environmental sciences proceedings

Proceeding Paper

Reclamation of Sodic Soils and Improvement of Corn Seed Germination Using Spent Grains, Cheese Whey, Gypsum, and Compost †

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† Presented at the 2nd International Laayoune Forum on Biosaline Agriculture, 14–16 June 2022; Available online: https://lafoba2.sciforum.net/.

Abstract: Incubation and germination experiments were carried out to evaluate spent grain, cheese whey, gypsum, and compost for reclamation of sodic soils and enhancing corn (*Zea mays* L.) germination. Results indicated that all organic amendments effectively reduced exchangeable sodium percent (ESP), sodium adsorption ratio (SAR), and soil pH, while they enhanced soil organic matter, macronutrients, and corn germination percentages compared with gypsum and control. The positive impacts of all amendments followed the arrangement: spent grain > cheese whey > compost > gypsum > control. Moreover, one-month incubation was enough time for amendments to mitigate soil sodicity before crop plantation.

Keywords: sodic soils; industrial by-products; cheese whey; organic amendments; *Zea mays* L.

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Citation: Aboukila, E.; Nilahyane, A. Reclamation of Sodic Soils and Improvement of Corn Seed Germination Using Spent Grains, Cheese Whey, Gypsum, and Compost. *Environ. Sci. Proc.* **2022**, *16*, 36. https://doi.org/10.3390/environsciproc2022016036

Academic Editor: Abdelaziz Hirich

Published: 16 June 2022

1. Introduction

Globally, more than 60% of salt-affected soils are classified as sodic soils [1]. Sodic soils reclamation is generally more expensive compared with saline–sodic or saline soils [2]. However, sodic soil could be remediated by incorporation of organic matter or chemical amendments. Because of the lack of organic farm waste in many regions around the world, industrial organic by-products, such as brewer's spent grain (SG) and cheese whey, could be used as alternatives to conventional organic fertilizers. SG is a byproduct of beer production, constituting almost 85% of the total byproducts produced matters [3]. Cheese whey is a liquid byproduct of cheese and cottage cheese manufacture. For each kg of cheese produced, 9 kg of cheese whey is generated [4].

Spent grain and cheese whey disposal are often environmental issues. The properties of SG and cheese whey make them ideal candidates for recycle in agriculture. Developing this practice may mitigate the economic and environmental issues of degraded soil and excess wastes. The specific objectives of this research were to assess the capacity of SG, cheese whey, compost, and gypsum to reduce soil sodicity, improve soil sequestration of macronutrients, and enhance maize growth on sodic soils.

2. Materials and Methods

Sodic soils used for the experiment (*Typic Torrifluvents*) with clay loam texture were collected from the region of Abees, Alexandria, Egypt. Four types of amendments were applied in this study and included spent grain, cheese whey, compost, and gypsum. The characterizations of the SG, cheese whey and compost were calculated using methods outlined in ref. [5]. The amendments characterizations are shown in Table 1.

Table 1. Characterization of organic amendments used in this study (oven dry weight basis).

Analyte	Compost	Spent Grain	Cheese Whey
pH (1:5 w:w)	6.95	4.16	3.82
EC (dS m^{-1}, 1:5 w:w)	5.91	1.45	5.12
Organic Matter (%)	42.5	75	3.15
Total N (%)	2.26	6.12	2.63
Total P (%)	1.13	1.86	0.14
Total K (%)	0.59	2.74	0.33
Organic carbon (%)	24.65	43.5	1.83
C:N ratio	10.91	7.1	0.69
Moisture (%)	23	75	96
Fe (mg kg^{-1})	930	1130	nd [1]
Zn (mg kg^{-1})	215	368	nd
Mn (mg kg^{-1})	98	210	nd
Cu (mg kg^{-1})	67	98	nd
B (mg kg^{-1})	23	39	nd

[1] Not determined.

2.1. Incubation Experiment

Seven treatments were applied in this research and included 2 levels of cheese whey (W1 and W2), 2 levels of compost (C1 and C2), gypsum (G), spent grain (SG), and control (Ctrl). The application rates of cheese whey were 1% and 2% dry matter content. The base level of spent grain (SG) and compost (C1) was the quantity of spent grain or compost required to increase soil organic matter (SOM) by 1%. Compost was also added twice the base level (C2). Gypsum was added at equivalent rate of gypsum requirement to reduce ESP to 10%. Amendments were incorporated with 5 kg of sodic soil and packed in polyethylene pots. All pot treatments were incubated under natural field conditions, without plants, for a month. After incubation, sub-samples were analyzed for selected chemical properties (Table 2).

Table 2. Change in EC_e (ds m^{-1}), soil pH, SAR, ESP (%), OM (%), soil available N, P, K (mg kg^{-1}), and biomass (g pot^{-1}) after soil incubation with various treatments. Same letters within columns indicate no significant differences ($p < 0.05$, Tukey's test).

	EC_e	pH	SAR	ESP	OM	N	P	K	Biomass
Initial	3.91	8.75	26.9	31.0	1.66	78.5	4.45	352	-
Ctrl	3.55a	8.60a	20.1a	23.7a	1.57d	75.8c	4.62e	341c	2.25d
W1	3.28ab	7.86de	9.2b	11.0b	1.90cd	115.7c	5.33de	426bc	5.09b
W2	3.23b	7.71e	8.2b	9.5b	2.32abc	125.0bc	5.96cd	554ab	4.81bc
C1	2.48c	8.07c	11.0b	12.3b	1.98bcd	183.2d	6.64c	415bc	2.92d
C2	2.41c	7.92cd	10.3b	11.9b	2.52ad	288.3a	8.80b	484bc	3.32cd
G	2.59c	8.32b	11.0b	12.4b	1.47d	87.7c	4.85de	369c	2.28d
SG	2.70bc	7.48f	9.1b	10.9b	2.80a	325.0a	10.85a	669a	7.03a

2.2. Germination Experiment

After incubation, the pots were sown with 4 corn seeds (*Zea mays* L.). The germination experiment continued for 15 days. At the end of the germination experiment, the germination percentage was determined, and then dry weight was recorded.

