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Technical Note

MOISTURE PROPERTIES OF A SALINE SODIC SOIL AS AFFECTED BY GROWING KALLAR GRASS USING BRACKISH WATER

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Abstract

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Soil samples collected from highly saline sodic soil (0–300 cm) irrigated with poor quality water after growing kallar grass for different time periods were analysed for physico-chemical characteristics. The moisture contained by the sub soil layers and the saturation percentage (SP) of soil increased which consequently decreased the soil moisture deficit throughout the profile. Relative hydraulic conductivity also increased which may have accelerated the leaching of salts downward resulting in reduced EC, pH, sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) which increased SP of soil. In general, an improvement in the properties of highly saline sodic soil was observed after growing kallar grass and the so-called equilibrium stage was reached after 4 years growth of the grass.

Introduction

Leaching of soluble salts is a desirable process for the reclamation of saline sodic soils. Because applied surface water leaches the salts down to deeper layers, the crop root zone becomes clear of salts which inhibit plant growth.

However, this reclamation process is dependent on many factors, i.e., soil hydraulic conductivity and quality of water applied. In Pakistan, growth of kallar grass (*Leptochloa fusca*) has been suggested for the amelioration of saline sodic soils using saline irrigation water (Sandhu and Malik, 1975).

The hazards of using poor quality water with regard to plant development and crop yield have been reported by many researchers. Its use decreases the infiltration and hydraulic conductivity and increases crust formation (Frankel et al., 1978; Oster and Schoroer, 1979). Water of high sodium adsorption ratio (SAR) reduces soil structural stability due to consequent clay dispersion, swelling and reorientation (Chen asd Banin, 1975; Frankel et al., 1978). In contrast, an increase in infiltration rate has also been reported by Hades and Frankel (1982) on long term use of saline sodic water. The permeability of soil to water depends both on exchangeable sodium percentage (ESP) of the soil and on the salt concentration of percolating solutions. Permeability tends to decrease with increasing ESP and decreasing salt concentration (Quirk and Schofield, 1955; McNeal and Coleman, 1966; McNeal et al., 1968).

This paper reports changes in moisture properties along with chemical changes of the soil profile observed after growing kallar grass on a highly salt-affected soil for 4 years, using brackish irrigation water.

Materials and Methods

The experimental site was located at the Biosaline Research Station (BSRS) of the Nuclear Institute for Agriculture and Biology (NIAB) near Lahore, Pakistan. The station is located at longitude 74°5' and latitude 31°6'. Averge annual rainfall is ~500 mm. Kallar grass was planted on 12 plots (100×100 m^2) on a highly saline sodic soil and three plots of the same size were kept as a control. The control plots were preserved (original/fallow) without any vegetation. The physico-chemical analysis of control soil is presented in Table I.

The water used for irrigation (analysis given in Table II) was pumped from a local well and was categorised as C_3S_2 (brackish) according to the USDA (1954) and unfit for irrigation. Irrigation records are not available, but flood irrigations were applied (~7.62 cm) according to the requirement of grass (after ~15 days). The contribution from rainfall was neglected due to excess irrigation of fields with brackish water. The irrigation of control soil was stopped 6 months later because water could not permeate, even to a depth of 2 cm.

In order to ensure maximum natural uniformity among the field plots and to avoid the effect of spatial variability, four plots were selected for further studies (three planted and one control or fallow). Selection of such plots was based upon initial chemical evaluations and similarity in plant cover in planted plots. Kallar grass, being a perennial grass, was continuously grown for up to 4 years. The grass was harvested from the field in 5–7 cuttings per year. The green matter yield was ~50 tons $ha^{-1}year^{-1}$ (Malik et al., 1986). At the end

