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Role of Sesbania in Increasing Reclamation Efficiency of Chemically Amended Calcareous Soil

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Abstract:

This study was conducted to evaluate the effect of sesbania in increasing efficiency of reclamation of chemically amended salt affected soil. Phosphogypsum and elemental Sulfur were the two amendments used for reclamation of saline alkali soil at Al-Tuwaitha salinity research station 20km south east of Baghdad. Sesbania-barley crop rotation was implemented for two consecutive years. Sesbania (Sesbania aculeate L.), as a legume crop, was utilized as a source for organic carbon. It was harvested at the flowering stage. The harvested biomass was air-dried, chopped and thoroughly incorporated with the upper 40 cm of soils, and incubated for 8 weeks at moisture level equivalent to 1/3 bar suction. The plots were then cropped to barley (Hordium vulgare L.). Sesbania incorporation in soil was repeated for two consecutive seasons. Organic carbon was increased by 25.4% and 13.5% in soils amended with phosphogypsum and elemental sulfur respectively. Available nutrients N, P, and K, under phosphogypsum, were up to 639, 52.4 286 mg.kg^{-1} soil respectively. Yield of barley grain was increased by 47% and 29.47%

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over control for phosphogypsum and elemental sulfur respectively. Soil salinity, however, was reduced by 77.7%, 72.72% and 66.40% compared to the start of study for phosphogypsum, elemental sulfur and ground water respectively. Results of this study suggest that sesbania with Phosphogypsum is potentially good amendment to be considered in reclamation process of Iraqi saline soils.

Key words: Sesbania, Crop rotation, Amendments, Phosphogypsum, Sulfur

INTRODUCTION:

Large area (more than 70%) of lower Mesopotamian plain had been converted into saline alkali soils. Scarcity of fresh water, however, makes it rather difficult to apply conventional leaching practices of excess salts out of such soils [1]. Therefore, saline ground water was suggested to be used for reclamation and irrigation [2]. [3] Found that annual addition of gypsum to medium textured soil irrigated with saline ground water of 5.5 $dS.m^{-1}$ resulted in considerable improvement in soil characteristics and significantly increased the yield of cotton. It has been suggested that Sufficient calcium ions must be applied either to soil or to water itself to reduce the sodium adsorption ratio (SAR) in soil solution and maintaining good soil tillage [2, 4, 5, 6]. [7, 8] found that Increasing electrolytes concentration in irrigation or leaching water increase leaching efficiency of salts out of soil profile and improve soil conditions as well.

Reviewing the literature showed that phosphogypsum (PG) is a good direct source for Ca ions. Elemental sulfur (S), on the other hand, may be used as indirect source of Ca [2, 9]. It is well known that elemental sulfur is subjected to biological oxidation to SO_4 [10]. Sulfate ions react with water molecules to formulate H_2SO_4 which in return react with lime ($CaCO_3$) to

liberate Calcium ions to soil solution. Therefore, PG and S are often used for sustainable cropping of such kind of soils which are usually irrigated with saline ground water.

Use of chemical amendments like Phosphogypsum, Sulfuric acid and Elemental sulfur are common practice in Iraq for increasing efficiency of leaching of salt affected soils and/or alleviate sodium hazard to soil and crops. Saline ground water at present is used for cropping of salt affected soils in remote area where fresh water is not available [2]. Amount of Chemical amendment to be added is equivalent to amount of Sulfuric acid to be added per unit area as suggested by USSL Staff [11]. Salt-affected soils of lower Mesopotamian soils are mostly saline alkali soils of heavy to medium texture class. These soils are alluvial soils classified as Hyperthermic Torrifluvents.

The Biochemical amelioration is one of appropriate applications for cultivation and rehabilitation of soils under salt stress conditions by combining the use of chemical amendments and planting some of plants such as sesbania and alfalfa and incorporate of the green residues in the surface soil layer [12,13, 14, 15, 16]. [17] were found after three years of reclamation of alkaline soil using gypsum and planting of karnal grass to reduce the sodium adsorption ratio (SAR) and pH value and increased organic carbon by 64% and available nitrogen by 38% compared to control treatment as well as improved biological soil properties.[13] found that the addition of gypsum with levels at 50% and 75% and 100% of the gypsum requirements to saline sodic soil with incorporate sesbania residues led to improve of the physical and chemical soil properties and increase the uptake of nitrogen and phosphorus in the leaves and grains of rice and increase its yield.

