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Tuzdan Etkilenmiş Toprakların Kochia indica İle Biyolojik Islahı

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Özet

Toprak tuzluluğu dünya çapında tarımsal üretimde başlıca faktörlerden birisidir. Bu nedenle, bu tip toprakların ıslahı dünya besin üretiminin yanında yine sürdürülebilir gelişme için en acil ihtiyaçtır. Tuzlu boş arazilerin sürdürülebilir kullanımı; tuza toleranslı bitkilerin (çalı, çim ve ağaç gibi) kullanımı gibi biyolojik ıslah yöntemleriyle beraber etkili yönetim stratejilerinden yararlanarak mümkün olabilir. Tuzdan etkilenmiş ve üretim yapılmayan arazilerin biyolojik anlamda ıslahı geçerli bir yöntem olabilir. Bahsedilen hedeflere ulaşmak için, Mısır-İskenderiye'de bulunan toprak tuzluluk laboratuarında iki saksı denemesi kurulmuş, toprak tuzluluğu ile karşılıklı etkileşimi incelemek için kontrol grubuna ilaveten 4 farklı tuz seviyesi uygulanarak büyüme, bazı katyonların miktarı ve biyoverim değerlerine 2 farklı tipteki (alüvyal ve kalkerli) toprakta yetiştirilen Kochia indica bitkisinde inceleme yapılmıştır. Orta seviyede tuzlu toprakta her iki yetiştirme döneminde de büyüme parametrelerinde artış gözlenmiştir. Tuz seviyelerinden ikincisi ilk sezonda ve 3.sü incelenen özellikler yönünden en yüksek değerlere sahip olmuşlardır. Sonuçlar, bitkilerde büyüme karakterlerinin toprak tuzluluğunun artışı nedeniyle 2. Sezonda gelişme gösterdiğini ortaya koymuştur. Diğer taraftan, yaprak/sap oranı toprak tuzluluğunun artışına paralel olarak artmıştır. Yine de, daha önce elde edilen sonuçlar her iki sezonda da geçerliliğini korumuştur. Artan toprak tuzu, bitki dokularındaki Na^+miktarını önemli seviyede artırmıştır. Bunun yanında, K^+, K^+/Na^+ oranı ve Ca^{2+} miktarındaki artış, kontrole kıyasla aynı uygulamalarda önemsiz seviyede azalmıştır. Mg^{2+}için net bir etki görülmemiştir. Hasatta, tuz seviyelerinden 3.sü her iki sezonda en yüksek verime ulaşmıştır. Toprak analizleri yönünden Kochia indica bitkisinin ardarda gelişmesine gore toprak kalitesi, katyonlar, anyonlar (HCO_3^-hariç), SAR, EC, dS/m ilk sezonun sonunda düşüş göstermiş ve ikinci sezonun sonunda en düşük seviyeye ulaşmıştır ki bunun nedeni; yıkanma ve tuzun halofit bitki olan Kochia indica tarafından akümülasyonu ile yaprak vakuollerinde birikiminden kaynaklanmış olabilir. Toprak tipleri incelenen özellikler yönünden hem vejetatif dönemde hem de hasatta önemli seviyede etki göstermiştir.

Anahtar kelimeler: *Kochia, toprak tuzluluğu, yetiştirme, verim, biyo-ıslah*

Biological reclamation of salt affected soil through re-vegetation of Kochia indica

