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Improving Salt-Affected Soils and Productivity of Alfalfa by Using some Soil Conditioners and Subsoiling Tillage

Abd El-Tawab, A. G.[1*]; M. A. Abdel-Salam[2]; M. R. M. Ahmed[1] and Taghred A. Hashim[2]

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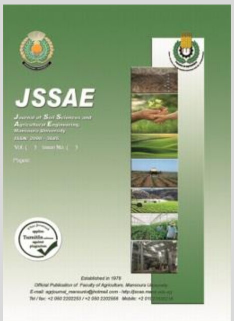
[1]Soils, Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt
[2]Department of Soil and Water, Faculty of Agriculture, Benha University, Egypt



ABSTRACT

Due to the importance of improving salt-affected soils in Egypt's agricultural security policy, a field experiment was conducted in the winter season of 2021/2022 at Kom Abou-Khallad village, Nasser City, Beni-Suef Governorate, Egypt, aiming to determine the impact of various amendments with two-tillage systems on certain properties of salt-affected soil, as well as the growth and productivity of alfalfa plants. Different amelioration techniques were applied using soil conditioners (natural gypsum, modified cement dust, phosphogypsum, and filter mud) that were carried out under two tillage systems, namely, shallow and deep (subsoil). The results show that subsoil tillage decreased bulk density, penetration resistance, pH, EC, and ESP and increased total porosity, hydraulic conductivity, available water and soil organic matter as well as increased the fresh and dry yield of alfalfa plants and protein (%), N, P and K uptake in alfalfa shoots. Treated alfalfa plants cultivated in salt-affected soil with soil conditioners, especially filter mud (FM1) at a rate of 100% G.R resulted in a decreased hazardous effect of salinity by improving soil properties, which consequently increased its productivity.

Keywords: Amelioration, salt-affected soil, subsoiling tillage, gypsum, alfalfa.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most valuable forage crops having an intermediate salt-tolerant level. In this concern, the alfalfa plant has historically been classified as moderately sensitive to saline conditions, with significant yield declines as the electrical conductivity of the saturated soil paste extract (ECe) exceeds 2 dS m^{-1} (Ayers and Westcott, 1985). Moreover, Putnam *et al.* 2017) mentioned that some ‘pre-selected’ alfalfa varieties can thrive in much higher salt concentrations, either in soil or in irrigation water, without significant negative effects on its yield.

Salt-affected soil is one of the most agricultural problems that limit plant growth and development all over the world, particularly in arid and semi-arid regions. Wang *et al.* (2003) reported that soil salinization is predicted to have repercussions on the world which resulted in losing about 50% of agricultural soil by the middle of the twenty-first century, and about 30% of agricultural soil during the following 25 years. In this concern, Flowers *et al.* (2010) mentioned that about 12 billion American Dollars were lost on 50% of the agricultural land of the world due to salt stress. Accumulation of salts in these soils harmed their physical and chemical properties such as pH, EC, ESP, SAR and available water capacity, consequently, nutrient availability which finally reduced crop productivity. Therefore, cultivation of these soils faces many challenges such as surface crusting, poor structure, low hydraulic conductivity, and low infiltration of water (Dodd *et al.*, 2013). These damages in soil properties resulted in delaying seedling emergence and inhibition in roots penetration (Worku, 2015). In addition, Norton and Strom (2012) mentioned that the effects of Na^{+} and Cl^{-1} lead to a decrease in the plant's ability to absorb water and essential nutrients for growth, therefore resulting in a reduction in growth and yield of plants although soil has suitable water.

Improving salt-affected soil with low permeability needs comprehensive efforts and techniques due to many important factors, subsoiling tillage has been considered a good method for this purpose in the past few years (Moukhtar *et al.*, 2003). Deep tillage improves the operation and allows water to move down during the compacted layer. Abdel-Mawgoud *et al.* (2006) pointed out that subsoiling improves soil structure, thus improving water movement to the permanent pipe system. They added deep tillage will enhance the downward movement of irrigation water carrying salts from the surface layer. Deshesh (2021) stated that in case of the soil characterized by high bulk density and low infiltration rate, subsoiling tillage is beneficial for improving the physical and chemical soil properties of the salt-affected soil and increased crop production.