It is very well known that organic carbon has considerable effect in improving soil structure consequently increasing movement of water and its content of soluble salts moving down the soil profile. Therefore, this study was

designed to evaluate the effect of combination of organic and inorganic amendments in soil reclamation process on chemical and physical properties of soil and to increase the efficiency of reclamation process.

MATERIALS AND METHODS:

Sesbania *(Sesbania aculeata L.)* – barley *(Hordeum vulgare L.)* crop rotation was implemented for two consecutive years at Al-Tuwaitha salinity research station, Baghdad, Iraq. Soil properties are given in table (1). Irrigation water is saline ground-water obtained from a well of 30 meter depth supplied with submersible pump. Experimental area was divided in a plots of 9 m^2 area each. Treatments were sulfur and phosphogypsum replicated 3 times in randomize complete block design. Required amount of PG and S is usually calculated on the base of amount of Ca^{+2} liberated from soil-$CaCO_3$ to reduce SAR in soil solution to less than 9 which is the appropriate level for reclaimed soils [1, 11]. Amount of PG or S was added to soil surface and thoroughly incorporated in the upper 30 cm of the soil. All plots were cropped to sesbania as a first crop and all irrigated with the above mentioned ground water to field capacity moisture level content (1/3 bar soil water tension) using tensiometer.

Sesbania was harvested at flowering stage. Dry matter weight was determined. Plant biomass was air-dried, grounded to pass 2.0 cm sieve then incorporated in soil. All plots received equal amount of grounded organic material. Applied sesbania dry matter was thoroughly mixed in the upper 30 cm of soil after receiving Nitrogen in 40 kg rate per hectare as urea. That is to increase rate of organic matter decomposition in soil.

Table1. Characteristics of the soil used in the study

Characteristic	Value
EC(1:1) $dS.m^{-1}$	*28.6*
pH (1:1)	*7.14*
Soluble ions ($mmol.L^{-1}$)	
Na	*152.70*
Ca	*20.30*
Mg	*36.40*
SAR	*20.30*
$CaCO_3$ ($gm.kg^{-1}$soil)	*316*
CEC ($Cmol_c.kg^{-1}$soil)	*23.3*
O.C %	*0.40*
O.M ($gm.kg^{-1}$soil)	*1.07*
Available nutrients ($mg.kg^{-1}$soil)	
N	*85.0*
P	*15.5*
K	*187*
Texture	Clay
Field capacity %	26

Soil samples (0-30cm depth) were collected from each plot. Samples were air dried, ground to pass 2.0 mm sieve and analyzed for total C and plant available N, P and K using the standard methods described by [18].

After the incorporation period all plots were cropped to barley. Phosphorus was added in 80 kg P/ha as TSP and N was added in 400 kg N/ha as urea. Plants were harvested, seeds and straw were determined.

RESULT AND DISCUSSION:

Characteristics of soil and water:

Table (1) shows the physical and chemical properties of the soil used in this study. Soil salinity as measured by 1:1 soil: solution ratio extract is 28.6 $dS.m^{-1}$, pH is <7.5 and SAR is 20.3. Accordingly, the soil is classified as a saline alkali soil according to US Soil Salinity Laboratory Staff [11].

Irrigation water is relatively of high salt content with EC 5.8, SAR is 12.6, and pH is 7.3. Therefore, the ground water

of the region used for irrigation is classified as saline water of class S_2 according to Soil Salinity Laboratory Staff classification of irrigation [11].

High sodium content in the soil and ground water coupled with heavy textured soil will lead to sever soil dispersion upon cropping [19]. Therefore, chemical amendments for such kind of soil are inevitable [20]. This may support the current investigation of application of PG or elemental sulfur as chemical amendments.

Effect of chemical amendments on nutrients content of sesbania:

Table (2) shows nutrients content of sesbania grown in the experiment. Lowest N content of plant was found under of zero amendments (control). However N content of sesbania increased by 48.6% and 28.6% over that of control for PG and S respectively. Results also showed that plant content of P, K, Ca, and Mg are in the following order: PG> S> GW. However, sesbania content of Sodium was the least under PG treatment which may be attributed to effect of Ca that released from PG to suppress Na uptake by plant. This result may clearly indicate that PG may be an efficient chemical amendment in such soil irrigated with saline ground water.

