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COMPARISON OF CONTINUOUS AND INTERMITTENT LEACHING METHODS FOR THE RECLAMATION OF A SALINE SOIL

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ABSTRACT

Soil salinization is diminishing the agriculture productivity in the country. If remedial measures are not taken to tackle this problem, the fertile land will go out of cultivation in the near future. Several experiments have been conducted to reclaim the salt affected soils. However, growers still do not know how long it takes to reclaim saline soils. An experiment was carried out in the experimental field at the Centre for Bio-saline Agriculture at Latif Experimental Farm to compare the continuous and intermittent leaching methods for the reclamation of a saline soil. Six plots each of 2 m x 2 m were prepared on a saline soil. Three randomly selected plots were leached by continuous leaching method, while the remaining three plots were leached by intermittent leaching method. Analysis of soil samples showed that the soil was clay loam in texture between 0 and 60 cm depth. The average soil bulk density ranged between 1.13 and 1.20 g/cm3 and porosity ranged from 52 to 55%. Data analysis results revealed that after carrying the experiments for two months, continuous leaching method removed 61.59% of salts from the top 0-60 cm soil depth, whereas the intermittent leaching method removed only 46.14% of the salts from the same depth. When the two treatments were compared after five months of experimental work, intermittent leaching method removed 75.23% of salts from the top 60 cm layer as compared to 64.01% with continuous leaching method. Soil pH, SAR and ESP after two and five months of the experiment remained almost the same, however after two months of the experiment pH slightly increased in intermittent leaching and after five months of the experiment in continuous leaching method. Similar trend was observed in SAR and ESP which slightly increased in intermittent leaching method after two months of the experiment and in continuous leaching method after five months of the experiment. The statistical analysis of data showed highly significant ($p < 0.01$) decrease in EC of soil saturation extract and non significant

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(p> 0.05) decrease in pH, SAR, and ESP of all plots after two and five months of the experiment. The present study suggests that continuous leaching is the suitable method of leaching when time for leaching is a limiting factor. However, for better results for long duration (up to five months) intermittent leaching methods is more efficient.

Keywords: Leaching, continuous, intermittent, texture, salt.

INTRODUCTION

Pakistan has total geographical area of about 79.61 million hectares (mha), out of which about 25% (21.5 mha) is used for crop production and nearly 78% of the cropped area (17 mha) is irrigated. Since the arable land is almost twice the area presently under cultivation. Historically the land cultivated has been that, which was the easiest to develop and least costly. The remaining potentially arable land is difficult to develop and quite costly (Ghafoor *et al.,* 2004). Hence the total area under agriculture in the country is approximately the same since 1947, but unfortunately, the land is dwindling rapidly due to salinization. If remedial measures are not taken to tackle this problem, gradually the land will go out of cultivation in the near future.

Soil salinization has seriously affected the crop productivity of large areas of Pakistan. About 0.2 to 0.4% of the total culturable land is being put out of cultivation each year due to salinity and water logging (Khan, 1998). It is further estimated that about 6.30 mha of land area is salt-affected, out of which 1.89 mha is saline, 1.85 mha is permeable saline-sodic, 1.02 mha is impermeable saline-sodic and 0.028 mha is sodic in nature (Alam *et al.,* 2000). Saline soils have salinity level of 4 dS/m, ESP less than 1 and pH less than 8.5, Sodic soil contains ESP more than 15, salinity level less than 4 dS/m, and pH between 8.5 and 10, sodium concentration appeared any where in the plant root zone with no visible indication of its presence (Ahmed, 1993). According to (Qureshi and Barrett-Lennard, 1998) soils having EC less than 4 dS/m is considered as salt free soil, 4-8 dS/m slightly saline, 8-15 dS/m moderately saline and more than 15 dS/m strongly saline. Main sources of salinization in Indus Plain are shallow saline water tables and irrigation with marginal quality ground water (Aslam and Prathapar, 2006). It is generally believed that the development of salt-affected soils in Pakistan is the result of waterlogging due to seepage from the canal system. However, reconnaissance soil surveys covering the Indus Plains have revealed that salinity and waterlogging are not a "twin menace". However, more than 70% of the salt-affected soils have fossil salinity/sodicity, while the rest have secondary salinity (Akhtar *et al.,* 1990).