Leaching the soluble salts by applying proper soil conditioners such as natural gypsum and organic residues is a good method for reclamation salt salt-affected soil. Bayoum (2019) found that using gypsum decreased salinity, enhanced the removal of soluble sodium, reduced ESP and soil reaction as well as increased soluble and exchangeable Ca^{2+} and water conductivity of reclamation of salt-affected soil. Moreover, there are a great amount of industrial byproducts such as filter mud, cement dust and phosphogypsum which can used economically in the reclamation of salt-affected soil. Filter mud is a byproduct in sugar cane factories In Egypt these factories produce about $(400\text{-}500)\times10^{3}$ ton/year which increases the environmental pollution thrown in the river Nile (Reda, 2007). Also, cement dust is used as a fertilizer or soil

[*] Corresponding author.
E-mail address: Aligamaloto@gmail.com

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conditioner in many parts of the world due to its high content of potassium and lime. Amin *et al.* (2011) pointed out that the green yield and total dry matter of alfalfa plants were increased due to the application of cement dust to sandy soil which is mainly explained by these byproducts rich in K, P, Fe and Cu. In addition, phosphogypsum is a byproduct of the phosphate fertilizer industry. It is an alternative amendment to gypsum used to reduce salinity. Phosphogypsum application decreased EC, pH, SAR, ESP, and bulk density (Abou Youssef, 2002, Abd El-Fattah, 2014 and Outbakat *et al.*, 2022).

The present work was undertaken to investigate the effect of some physical methods for reclaimed salt-affected soil such as subsoiling as well as the effect of some chemical amendments such as natural gypsum, modified cement dust, phosphogypsum and filter mud on the improving physical and chemical properties of the salt affected soil as well as its effect the productivity of alfalfa plants grown in heavy clay saline soil.

MATERIALS AND METHODS

Experimental work

A field experiment was conducted on clay soil at Kom Abou-Khallad village (Latitude 29°12' N, Longitude 31° 2' E, and 24.1 m above sea level), Beni-Suef Governorate, Egypt in the 2021–2022 growing season to study the effect of some soil ameliorations,i.e., natural gypsum, cement dust, phosphogypsum and filter mud as chemical conditioners as well as two tillage system as physical method on improving salt affected soil and alfalfa productivity. Table (1) represents some physical and chemical properties of the studied soil according to the method described by A.O.A.C. (1990).

Table 1. Some physio-chemical characteristics of the experimental soil.

Soil properties	Values	Soil properties	Values
Particle size distribution		Soluble cations (soil paste, m molcl^{-1})	
Sand (%)	11.7	Ca^{2+}	19.65
Silt (%)	25.5	Mg^{2+}	17.85
Clay (%)	62.8	Na^{+}	59.79
Textural grade	Clay	K^{+}	0.69
Soil chemical properties:		Soluble anions (soil paste, m molcl^{-1})	
Soil pH_s (soil paste)	8.61	CO_3^{2-}	---
EC_e (dS/m. soil paste extract)	9.79	HCO_3^-	6.15
$CaCO_3$ (%)	8.64	Cl^-	65.32
Organic matter (%)	1.61	SO_4^{2-}	26.51
CEC (cmolc k.g^{-1})	37.56	ESP (%)	16.07
Soil physical properties		Available macronutrients (mg kg^{-1})	
P.D (Mg m^{-3})	2.70	N	16.46
B.D (Mg m^{-3})	1.35	P	11.24
T.P (%)	48.13	K	184
Moisture % (w/w)		Gypsum requirement (Mg ha^{-1})	15.5
Field capacity	43.45	Hydraulic conductivity (cm h^{-1})	0.13
Wilting point	22.63	SPR = Soil penetration resistance	
Available water	20.82	(MPa) at soil moisture contents (30%)	4.06

An agricultural drainage water (C3-S1) EC = 2.18 (dS m^{-1}) & SAR = 7.12 was used for irrigating the experiment.

The treatments and the design of the experiment

A split-plot design in a complete randomized block was used in four replicates, where tillage systems,i.e., shallow tillage (15 cm) and subsoiler tillage (50 cm) were arranged in the main plots, while the soil conditioners T_1 = C = Control (without soil conditioners), T_2 = NG= natural gypsum (100 G.R %, 15.50 Mg ha^{-1}), T_3 = CD1= cement dust (100 G.R %, 10.8 Mg ha^{-1}), T_4 = CD2= cement dust (50 G.R %, 5.4 Mg ha^{-1}), T_5 = PG1= phosphogypsum (100 G.R %, 13.2 Mg ha^{-1}), T_6 = PG2= phosphogypsum (50 G.R %, 6.6 Mg ha^{-1}), T_7 = FM1= filter mud (100 G.R %, 18 Mg ha^{-1}) and T_8 = FM2= filter mud (50 G.R %, 9 Mg ha^{-1})

Field experiment

Alfalfa (*Medicago sativa,* C.V Ramah1) seeds were sowed after treated Rhizobium sp. directly before planting on 15 October 2021. All experimental plots were fertilized according to the recommended dose of Agricultural Ministry, where nitrogen was applied at a rate of 36 kg N ha^{-1} as ammonium sulphate (20.6 % N) before planting and 95 kg P_2O_5.ha^{-1} as calcium superphosphate fertilizer (15 % P_2O_5) before planting during land preparation and then added 36 kg P_2O_5.ha^1 as calcium superphosphate fertilizer (15.5 % P_2O_5) every four months. Also, 114 kg K_2O.ha^{-1} as potassium sulphate (48 % K_2O) was added before planting, and 57 kg K_2O.ha^{-1} as potassium sulphate (48 % K_2O) every four months. Other cultural practices for alfalfa production were done in the district. Six cuts were taken during the season and then plants were harvested in October 2022.