3. Results and Discussion

3.1. Incubation Experiment

All treatments produced significant decreases in soil EC_e compared with the respective initial values (Table 2). This reduction of salt concentration is attributed to the high leaching of solute in the treated soil. These reductions in soil EC_e can be illustrated by the mobilization of Ca via increasing the dissolution of soil calcite, which exchanges Na at cation exchange complex and forms Na_2SO_4, $MgSO_4$, and other high solubility salts. Moreover, these reactions promote water infiltration, soil flocculation, and stability [6]. As a result, the majority of these soluble salts leached with the drainage water. Post incubation soil analysis showed that soil pH was significantly decreased in all treatments compared with control (Table 2). Soil pH reduced to less than 8.5, the critical value of pH for salt-affected soil. Spent grain and cheese whey are acidic. Thus, they might be preferably used than compost as organic amendments for decreasing soil pH and reclamation of sodic soils. It is likely that incubation of organic treatments probably enhanced the partial pressure of CO_2 because of increases of the microbial activity. This possibly caused by the formation of organic and inorganic acids, which lead to decreasing pH in organic treated soils [7]. Furthermore, solubilization of minerals such as Ca and Mg [8] because of microbial activity assists the decrease of pH in sodic soils by exchanging with Na from the cation exchange complex [9].

The SAR levels reduced by 25.3%, 65.7%, 69.4%, 59.2%, 61.5%, 59.0%, and 66.1% for Ctrl, W1, W2, C1, C2, G, and SG, respectively. The releasing of Ca and Mg by organic treatments increased their contents in soil solution and facilitated the exchange with exchangeable Na on the cation exchange complex and release Na to soil solution. Thus, it helped Na loss by leaching. As a result, soil SAR reduced. Furthermore, extra Ca release from gypsum promoted the exchangeable Na release to soil solution, and consequently enhanced additional decreases of soil SAR [10]. All treatments, except for control, were effective in decreasing the soil ESP to less than 15% (Table 2). The significant decrease in the exchangeable Na levels led to the reduction in the soil ESP. Organic amendments and gypsum were statistically equally successful in decreasing the soil ESP. This reduction could be attributed to the releasing of Ca from gypsum, organic amendments, and the solubilization of soil calcite by organic amendments that probably promote the Na–Ca exchange rate among the cation exchange complex and soil solution.

All organic treatments produced significant increases in SOM. The greatest increases were recorded with the SG and C2 treatments compared with control (Table 2). It is noted that SOM in gypsum treated soil decreased by 6.6%. The size of the increase in SOM tends to correlate with the quantities of organic matter applied by each amendment. Comparable results were observed by ref. [11] who reported a significant level of SOM in calcareous soil treated with SG or compost compared with the untreated ones. Similarly, ref. [12] stated that increasing application rate of mozzarella cheese whey led to increasing SOM in both clay and calcareous soil. Soil-available N, P, and K concentration were increased using all amendments compared with the Ctrl. Therefore, all of amendments were efficient at contributing soil available N, P, and K to sodic soil (Table 2). The SG significantly produced larger levels of N, P, and K compared with other organic amendments. Mineralization of organic materials present in the added organic treatments leads to increases in the soil available N, P, and K. Furthermore, organic amendments could be added before sowing to have enough time for the mineralization processes of organic compounds, thus increasing the availability of plant nutrients. Comparable conclusions were reported by ref. [12].

3.2. Germination Experiment

No significant differences in the final germination percent (FGP) were found between treatments in sodic soil. However, there were significant differences in biomass yield among the treatments (Table 2). Spent grain (SG) was the most effective one in enhancing seed germination in sodic soil. The biomass yield of SG significantly increased to 312% in comparison with untreated soil (Ctrl). This was due to the superior effect of the spent grain (SG) in ameliorating soil sodicity by decreasing soil pH, exchangeable Na, soluble Na, ESP, and SAR, and increasing N, P, and K. Gypsum treated soil was a less effective amendment and produced poor seed germination as control. This may be due to the fact that the gypsum was a less effective treatment in decreasing soil pH. Moreover, it does not support sodic soil with any remarkable amount of OM, N, P, or K, compared with organic treatments.

4. Conclusions

All organic amendments examined in the present study were efficient at remediating sodic soil properties and improving corn seed germination. The commonly used amendment gypsum was less effective than organic amendments in ameliorating sodicity and improved corn seed germination in sodic soils. Hence, use of such industrial organic wastes as spent grain and cheese whey in sodic soil reclamation provides an environmentally friendly and economic practice of disposal and consequently enhancing soil quality and crop yield. The addition of spent grain or cheese whey to sodic soil was confirmed to be a very efficient method of decreasing pH, ESP, and SAR and increasing organic matter, nitrogen, phosphorous, potassium, and corn yield. Increasing the application rates of cheese whey and compost did not significantly enhance biomass yield or reduce sodicity compared to lower application rates. The economics of sodic soil reclamation require a low-cost method for successful implementation. Spent grain and cheese whey avoid the cost of composting. Thus, they are more economical amendments than compost.

Author Contributions: Conceptualization, E.A.; methodology, E.A.; validation, E.A. and A.N.; writing—review and editing, E.A. and A.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Acknowledgments: The authors thank college of agriculture, Damanhour University, Egypt for funding this research.

Conflicts of Interest: The authors declare no conflict of interest.

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