Department of Natural resources, Omar Elmukhtar University, Libya
*Email: Jamal.elgosni@gmail.com

ديناميكية حموضة التربة في التربة الكلسية وتأثير المواد العضوية والكبريتية عليها تحت ري بمياه مختلفة النوعية

جمال سليمان طاهر[1*]، عوض محمد[2]، شكري الصبيع[3]
[2،1] قسم علوم البيئة، كلية العلوم، جامعة عمر المختار، ليبيا.
[3] قسم الموارد الطبيعية، كلية العلوم، جامعة عمر المختار، ليبيا

Received: 03-11-2025	**Accepted:** 20-12-2025	**Published:** 03-01-2026
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Abstract
This study investigated the effects of sheep manure compost, elemental sulfur, and irrigation water quality on soil pH under maize (Zea mays L.) cultivation. A pot experiment was conducted under greenhouse conditions at Al-Fataih area, north of Derna City, Libya. Sheep manure compost was applied at rates of 0, 3, 6, 9, and 12% (w/w), while elemental sulfur was applied at rates of 0, 1, 2, 3, and 4% (w/w). Two irrigation water qualities (tap water and drainage water) were used. Results showed that irrigation with drainage water significantly increased soil pH, whereas compost and sulfur applications significantly reduced soil pH. The interaction between compost and sulfur was highly significant, while the three-way interaction was not significant. These findings confirm the effectiveness of organic and sulfur amendments in mitigating alkalinity in calcareous soils.

Keywords: Sheep manure compost; Elemental sulfur; Irrigation water quality; Soil pH; Calcareous soil; Maize .

الملخص:
هدفت هذه الدراسة إلى بحث تأثير سماد روث الأغنام، والكبريت العنصري، وجودة مياه الري على درجة حموضة التربة في زراعة الذرة (Zea mays L.). أُجريت تجربة في أصص زراعية ضمن ظروف دفيئة في منطقة الفاتح، شمال مدينة درنة، ليبيا. استُخدم سماد روث الأغنام بنسب 0، 3، 6، 9، و12%

(وزن/وزن)، بينما استُخدم الكبريت العنصري بنسب 0، 1، 2، 3، و4% (وزن/وزن). استُخدم نوعان من مياه الري (مياه الصنبور ومياه الصرف). أظهرت النتائج أن الري بمياه الصرف زاد بشكل ملحوظ من درجة حموضة التربة، بينما أدى استخدام السماد والكبريت إلى انخفاض ملحوظ في درجة حموضة التربة. كان التفاعل بين السماد والكبريت ذا دلالة إحصائية عالية، في حين لم يكن التفاعل الثلاثي ذا دلالة إحصائية. تؤكد هذه النتائج فعالية المُحسّنات العضوية والكبريتية في تخفيف قلوية التربة الكلسية.

الكلمات المفتاحية: كمبوست روث ؛ الكبريت العنصري؛ جودة مياه الري؛ درجة حموضة التربة؛ التربة الكلسية؛ الذرة.

1. Introduction:

Soil pH is a major factor affecting nutrient availability and crop productivity, especially in calcareous soils prevalent in arid and semi-arid regions. Organic amendments and sulfur are commonly used to improve soil chemical properties. However, irrigation water quality may modify their effectiveness. This study aimed to evaluate the individual and combined effects of sheep manure compost, sulfur, and irrigation water quality on soil pH under maize cultivation.

(Ghulam Murtaza et al 2020) stated that the applications of chicken manure, at low level of water salinity (EC< 2 mmhos/cm), obviously increased the uptake of such nutrients indicating the beneficial effect of such manure. Organic fertilizers and sulfur are used nowadays to improve soil characteristics and fertility index of soil. Huge amounts of organic fertilizers such as sheep manure, poultry and sheep manure compost could be added to soil for the farming purposes.

