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Short-term Effects of N-fixing Legumes on Some Properties of Calcareous Salt-affected Soils

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Abstract: Cultivation of legumes in calcareous salt-affected soils may decrease soil sodicity. A field experiment was conducted in Soba Research Station, 15 km south of Khartoum, to determine the potential of three N fixing legumes: guar (*Cyamopsis tetragonolobus*), hyacinth bean (*Dolichos lablab L.*) and cowpea (*Vigna unguiculata* L) in amelioration of sodic soils. The treatments consist of control (without plant and gypsum), gypsum, cowpea; guar and hyacinth bean relying on either inorganic nitrogen or N fixation. Treatments were arranged in a Randomized Complete Block Design with four replications. Soil samples (0-25 and 25-

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50 cm depths) were taken before and after harvest and analyzed for pH, electrical conductivity (ECe), soluble cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), soluble HCO_3^- and sodium adsorption ratio (SAR). Results of the first season indicated that pH and ECe were not significantly different among treatments whereas; Ca^{2+}, Na^{+} and SAR were significantly ($P \leq 0.001$) different among treatments. Total dry matter of hyacinth bean relying on N- fixation was higher than the hyacinth bean relying on inorganic N by 49.4%. In the second season, total dry matter of guar relying on N-fixation was 36% higher than that relying on inorganic N whereas hyacinth bean relying on N-fixation has increased soil soluble HCO_3^{-1} and decreased SAR. It may be concluded that cultivation of N-fixing plants in calcareous salt-affected soils could be a promising alternative to chemical amendments which may be expensive for small farmers.

Keywords: Amelioration, phytoremediation, sodic soils, solubilization

INTRODUCTION

The worldwide occurrence of sodic and saline-sodic soils reaching 560 million hectares emphasizes the need for efficient, inexpensive and environmentally acceptable management. Soil salinization therefore, threatening is the agricultural production needed to feed the ever increasing world population and is considered the top most stress limiting dryland farming systems (Landon, 2014).

Aydemir and Sünger (2011) estimated global potential of 10 to 16% increase in salinity per year. In Sudan, large areas (mainly in semi-desert, arid and semi-arid regions) were classified as saline and /or sodic soils with low N content (0.01 to 0.02%). Low fertility and poor physical conditions are the main constrains for crop production in saline-sodic and sodic soils (Sumner, 1993; Qadir and Schubert, 2002). Such problematic soils occupy important agricultural lands around the urban centers and thus can be used for the production of high value crops (Nachtergaele, 1976). In Sudan, proximity of these soils to good quality water from the River Nile prompted horizontal expansion on such marginal lands (Mustafa, 1984; Mubarak *et al*. 1992; Abdelmagid *et al*., 1996). Improved cropping systems under salt-affected soils is a function of optimum management of irrigation and drainage systems, soil amendments, conditioners, and residue management (Cuevas *et al*., 2019).

Previous studies on amelioration of salt-affected soils were concentrated on the use of gypsum or organic amendments (Tejada *et al*., 2006; Liang *et al*., 2005; Leogrande and Vitti, 2018; Zaka *et al*., 2018) biochars (Sadegh-Zadeh *et al*., 2018). However, trials on phytoremediation through solubization of native $CaCO_3$ through H proton release from N fixing legumes is limited (Mubarak *et al*., 2010). Phytoremediation or vegetative bioremediation is considered as cost-effective alternative for cultivation of salt-affected soils (Jesus *et al*., 2015). Elsheikh (1998) reported that some legumes proved to be tolerant to salinity when inoculated with some rhizobia. However, the potential of using N-fixing plants for reclamation of calcareous saline-sodic soils rely on both salt tolerance and effective establishment of symbiotic relationships (Abiala *et al*., 2018). Therefore, planting legumes capable of fixing N in saline soils proved to be an alternative management practice for reclamation of sodic soils with high calcium content through dissolution of Ca^{++} found in the non-soluble calcium carbonate concretions Qadir *et al.* (2003a, 2003b) reported that Na leaching from calcareous salt affected soils was equivalent to that of gypsum. Similarly, Gharaibeh *et al*. (2011) found a reduction of 47, 64 and 58% in ESP with *Atriplex halimus*, combining Atriplex and gypsum and gypsum, respectively. However, higher reductions of 83.4 and 86.8% in Na^+ content and SAR were recorded through phytoremediation using *Phragmites australis* combined with gypsum (Abro *et al*., 2017). Because of high K^+/Na^+ ratio in shoot, low Na^+ translocation from roots to shoot and elevated levels of soluble HCO_3^- in the soil solution, planting N-fixing honey mesquite (*Prosopis grandulosa*) in calcareous sodic soils was effective in managing saline-sodic soils (Mubarak *et al*., 2017). Most soils around the capital Khartoum are saline or saline – sodic with high content of insoluble calcium carbonates and mainly cropped with fodder sorghum. The aim of this study was to determine the potential of different N-fixing legumes: guar (*Cyamopsis tetragonolobus*), hyacinth bean (*Dolichos lab lab* L.) and cowpea (*Vigna unguiculata* L) for amelioration of sodic soils through dissolution of native $CaCO_3$.