TABLE I

Chemical composition of the control/fallow soil

Depth (cm)	K^+	Na^+	$Ca^{2+}+Mg^{2+}$	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	pH	SAR	ESP	EC (dS m^{-1})	Clay	Silt	Sand
	(meq dm^{-3}) in extract saturation											(%)		
0–50	0.4	226	3.0	72.4	108.4	14.2	39.4	9.4	130	72	[illegible]	22	23	55
50–100	0.15	207	2.5	62.1	101.4	16.3	22.2	9.5	185	73	29.2	23	25	52
100–200	0.20	128	2.5	40.7	68.?	8.6	13.5	9.4	115	63	12.4	18	25	57
200–300	0.05	127	2.5	45.4	43.?	Nil	33.9	9.4	118	20	12.3	20	29	51

TABLE II

Chemical composition of tube well water used to irrigate the soils

EC (dS m^{-1})	pH	Soluble sodium (%)	Residual sodium carbonate	Sodium adsorption ratio	Na^+	K^+	$Ca^{2+}+Mg^{2+}$	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}
					(meq dm^{-3})						
1.4	7.6	72.5	9.61	7.5?	10.15	0.2	3.65	0.7	12.96	0.4	[illegible]

of every growth year of grass (November), soil samples were collected at four consecutive depths (0–50,50–100,100–200 and 200–300 cm) randomly from three sites from each plot. Soil samples from each plot were mixed and saturation extracts obtained from the composite samples were analysed in the laboratory using standard methods (USDA, 1954). The chemical parameters discussed in the paper were averaged for triplicate plots at specified depths. The variation in individual values from their mean (standard deviation) was too little to be presented in the graph. This is further proof of uniformity in the field plots.

Polyvinyle chloride (PVC) access tubes (50 mm diameter), capped at the bottom and top to prevent water intrusion, were inserted in the drilled holes of sampling sites up to 3-m depth. Moisture content was determined using a neutron moisture probe with intervals of 25-cm depth up to 2.5 m depth on a fortnightly basis. Before starting the experiment, a 50-mCi neutron moisture probe (Model 503 Hydroprobe) was calibrated in the same soil with PVC and aluminium tubes together. The calibration slope and intercept values determined were 45.13 and 11.64 respectively, between ratio (measured counts/standard counts) and volume percent of water. The reproducibility and accuracy of calibration have been found to be good as indicated by an r value of 0.995 at the 0.01 probability level.

Saturated hydraulic conductivity (HC_s) was determined for each sample by the constant head method using Darcy's law. Air dried, ground and 2-mm sieved samples were filled in brass tubes to uniform density. Gravel and sand were spread on the top and bottom of the soil to minimise surface disturbances. Distilled water was applied for determination of HC_s to obtain uniformity in the results for comparison purposes. Use of brackish water might have produced greater HC_s values, but relative HC_s might not be affected. Hydraulic conductivities at particular depths were divided by the base HC_s values (from our first experiment on control soil) to obtain relative HC_s values.

Results

The cultivation of kallar grass for 1 year increased the moisture retained (θ) by the soil layers throughout the profile compared to original/fallow soil. The θ presented in Fig. 1 was averaged at the end of every growth year from 24 measurements at each depth. The differences in θ among the individual measurements at comparable depths were quite small and could be ignored in such a vast field study. The increase in θ throughout the year was gradual, it was observed never to be abnormal or sharp. This supports our assumption that soil properties were uniform in the selected plots. As a result of second and third year growth, θ decreased throughout the profile, but its values were still greater than those for fallow soil. After 4-years growth, θ increased over control