Roberta A.B. Gonçalves et al (2007) Observed the changes in the hydraulic conductivity were more pronounced in subsurface soil layers (to about the 1-m depth), which could be a consequence of the concentration of sodium in the leaching fraction and its subsequent increasingly damaging effect in the soil subsurface.

2. Materials and Methods

The experiment was conducted under greenhouse conditions using calcareous soil classified as Typic Calciorthids. Sheep manure compost and elemental sulfur were incorporated into the soil two weeks before sowing. Maize seeds were planted on July 1, 2021. Irrigation treatments included tap water and drainage water. The experiment followed a split–split plot design with three replications.

2.1 Soil Analysis

Soil pH was determined in a 1:1 soil-to-water suspension using a glass electrode according to Jackson (1973). Particle size distribution was determined using the hydrometer method (Black, 1965).

Selected physical and chemical properties of the experimental soil shown in Table(1)

Table(1) Selected physical and chemical properties of the experimental soil

Parameter	Value
Sand (%)	54.90
Silt (%)	22.50
Clay (%)	22.60
Textural class	Sandy clay loam
CaCO3 (%)	18.16
Organic matter (%)	0.44
pH (1:1)	7.82
Ec(1:1)	2.3
Ca^{2+}	0.98

Mg^{2+}	0.60
Na^{+}	1.23
K^{+}	0.08
CO^{-}_{3}	0.0
HCO^{-}_{3}	0.42
Cl^{-}	0.98
SO^{-}_{4}	1.45

Two types of irrigation water with different qualities were used a this study namely (i) tap water and (ii) drainage water (drainage water) was collected from the Untreated sewage water of the eastern coast of Derna City.
Some chemical properties of the irrigation waters are shown in Table (2).

Table(2): Some chemical properties of the irrigation**.**

Parameter	Tap water	Drainage water
pH	7.81	8
EC(ds/m)	0.42	3.40
Ca^{++}	2.50	3.78
Mg^{++}	1.83	2.33
Na^{+}	1.96	15.91
K^{+}	0.15	1.85
CO_3^{-}	0.0	0.0
HCO_3^{-}	3.07	11.51
Cl^{-}	2.02	15.32
SAR	1.32	9.11
SARadj	3.88	21.85
RSC	-1.36	2.41

Two soil amendments were used in the experiment; the sheep manure compost and Sulfur. The main chemical characteristics of the compost are presented in Table(3)

Table (3): Main chemical properties of sheep manure compost.

Parameter	Compost Values
pH	8.26
EC(1:5)ds/m	5.4
Ca^{++}	7.4
Mg^{++}	3.6
Na^{+}	4.31
K^{+}	1.85
CO_3^{-}	0
HCO_3^{-}	2.96
Cl^{-}	12.95
SO_4^{-}	1.18
O.M %	31.4
Total N %	0.90

2.2 Statistical Analysis
Data were analyzed using analysis of variance (ANOVA). Mean separation was performed using LSD at 0.05 probability level (Steel and Torrie, 1982).

3. Results and Discussion

The experimental soil used in this study was classified as a highly calcareous soil (Typic Calciorthids) with a sandy clay loam texture and alkaline reaction. Such soils are widely distributed in arid and semi-arid regions and are characterized by high CaCO3 content, which limits nutrient availability and reduces crop productivity (Brady & Weil, 2008).

3.1 Effect of Irrigation Water Quality on Soil pH

Irrigation water quality had a significant effect on soil pH (Table 4). Irrigation with drainage water resulted in higher soil pH values compared with tap water. This increase is mainly attributed to the high salinity, alkalinity, and sodium concentration of drainage water, which enhance salt accumulation and alkalization processes in soil (Ayers & Westcot, 1985; FAO, 1979).

The obtained results confirm that the long-term use of low-quality irrigation water can alter soil chemical equilibrium, particularly in calcareous soils with limited buffering capacity. Similar observations were reported by Westcot (1979), who emphasized that saline and sodic irrigation water may increase soil pH and negatively affect soil structure and fertility if not properly managed.