MATERIALS AND METHODS

Study site

A field experiment was conducted in Soba Research Station, Agricultural Research Corporation, 15 km south of Khartoum, Sudan (latitudes 15°24′ and 15° 30′ N and longitudes 32° 32′ and 32° 28′ E).The Research Station is solely devoted for studies in salt affected soils since its establishment in 1973.The soil was classified as fine semctitic, hyperthermic, sodic, haplocambid (Soil Survey Staff, 1996). Some of the physical and chemical properties of the top 0-25 and 25-50 cm depths are presented in Table 1.

Table 1. Some physical and chemical properties of the experimental site

Soil property	Depth (cm)	
	0-25	25-50
$pH_{(paste)}$	7.5±0.1	7.6±0.1
ECe (d Sm^{-1})	5.85±0.7	6.30±0.9
K^+ (meq L^{-1})	0.22±0.02	0.18±0.01
$CaCo_3$ (g kg^{-1})	64.3±1.6	68.9±0.7
Na^+ (meq L^{-1})	39.2±11.7	56.6±4.2
Ca^{++} (meq L^{-1}**)**	23±4.82	21.50±4.5
Mg^{++} (meq L^{-1})	3.0±0.5	3.83±1.0
SAR	10.9	16.1
Sand (g kg^{-1})	394	346
Silt (g kg^{-1})	119	127
Clay (g kg^{-1})	487	527
Texture	Clay	Clay

SAR: Sodium Adsorption Ratio

Experimental

Before planting, the land was prepared by disc ploughing (30 cm), followed by disc harrowing to break clods and leveling. Thereafter, the land was divided into 32 plots (4 m X 4 m) and ridges were constructed manually at a space of 80 cm.

The treatments of the experiment were as follows:
Control (No fertilizer, no plant, and no gypsum) and designated as T_0

Gypsum (according to gypsum requirement; no plant; gypsum effects only) and designated as T_1
Guar (relying solely on N fixation) and designated as T_2
Guar (relying solely on inorganic N) and designated as T_3
Cow pea (relying solely on N fixation) and designated as T_4
Cow pea (relying solely on inorganic N) and designated as T_5
Hyacinth bean (relying solely on N fixation) and designated asT_6
Hyacinth bean (relying solely on inorganic N) and designated asT_7

One day before sowing the first (03/11/2014) and second seasons (01/07/2015), gypsum (calculated as gypsum requirement according to Oster and Frenkel (1980) was applied at the rate of 5 ton ha^{-1} in the form of $CaSO_4.2H_2O$, it was manually incorporated in the top 0-30 cm depth of the specified treatment. Treatments relying on N fixation, received 10 kg N ha^{-1} in the form of urea applied at sowing as a starter N dose (Afza *et al.*, 1987) whereas, plants relying solely on inorganic N, received 86 kg N ha^{-1} in the form of urea. Seeds of legumes (relying solely on N fixation) were inoculated with rhizobium obtained from the National Center for Research, Sudan. For cowpea and hyacinth bean, the TAL 20 strain was used and 16A strain was used for guar.

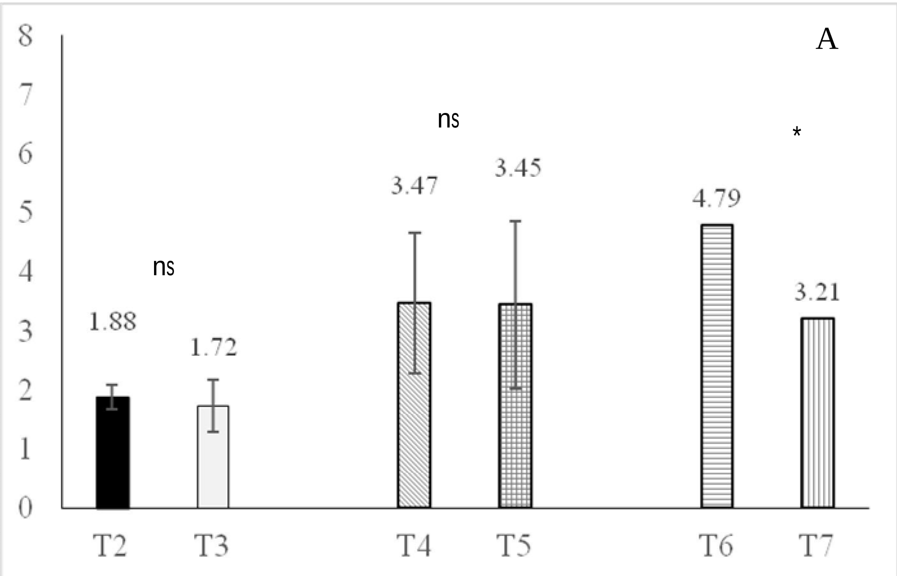
Guar seeds were sown on ridges at spacing of 30 cm between holes at the rate of 14.5 kg ha^{-1}a. Cow pea and hyacinth seeds were sown on ridges at spacing of 25 cm between holes at the rate of 40 and 48 kg ha^{-1}, respectively. Plots were arranged in a Randomized Complete Block Design (RCBD) with 4 replications (total of 32 plots). All plots were immediately irrigated from Blue Nile water (0.25 dS m^{-1}) using small canals at the rate of 420 m^3per 4200 m^2 (i.e 10 cm water head). Throughout the growing season, irrigation water was applied every 14 days (total of 7 Irrigations during the growing season). Maximum and minimum temperatures and humidity during the growing season were 41^{o}C, 16^{o}C and 60%, 8%, respectively.

