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Leaching Behaviour and Salt Dynamics in Soil Column of Some Calcareous Vertisols

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ABSTRACT

The leaching behaviour of some calcareous soils , representing soil groups Typic Chromustert,Vertic Ustochrept and Paralithic Ustochrept was carried out in PVC columns of 35 cm long and 10.8 cm internal diameter.The air dried and sieved (2 mm) soils were packed to the bulk density of 1.5 g/cc within these columns.The water was applied to the column through a filter paper placed over it and finally covered it with polythene sheet to check the evaporation loss.Each soil group was replicated three times. The results indicated that the application of 2.5,3.0 and 2.6 pore volumes of water in 0 to 30 cm soil layers in Typic Chromustert,Vertic Ustochrept and Paralithic Ustochrept,respectively reduced the average ECe values below 4 dS/m.The above mentioned amount of water application was sufficient to leach out 97, 97 and 94 per cent salt from the 30 cm soil zone in Typic Chromustert,Vertic Ustochrept and Paralithic Ustochrept soils groups, respectively. Exponential relationships between the ratio of electrical conductivity of saturation extract (dS/m) after and before leaching, respectively and the ratio of depth of applied water for leaching and soil depths decided, respectively were established for these three soils. These relationships revealed that for 80 per cent reduction in soil salinity about 0.64, 0.80 and 0.69 cm leaching water per cm soil depth should be applied for the three respective soil groups.

Introduction

Soil salinization is one of the most serious form of soil degradation which has turned millions of hectares of agricultural land in the country to saline and in turn unfit for economic crop production. Since soluble salts are transported in solution phase ,their distribution and removal can be controlled through proper water management. Salt leaching forms an important aspect of management of salt affected soils in order to obtain a favourable salt distribution in the profile. Leaching prevents salt accumulation and leads to reduce salt build-up in the root zone. The research results (Dahiya *et al.*, 1980; Singh and Bhargava 1995; Singh 1996,1997) reveal that leaching requirements vary with wide range of values i.e. from 0.3 cm/cm to 4.3 cm/cm of soil. Therefore, it is important to work out leaching requirements for different soil types. Distribution and removal of water soluble salts mainly depend on soil type and quantity and methods of water application (Singh 1997). On the basis of laboratory and field experiments of several workers (Singh *et al.*, 1979; Dahyia *et al.*, 1980) have reported that leaching under intermittent application of water is more efficient than that of under ponding, where as some others (Verma and Gupta, 1989) reported that salt removal was independent of modes of water application. Soil characteristics also exert profound effect on salt removal efficiency of applied water (Verma and Gupta,1989). Most of these studies involved coarse textured soils and considered all salts as one component while information on leaching behaviour of fine textured calcareous soils and behaviour of individual ions during leaching is meagre.

In an attempt to evaluate leaching behaviour of some calcareous vertisols, a laboratory experiment was conducted in PVC columns.The purpose of this study was to investigate the leaching requirements and salt dynamics of three different types of calcareous vertisols i.e. Typic Chromustert,Vertic Ustochrept and Paralithic Ustochrept.

Materials and Methods

Surface soil samples (0.0 to 15.0 cm) from three different locations were collected from Kharad watershed of Bhal region, which is situated in central part of western extremity of Gujrat state. The soils mainly belonged to the three soil groups i.e. Typic Chromustert,Vertic Ustochrept and Paralithic Ustochrept.The main characteristics of the Typic Chromustert soil were poorly drained (a member of fine montmorrilonite), very deep, calcareous in nature and developed on weathering basaltic materials. These soils represented deep black soils and comprised one of the dominant soil types of the Bhal area. The sand,silt and clay contents in this soil group were 18, 20 and 62 per cent, respectively, whereas calcium carbonate ($CaCO_3$) content varied from 12 to 14.5 per cent.Vertic Ustochrept soil group represented somewhat poorly drained,deep to very deep, which was calcareous in nature.The lime in powdery form was disseminated in the soil matrix along with hard nodular lime, that increased with depth. The $CaCO_3$ content varied from 17 to 20 per cent and sand, silt and clay contents were 22, 33 and 45 per cent, respectively. Paralithic Ustochrept represented medium black soil, which were moderately well drained, moderately deep, calcareous and developed from basaltic rock. The $CaCO_3$ content varied from 21 to 22 per cent in this soil group and it contained 30, 32 and 38 per cent sand, silt and clay, respectively. The Typic Chromustert soils had initial ECe of 100 dS/m and pH 7.8. The water soluble Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, SO^{4-} and Cl^{-} contents of this soil were 99.3, 163.4, 736.8, 1.5, 8.0, 216.6 and 778.4 mmol/l, respectively. The Vertic Ustochrept soil had initial ECe of 57 dS/m, pH 7.6 and the water soluble Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-} and Cl^{-} contents were 62.4, 157.6, 1.2, 7.2, 186.8 and 376 mmol/l, respectively, whereas the Paralithic Ustochrept had initial ECe value of 99 dS/m and pH 7.1. This soil contained 115.2, 268.4, 608.5, 1.6, 9.5, 186 and 795.0 mmol/l water soluble Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-} and Cl^{-}, respectively.

In PVC columns of 35 cm long and 10.8 cm internal diameter dried 2 mm sieved soil samples were compacted uniformly to a bulk density 1.5 ± 0.2 cm Mg/m^3 upto column length of 30 cm. Each column was positioned vertically in a wooden stand. The leaching was applied to the soil column on each day at 9.30 a.m. To check the evaporation loss, each column was covered with polythene sheet on the top after application of water. Three replications were run for each column. Effluents were collected and its EC values were determined in each day.At the end of experiment the water soluble ions in the soils were determined by using method suggested by Richards (1954).