Natural gypsum

The natural gypsum ($CaSO_4.2H_2O$, particles 1-2 mm) for agricultural gypsum requirements were received from the Agricultural Ministry. The Natural gypsum was added to plots and mixed with the surface layer (0-30 cm) during soil preparation processes at the rate NG (100 G.R %, 15.5 Mg ha^{-1}).

Cement dust (by-pass)

Cement dust (by-pass) is a highly soluble and reactive byproduct of the cement industry, kiln dust is also obtainable in limited quantities locally. Cement dust was received from Wadi El Nile Cement Company from Beni-Suef Governorate. Some characteristics of the used cement dust are presented in Table (2).

The modified cement dust with commercial sulfuric acid (H_2SO_4) 98% (4 cement dust * 1 sulfuric acid 98% (w/w)) added to plots at rates CD1= Cement dust (100 G.R %, 10.8 Mg ha^{-1}) and CD2= Cement dust (50 G.R %, 5.4 Mg ha^{-1}) and thoroughly mixed with soil at the depth (0-30 cm) during soil preparation processes.

Table 2. The main chemical constituents of cement by-pass.

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl
Conc. (%)	11.88	2.97	2.60	47.81	0.68	12.13	2.28	4.38	4.81

Phosphogypsum

Phosphogypsum is a waste byproduct of the phosphate rock processing used to make phosphoric acid and phosphate fertilizers such as superphosphate. The phosphogypsum was added to plots at rate PG1= phosphogypsum (100 G.R %, 13.2 Mg ha^{-1}) and PG2= phosphogypsum (50 G.R %, 6.6 Mg ha^{-1}). Some chemical constituents in phosphogypsum are listed in Table (3).

Table 3. Some chemical constituents of phosphogypsum:

Constituents	Concentration %	
	Impure PG	Treated PG using H_2SO_4
CaO	28.31	33.81
SO_3	40.45	48.31
SiO_2	8.29	4.33
Al_2O_3	0.17	0.03
Fe_2O_3	0.31	0.02
MgO	0.21	0.005
P_2O_5	1.98	0.026
F	0.26	0.002
Na_2O	0.29	0.002
K_2O	0.02	0.003

Filter mud (press mud)

Filter mud waste byproducts for sugar factories in Abu-Qurqas Centre located in the Minia Governorate of Egypt were used in this study at two levels (100 G.R %, 18 Mg ha^{-1}) and (50 G.R %, 9 Mg ha^{-1}). It is a soft, spongy, lightweight material of dark brown or dark gray. The Filter mud wastes were added to plots and thoroughly mixed with soil at the depth (0-30 cm) during soil preparation processes. Some chemical characteristics of the studied filter mud are determined in 1:5 water suspension according to A.O.A.C. (1990) and listed in Table (4).

Table 4. Some characteristics of filter mud (press mud):

Composition and characteristics	Filter mud (F.M)
Density (g cm^{-3})	0.26
SP (%)	324
pH (1: 5)	6.65
EC (1: 5) dS m^{-1}	5.07
Organic carbon (%)	27.75
Organic matter (%)	47.84
C/N Ratio	12.50
Total nitrogen (%)	2.52
Total Phosphorous (%)	0.95
Potassium (%)	0.64
Total Ca (%)	5.14

Methods of analysis

Soil analysis:

After harvesting soil samples from each plot were taken for physical and chemical analysis according to A.O.A.C. (1990).

Soil penetration resistance (SPR):

was determined by a hand penetrometer device (Herrick and Jones, 2002).

Gypsum requirements:

were calculated using the Schoonover method (1952).

Plant analysis: N, P, and K content in alfalfa plants were determined according to methods described by A.O.A.C. (1990).

Some soil measurements: Exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were calculated using the following formula (Richards, 1954).

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad \text{and} \quad ESP = \frac{100(-0.01216+0.01475\,SAR)}{1+(-0.01216+0.01475\,SAR)}$$

Statistical analysis

The obtained results were subjected to statistical analysis according to the methods described by Snedecor and Cochran (1980). L.S.D. at 0.05 level of probability was used to compare between treatments.

RESULTS AND DISCUSSION

Soil chemical properties:

The data in Table (5) show the effect of some soil ameliorations on some chemical properties, i.e., pH, EC, ESP, and OM after alfalfa harvesting. Concerning the main effect of the tillage system, the data reveal that deep tillage improved all studied chemical properties. Subsoiling decreased soil pH, EC and ESP, while soil organic matter was increased under a deep tillage system. The relative reduction in soil pH, EC and ESP due to deep tillage were 0.86, 10.0 and 14.31% over shallow tillage, respectively. However, soil organic matter (%) increased by about 6.55% in the same respect. The beneficial effect of deep tillage on some chemical properties may be due to a decrease in soil compaction by subsoiling (Thomas *et al.*, 2007). Also, Sasal *et al*., (2006) mentioned that deep tillage caused a significant increase in soil porosity, which in turn, enhanced the leaching processes and plant growth which resulted in increasing soil organic matter and decreasing soil salinity and ESP. Similar results were obtained by Sharma *et al.*, (2016) and Taha *et al.*, (2021).