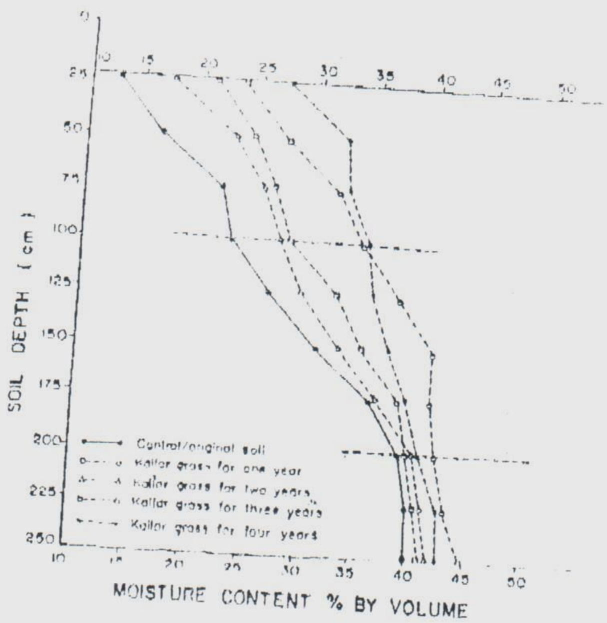
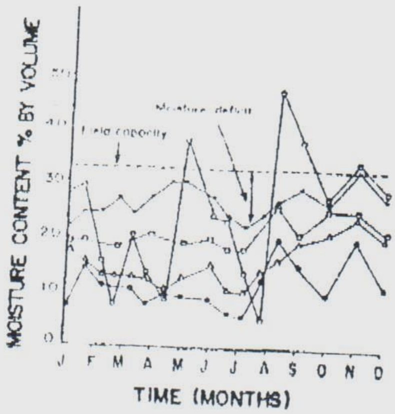


Fig. 1. Average moisture content along the depth of the soil profile as a function of kallar grass growth time. Each point is the mean of 24 readings.

as well as fields cultivated for 3 years. Its effect was pronounced up to 1 m depth, below which it reduced, but differences were quite small (Fig. 1).

Soil moisture deficit/excess has been calculated by comparing the field capacity of soil at each depth. Figure 2 shows the existing soil moisture deficit (0–25 cm) as a function of the cropping period of kallar grass. We think it is meaningful to present the moisture conditions at 25-cm depth for agricultural purposes. Soil moisture deficit showed fluctuations during the first year and soil also achieved moisture excess during the months of April and July. Cultivation of grass for 4 years reduced the soil moisture deficit and the magnitude of its fluctuations.

Relative saturated hydraulic conductivity (HC_s) increased in all the cropped fields over the control. The magnitude of the increase in relative HC_s increased with the depth of soil profile (Fig. 3a). Changes in soil saturation percentage (SP) were not consistent as it increased after 1 year kallar grass growth and then decreased during the second and third year. However, SP increased during the fourth year as compared to the second and third year (Fig. 3b). A



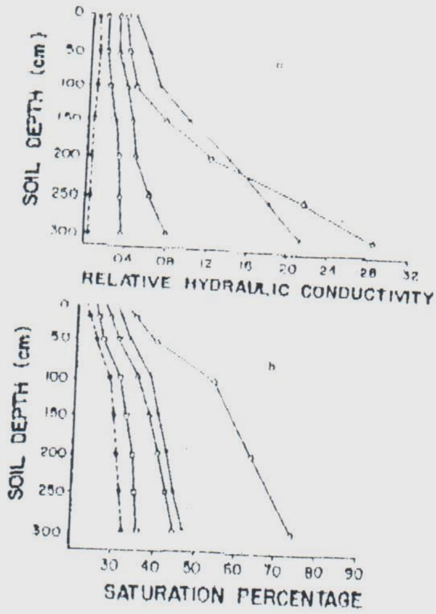


Fig. 2. Soil moisture deficit as a function of kallar grass growth time compared with field capacity at 25-cm depth. Each point is the mean of 24 readings. Symbols as in Fig. 1.

Fig. 3. Effect of kallar grass on: (a) relative saturated hydraulic conductivity; (b) saturation percentage. Each point is the mean of three replicates. Symbols as in Fig. 1.

similar, but opposite trend, was observed for changes in EC, pH, SAR and ESP of soil (Fig. 4).

A significant reduction in these parameters was observed after growing kallar grass for 1 year. However, values of these parameters slightly increased after the second and third years, but were still smaller than those for the original/fallow area. No changes in moisture and chemical properties in the original soil profile, examined in the study, were observed during and at the end of 4 years after application of brackish water for a considerable period of time or on fallow soil.