Abstract

Soil salinity has become one of the major determinants of global crop productivity. Consequently, reclamation of these soils is the most urgent requirement for world food production and also for sustainable development. Sustainable use of saline wastelands could be possible through effective management strategies that including the biological reclamation techniques by using salt tolerant plants (i. e., shrubs, grasses and trees). The use of biological means to reclaim salt affected soils of unproductive agricultural lands may be a viable option. To achieve the aforementioned objectives, two pot experiment were carried out in the soil salinity laboratory, Alexandria, Egypt, to study the mutual influence of soil salinity (4 initial soil salinity levels referred as S_1, S_2, S_3 and S_4 in addition to the control) on growth, some cations content, and biomass production of Kochia indica plants which were grown in two different types of soils (alluvial and calcareous).Moderate levels of initial soil salinity was significantly increased most of the growth characters in both seasons. The S_2 treatment in the first season and the S_3 treatment gave the highest values for all the characters which were mentioned previously. The results indicate that there were improving in the growth characters of plants in the second season due to improving the initial soil salinity. On the other hand, leaf / stem ratio increased with increasing initial soil salinity. However the previous results were valid for both seasons. Increasing initial soil salinity significantly increased Na^+ concentration in the plant tissues. On the other hand K^+, K^+/Na^+ ratio and Ca^{2+} content insignificantly decreased with the same treatment as compared with control. No clear effects were recorded for Mg^{2+}. At harvest, the S_3 treatment in both seasons gave the highest productivity. As for the effect of successive growing of Kochia indica on the soil quality, cations, anions (except for HCO_3^-), SAR, and electrical conductivity E.C., dS/m decreased in the soil analysis by the end of the first season and reached its lowest values by the end of the second season, this may be due to the leaching and to the accumulation of salts by Kochia indica as a halophyte plant which is capable of accumulating salts into their leaves' vacuoles. Soil types significantly affected by most of the studied characters at vegetative stage and at harvest too.

Key wards: *Kochia, soil salinity, growth, yield, bio-reclamation*

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Introduction

Land degradation is a major global issue because of its adverse impact on agricultural productivity and sustainability. Population pressure along with the demand for more food, fodder and fuel wood has generated a chain of interrelated economic, social and environmental issues associated with the land degradation especially in developing countries in arid and semi-arid regions. Restoration of productivity of saline lands, improving of ameliorative conditions, compacting desertification and rising of fertility of soils are some of the most important tasks at recent time. The methods of ecological restoration of saline lands with the use of halophytes successfully solve this task.

The deficit in fodder supply is a major problem in the agricultural production of the developing countries of the arid regions of the world. Because salinity is associated with aridity, these countries are also suffering from the occurrence of salt affected soils which minimize the development of crop production. The salt affected soils are spreading near to the sea coasts due to the saline intrusions. As a rule, salt affected soils remained abandoned and such soils are seldom ameliorated because salinization is faster than amelioration.

Halophytes are geologically, physiologically and biochemically specialized plants which are able to function and produce in the conditions of saline soils **(**Ravindran et al., 2007). Domestication of halophytes will make a promising solution for increasing fodder supply and utilization of the abandoned salt affected soils.

Kochia as a halophyte plant receiving attention by many researchers because it represents a good alternative as a grazing or forage crop, it's a good plant for saline soils reclamation in arid regions. Several scientists reported that kochia is a prospective forage crop for salt-affected soil (Youssef et al., 2009).

The other side of the picture is that amendments are very costly and the small farmers can hardly afford to purchase these materials for reclamation purpose. Moreover, good quality water is also in short supply for leaching and mixing purposes. Recent studies report that badly salt affected soils can be utilized economically by growing halophytes which are classified as salt loving plants. The present study gives a detailed account of halophytes as alternative to chemical or other methods for reclamation, management and utilization of salt affected soils. It is also an attempt to investigate and identify the fast and luxuriantly growing halophytic forage which are salt accumulators and to assess the feasibility of salt bioaccumulation of salts in their tissues as well as higher reduction of salts in the soil

Materials and Methods

Two pot experiments were carried out in the soil salinity laboratory, Alexandria, Egypt, to study the mutual influence of soil salinity on growth, chemical composition, and productivity of *Kochia indica* plants grown in two different types of soils (alluvial and calcareous). A total of 30 pots which had 23 cm in diameter and 35 cm deep were used in the experiment. Fifteen pots were containing alluvial soil ($CaCO_3$ 6.39 %), the mechanical analysis showed that the soil texture was sandy loam and composed of 68.2% sand, 15.9% silt and 15.9% clay. The remainder pots contained calcareous soil, ($CaCO_3$ 40.52 %), the mechanical analysis showed that the soil texture was sandy clay loam and composed of 69.2% sand, 7.7% silt and 23.1% clay. The soils were previously artificially salinized except the control treatment until it reached 2.49, 3.94, 10.69, 16.77, 19.94 dS/m for alluvial soil and 1.82, 5.13, 10.28, 16.90, 19.10 dS/m for the calcareous soil, those values were the initial soil salinity of the experiment and abbreviated as control, S_1, S_2, S_3, S_4, respectively.