At harvest of the 1st and 2nd seasons (12/02/2015 and 01/10/2015, respectively), plants in each plot were removed with sharp sickles at about 5 cm above the soil surface, air-dried in the field (for 7 days) where the temperature ranged from 16 to 40^{o}C and weighed (recorded as t dry matter ha^{-1}). Similarly, undisturbed soil samples were taken from each plot and from the 0-25 cm depth by insertion of 25 cm poly vinyl chloride (PVC) tubes of 4 inches diameter and also from the 25-50 cm depth using 5 cm diameter auger (64 samples). All samples were air-dried, crushed to pass 2.00 mm sieve and analyzed for $pH_{(paste)}$ according to Mclean (1982), electrical conductivity (Richard, 1954), soluble Na^{+}, K^{+}, Ca^{++} and Mg^{++} (Chapman and Pratt, 1961) and and HCO_3^- (Bower and Wilcox, 1965). Sodium adsorption ratio (SAR) was calculated according to Miller (1990). The SAS (1999) software was used to determine significant differences between means of treatments.

RESULTS

Dry matter yield

In both seasons, with the exception of cowpea, dry matter of hyacinth bean and guar relying on N fixation was significantly higher than of plants relying solely on inorganic N by 50 and 36%, respectively (Figures 1 A and B).



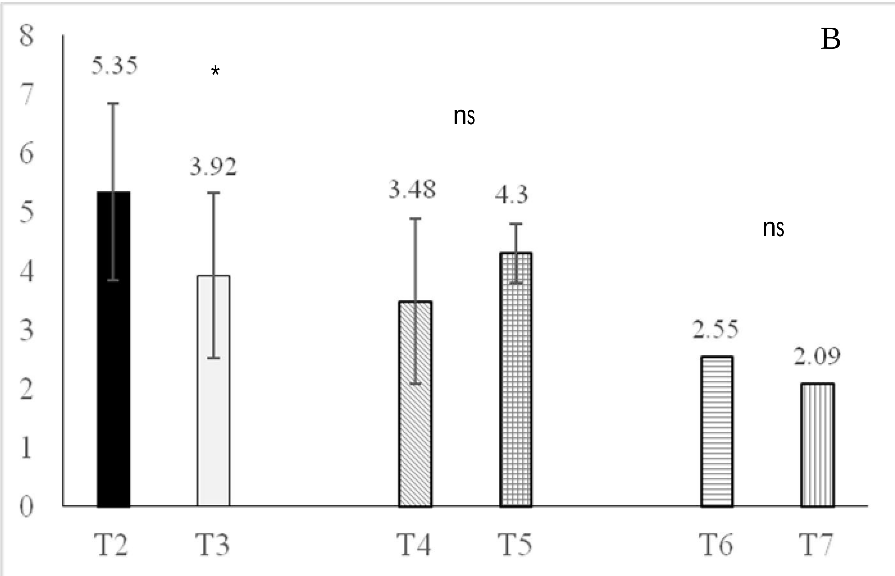


Figure 1. Dry matter yield (t ha^{-1}) of legumes in the 1st (A) and 2nd seasons (B)

T1; Gypsum: T2; Guar (relying solely on N fixation); T3: Guar (relying solely on inorganic N); T4: Cow pea (relying solely on N fixation); T5: Cow pea (relying solely on inorganic N); T6: Hyacinth bean (relying solely on N fixation) and T7: Hyacinth bean (relying solely on inorganic N).

Soil chemical properties

First season

The effect of treatments on soil properties after harvest of the 1st season is presented in Table 2. At both depths, there were no significant changes in pH and EC. The lowest content of Ca^{++} was recorded in plots sown with guar relying solely on inorganic N whereas hyacinth bean and cowpea relying on inorganic N recorded the highest Ca^{++} content. Most legumes have almost similar Ca^{++} content to that found in gypsum plots. The content of Mg^{++} in the lower depth was higher in plots with guar and hyacinth bean relying on inorganic N. In the top 0-25 cm depth, all plots cultivated with legumes recorded significantly lower Na content than the control and plot treated with gypsum. Among plants relying on N-fixation, only plots sown with guar showed the highest Na^{+} content. In the lower depth, plots sown with cow pea relying on N-fixation also showed almost similar content to gypsum added plots. Although, plots sown with guar relying on N-fixation showed similar K^+ content to gypsum plots, none of the remaining legumes increased K^+ content. Planting hyacinth bean relying on either N-fixation or inorganic N produced similar content of soluble HCO^{-3} to gypsum treated plots whereas plots with other legume plots contained 21.0-32.4% less HCO^{-3} than the gypsum treatment. In the top 0-25 cm depth, adding gypsum was found to decrease SAR from control plots by 29% whereas corresponding decrease due to planting legumes was found to range from 32 to 62%. The decrease in SAR in plots with legumes relying on inorganic N and N-fixation ranged from 32-48 and 37-62%, respectively. However, in the lower depth (25-50 cm), SAR in plots with gypsum and hyacinth bean relying on N-fixation was 90 and 49% that determined in control plots, respectively.