3.2 Effect of Sheep Manure Compost on Soil pH

Sheep manure compost application significantly reduced soil pH compared with the untreated control (Table 4). Increasing compost rates from 0 to 12% (w/w) resulted in a gradual and consistent decrease in soil pH under both irrigation water types. This reduction is attributed to the production of organic and inorganic acids during compost decomposition, as well as enhanced microbial activity, which promotes proton release into the soil solution (Hashem et al., 1992; Brady & Weil, 2016).

In calcareous soils, organic amendments are known to improve chemical balance by promoting carbonate dissolution and increasing soil buffering capacity. These findings are consistent with those reported in previous studies, which demonstrated that organic manure applications effectively reduce soil pH and improve nutrient availability in alkaline soils (FAO, 2017).

3.3 Effect of Elemental Sulfur on Soil pH

Elemental sulfur application significantly decreased soil pH, with greater reductions observed at higher sulfur rates (Table 4). The acidifying effect of sulfur is mainly due to its biological oxidation by soil microorganisms, resulting in the formation of sulfuric acid, which neutralizes soil alkalinity and dissolves calcium carbonate (Jackson, 1973).

Table(4): Effect of Elemental Sulfur on Soil pH

Treatment 1-Sheep manure %	pH(1:1)
0	7.35
3	7.29
6	7.25
9	7.20
12	7.18
L.S.D$_{005}$	0.01***
2-Sulfur %	
0	7.29
1	7.27
2	7.26
3	7.22
4	7.22
L.S.D$_{005}$	0.01***
3-Water quality	

Tap	7.24
Drainage	7.27
L.S.D005	0.01***

Application of S, as a soil amendment, is a common practice worldwide to improve the physical and chemical properties of calcareous soils, in addition to other type of soils. Under optimal condition, S is converted into sulphuric acid within a few weeks by soil microorganism (Balwan et al., 2006)

These results are in agreement with earlier findings indicating that sulfur is an effective amendment for reducing soil pH in calcareous soils The sulphuric acid then acts to reduce the relatively high pH values of the calcareous soils and dissolve native lime (Ammal et al., 2000).

3.4 Interaction Effects of Compost, Sulfur, and Irrigation Water Quality

The two-way interaction between sheep manure compost and sulfur was highly significant for soil pH (Table 5). The combined application of compost and sulfur produced a greater reduction in soil pH than either amendment applied alone. This synergistic effect can be explained by the role of organic compost in enhancing microbial activity, which accelerates sulfur oxidation and acid production.

Conversely, the interaction between sheep manure compost and irrigation water quality did not show a consistent significant effect on soil pH. Similarly, the three-way interaction among compost, sulfur, and irrigation water quality was not significant. This indicates that although irrigation water quality influenced overall soil pH levels, the acidifying effects of compost and sulfur were relatively stable under both tap and drainage water irrigation.

Statistical analysis revealed that the interaction among sheep manure compost, sulfur application, and irrigation water quality significantly affected most of the studied soil chemical properties.

3.5 Implications for Soil Management

Despite the increase in soil pH caused by drainage water irrigation, the application of sheep manure compost and sulfur effectively mitigated this adverse effect. The highest amendment rates produced the greatest pH reduction under both irrigation water qualities. These results highlight the importance of integrated soil management practices when low-quality irrigation water is used, particularly in calcareous soils common in arid regions (Ayers & Westcot, 1985; FAO, 2017).

The effect of this interaction on the soil pH is presented in Table(6)The data indicate that sulfur and town compost decreased soil pH slightly as compared to soil pH of the control (without sulfur or compost application) under the irrigation with tap water or drainage water. The highest rates of sulfur and compost were more effective on decreasing soil pH as compared to individual amendment, under the irrigation with tap water or drainage water.