Reclamation of saline soils is easier, least time consuming and most economical and consists of flooding and leaching salts from soil, whilst the reclamation of sodic soils involves application of chemical amendments (Ghafoor *et al.,* 2004). Therefore farmers prefer the reclamation of saline soils over sodic soils. Saline soils are often reclaimed by leaching. Leaching is the process of dissolving and transporting soluble salts by the downward movement of water through the soil with the application of excessive water on to the soil surface. Traditionally there are two methods of leaching i.e. continuous leaching and intermittent leaching. Continuous leaching is accomplished by continuously ponding water on the soil surface and in intermittent leaching ponded water application is interrupted with rest periods allowing redistribution of salts held in macro pores. Several experiments have been conducted to test the efficiency of continuous and intermittent leaching methods. However, growers still do not know how long it takes to reclaim saline soils. Little work has been done on studying the time required for the leaching a particular soil with continuous leaching or intermittent leaching method. Due to the above facts the present study was carried out in the experimental field at the Centre for Bio-saline Agriculture at Latif Experimental Farm to compare the continuous and intermittent leaching methods for reclaiming saline soil.

MATERIALS AND METHODS

Field experiment was conducted at the Centre for Bio-saline Agriculture at Latif Experimental Farm near Kalari village, about two kilometers away from Tandojam on Mirpurkhas road. It lies between 25°25'60” N and 68°31'60” E and at an elevation of 75 ft (23 m) from the sea level. Two treatments namely, continuous leaching and intermittent leaching methods were applied with three replicates in a completely randomized block design (RCBD) with plot size of 2 m x 2 m.

Preparation of plots

Experimental plots were prepared by constructing bunds of about 0.3 m height and 0.3 m width with the help of hand tools. These bunds were properly compacted to minimize the wastage of water by leakages. Moreover to avoid any lateral water movement and solute transport, the plots were lined with polyethylene sheets down to a depth of 100 cm at the edges (Fig. 1).

Soil sampling

For the determination of soil physical and chemical properties, soil samples were collected before and after application of the treatments. From each plot, soil samples were collected at 0-15, 15-30, 30-45, 45-60 cm depths by using soil auger. For determination of dry bulk density, a core sampler was used to collect the undisturbed soil samples. These samples were labeled, packed and brought to the laboratory for analysis.

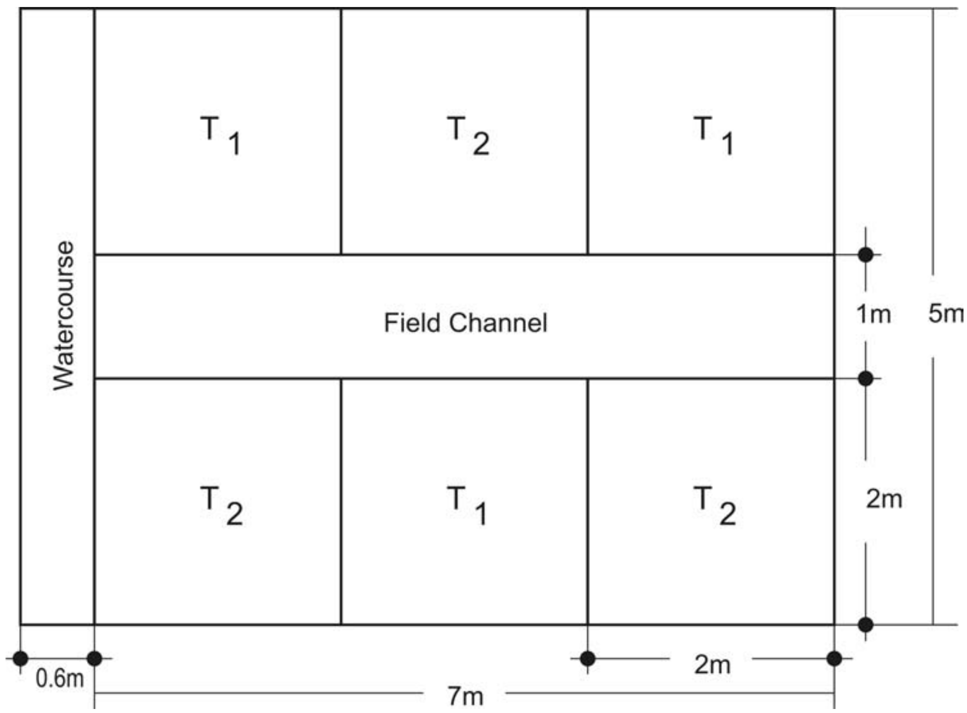

Figure 1. Layout of the experimental field

Soil physical analysis

Soil texture was determined by Bouyoucous Hydrometer method. The dry density of the soil was determined by gravimetric method.