SAR: Sodium adsorption ratio, P: probability of the test
Values in columns within each depth followed by similar letter (s) are not significantly different at $P \leq 0.01$ or 0.05 using Least Significant Difference (LSD)
T0: control (No fertilizer, no plant, and no gypsum); T1; Gypsum: T2; Guar (relying solely on N fixation); T3: Guar (relying solely on inorganic N); T4: Cow pea (relying solely on N fixation); T5: Cow pea (relying solely on inorganic N); T6: Hyacinth bean (relying solely on N fixation) and T7: Hyacinth bean (relying solely on inorganic N).
NS: not significant

Second season

The effects of treatments on soil properties of the 0-25 and 25-50 cm depths were shown in Table 3. In the top 0-25 cm depth, plots with cowpea and hyacinth bean relying on inorganic N recorded 0.1-0.2 units increase in pH over gypsum pots. In the topsoil, with the exception of cowpea relying on inorganic N, treatments with legumes relying on N-fixation and inorganic N had 30-38 and 38-65% lower EC than gypsum treatment, respectively.

Table 2. Soil chemical properties of the 0-25 and 25-50 cm depths after harvest of the 1st season (average ± standard deviation, n=4)

0	pH	EC	Ca	Mg	Na	K	HCO_3^-	SAR
					meq L^{-1}			
				0-250cm				
T0	7.5±0.2	2.39±0.9	16.63±8.20a	3.00±2.55 a	43.5±2.5 a	0.21±0.02 b	7.0±0.7 b	15.6±9.7 a
T1	7.3±0.1	3.36±0.8	16.85±2.78 a	4.15±2.28 a	36.8±3.2b	0.33±0.14 a	7.9±0.8ab	11.1±0.9 b
T2	7.4±0.1	2.22±1.5	17.25±5.63 a	3.25±0.65 a	29.7±1.3c	0.25±0.04 a	9.9±2.9ab	9.8±5.3bc
T3	7.6±0.4	2.11±0.9	11.13±5.11b	2.13±1.11 a	17.5±1.2d	0.22±0.04 b	8.9±1.8ab	8.1±0.6 c
T4	7.8±0.4	2.51±0.4	16.38±7.60 a	2.88±1.49 a	12.6±5.4e	0.19±0.04 b	11.6±5.3 a	5.9±0.3d
T5	7.7±0.2	1.00±0.7	18.80±0.48a	2.25±1.32 a	23.5±3.1d	0.16±0.05 b	8.9±3.8ab	8.3±0.8c
T6	7.6±0.5	2.76±1.8	13.75±5.68b	2.75±2.22 a	13.9±8.6e	0.20±0.07 b	8.4±3.1ab	6.7±0.7 d
T7	7.9±0.5	2.26±1.4	18.38±8.19 a	2.13±1.38 a	20.0±1.8d	0.17±0.07 b	10.9±2.9ab	10.6±0.3b
P≤	ns	ns	**	ns	**	**	ns	**
				25-50 cm				
T0	7.8±0.5	3.20±2.4	11.13±8.08 b	4.38±2.29 b	37.7±2.0a	0.17±0.04 a	5.0±1.4 c	15.2±4.9a
T1	7.5±0.2	3.45±1.4	18.50±5.12 a	2.25±0.96 c	39.5±2.8a	0.26±0.24 a	10.8±3.1 a	13.7±0.9b
T2	7.5±0.1	3.67±2.1	14.50±7.33ab	2.25±1.50 c	39.7±3.7a	0.18±0.09 a	7.6±1.3 b	13.3±0.9b
T3	7.6±0.1	2.48±1.3	10.50±5.24bc	4.25±0.50 b	35.8±2.0b	0.10±0.09 a	8.5±3.0 b	14.4±0.9ab
T4	7.6±0.2	1.61±1.6	03.63±1.18 c	6.00±1.29 a	33.9±4.9b	0.19±0.07 a	7.3±1.1bc	15.5±2.1a
T5	8.2±0.3	2.97±1.1	16.38±1.25ab	6.50±1.29 a	24.2±1.6 d	0.18±0.04 a	8.5±2.3b	9.5±3.6 d
T6	7.8±0.6	3.19±0.6	17.25±4.57ab	2.75±0.29c	17.3±7.4e	0.19±0.04 a	9.8±1.5ab	7.5±2.8e
T7	7.6±0.6	4.59±1.8	20.00±1.47 a	5.50±2.04 a	31.6±2.6c	0.20±0.02 a	12.1±3.8 a	11.2±0.8 c
P≤	ns	ns	**	**	**	ns	*	**