Respecting the main effect of soil conditioners, the data show that all studied soil conditioners improved the chemical soil properties compared with the control, where it decreased soil pH, EC and ESP as well as increased soil organic matter. It is obvious to notice that as the level of soil conditioners increased, the effectiveness of chemical properties increased. In general, natural gypsum is the best conditioner in its effect on decreasing soil pH and ESP while filter mud (FM1) at 100 GR had the highest effect on improving soil salinity and soil organic matter. The promotive effect of the soil conditioners may be attributed to the application of these amendments resulted in the enhancement of the soil infiltration ratio of the soil and, in turn, increased soil porosity which helps on leached soluble saline (Bairagi *et al.*, 2017). In this concern, Stamford *et al.*, (2015) reported that these conditioners were acid-forming substances, consequently reducing soil reaction and ESP. In addition, Taha and Abd Elhamed, (2021) stated that the improvement in pH, EC and ESP due to soil conditioners led to increased root growth, consequently increased soil organic matter. Similar results were obtained by Sarwar *et al.,* (2011) and El-Sheref *et al.,* (2019).

Considering the effect of the interaction between the tillage system and soil conditioners on chemical soil properties after alfalfa plant harvesting, the results reveal that all studied chemical properties were significantly affected by the interaction between the two factors, except soil reaction which did not affect. The positive effect of soil conditioners on improving EC, ESP and OM were increased under deep tillage systems than shallow ones. These results are in good agreement with those obtained by El-Saady, (2004) and Gendy, (2011).

Table 5. Effect of different amelioration techniques on some chemical properties of soil after harvest Alfalfa:

Different amelioration technique: Tillage	Soil conditioners	pH_s	EC_e dS m^{-1}	ESP %	Organic matter %
Shallow tillage (15 cm)	Control	8.24	9.54	15.15	1.51
	G	8.03	8.12	11.01	1.84
	CD1	8.11	8.58	13.10	1.83
	CD2	8.16	8.82	13.53	1.79
	PG1	8.10	8.69	12.80	1.86
	PG2	8.20	8.84	13.96	1.80
	FM1	8.12	7.88	12.67	2.14
	FM2	8.13	8.20	14.61	1.88
	Mean	8.14	8.58	13.35	1.83
Subsoil tillage (50 cm)	Control	8.14	8.98	14.67	1.55
	G	7.99	7.26	9.94	1.97
	CD1	8.08	7.41	10.80	1.96
	CD2	8.12	7.78	12.36	1.92
	PG1	8.06	7.07	10.23	1.98
	PG2	8.14	7.31	11.05	1.93
	FM1	8.08	6.50	11.12	2.29
	FM2	8.10	7.12	11.31	2.01
	Mean	8.09	7.43	11.44	1.95
Mean of soil conditioners	Control	8.19	9.26	14.91	1.53
	G	8.01	7.69	10.48	1.91
	CD1	8.10	8.00	11.95	1.90
	CD2	8.14	8.30	12.95	1.86
	PG1	8.08	7.88	11.52	1.92
	PG2	8.17	8.08	12.51	1.87
	FM1	8.10	7.19	11.90	2.22
	FM2	8.12	7.66	12.96	1.95
LSD 0.05	A	0.01	0.21	0.45	0.10
	B	0.02	0.19	0.40	0.06
	AB	NS	0.27	0.56	0.08

C = Control (without natural gypsum)
NG= Natural gypsum (100 G.R %, 15.50 Mg ha^{-1})
CD1= Cement dust (100 G.R %, 10.8 Mg ha^{-1})
CD2= Cement dust (50 G.R %, 5.4 Mg ha^{-1})
PG1= Phosphogypsum (100 G.R %, 13.2 Mg ha^{-1})
PG2= Phosphogypsum (50 G.R %, 6.6 Mg ha^{-1})
FM1= Filter mud (100 G.R %, 18 Mg ha^{-1})
FM2= Filter mud (50 G.R %, 9 Mg ha^{-1})
pH_s = pH in soil saturated paste
EC_e= Electrical conductivity in soil-saturated paste extract
ESP%= Exchangeable sodium percentage
O.M % = Organic matter

Soil physical properties:

The effect of some amelioration techniques on some soil physical properties, namely, bulk density (BD), total porosity (TP), hydraulic conductivity (HC), and soil penetration resistance (SPR) after alfalfa harvesting are given in Table (6). Regarding the main effect of the tillage system, the results show that deep tillage had a beneficial effect on BD, TP, HC, and PR. Compared with shallow tillage, subsoiling decreased bulk density and penetration resistance by about 8.87 and 4.67%, respectively, while total porosity and hydraulic conductivity increased by about 7.57 and 11.11% in the same respect. The beneficial effect of subsoiling tillage is mainly due to the breaking of soil clods and bigger granular to smaller ones as well as cracking the hard pans (Antar *et al.*, 2008) and Ordoñez-Morales *et al.*, (2019). Gendy, (2011) and Deshesh, (2021) obtained the same trends.