$$\text{Dry bulk density } (\rho_d) = \frac{\text{Dry weight of soil}}{\text{Total volume of soil}}$$

Soil Porosity was determined by using relation:

$$n = 1 - \frac{\rho_d}{\rho_s} x100$$

Where

- n = soil porosity (%)
- ρ_s = particle density (g/cm^3)
- ρ_d = dry bulk density (g/cm^3)

Soil chemical analysis

Electrical Conductivity (EC) of soil saturation extract was determined by using digital EC meter, soil pH was determined by digital pH meter, soluble Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Carbonates (CO_3^{2-}), Bicarbonates (HCO_3^-), and Chlorides (Cl^-) were determined by titration method, while sodium (Na^+) was analyzed by EEL-Flame photometer. However, the other chemical properties such as sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were calculated using the formulae:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

And

$$ESP = \frac{100(-0.0126 + 0.01475 \, x \, SAR)}{1 + (-0.0126 + 0.01475 \, x \, SAR)}$$

Chemical analysis of water

Since the quality of water affects the efficiency of saline soil leaching, therefore water samples were collected from the water course during application of water to the plots. These samples were analyzed in laboratory for determination of EC (dS/m), pH, SAR and RSC.

Leaching of salts

The leaching of salts from experimental plots was carried out with two different methods namely continuous leaching and intermittent leaching. For this purpose, three randomly selected plots were leached by continuous leaching method, while the remaining three plots were leached by intermittent leaching method.

Volume of water

In intermittent leaching, water was applied in 5 equal splits of 15 cm, each at the interval 10-15 days, whereas in continuous leaching method water was continuously ponded up to the depth of 15 cm.

RESULTS AND DISCUSSION

Soil physical properties

Table 1 shows the textural class of composite soil samples, dry bulk density and soil porosity for 0-15, 15-30, 30-45 and 45-60 cm depths of the experimental site. The results indicate that the soil texture for all six plots was clay loam. The average bulk density ranged between 1.13 and 1.20 g cm^3, whereas soil porosity was 52 to 55%. It was further observed that, soil physical properties remained unchanged at the end of the experiment.

Table 1. Pre-experiment physical properties of soil.

Sampling Depth (cm)	Dry Bulk Density (gm/cm³)	Soil Porosity (%)	Textural Class
0-15	1.13	55.0	Clay Loam
15-30	1.15	53.50	Clay Loam
30-45	1.18	52.50	Clay Loam
45-60	1.20	52.00	Clay Loam

EC before and after two months of the leaching

The results of the average electrical conductivity of soil saturation extract (ECe) before and after leaching with continuous (CL) and intermittent leaching (IL) methods for two months are shown in Figure 2. Before the application of the treatments, the average ECe was 5.99 dS/m. After two months of experimental work, the average ECe of the soil profile was remarkably decreased to 2.3 dS/m with continuous leaching (CL) method. By comparison, the average ECe decreased to 3.23 dS/m in the plots with intermittent leaching (IL). This shows that with continuous leaching method 61.59% of salts were leached from the top 0-60 cm depth as compared to 46.14% with intermittent leaching method. This is probably due to the fact that in continuous leaching method the water flows mostly in the macropores and the salts in the micropores diffuse out into the moving water which then percolates downward to the shallow groundwater carrying salts in the leachate. Hence, this method takes less time than other methods of leaching, but it consumes large quantities of water. The statistical analysis of data showed highly significant ($p< 0.01$) decrease in ECe of all plots after two months of the experiment.

The findings of this experiment are also supported by Gupta and Gupta (1987) who suggested that continuous leaching is the preferred method when time is a limiting factor. While Hoffman (1980) suggested that about 70% of the soluble salts initially present in a saline soil can be removed by leaching with a depth of water equivalent to the depth of soil to be reclaimed, if water is ponded continuously on the soil surface and drainage is adequate.