The experimental design was factorial in complete randomized design with three replicates of each treatment. Seeds were sown on mid March in both seasons; irrigation was applied at the field capacity. Phosphorus and potassium fertilizers were added to the soil before sowing at the rate of 200 kg / feddan calcium super phosphate (15.5% P_2O_5) and 100 Kg./feddan of potassium sulphate (48% K_2O). Four weeks after sowing, plants were thinned to two plants per pot. A dose of 100 Kg / feddan ammonium sulphate (20.6.5% N) was added in two equal parts, the first after thinning and the second 30 days later.

A representative vegetative plant sample was taken after 90 days from sowing for each treatment from three replicates for measuring plant height (cm), number of branches / plant, fresh weight of plant (g) , dry weight of plant (g) and leaf/stem ratio. The dried leaves were then thoroughly ground to a fine powder and the content of sodium and potassium were determined in the digested material using Jenway flame photometer as described by Chapman and Pratt (1961). K/Na ratio was also calculated for each treatment. Calcium and magnesium were determined according to Jackson (1967**)**. A representative plant sample was taken at harvest to determine the biomass production as dry matter yield (g) of Kochia plants under the different treatments.

Soil samples were taken at 30 cm depth from each pot for salinity measurements at the beginning and the end of each experiment. The obtained results were subjected to statistical analysis of variance of the complete randomized design according to method described by Snedecor and Cochran (1982**).**

Results and Discussions

Effect of soil salinity and soil types on some growth characters of Kochia indica.

Data presented in Table 1 show the effect of soil salinity on *Kochia indica* grown in alluvial and calcareous soil in two successive seasons. However increasing the initial soil salinity level significantly increased plant height, branches number / plant as well as fresh and dry weight of (aboveground biomass) /plant as compared with the control plants. The magnitudes of reduction differed from character to another.

It is worthy to note also that all the previous characters were stimulated by moderate external soil salinity. Further increase in the initial soil salinity adversely affected all the previous characters. The same table also shows that S2 treatment in the first season and S3 treatment gave the highest values for all the previous characters. The results indicate also that there were improving in the growth characters of plants in the second season due to improving the initial soil salinity.

Table 1. Effect of initial soil salinity and soil types on some growth parameters of *Kochia indica* (90 days after sawing)

Treatments	Plant height (cm)		Number of branches / plant		Fresh weight of plant (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	88.59 ab	114.67 a	29.33 a	39.83 a	16.56 b	23.24 a
S1	89.90 ab	116.67 a	29.68 a	40.00 a	17.16 ab	23.8 a
S2	93.25 a	111.17 a	30.12 a	42.31 a	23.67 a	22.95 a
S3	76.40 b	116.00 a	28.50 a	41.33 a	21.96 a	23.71 a
S4	74.40 b	112.50 a	27.17 a	38.17 a	18.54 ab	22.75 a
			Soil type			
Alluvial	81.33 a	122.00 a	26.67 b	41.87 a	18.27 a	26.19 a
Calcareous	87.69 a	106.4 b	31.25 a	37.47 b	20.88 a	20.39 a

Treatments	Dry weight of plant (g)		Leaf/stem ratio	
	1st season	2nd season	1st season	2nd season
Control	7.56 a	8.54 a	101.25 b	112.31 a
S1	7.35 a	8.73 a	125.9 ab	107.31 b
S2	8.94 a	8.30 a	127.61 a	119.38 a
S3	7.95 a	9.02 a	131.17 a	117.94 a
S4	8.16 a	8.44 a	147.58 a	114.38 a
		Soil type		
Alluvial	7.77 a	10.46 a	127.61 a	119.09 a
Calcareous	8.19 a	6.75 b	125.79 a	109.44 a

On the other hand, raising of the initial soil salinity was significantly increased leaf stem ratio in both seasons. The increase may be due to the increasing in salt accumulation in leaves than the stem and consequently increasing the succulence of the leaves more than the stem.