Table(5): Effect of sheep manure compost, sulfur and irrigation water quality on soil pH**.**

Compost%	Rate of sulfur %					Average
	0	1	2	3	4	
Tap water						
0	7.38	7.39	7.29	7.31	7.26	7.33
3	7.29	7.34	7.24	7.24	7.24	7.27
6	7.24	7.24	7.27	7.19	7.25	7.24
9	7.24	7.11	7.21	7.18	7.16	7.18
12	7.22	7.16	7.20	7.13	7.13	7.17
Average	7.27	7.25	7.24	7.21	7.21	
Wastewater						
0	7.42	7.40	7.35	7.36	7.30	7.37
3	7.37	7.36	7.26	7.26	7.30	7.31
6	7.28	7.29	7.27	7.20	7.28	7.26

9	7.26	7.14	7.31	7.20	7.16	7.21
12	7.22	7.23	7.21	7.18	7.15	7.20
Average	7.31	7.28	7.28	7.24	7.24	

The role of sulfur in soil pH reduction is due to the acidic nature of reactions of oxidation of the applied sulfur in the soil by soil microorganisms which are able produce sulfuric acid in amounts enough to lower the pH. The application of town compost with sulfur enhanced the reduction of soil pH. This result are in agreement with those finding by
Monika Tabak *et al*. (2020) who stated that the decomposition of the organic matter in presence of CaC_3, could be a contributing factor to reduction of pH under conditions of the irrigation with saline water. In general the pH values of soil under the irrigation with drainage water were higher than those of the soil under the irrigation with tap water. This result can be attributed to the higher pH value(8.0) of the drainage water than the pH value(7.8)

3.2. Soil electrical conductivity (EC)

The effect of sulfur application, sheep manure compost, and irrigation water quality on soil electrical conductivity (EC) is shown in Table (6). The results indicated a progressive increase in soil EC values with increasing rates of sulfur and compost under both tap and drainage water irrigation. The highest EC values were recorded under irrigation with drainage water combined with the highest levels of sulfur and sheep manure compost, reflecting the higher salt content of drainage water.

Table(6): Effect of sheep manure compost, sulfur and irrigation water quality on soil electrical conductivity(EC,ds/m).

Compost %	Rate of sulfur %					Average
	0	1	2	3	4	
Tap water						
0	1.80	3.15	3.25	3.50	3.35	3.01
3	2.30	3.15	3.15	2.85	3.55	3.00
6	2.45	4.05	5.15	5.40	4.15	4.24
9	3.35	4.75	5.60	4.60	5.75	4.81
12	4.10	5.25	5.15	5.95	6.35	5.36
Average	2.80	4.07	4.46	4.46	4.63	
Waste Water						
0	2.40	4.35	5.15	5.10	5.75	4.55
3	4.45	5.10	4.20	4.45	5.20	4.68
6	2.55	6.05	5.95	6.60	4.60	5.15
9	4.95	7.10	6.25	6.30	6.40	6.20
12	4.15	6.00	7.10	6.75	7.05	6.21
Average	3.70	5.72	5.73	5.84	5.80	

4. Conclusion

Generally, a significant increase in most of the chemical properties of soil irrigated with drainage water than that irrigated with tap water were observed with sheep manure compost or sulfur application. The severe salt accumulation in soil at the end of the season is due to that the irrigation was carried out to the field capacity during the growth season. Application of sheep manure compost and sulfur increased significantly the yield of maize..

The aforementioned results elucidate that sheep manure compost and sulfur decreased soil pH of soil. Generally, a significant increase in most of the chemical properties of soil irrigated with drainage water than that irrigated with tap water were observed with sheep manure compost or

sulfur application. The severe salt accumulation in soil at the end of the season is due to that the irrigation was carried out to the field capacity during the growth season.
Application of sheep manure compost and sulfur increased significantly the yield of maize. The drainage water decreased the growth of maize, while the application of soil amendments (sulfur or sheep manure compost) increased the growth. It is a good practice to use better water quality for the seedling stage. In the following stage, water of higher salinity could be used with less risk.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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