ECe before and after five months of the leaching

The results of average ECe before and after leaching with continuous (CL) and intermittent leaching (IL) methods for five months are plotted in Figure 3. It is apparent from figure that the average ECe of the soil profile after five months of the experiment work with intermittent leaching (IL) method was remarkably decreased to 1.48 dS/m as compared to the continuous leaching (CL) method in which the ECe decreased to 2.16 dS/m.

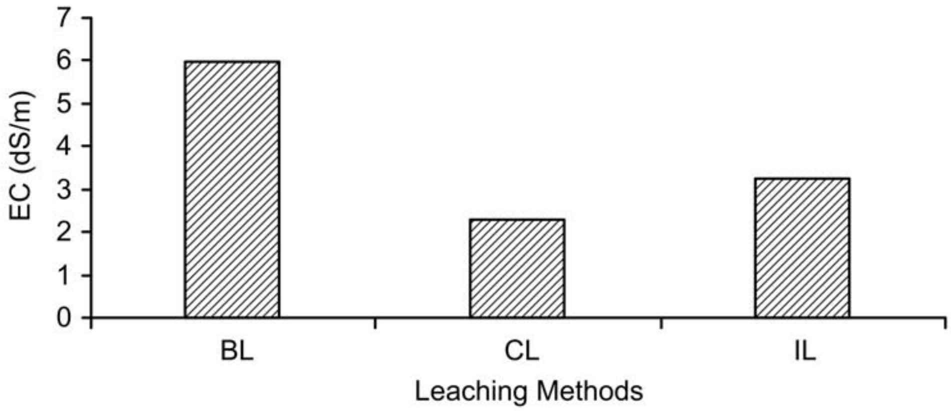

Figure 2. Comparison of electrical conductivity of soil saturation extract before and after two months of leaching with continuous (CL) and intermittent leaching (IL) methods.

The above discussion indicates that the intermittent leaching method removed 75.23% of salts down from the top 0-60 cm soil depth, whereas the continuous leaching method removed only 64.01%. The main reason for the observed differences is due to the fact that the intermittent leaching method allows extra time for salts held in micropores to diffuse and then leached down with flowing water. This suggests that intermittent leaching method is more effective than that of continuous leaching method when leaching is carried out for more time. The statistical analysis of data showed highly significant ($p < 0.01$) decrease in EC of soil saturation extract of all plots after five months of the leaching.

These results are also supported by Siyal *et al*. (2003) who suggested that the intermittent leaching was efficient only when leaching was carried out during periods of low evaporation rate. While Tagar *et al.* (2007) suggested that under given soil and climatic conditions, intermittent leaching method was most efficient method of salt leaching followed by continuous leaching method even when poor quality water was used. Similarly, Al-Sibai (1997) also advocated for intermittent leaching method for the successful leaching and he proved possibility of water savings of 25% under laboratory conditions. In another study, Shuxiang (1998) reported that leaching efficiency of intermittent leaching was higher than that of continuous leaching.

Soil pH

The results of soil pH before and after leaching with CL and IL methods after two and five months are illustrated in Fig. 4 and 5. It is evident from the figures that the soil pH after two months of the experiment, slightly increased under intermittent leaching and after five months of the experiment under continuous leaching method. However, the statistical analysis showed non significant ($p > 0.05$) results after leaching for two and five months.

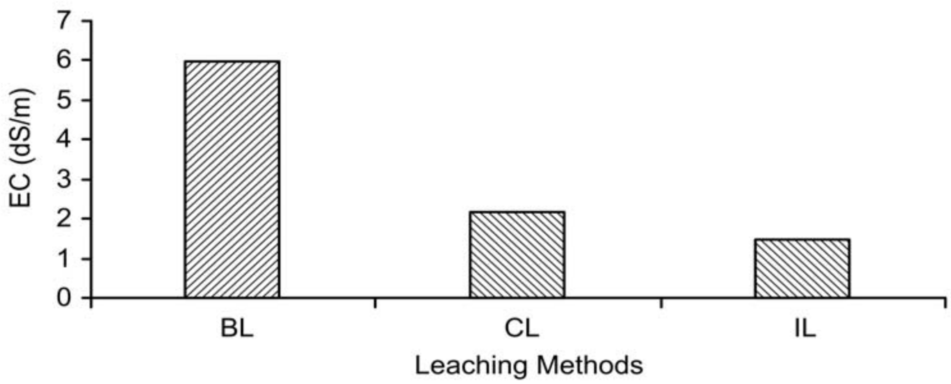

Figure 3. Comparison of electrical conductivity of soil saturation extract before and after leaching for five months with continuous (CL) and intermittent leaching (IL) methods

Sodium adsorption ratio (SAR)

Fig. 6 and 7 show SAR before and after leaching with continuous (CL) and intermittent leaching (IL) methods for two and five months. The results indicate that SAR after two months of the experiment slightly increased under intermittent leaching and after five months of the experiment under continuous leaching method. The statistical analysis showed non significant ($p > 0.05$) results after leaching for two and five months.