These results are in agreement with those obtained by (Yan et al., 2006) and (Ravindran et al., 2007) who reported that low NaCl concentrations stimulate growth of some halophytic species. Such stimulatory effect of moderate salinity on growth of some halophytic plants may be attributed to improved shoot osmotic status as a result of increased ions uptake metabolism. On the other hand, the reduction in growth as a result of high soil salinity levels may be attributed mainly to the osmotic inhibition of water absorption, the excessive accumulation of ions such as Na^+ or Cl^- in plant cells and inadequate uptake of essential nutrients (Munns and Tormatt , 1986) . However, our findings may account much more to the findings of (Samini and Bassiri ,1982**)** who reported that highly soluble salts in the root zone cause physiological scarcity in plant to absorb water .Thus, the availability of water may then become so critically low hence growth parameters are inhibited. Moreover, (Ashour et al., 1999) attributed the reduction in growth at high salinity levels to reduced turgor and high energy cost of massive salt secretion and osmo-regulation. Similar results were obtained by (Tawfik et al., 2008)

Regarding to the soil types effect on the previous characters, the same table also show significant differences between soil types in both seasons for plant height, number of branches/plant, dry weight of plant, and leaf/stem ratio. It is worthy to note that, alluvial soil in the second season recorded higher values for all the growth characters than its counterpart that grown in calcareous soil, this may be due to the lower initial soil salinity of alluvial soil than calcareous soil. This may be due to their relatively higher clay and organic matter content.These results are in general agreement with those obtained by (Mahmood et al., 1996). In this concern (Zedler et al., 2003) hypothesized that beneficial effects of plants in reclamation are not well understood but appear to be related to the physical action of the plant roots, the addition of organic matter, the increase in dissolution of $CaCO_3$, and crop uptake of salts. The interaction between soil salinity and soil types was not significant for all the studied characters.

Effect of soil salinity and soil types on some cations of Kochia indica:

Data presented in Table 2 revealed that increasing initial soil salinity significantly increased Na^+ concentration in the plant tissues, this may be due to the accumulation of Na^+ in the leaves for osmotic adjustment. It's also cleared that Na^+ is the major cation of the cationic content of the leaves, this may be due to the higher influx of Na^+ into leaves which reflect the importance of Na^+ for osmotic adjustment.

In general K^+ content insignificantly decreased with increasing initial soil salinity as compared with control treatment. Moreover, K^+ was the lowest cation of the cationic content; this may be due to the selectivity of Na^+ over K^+ as a major cation for osmotic adjustment.

Furthermore, K^+/Na^+ ratio and Ca^{2+} significantly decreased with increasing soil salinity, the decreasing in K^+/Na^+ ratio may be due to the high accumulation of Na^+ in the leaves faster than the accumulation of K^+. In this concern,(Khan et al., 2009) stated that salinity tolerance is inversely associated with K^+/Na^+ ratio and Ca^{2+} content where the higher K^+/Na^+ ratio and higher Ca^{2+} content is related to the lower salinity tolerance and vice versa. No specific trend was found in Mg^{2+} content with increasing soil salinity. The results agreed with that obtained by (Tawfik et al., 2008).

The greatest accumulation of sodium by plants at high salt concentration may be attributed to the damage of the protoplasm of plant cells and as a result of the selective salt absorption is replaced by passive absorption which causes abnormal accumulation of salts in plant organs (Kader and Lindberg, 2005). They added that under saline conditions sodium influx across the plasmalemma to the vacuole might play a major role in permitting turgor maintenance. (He et al., 2005) added that the accumulation of sodium ions inside the vacuoles reduce the toxic levels of sodium in cytosol and increase the vacuolar osmotic potential with the concomitant generation of a more negative water potential that favors water uptake by the cell and better tissue water retention under high salinity levels. Similar results were obtained by (Tawfik et al., 2008). On the other hand, the depressing effect of salinity on potassium could be attributed to the difficulty of its uptake due to competition with the high concentration of the sodium in the root medium. (Lacerda et al., 2005) reported that the greatest salinity tolerance observed in plants under saline conditions was associated with lower of Na/K ratio and greater capacity for osmotic adjustment.