SAR: Sodium adsorption ratio, P: probability of the test

Values in columns within each depth followed by similar letter (s) are not significantly different at P ≤ 0.01 or 0.05 using Least Significant Difference (LSD)

T0: control (No fertilizer, no plant, and no gypsum); T1; Gypsum: T2; Guar (relying solely on N fixation); T3: Guar (relying solely on inorganic N); T4: Cow pea (relying solely on N fixation); T5: Cow pea (relying solely on inorganic N); T6: Hyacinth bean (relying solely on N fixation) and T7: Hyacinth bean (relying solely on inorganic N).

NS: not significant

However, in the lower depth, from legumes relying on N-fixation, guar and hyacinth bean had reduction in EC almost similar to that resulting from gypsum application. Soluble Ca^{++} in the topsoil showed generally high content whereas in the lower depth, the content was lower and erratic but generally similar or lower than that found in gypsum treatment. In the 25-50 cm depth, application of gypsum has resulted in 47% reduction of soluble Mg^{++} from no gypsum plots whereas 33-77% (average of 51%) reduction was found on plots planted with legumes. In the upper soil depth, the content of soluble Na^{++} in treatments with gypsum, guar and hyacinth bean were similar. In the sub-soil, apart from control and hyacinth bean relying on inorganic N plots where Na^{++} was high, growing other legumes led to similar soluble Na^{++} almost similar to that of gypsum treatment. In both depths, soluble HCO_3^- under gypsum and most legume treatments was higher than control plots by 70-78 and 15-90% (average of 55%), respectively. Despite the low SAR values in all treatments, plots planted with cowpea and hyacinth beans relying on N-fixation recorded the lowest SAR values.

Table 3. Soil chemical properties of the 0-25 and 25-50 cm depths after harvest of the 2nd season (average ± standard deviation, n=4)

Treatment	pH	EC	Ca meq L-1	Mg	Na	K	HCO3-	SAR
0-250cm								
T0	7.4±0.01c	2.95±0.24b	16.33±0.85ab	8.40±1.42b	11.76±1.45c	Nd	2.90±0.7b	3.36±0.49cd
T1	7.4±0.05cd	3.16±0.24b	16.67±1.43ab	7.00±1.08bc	19.79±2.47a	Nd	5.17±024a	5.79±0.89ab
T2	7.3±0.05d	2.14±0.19c	12.33±2.49bc	6.00±0.88c	14.20±4.96bc	Nd	5.00±0.47a	4.71±1.51bc
T3	7.4±0.05c	1.11±0.62d	03.17±0.62d	1.83±0.24d	7.80±0.71d	Nd	2.33±0.24b	4.96±0.29bc
T4	7.3±0.07cd	2.21±0.11c	17.05±3.22a	6.12±2.69c	6.96±0.72d	Nd	2.33±0.24b	2.08±0.35de
T5	7.6±0.08a	3.71±0.23a	19.41±1.54a	2.92±0.86d	17.45±3.88ab	Nd	5.50±0.82a	5.26±1.28b
T6	7.3±0.01cd	2.83±0.45b	17.67±1.03a	12.00±0.41a	6.71±0.96d	Nd	3.33±0.24b	1.74±0.24e
T7	7.5±0.17b	1.96±0.63c	10.58±7.90c	3.58±0.42d	16.40±0.99ab	Nd	2.83±0.47b	6.91±1.89a
P≤	**	**	**	ns	**		**	**
25-50 cm								
T0	7.7±0.16	4.29±0.23a	18.95±1.67a	3.55±0.61a	23.76±4.73a	Nd	3.00±0.24c	7.17±1.69b
T1	7.9±0.30	1.80±0.19cd	09.79±0.86bc	1.88±0.91bc	9.96±3.07cb	Nd	5.10±1.27a	4.82±1.23bc
T2	7.4±0.19	2.40±0.08bc	8.26±0.26bc	1.74±0.80bc	14.41±5.20b	Nd	3.17±0.47c	6.73±047bc
T3	7.9±0.30	0.83±0.21d	3.00±0.41c	0.83±0.24c	5.42±2.42c	Nd	3.50±0.00c	3.95±1.70c
T4	7.6±0.23	3.55±0.89ab	13.28±3.92ab	2.05±0.50b	15.82±1.25b	Nd	5.00±0.71a	5.88±0.94bc
T5	7.7±0.28	2.69±0.51bc	10.82±0.87b	1.85±0.61bc	13.45±6.96b	Nd	5.00±1.31a	5.27±1.19bc
T6	7.7±0.07	1.76±0.68cd	6.85±2.91bc	1.65±0.91bc	11.63±3.44cb	Nd	4.33±0.62b	5.73±0.58bc
T7	7.6±0.15	4.28±0.29a	12.47±2.00ab	2.37±0.46b	27.79±7.38a	Nd	5.50±0.71a	10.51±3.67a
P≤	ns	**	**	**	**		*	**

SAR: Sodium adsorption ratio, P: probability of the test

Values in columns within each depth followed by similar letter (s) are not significantly different at P ≤ 0.01 or 0.05 using Least Significant Difference (LSD)
T0: control (No fertilizer, no plant, and no gypsum); T1; Gypsum: T2; Guar (relying solely on N fixation); T3: Guar (relying solely on inorganic N); T4: Cow pea (relying solely on N fixation); T5: Cow pea (relying solely on inorganic N); T6: Hyacinth bean (relying solely on N fixation) and T7: Hyacinth bean (relying solely on inorganic N), Nd: not determined.