Discussion

An appreciable increase in relative HC_s was found in planted soil compared to control/fallow soil. The increase in moisture content (θ) retained by the

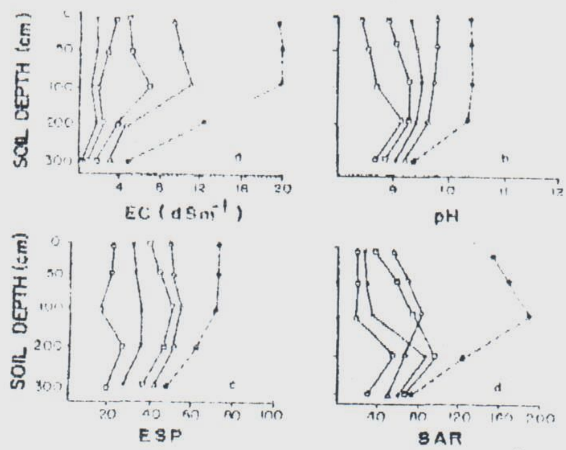


Fig. 4. Effect of kallar grass growth on soil chemical properties: (a) EC; (b) pH; (c) ESP; (d) SAR. Each point is the mean of three replicates. Symbols as in Fig. 1.

soil layers may be a cause of the increase in relative HC. A number of relationships showing the dependence of hydraulic conductivity on θ have been reported (i.e., Ragab et al., 1981; Talsma, 1985). The increase in θ reduced the soil moisture deficit at all the studied depths. The moisture excess observed during the months of April and July may be due to dilution of brackish water by rainfall. Most of the rainfall at the experimental site occurs during the months of April and July.

The cultivation of kallar grass for 1 year drastically altered the chemical composition of soils, which is reflected in reduced pH, EC, SAR and ESP of the soil profile compared to control/fallow soil. The growth of grass for 2 years with the same water caused an increase in pH, EC, SAR and ESP compared to first year growth. Further growth of grass for 3 and 4 years again reduced the pH, EC, SAR and ESP of soil. This is probably a clear indication of attainment of equilibrium conditions between irrigation water and solid phase in the soil.

The increase in SP of the soil profile is reflected in reduced ESP of the profile due to exchange of Na^+ with Ca^{2+} on exchange sites of soils (Malik et al., 1986) which improved the soil structure. It may be a major factor in improving soil structural porosity and consequently restoring the soil moisture properties. The role of kallar grass and brackish water in the soil properties examined cannot be separated in the light of the observed data. It has been shown (Hadas and Frenkel, 1982) that the use of brackish water increases the infiltration rate of a saline sodic soil, but the application of brackish water on original-

/fallow soil without kallar grass did not cause any change in soil properties. The growth of grass restored biological activity and accelerated the leaching of salts down below the 0-m depth (Malik et al., 1988). It has already been shown (our unpublished data) that uptake of salts by kallar grass is negligible compared to soluble salts, which are leached down through the soil profile.

The use of brackish irrigation water for growth of kallar grass maintained the so-called equilibrium of salts by leaching as well as adding the salts in the soil profile. Maximum reduction (threshold) in soil EC, pH, SAR and ESP was observed after a 1 year period up to 1 m depth. Further growth of grass for 2 and 3 years (transitional period) caused an increase in the above-mentioned chemical parameters over threshold values. Values close to the threshold values were again observed after 4 years growth of kallar grass.

An almost equilibrium stage developed at the end of 4-years growth of kallar grass using brackish irrigation water on a saline sodic soil, so the salt-affected soils can be effectively utilised for production of biomass on a large scale, even using poor quality irrigation water. The bad soil and bad water could be used for biomass production along with an improvement in the physico-chemical characteristics of the soil during the process and biomass could be used in a variety of ways (Malik et al., 1986). The use of good quality irrigation water on saline sodic soil may cause a decrease in hydraulic conductivity (Mcintyre, 1979). However, the introduction of good quality irrigation at the equilibrium stage (after initial leaching with poor quality water) for complete reclamation of such soils needs further investigation.

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