Table 2. Total elements (Kg/ha) absorbed by Sesbania *(Sesbania aculeate L.)* grown in saline soil

Treatments	N	P	K	Na	Ca	Mg
Gw	262.48	16.24	151.92	14.32	60.64	21.24
PG	390.00	30.32	314.16	8.44	97.45	33.56
S	337.48	19.45	212.43	10.46	80.24	21.00
(0.05)LSD	8.44	1.16	8.80	0.64	2.72	0.72

Effect of incorporation of sesbania dry matter in soil on yield of Barley:

Yield of barley grown in the experimental units received various treatments of PG, elemental S and grounded plant

material of sesbania is given in Table (3). Grain yield of barley for the two seasons was significantly increased compared with control treatment and the highest yield was in treatments received chemical amendments. In the second year Grain yield of barley under PG and S treatments was higher than the first year, which increased by 47.10% and 29.47% respectively, over that of control treatment. This clearly confirms the improvement of soil properties which in return increased crop yield [13].

Table 3. Grain yield of barley (Kg/ha) grown in amended saline soil received sesbania dry matter

Treatments	Yield of Barley First Year	(%)*	Yield of Barley Second Year	(%)*
Gw	*1208*	-	1452	-
PG	*1656*	37.08	2136	47.10
S	*1400*	15.89	1880	29.47

57.6 87.6(0.05) LSD

*: percentage of increasing in yield in compare to control (GW: ground water).

Effect of sesbania and chemical amendments on nutrients content of Barley:

Table (4) shows there are significant differences between nutrients content of barley leaves grown in chemically amended salt-affected soil. The content of N, P, K, Ca, and Mg and K/Na ratio were significantly increased compared with control treatment(GW), while Na content of barley leaves was decreased under PG and S amendments compared with (control). However K/Na ratio of barley leaves increased by 45.8% and 25.0% over that of control for PG and S respectively. Results also showed that leaves content of N, P, K, Ca, and Mg are in the following order: PG> S> GW. However, barley leaves content of Sodium was the least under PG treatment which may be attributed to effect of Ca that released from PG to suppress Na uptake by plant. These results show the important role of Sesbania, phosphogypsum and elemental sulfur to

improve soil fertility and the growth of barley in salt-affected soils irrigated with saline ground water.

Table 4. Total elements (Kg.ha^{-1}) absorbed by Barley leaves *(Hordeum vulgare L.)* grown in saline soil

Treatments	N	P	K	Na	Ca	Mg	K/Na
Gw	*5.48*	*0.31*	*14.96*	20.74	*0.82*	*1.57*	*0.72*
PG	*6.60*	*0.62*	*17.64*	*17.40*	*1.05*	*1.95*	*1.05*
S	*6.00*	*0.43*	*16.76*	*18.60*	*0.96*	*1.72*	*0.90*
LSD(0.05)	*0.19*	0.05	0.25	0.51	0.18	*0.14*	0.*05*

Effect of chemical amendments and sesbania on soil characteristics:

Result of analysis of PG and S amended soil at the end of second year of sesbania -barley rotation are given in Table (5). Obviously, soil salinity is reduced by 77.7%, 72.72% and 66.40% compared to the start of study (table 1.) for phosphogypsum, elemental sulfur and ground water respectively. SAR under PG and S is reduced to level that low enough for soil to support good barley crop. Organic carbon was increased by 25.4% and 13.5% in soils amended with phosphogypsum and elemental sulfur respectively, and available nutrients(N, P, K) content of the soil was the highest under PG treatment were up to 639, 52.4 286 mg.kg^{-1} soil respectively, and the lowest under GW treatment. That is probably attributed to release of organic carbon and root exudates [21, 22, 23, 24].

In summary results of this study suggest that PG is potentially good amendment to be considered in reclamation process of saline alkali soils of Iraq. Result also showed that crop rotation is appropriate management practices to increase efficiency of reclamation process as indicated by physical and chemical status of the soil as well as the grain yield of barley. Furthermore, incorporation of grounded sesbania dry matter in soil markedly enhanced the reclamation process as indicated by the yield of barley and improvement of soil properties.

Table 5. Characteristics of chemically amended soil after the second year of sesbania- barley rotation

Treatments	EC(1:1) $dS.m^{-1}$	pH	SAR	O.C %	OM $g.kg^{-1}$soil	Available nutrients $mg.kg^{-1}$soil		
						N	P	K
GW	9.6	7.15	12.10	0.59	14.2	215	30.6	450
PG	6.4	7.10	8.85	0.74	16.8	286	52.4	639
S	7.8	7.14	10.12	0.67	15.5	241	41.8	526

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