Table 6. Effect of different amelioration techniques on some physical properties of soil after harvest Alfalfa:

Different amelioration technique: Tillage	Soil conditioners	Bulk density (Mg m^{-3})	Total porosity (%)	Hydraulic conductivity (mm h^{-1})	Soil penetration resistance (MPa) at soil moisture contents (30%)
Shallow tillage (15 cm)	Control	1.30	52.00	0.170	3.62
	G	1.23	54.49	0.283	3.43
	CD1	1.24	54.13	0.281	3.46
	CD2	1.28	52.71	0.274	3.57
	PG1	1.22	54.84	0.285	3.40
	PG2	1.27	53.07	0.276	3.54
	FM1	1.17	56.62	0.294	3.27
	FM2	1.20	55.56	0.289	3.35
	Mean	1.24	54.18	0.27	3.46
Subsoil tillage (50 cm)	Control	1.18	56.30	0.243	3.21
	G	1.12	58.57	0.305	3.04
	CD1	1.13	58.24	0.303	3.07
	CD2	1.16	56.95	0.296	3.16
	PG1	1.11	58.89	0.306	3.02
	PG2	1.15	57.27	0.298	3.14
	FM1	1.07	60.51	0.315	2.90
	FM2	1.09	59.54	0.310	2.97
	Mean	1.13	58.28	0.30	3.06
Mean of soil conditioners	Control	1.24	54.15	0.207	3.42
	G	1.18	56.53	0.294	3.24
	CD1	1.19	56.19	0.292	3.27
	CD2	1.22	54.83	0.285	3.37
	PG1	1.17	56.87	0.296	3.21
	PG2	1.21	55.17	0.287	3.34
	FM1	1.12	58.57	0.305	3.09
	FM2	1.15	57.55	0.300	3.16
LSD 0.05	A	0.04	1.23	0.011	0.10
	B	0.01	0.21	0.010	0.02
	AB	0.02	0.29	0.016	0.02

C = Control (without natural gypsum)
NG= Natural gypsum (100 G.R %, 15.50 Mg ha^{-1})
CD1= Cement dust (100 G.R %, 10.8 Mg ha^{-1})
CD2= Cement dust (50 G.R %, 5.4 Mg ha^{-1})
PG1= Phosphogypsum (100 G.R %, 13.2 Mg ha^{-1})
PG2= Phosphogypsum (50 G.R %, 6.6 Mg ha^{-1})
FM1= Filter mud (100 G.R %, 18 Mg ha^{-1})
FM2= Filter mud (50 G.R %, 9 Mg ha^{-1})
BD = Bulk density (Mg m^{-3})
TP= Total porosity (%)
HC = Hydraulic conductivity (mm h^{-1})
SPR = Soil penetration resistance (MPa) at soil moisture contents (30%)

As for the main effect of soil conditioners, the results reveal that compared with no soil conditioners, using soil conditioners improved BD, TP, HC, and PR after the harvest alfalfa plant. It is worth observing that filter mud at 100 GR is the most effective in improving these physical properties, where it decreased BD and PR by about 8.16 and 44.93% over control, respectively. In this concern, Taha and Abd Elhamed, (2021) explain the promotive effect of soil conditioners on soil physical properties to the decomposition of these conditioners, which leads to the release of exchangeable calcium, consequently encouraging the aggregation formation. These results are in line with those obtained by Mansour *et al.* (2014) and Abbady (2022).

The data on the interaction between soil conditioners and tillage systems show that the studied physical soil properties were affected by the interaction between the two factors. The effect of soil conditioners on soil physical properties was more pronounced under deep tillage. In general, the best values of BD (1.12 Mg m^{-3}), TP (58.57%), HC (0.305 mm h^{-1}), and PR (3.09 MPa) were obtained under the application of 18 Mg ha^{-1} filter mud (FM1) under deep tillage. On the other hand, no soil conditioners treatment under shallow tillage exhibited the worst values of these physical properties (1.24, 54.15, 0.204, and 3.42, respectively in the abovementioned order).

Nutrients availability:

The data on the influence of the application of soil conditioners under two tillage systems on soil fertility in terms of N, P, and K availability after alfalfa harvest are presented in Table (7). The data on the main effect of the tillage system reveal that deep tillage increased soil available NPK than shallow ones. The relative increment in soil available N, P, and K after harvest of alfalfa due to subsoiling reached 47.79, 56.04, and 22.37% when compared with shallow tillage, respectively. Bennie and Botha, (1986) mentioned that the promotive effect of deep tillage on nutrient availability may be due to deep tillage improved microorganism activity, breaking the hard pan and increasing the infiltration rate of soil. These results are in line with those obtained by Memon *et al.,* (2013) and Taha and Abd Elhamed, (2021).