Exchangeable sodium percentage (ESP)

Fig. 8 and 9 show ESP before and after leaching with CL and IL methods for two and five months. The results reveal that ESP after two months of the experiment slightly increased under intermittent leaching and after five months of the experiment under continuous leaching method. The statistical analysis showed non significant ($p > 0.05$) results after leaching for two and five months.

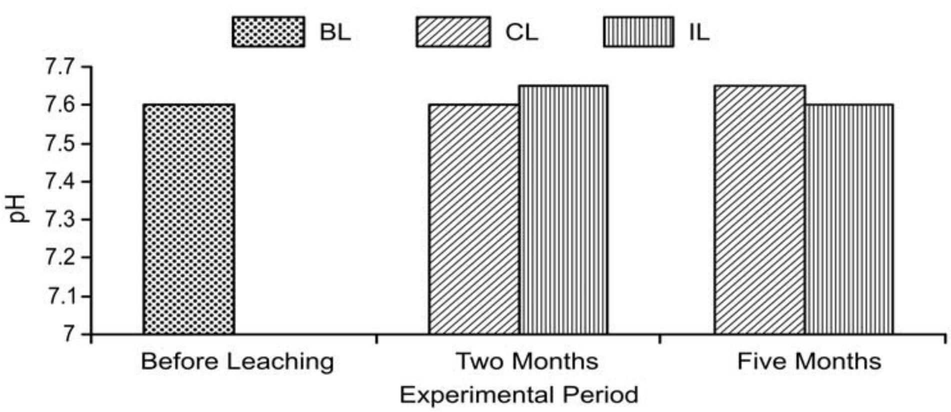

Figure 4. Comparison of soil pH before and after leaching for two and five months with continuous (CL) and intermittent leaching (IL) methods

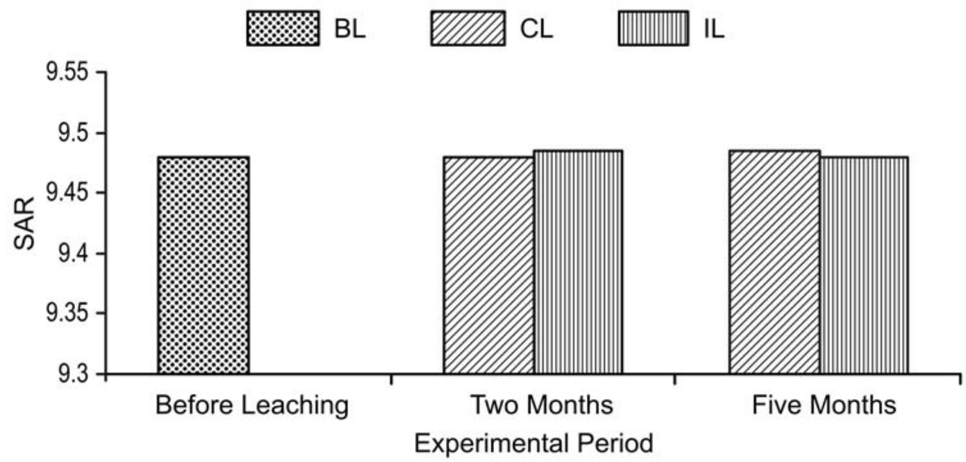

Figure 5. Comparison of SAR before and after leaching for two and five months with CL and IL methods.