Table 2. Effect of initial soil salinity and soil types on some cations in the leaves of *Kochia indica* (90 days after sawing).

Treatments	Na^+, meq/g	K^+,meq/g	K^+/ Na^+ratio	Ca^{2+}, meq/g	Mg^{2+},meq/g
Salinity					
Control	1.30 c	0.41 a	0.31 a	0.79 a	0.87 a
S1	1.46 b	0.45 a	0.31 a	0.71 a	0.85 a
S2	1.55 ab	0.32 a	0.21 b	0.73 a	0.85 a
S3	1.60 a	0.37 a	0.23 b	0.60 b	0.88 a
S4	1.65 a	0.33 a	0.20 b	0.61 b	0.84 a
Soil type					
Alluvial	1.42 b	0.44 a	0.30 b	0.62 b	0.76 b
Calcareous	1.60 a	0.30 b	0.20 a	0.74 a	0.96 a

Recently (Khan et al., 2009) proved that specific ions such as sodium may have toxic effects on plants: reducing growth or causing damage to cells and membranes.They added that, the decrease in K was due to the presence of excessive Na in the growth medium because high external Na content is known to have an antagonistic effect on K uptake in plant

Furthermore, sodium uptake causes plasma membrane depolarization, leading to activation of outward-rectifying K channels and a consequent K loss (Shabala et al., 2005).

With regard to soil types, data in Table 2 showed that plants grown in calcareous soil accumulate more Na^+, Ca^{2+}, and Mg^{2+} than its counterpart that grown in alluvial soil, this may be due to that levels of soil salinity were relatively higher in calcareous soil than alluvial soil. The interaction between soil salinity and soil types was not significant for all the studied characters.

Effect of soil salinity and soil types on biomass production of Kochia indica at harvest:

Data presented in Fig 1 showed significant differences in the results in both seasons, however S_3 treatment record the highest biomass production in both seasons indicating that increasing initial soil salinity increased the productivity of Kochia plants. The results indicate also that there were improving in the productivity of plants in the second season due to improving the initial soil salinity. These results are in agreement with those obtained by (Youssef et al., 2009). In this concern, (Masters et al., 2007) stated that the deleterious effects of salinity on yield are thought to result from low water potentials, ion toxicities, nutrient decencies, or combination of these factors.

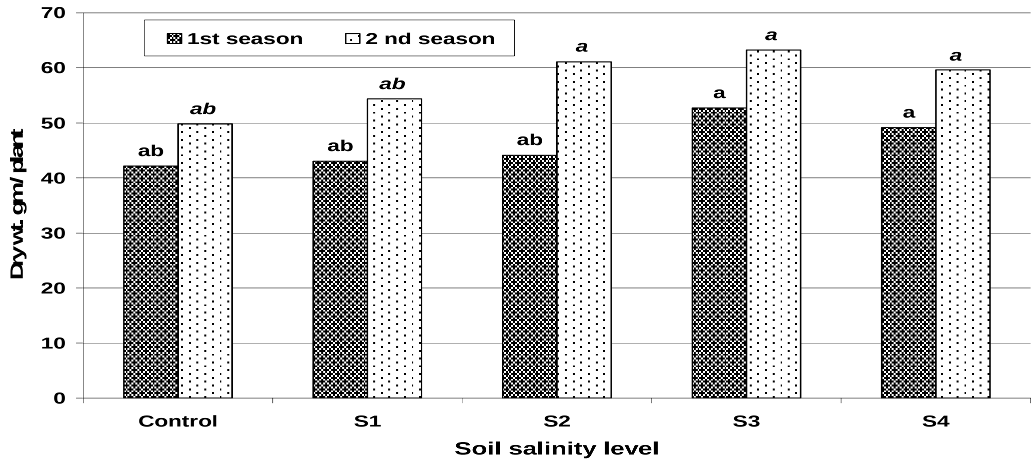

Fig 1. Effect of soil salinity on biomass production of *Kochia indica* (gm / plant) at harvest

With regard to soil types, data in Fig (2) indicated that no significant difference was found in first season, however, in the second season plants grown in alluvial soil significantly surpassed the plants grown in calcareous soil, this may be due to the lower soil salinity in alluvial soil in the second season than the first season. Similar results were obtained by (Mahmood et al., 1996). The interaction between soil salinity and soil types was not significant in this character.