As for the main effect of soil conditioners, the data in Table (7) clearly reveal that N, P and K availability after alfalfa harvest were positively responded to soil conditioners application. Filter mud application at the level of 100 and 50 % GR produced the highest values of soil available N, P and K (70.2 and 65, 21.91 and 20.15, and 223 and 209 mg kg^{-1}, respectively). In general, filter mud and gypsum alternatives are the most effective soil conditioners than the others. In addition, it could be observed that the nutrient availability was increased as the level of conditioners increased. The beneficial effect of filter mud on nutrient availability may be attributed to filter mud containing a high content of organic matter which releases more nutrients during its decomposition. Whereas, the positive effect of natural gypsum or its alternative may be due to its effect on improving soil pH, microorganism activity, and plant growth Taha and Abd Elhamed, (2021). Similar results were obtained by Taha and Abd Elhamed, (2021) for filter mud and Rashid *et al.,* (2008) for gypsum and its alternative.

Concerning the effect of the interaction between the two factors, the data show that NPK availability after alfalfa harvest were affected by the interaction between tillage and soil conditioners. The applications of soil conditioners were more effective under deep tillage than shallow ones. In general, the highest values of soil available N, P and K (83.1, 26.72, and 248 mg kg^{-1}, respectively) were obtained for the treatment of filter mud (FM1) at a high rate under deep tillage. Whereas, the treatment of no soil conditioners under a shallow tillage system exhibited the lowest values of soil available N, P and K (26.9, 8.52 and 125 mg kg^{-1}, respectively)

Table 7. Effect of different amelioration techniques on soil fertility after harvest alfalfa:

Different amelioration technique		N	P	K
Tillage	**Soil conditioners**	**(mg Kg^{-1})**	**(mg Kg^{-1})**	**(mg Kg^{-1})**
Shallow tillage (15 cm)	Control	26.9	8.52	125
	G	43.5	12.81	172
	CD1	44.2	13.07	173
	CD2	42.7	12.61	160
	PG1	47.0	13.85	178
	PG2	44.2	13.07	163
	FM1	57.3	17.10	198
	FM2	53.1	15.73	190
	Mean	44.86	13.33	169.9
Subsoil tillage (50 cm)	Control	35.1	13.13	144
	G	65.8	20.02	215
	CD1	66.8	20.41	216
	CD2	64.8	19.70	193
	PG1	70.2	21.65	223
	PG2	66.8	20.41	196
	FM1	83.1	26.72	248
	FM2	77.8	24.57	228
	Mean	66.3	20.80	207.9
Mean of soil conditioners	Control	31.0	10.83	135
	G	54.6	16.42	194
	CD1	55.5	16.74	195
	CD2	53.7	16.16	177
	PG1	58.6	17.75	201
	PG2	55.5	16.74	180
	FM1	70.2	21.91	223
	FM2	65.4	20.15	209
LSD 0.05	A	6.37	2.15	12.45
	B	1.68	0.52	3.79
	AB	2.37	0.72	5.36

C = Control (without natural gypsum)
NG= Natural gypsum (100 G.R %, 15.50 Mg ha^{-1})
CD1= Cement dust (100 G.R %, 10.8 Mg ha^{-1})
CD2= Cement dust (50 G.R %, 5.4 Mg ha^{-1})
PG1= Phosphogypsum (100 G.R %, 13.2 Mg ha^{-1})
PG2= Phosphogypsum (50 G.R %, 6.6 Mg ha^{-1})
FM1= Filter mud (100 G.R %, 18 Mg ha^{-1})
FM2= Filter mud (50 G.R %, 9 Mg ha^{-1})

Yields:

Data in Table (8) represent the response of alfalfa yields in terms of total fresh and dry yields for six cuts to the tillage system and soil conditioners. The data show that deep tillage produced fresh and dry yields higher than shallow tillage by about 44.96 and 47.83%, respectively. The beneficial effect of subsoiling on alfalfa yields is mainly due to its effect on improving soil properties as mentioned before (Tables 5, 6 and 7). These results are in harmony with those obtained by Abdel-Mawgoud *et al.,* (2006) and Antar *et al.,* (2014).

As for the main effect of soil conditioners, the results show that the application of different soil conditioners resulted in a significant increment in total fresh and dry alfalfa yields than control. It is worthy to notice that the highest fresh and dry yields of alfalfa were obtained under 100 GR filter mud (86.5 and 19.9 Mg ha^{-1}) followed by 100 GR natural gypsum (80.0 and 18.4 Mg ha^{-1}), respectively. The superiority of such conditioners on alfalfa yields may be due to their beneficial effect on soil physical and chemical properties as well as soil fertility as discussed before, consequently improving plant growth. Similar results were obtained by Reda, (2007).