DISCUSSION

In this study, the decrease in salt content with cultivation of legumes indicates their positive effect in amelioration of salt-affected soils. Extensive rooting system of alfalfa was found by Cao *et al*. (2012) to decrease soil EC in the 0-20 cm layer compared to non-cropped treatment and with marked ascending decreasing in salt content with years of cultivation. However, the latter authors also found significant increase in pH only during the first two years of cultivation. Growing plants under environmental stress such as salinity may accelerates respiration and raise levels of HCO_3^- which may react with H^+ pumped in the rooting zone of the alkaline soil medium to induce increase in pH (Lambers *et al*., 1998; Tabatbai and Donald, 2005). The increase of Ca^{++} levels accompanied by decrease of Na^+ under plants relying on nitrogen can be explained by the positive effects of legume plants on dissolution of $CaCO_3$ through acidify their rhizosphere (Mengel and Steffens 1982; Schubert and Yan 1997) that was associated with H-proton released during N-fixation process with increasing CO_2 pressure in the root zone. This result is in line with Mubarak and Nortciff (2010). The accumulation of Ca^{++} under gypsum treatment might indicates high amount of Ca^{++} released from gypsum (Qadir *et al*., 2003a). Qadir *et al*. (2003) reported that enhanced dissolution of native calcite within the root zone to provide adequate Ca^{++} for the Na^+ exchange at the cation exchange sites. The plantation on calcareous sodic soils assists in enhancing dissolution rate of calcite ($CaCO_3$) through plant soil interaction resulting in increased levels of Ca^{++} in soil solution, increase in partial pressure of CO_2 due to root and microbial respiration and release of H^+ from plant roots to increase the soluble Ca^{++} and decrease the soluble Na^+ (Qadir *et al*., 2002; 2007). Decrease in sodicity measured as concentration of soluble Na was previously reported by Singh *et al*. (2013). The later authors showed significant decrease in ESP when *Jatropha curcas* was planted in sodic soils. Positive general increase in HCO_3^-content in plots with legumes reported here is in line with Cao *et al.* (2012) who reported that the HCO_3^- concentration was significantly high under alfalfa, especially in the sub-soil. These observations may be explained in two ways: first, the presence of CO_2 that favors the dissolution of calcite by forming Ca $(HCO_3)_2$and second, under calcareous salt-affected soils, H^+ released by N_2-fixing legumes may react with the calcite and releases HCO_3^-. This finding is earlier supported using leguminous plants such as mesquite (*Prospois glandulosa*) and different beans (Mubarak *et al*., 2017; Mubarak and Nortcliff, 2010). The latter authors attributed the extra content to the solubilization of calcite by H^{+} ions released during N fixation. The present study reported a decrease in SAR values in plots planted with legumes which might be attributed to release in Ca^{++}ions from calcite with possible Na^{+} replacement. These are in line with Qadir *et al*. (2002) who recorded that the chemical treatment and phytoremediation had decreased soil sodicity. Likewise, Mishra and Sharma (2011) stated that the SAR declined in the soil profile under *Prosopis juliflora*, *Dalbergia sissoo*, and Eucalyptus.

In conclusion, planting legumes in calcareous salt-affected soils could be promising alternative to chemical amendments which may be cost-prohibitive for small farmers in dryland regions.

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REFERENCES

Abdelmagid. H. M, Mubarak. A. R, Eltilib. A.M.A., and Ali. A. M. 1996. Poultry manure as an ameliorative fertilizer for salinized soils sown to snap beans in a semi-arid environment. Egyptian Journal of Applied Science 11 (9): 199-210.

Abiala, M. A., Abdelrahman M., Burritt D. J., and Tran Lam-Son P. 2018. Salt stress tolerance mechanisms and potential applications of legumes for sustainable reclamation of salt degraded soils. Land Degradation and Development. 29: 3812-3822.

Abro, A. A. O., Farooque, A. B., Oan, M. S., Abdul R., and Amanullah, M.. 2017. Desodification from calcareous saline sodic soil through phytoremediation with *Phragmites australis* (Cav.) Trin. Ex Steud. and gypsum. International Journal of Phytoremediation 19(12): 1142-1149.

Aydemir, S., and Sünger, H. 2011. Bioreclamation effect and growth of a leguminous forage plant (*Lotus corniculatus*) in calcareous saline-sodic soil. African Journal of Biotechnology 10 (69): 15571-15577.