Restoration of saline soil through revegetation of Kochia indica

Table 3-8 cleared that all the cations, all the anions (except for HCO_3^-), SAR, and electrical conductivity E.C., dS/m increased with increasing initial soil salinity in each season, however, all the previous characters decreased in the soil analysis by the end of the first season and reached its lowest values by the end of the second season , this may be due to the leaching and to the accumulation of salts by *Kochia indica* as a halophyte plant is capable of accumulating salts into their leaves' vacuoles. These results are in agreement with those obtained by (Zedler et al., 2003). In this concern, (Yan et al., 2006) indicates that there are different adaptive strategies for Kochia. Scoparia seedlings in organic acid metabolism under salt and alkali stress. Furthermore (Ahmed and Chang, 2002) stated that kallar grass accomplished the best removal of salts but had very little beneficial effect on pH and SAR.

Numerous suggestions have been advanced to remediate the effects of salts in the soil by some halophytic plant species by their ability to mitigate salts in soil solution either by plant uptake or chemical alteration of the soil. remediation method as the most environmentally sustainable method in dealing with the saline-sodic condition. In this concern, (Ravindran et al., 2007) hypothesized that beneficial effects of plants in reclamation are not well understood but appear to be related to the physical action of the plant roots, the addition of organic matter, the increase in dissolution of $CaCO_3$ and crop uptake of salts. They added that Suaeda maritima and Sesuvium portulacastrum exhibited greater accumulation of salts in their tissues as well as higher reduction of salts in the soil medium.

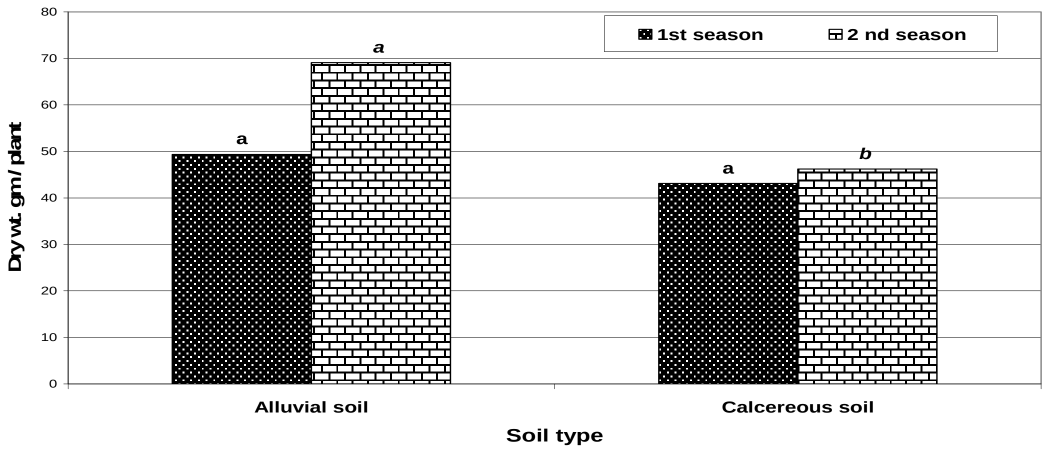

Fig 2. Effect of soil types on biomass production of *Kochia indica* (gm / plant) at harvest

Table 3. Soil paste extract analyses of the calcareous soil before sowing

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8.4	1.82	5.35	2.69	0.89	9.37	3.4	7.33	7.57	4.67
S_1	8.3	5.13	11.57	7.43	2	31.08	2.97	37.14	11.97	10.08
S_2	8.2	10.28	17.06	15.11	2.98	71.14	3.7	79.16	23.43	17.74
S_3	8.1	16.9	23.83	25.35	2.61	117.45	2.2	116.1	50.94	23.68
S_4	8.1	19.1	26.17	29.41	2.96	139.14	2.77	141.05	53.86	26.39