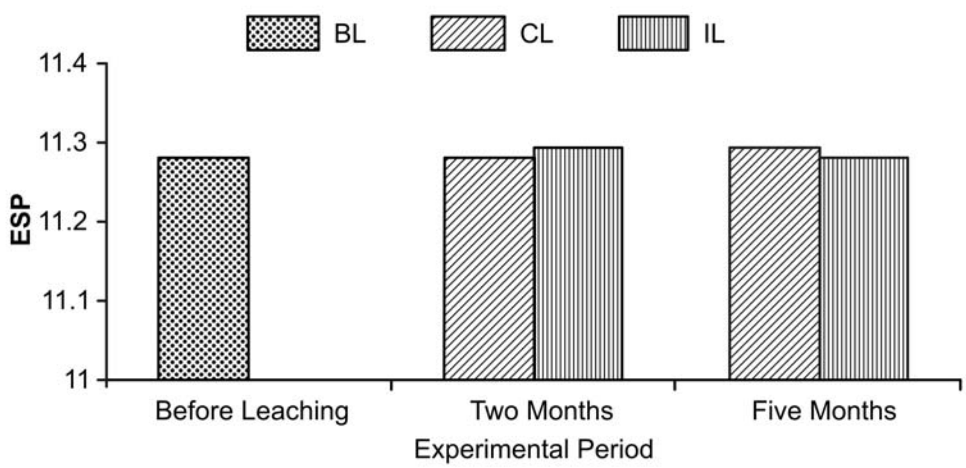

Figure 6 Comparison of ESP before and after leaching for two and five months with CL and IL methods.

The increase in soil pH, SAR and ESP in soil profile after two months of the experimental work under intermittent leaching method was probably due to capillary rise of water, which carried salts in the upward direction, whereas after five months of the experimental work under continuous leaching method might be due to the constant application of water containing salts. These findings are in agreement with those found by Western Fertilizer Handbook (1995) who reported that the leaching will reduce salinity levels in the soil, but will not affect much the soil ESP. Similarly, Qadir *et al*. (1996) suggested that simple leaching cannot reclaim the sodic and saline sodic soils effectively.

Total water consumption

Figure 10 shows the total water consumed by intermittent and continuous leaching methods during the experiment. The results revealed that the total water consumed by continuous leaching was 44% more than that of with intermittent leaching method.

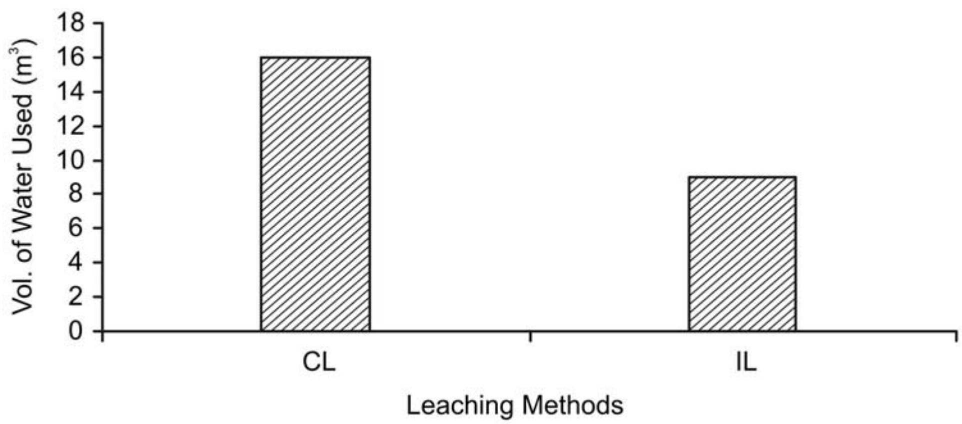

Figure 7. Comparison of the total volume of water consumed by continuous and intermittent leaching methods.

CONCLUSION

The present study was conducted to compare the continuous and intermittent leaching methods for reclaiming a saline soil. The following conclusions can be drawn from this study.

The results of the study suggests that after carrying experiments for two months, continuous leaching method removed 61.59% of salts from the top 0-60 cm soil depth and the intermittent leaching method removed only 46.14% of the salts from the same depth. Whereas after five months of experimental work, intermittent leaching method removed 75.23% of salts from the top 60 cm layer as compared to 64.01% with continuous leaching method. Moreover, intermittent leaching method consumed 44% less water than that of continuous leaching method.

The present study suggests continuous leaching method is the best method to use when time for leaching is a limiting factor. However, for better results for long duration (up to five months) intermittent leaching methods is more efficient.

Since the soil in experimental plots was clay loam, therefore these suggestions are applicable for only clay loam soils while the results may differ for other types of soil.

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