Bower, C.A., and Wilcox, L.V. 1965. Soluble salts. In: *Methods of Soil Analysis*, C.A. Black, (ed.), American Society of Agronomy, Madison, WI. p. 933-951.

Cao, J., Li X., Kong X., Zed R., and Dong L. 2012. Using alfalfa (Medicago sativa) to ameliorate salt-affected soils in Yingda irrigation district in Northwest China. Acta Ecologica Sincia 32: 68-73.

Chapman, H.D., and Pratt, P.F. 1982. *Methods of analysis for soils, plants and water*. Methods of soil analysis Part 1: Physical and mineralogical methods, 2nd ed. Agronomy series No: 9. Madison (WI): Am. Soc. of Agronomy and Soil Sci of Am. Inc. Publisher; p. 363–381.

Cuevas, J. I. N., Daliakopoulos, F. del Moral, J. J. Hueso, and I. K. Tsanis. 2019. A Review of Soil-Improving Cropping Systems for Soil Salinization. Agronomy 9: 295-302.

Elsheikh, S. A. E. 1998. Response of legume –Rhizobium symbiosis to salinity in the Sudan: a Review. University of Khartoum Journal of Agric. Science 6 (2): 142-156.

Gharaibeh, M.A., Eltaif, N. I., and Albalasmeh, A. A. 2011. Reclamation of highly calcareous saline – sodic soil using *Atriplex halimus* and by-product gypsum. International Journal of Phytoremediation 13: 873-883.

Jesus, J.M., Danko A.S., Fiúza A., and Borges M.T. 2015. Phytoremediation of salt-affected soils: a review of processes, applicability, and the impact of climate change. Environmental Soil Pollution Research 22: 6511-6525.

Lambers, H., Chapin III F.S., and Pons T.L. 1998. *Plant Physiological Ecology*, Springer-Verlag, New York, 1998.

Landon J.R. 2014. *Tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics.* New York/ London: Routledge, Taylor and Francis Group.

Leogrande, R., and Carolina, Vitti. 2018. Use of organic amendments to reclaim saline and sodic soils: a review. Arid Land Research and Management 31: 1-21.

Liang, Y., Nikolic, M., Peng, Y. Chen, W., and Jiang, Y. 2005. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. Soil Biology and Biochemistry 37: 1185-1195.

Mclean, E.O. 1982. Soil pH and lime requirement In: *Methods of soil analysis*, A. L. Page, R. H. Miller, and D. R. Keeney, (eds.),: Part 2. Chemical and microbiological properties, 2nd ed. American Society of Agronomy and Soil Science Society of America, Madison, WI. pp. 199 – 223.

Mengel, K., and Steffens, D. 1982. Relationship between the cation/anion uptake and the release of protons by roots of red clover. Journal of Plant Nutrition and Soil Science 145: 229-236.

Miller, RW. 1990. *Soils* (6^{th}ed.). *Salt-affected soils and their reclamation.* 308-319. Prentice Hall International Editions, USA.

Mishra, A., Sharma, S. D., and Pandey, R. 2004. Amelioration of Degraded Sodic Soil by Afforestation. Arid Land Research and Management 181: 13 - 23.

Mubarak, A., Takeshi, T., Abdelkarim. H., Tsuneyoshi, E., and Norikazu, Y. 2017. Phytoremediation of calcareous salinesodic soils with mesquite (*Prosopis glandulosa*). Acta Agriculturae Scandinavica, Section B — Soil and Plant Science 67: 352-361.

Mubarak, A. R., and Nortcliff, S. 2010. Calcium Carbonate Solubilization through H-Proton Release from some Legumes Grown in Calcareous Saline-Sodic Soil. Land Degradation and Development 21 (1): 29-39.

Mubarak, A. R., Eltilib A. M. A., and Ali A. M. A. 1992. Effect of chicken manure and salinity on growth and leaf N, P and K content of okra (*Abelomoschus esculentus*) grown on two soil types. University of Khartoum Journal of Agricultural Science 2: 15-19.

Mustafa, M.A. 1984. Quality of bore hole waters and their influence on some irrigated soil characteristics in Khartoum province. Sudan Journal of Agriculture 10: 73-82.

Nachtergaele, F.O.F. 1976. Studies on saline and sodic soils in Sudan. Soil Survey Administration, SUD/71/553.*Technical Bulletin No*. 24.

Oster, J.D., and Frenkel, H. 1980. The chemistry of reclamation of sodic soils with gypsum and lime. Soil Science Society America Journal 44: 41-45.

Qadir, M., and Schubert, S. 2002. Degradation processes and nutrient constraints in sodic soils. Land Degradation and Development 13: 275-294.

Qadir, M., Steffens, D., Yan, F., and Schubert, S. 2003a. Proton release by N2-fixing plant roots: A possible contribution to phytoremediation of calcareous sodic soils. Journal of Plant Nutrition and Soil Science 166: 14-22.

Qadir, M., Oster, J.D., Schubert, S., and Noble, A.D. Sahrawat, K.L. 2007. Phytoremediation of sodic and saline-sodic soils. Advances in Agronomy 96: 197-247.