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Table 4. Soil paste extract analyses of the alluvial soil before sowing

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8.2	2.49	13.05	4.66	0.67	8.69	3.2	8.51	15.36	2.92
S_1	8.2	3.94	14.19	5.67	0.98	22.38	3.5	18.91	20.81	7.1
S_2	8.1	10.69	22.13	13.47	1.82	75.9	3.31	57.93	52.08	18
S_3	8	16.77	30	23.48	1.42	117.39	3.52	118.06	50.71	22.7
S_4	8	19.94	33	24.92	1.69	150.35	3.68	130.21	76.07	27.91

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Table 5. Soil paste extract analyses of the calcareous soil samples at the end of the first season

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8.2	2.49	13.05	4.66	0.67	8.69	3.2	8.51	15.36	2.92
S_1	8.2	3.94	14.19	5.67	0.98	22.38	3.5	18.91	20.81	7.1
S_2	8.1	10.69	22.13	13.47	1.82	75.9	3.31	57.93	52.08	18
S_3	8	16.77	30	23.48	1.42	117.39	3.52	118.06	50.71	22.7
S_4	8	19.94	33	24.92	1.69	150.35	3.68	130.21	76.07	27.91

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Table 6. Soil paste extract analyses of the calcareous soil samples at the end of the second season

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8.1	2.03	7.16	3.79	0.95	9.77	3.19	8.65	9.83	4.17
S_1	8.1	2.73	6.53	4.42	0.97	16.12	3.4	15.38	9.26	6.89
S_2	8.2	6.28	14.74	11.36	2.16	43.2	3.19	40.38	27.89	11.96
S_3	8.3	4.8	9.89	8	1.7	33.35	3.19	26.92	22.83	11.15
S_4	8.2	7.25	13.05	12.42	2.46	49.4	2.76	50	24.57	13.84

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Table 7. Soil paste extract analyses of the alluvial soil samples at the end of the first season

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8.1	2.25	11.79	4.21	0.62	7.85	3.62	7.69	13.16	2.77
S_1	8	3.8	12.42	5.47	0.97	21.6	3.4	18.27	18.79	7.22
S_2	8.2	5.5	11.37	6.94	0.94	39.1	3.4	29.81	25.14	13.07
S_3	8.1	7.65	13.68	10.74	1.3	53.6	3.19	53.85	22.28	15.34
S_4	8.4	9.13	12	10.53	1.58	71.3	3.62	59.61	32.18	21.24

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Table 8. Soil paste extract analyses of the alluvial soil samples at the end of the second season

Treatments	pH	E.C. dS/m	Cations, meq/ L.				Anions, meq/L.			SAR
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	
Control	8	2.66	16.21	5.47	0.51	9.77	2.55	6.73	22.68	2.97
S_1	8	3.22	14.31	5.69	0.55	16.65	2.55	11.54	23.11	5.26
S_2	8.2	4.45	10.95	5.47	0.74	28.95	2.55	27.88	15.68	10.17
S_3	8.3	4.88	10.1	6.32	0.79	33.35	2.76	30.77	17.03	11.64
S_4	8.4	5.06	10.1	6.32	0.79	36.8	2.98	28.84	22.19	12.84

E.C. = electrical conductivity; SAR = sodium adsorption ratio

Conclusion

The results indicate that establishment of salt-accumulating halophytes can sufficiently remediate the land to the point where native plants can re-establish. As well as the potential benefits for nature conservation and agriculture, an important outcome of remediation and re-vegetation is a reduction in soil erosion with accordingly to reduced salt and silt discharge into water courses. Furthermore, utilization of salt tolerant plants such as *Kochia indica* for rehabilitation and reclamation of salt-affected soil could be an appropriate option for alleviating desertification problems and providing alternative good quality and economic unconventional feed materials for animals

Recommendation

Improved varieties of plants for saline wetlands restoration that will drive high productivity ecosystems without continual human input.

Disseminate knowledge about using salt-tolerant plant varieties to develop sustainable agriculture in areas of the world where soils are salinized to solve wetland restoration problems.

Exchange information on the performance of varieties of salt-tolerant plants under various types of agro-ecosystems and wetland restoration sites.

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