The data of the interaction show that alfalfa yields were significantly affected by the interaction between the two factors. In general, the treatment of filter mud at 100 GR under deep tillage produced the highest values of fresh and dry yields (103.1 and 23.7 Mg ha^{-1}, respectively). Whereas, the lowest fresh and dry yield was recorded under no soil conditioners with shallow tillage (48.1 and 10.1 Mg ha^{-1}, respectively). These results are in harmony with those obtained by El-Sanat *et al.,* (2012) and Aki, (2021).

Table 8. Effect of different amelioration techniques on fresh and dry yield after harvest Alfalfa (Mg ha^{-1}):

Different amelioration technique		Fresh	Dry
Tillage	**Soil conditioners**	**yield**	**yield**
Shallow tillage (15 cm)	Control	48.1	10.0
	G	64.8	14.9
	CD1	60.2	13.9
	CD2	55.7	12.8
	PG1	65.5	15.1
	PG2	58.3	13.4
	FM1	70.0	16.1
	FM2	61.0	14.0
	Mean	60.5	13.8
Subsoil tillage (50 cm)	Control	61.2	15.5
	G	95.2	21.9
	CD1	88.6	20.4
	CD2	81.7	18.8
	PG1	96.4	22.2
	PG2	86.0	19.7
	FM1	103.1	23.7
	FM2	89.8	20.6
	Mean	87.7	20.4
Mean of soil conditioners	Control	54.6	12.8
	G	80.0	18.4
	CD1	74.4	17.1
	CD2	68.7	15.8
	PG1	81.0	18.6
	PG2	72.1	16.6
	FM1	86.5	19.9
	FM2	75.4	17.3
LSD 0.05	A	5.0	1.5
	B	2.9	1.0
	AB	4.4	1.3

C = Control (without natural gypsum)
NG= Natural gypsum (100 G.R %, 15.50 Mg ha^{-1})
CD1= Cement dust (100 G.R %, 10.8 Mg ha^{-1})
CD2= Cement dust (50 G.R %, 5.4 Mg ha^{-1})
PG1= Phosphogypsum (100 G.R %, 13.2 Mg ha^{-1})
PG2= Phosphogypsum (50 G.R %, 6.6 Mg ha^{-1})
FM1= Filter mud (100 G.R %, 18 Mg ha^{-1})
FM2= Filter mud (50 G.R %, 9 Mg ha^{-1})

Constituents content:

The effects of some soil amelioration on constituent content, namely protein percentage as well as N, P and K uptake in alfalfa shoots are given in Table (9). As for the tillage system, the data show that deep tillage had a positive effect on these constituents when compared with shallow ones. The relative increments of these constituents due to subsoiler tillage reached to 8.2, 60.9 56.9, and 57.7% over shallow tillage, respectively. The promotive effect of deep tillage on protein percentage and N, P and K uptake is mainly due to its effect on soil pH and nutrient availability as discussed former. Also, the increase in shoots dry weight under deep tillage explains the superiority of deep tillage on nutrient uptake, since nutrient uptake is calculated by multiplying the nutrient percentage by dry weight. These results are in accordance with those obtained by Alam *et al*., (2014) and Taha *et al.,* (2021).

Concerning the main effect of soil conditioners, the data in Table (9) clearly show that nutrient uptake and protein percentage were significantly affected by the different soil conditioners. Filter mud (FM1) at a rate of 100 GR is the more conditioner-affected these constituents. Compared with the control added 18 Mg ha^{-1} filter mud (FM1) increased protein percentage, and N, P and K uptake in alfalfa shoots by about 35.1, 69.5, and 67.8 and 86.6%, respectively. The superiority of filter mud on constituent contents in alfalfa shoots may be attributed to its effect on increasing shoots dry weight of alfalfa as mentioned before. The results are in line with those obtained by Genedy *et al.,* (2018) and El-Sheref *et al.,* (2019).

Table 9. Effect of different amelioration techniques on protein percentage and N, P and K uptake after harvest Alfalfa:

Different amelioration technique		Crude	Top uptake (kg ha^{-1})		
Tillage	**Soil conditioners**	**protein %**	**N**	**P**	**K**
Shallow tillage (15 cm)	Control	14.6	281	27.4	276
	G	16.6	395	39.3	400
	CD1	17.1	379	36.0	388
	CD2	16.1	329	31.9	324
	PG1	18.7	450	40.7	438
	PG2	17.6	379	34.0	348
	FM1	19.2	495	45.2	507
	FM2	18.1	407	38.6	426
	Mean	17.2	389	36.4	388
Subsoil tillage (50 cm)	Control	15.0	479	41.9	426
	G	18.0	631	61.7	633
	CD1	18.6	607	56.2	614
	CD2	17.5	526	49.8	514
	PG1	20.3	719	63.6	693
	PG2	19.1	605	53.3	550
	FM1	20.9	793	70.7	802
	FM2	19.7	650	60.5	671
	Mean	18.6	626	57.1	612
Mean of soil conditioners	Control	14.8	380	34.5	351
	G	17.3	513	50.5	517
	CD1	17.8	493	46.0	501
	CD2	16.8	427	40.7	419
	PG1	19.5	585	52.1	565
	PG2	18.3	492	43.6	449
	FM1	20.0	644	57.9	655
	FM2	18.9	529	49.5	549
LSD 0.05	A	0.57	94.2	8.2	67.1
	B	0.32	16.0	1.4	13.8
	AB	0.02	22.7	2.0	19.5