Qadir, M., Qureshi, R.H., and Ahmad, N. 2002. Amelioration of calcareous saline sodic soils through phytoremediation and chemical strategies. Soil Use Management 18:381–385.

Qadir, M., Steffens, D. Yan, Y., and Schubert, S. 2003b. Sodium removal from a calcareous saline-sodic soil through leaching and plant uptake during phytoremediation. *Land Degradation and Development* 14: 301-307.

Richard, L.A. 1954. *Diagnosis and Improvement of Saline and Alkali Soils, Handbook 60, USDA, Washington, D.C.*

Sadegh-Zadeh, F., Parichehreh M., Jalili B., and Bahmanyar M.A. 2018. Rehabilitation of calcareous saline-sodic soils by means of biochars and acidified biochars. Land Degradation and Development 29: 3262-3271.

SAS Institute Inc. 1999. *SAS/STAT User's Guide, Version 8, Cary, NC: SAS Institute In*c.

Schubert, S., and Yan, F. 1997. Nitrate ammonium nutrition of plants: effects on acid/base balance and adaptation of root cell plasmalema H^+ ATPase.Z. Pflanzenernähr. Bodenk 160: 275-281.

Singh, K., Singh, B., and Tuli, R. 2013. Sodic soil reclamation potential of *Jatropha curcas*: Along-term study. Ecological Engineering 58: 434-440.

Soil Survey Staff. 1996. Soil Taxonomy: *A Basic System of Soil Classification for Making and Interpreting Soil Surveys, Second Edition. Agriculture Handbook, No.436.* Natural Resources Conservation Service, United States Department of Agriculture: [1]-871.

Sumner, M.E. 1993. Sodic soils: new perspectives. Australian Journal of Soil Research 31: 683-750.

Tabatabai, M.A., and Donald L.S. 2005. *Chemical Processes in Soil*, Soil Science Society of America, Inc., Madison.

Tejada, M., Garcia, C., Gonzalez, J.L., and Hernandez, M.T. 2006. Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. Soil Biology and Biochemistry 38: 1413-1421.

Zaka, M.A., Ahmed, K., Rafa, H., Sarfraz, M., and Schmeisk H. 2018. Effectiveness of compost and gypsum for amelioration of saline sodic soil in rice wheat cropping system. Asian Journal of Agriculture and Biology 6: 514-523.

التأثير قصير المدي للبقوليات المبثتة للنيتروجين علي بعض خصائص التربة الجيرية المتاثرة بالأملاح

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مستخلص البحث:زراعة البقوليات في التربة الجيرية المتاثرة بالاملاح قد تقلل من صودية التربة، لذلك أُجريت تجربة حقلية بمحطة بحوث سوبا الملحية ، الخرطوم لتحديد إمكانيات ثلاثة نباتات بقولية مُثبِتة للنيتروجين: قوار ، لوبيا عفن ولوبيا حلو لإستصلاح الأراضى القلوية. تضمنت المعاملات: الشاهد(بدون نبات وجبص)، الجبص،قوار، لوبيا حلو ، ولوبيا عفن معتمدة علي النيتروجين المثبت او علي النيتروجين المضاف. تم توزيع المعاملات تبعا للتنظيم العشوائي الكامل والذي يحتوي علي أربعة مكررات. جمعت عينات التربة (0-25 و 25-50 سم) قبل الزراعة وبعد الحصاد لتحديد درجة الحموضة، التوصيل الكهربائي، والعناصر الذائبة (الكالسيوم، المغنسيوم، الصوديوم، البوتاسيوم)، البيكربونات الذائبة و نسبة إدمصاص الصوديوم. استخدم نظام التحليل الاحصائي (ساس) لتحليل البيانات واختبار دنكان متعدد المدي لفصل المتوسطات. أشارت نتائج الموسم الأول الى عدم وجود إختلاف معنوي بين المعاملات في درجة الحموضة والتوصيل الكهربائي بينما هناك إختلاف معنوي ($P \leq 0.004$) في محتوي الكالسيوم، الصوديوم ونسبة إدمصاص الصوديوم. وجد أن الكتلة الحيوية الجافة الكلية للوبيا عفن المثبت للنيتروجين حيويا كان أعلي معنويا من غير المثبتة للنيتروجين بمقدار 49.4%. فى ا لموسم الثانى، وجد أن المادة الجافة لمعاملة القوار المعتمدة علي تثبيت النيتروجين أعلي من المعاملة المعتمدة على النيتروجين المعدنى بمعدل 36% بينما لوبيا عفن المعتمدة علي تثبيت النيتروجين أدت الى نقصان نسبة إدمصاص الصوديوم وزيادة تركيز البيكربونات فى التربة. خَلُصت الدراسة إلي أن زراعة البقوليات المُثبتة للنيتروجين حيويا في الترب الجيرية المتأثرة

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بالأملاح قد تكون بديل أفضل من المحسنات الكيميائية عالية التكلفة لصغار المزارعين في السودان.