C = Control (without soil conditioner)
NG= Natural gypsum (100 G.R %) (15.50 Mg ha^{-1})
CD1= Cement dust (100 G.R %) (4.50 Mg ha^{-1})
CD2= Cement dust (50 G.R %) (2.25 Mg ha^{-1})
PG1= Phosphogypsum (100 G.R %) (5.50 Mg ha^{-1})
PG2= Phosphogypsum (50 G.R %) (2.70 Mg ha^{-1})
FM1= Filter mud (100 G.R %) (7.50 Mg ha^{-1})
FM2= Filter mud (50 G.R %) (3.75 Mg ha^{-1})

With regard to the interaction effect, the data clearly show that protein percentage and N, P and K uptake in alfalfa shoots were significantly affected by the interaction between the tillage system and soil conditioners. In general, the alfalfa plants treated with 100 GR filter mud under a deep tillage system yielded the highest values of these constituents in their shoots (20.9 % and 793, 70.7, and 802 kg ha^{-1}, respectively). On the other hand, the treatment of no soil conditioners under shallow tillage produced the lowest one (14.6 % and 281, 27.4, and 276 kg ha^{-1}, in the abovementioned respect).

CONCLUSION

It could be recommended to use natural gypsum or its alternative as well as filter mud under subsoiling to improve physio-chemical soil properties, soil fertility, and quality and quantity of alfalfa plants. Using filter mud at a rate of 100% GR under a deep tillage system is considered the best treatment for reclaiming the salt-affected soil and increasing alfalfa production.

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تحسين الأراضي المتأثرة بالأملاح وإنتاجية البرسيم الحجازى بإستخدام بعض محسنات التربة و الحرث تحت التربة

علي جمال عبد التواب رجب[1]، محمد علي أحمد عبد السلام[2]، محمد رضا محمود احمد[1] و تغريد ابو النصر هاشم عبد الحميد[2]

[1]معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر

[2]قسم الاراضي والمياة – كلية الزراعة بمشتهر– جامعة بنها – بنها – مصر

الملخص

أقيمت تجربة حقلية في قرية كوم أبو خلاد/ مركز ناصر/ محافظة بنى سويف/ مصر فى موسم النمو 2022/2021 بهدف تقييم استخدام بعض محسنات التربة (بدون ، جبس طبيعى بمعدل 15.5 طن/ هكتار ، تراب الإسمنت بمعدلين 10.8، 5.4 طن/هكتار ، فوسفوجبس بمعدلين 13.2، 6.6 طن/هكتار، طين المرشحات بمعدلين 18، 9 طن/هكتار) وكذلك استخدام نوعين من الحرث (حرث سطحي وحرث تحت التربة) على صفات التربة ومحصول البرسيم الحجازى وكان التصميم المتبع في التجربة هو القطع المنشقة مره واحده بأربع مكررات وقد وضع نظام الحرث (عميق وسطحى) في القطع الرئيسية بينما وضعت محسنات فى القطع المنشقة. ويمكن تلخيص أهم النتائج المتحصل عليها كما يلي:- أدى الحرث تحت التربة وإضافه محسنات التربة الى تقليل كلا من : الكثافه الظاهرية ، درجة اختراق التربة ، درجة الحموضه ، درجة الملوحة ، النسبة المئوية للصوديوم المتبادل. أدى الحرث تحت التربة وإضافه محسنات التربة الى زيادة كلا من : المادة العضوية ، المسامية الكلية ، التوصيل الهيدروليكي ، خصوبة التربة . زادت إنتاجية البرسيم الحجازى (المحصول الطازج والجاف) وكذلك امتصاص عناصر النيتروجين والفوسفور والبوتاسيوم والبروتين بالحرث تحت التربة وإستخدام محسنات التربة. من نتائج التداخل فأن إضافه إضافة 18 طن/هكتار طين المرشحات مع الحرث العميق أدى الى أفضل النتائج من حيث تحسين خواص التربة المتأثرة بالأملاح وإنتاجية وجودة محصول البرسيم الحجازى. ويمكن التوصيه بإستخدام طين المرشحات بمعدل 18 طن/هكتار مع الحرث تحت التربة لأستصلاح وتحسين خواص التربة المتأثرة بالأملاح وإنتاجيتها.