Results and Discussion

Salinity profile after leaching with different quantity of water have been presented in the table 1. It was indicated that as the amount of leaching water increased, the salt load decreased in all the three soils. In case of Typic Chromustert soil after leaching two pore volumes of water, salt content reduced from 100 dS/m to 1.1, 1.2, 1.9, 7.6, 18.0 and 22.9 dS/m in 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm soil layers, respectively. With similar amount of leaching water in Vertic Ustochrept soil salt content reduced from 57 dS/m to 0.8, 1.0, 2.7, 6.2, 7.4 and 8.9 dS/m in the similar layers, respectively whereas in Paralithic Ustochrept soil with similar quantity of water the salt content reduced from 99 dS/m to 1.2, 2.5, 2.9, 4.3, 16.4 and 18.5 dS/m,in 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm soil layers, respectively. After leaching 2.5 pore volume of water in all the three soils the salt content in 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm soil layers reduced to 0.8, 1.3, 2.3, 10.2 and 13.6, dS/m, respectively in Typic Chromustert and to 0.8, 1.0, 2.7, 6.2, 7.4 and 8.9 dS/m, respectively in Vertic Ustochrept soil, whereas in Paralithic Ustochrept soil the salt content reduced to 1.2, 1.6, 2.9, 3.8, 7.8 and 16.3 dS/m, in the respective depths. The results indicated that in case of Vertic Ustochrept soil leaching of 2.5 pore volumes of water were sufficient to reduce the salt load below 4 dS/m in 0-30 cm soil zone, whereas in case of Typic Ustochrept soils, the same amount of water was not sufficient to reduce the salt content below 4 dS/m. The reason was that in these two soils the initial salt content was just double than that of in Vertic Ustochrept soil.

After leaching three pore volumes of water in the Typic Chromustert soil ,the salt content reduced to 0.8,0.9,1.0,1.3 ,1.9 and 2.2 dS/m,in 0-5,5-10,10-15,15-20,20-25,25-30 cm soil layers,respectively.Study revealed that for Typic Chromustert soil, leaching of three pore volumes of water was sufficient to bring down the salt content below 4dS/m.In case of Paralithic Ustochrept soil leaching of 2 to 6 pore volumes of water reduced the salt content to 1.1, 1.2, 2.4, 3.0, 6.6 and 10.2 dS/m, in 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm, soil layers, respectively.

It was also indicated from the study that in Paralithic Ustochrept soil 2.5 pore volumes of water were sufficient to bring down the salt content below 4.0 dS/m only in 0-20 cm soil layers. The data of SAR and ESP after leaching different quantities soil water have been presented in table 1(a,b,c). The result revealed that leaching reduced SAR as well as ESP in all the three studied soils indicating no prospect of soil sodification for these soils after leaching.

Leaching with 2.5 pore volumes of water reduced average cations i.e. Ca^{2+},Mg^{2+},Na^{+} and K^{+} from 62.4, 157.6, 322.5 and 1.2 mmol/l to 2.7, 2.8, 14.8 and 0.25 mmol/l,respectively in Vertic Ustochrept soil. Similarly anions i.e. CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, Cl^{-} reduced from 7.2,186.8 and 376.0 mmol/l to 2.4,4.4 and 13.2 mmol/l,respectively.In case of Typic Chromustert soil after leaching the same amount of water ,the water soluble cations reduced from 99.3, 163.9, 736.8 and 1.5 mmol/l to 4.8, 13.3, 31.0, and 1.5 mmol/l and anions from 8.0, 216.6

Table 1. Residual ECe,SAR and ESP after leaching different amounts of water

Soil depth(cm)	ECe (dS/m)	SAR	ESP	ECe (dS/m)	SAR	ESP	ECe (dS/m)	SAR	ESP
(a) 1.5 pore volume									
0-5	2.2	5.2	6.0	1.2	2.8	2.8	1.3	3.9	4.3
5-10	3.8	8.2	9.8	2.2	5.4	6.3	3.5	8.1	9.7
10-15	6.1	17.4	19.6	6.4	11.5	13.8	6.0	11.8	13.9
15-20	21.0	41.1	37.2	9.0	24.3	25.7	19.5	38.8	35.9
20-25	50.0	56.3	45.0	18.2	0.7	37.0	32.9	37.4	35.0
25-30	95.0	62.2	47.5	26.0	47.3	40.7	71.0	54.6	44.2
(b) 2.0 pore volume									
0-5	1.1	2.7	2.7	0.8	2.4	2.2	1.2	3.8	4.2
5-10	1.2	2.3	2.1	1.0	3.0	3.1	2.5	5.9	6.9
10-15	1.9	4.0	4.4	2.7	4.1	4.6	2.9	7.3	8.7
15-20	7.6	12.5	14.7	6.2	16.0	18.3	4.3	12.6	14.8
20-25	18.0	32.1	31.5	7.4	18.1	20.3	16.4	37.6	35.1
25-30	22.9	31.0	30.8	8.9	25.5	26.7	18.5	40.3	36.8
(c) 2.5 pore volume									
0-5	0.8	2.0	1.7	0.7	2.1	1.8	1.2	4.9	5.0
5-10	1.3	5.4	6.3	0.8	2.1	1.8	1.6	5.1	5.9
10-15	1.3	4.7	5.4	1.0	2.5	2.4	2.9	13.3	15.5
15-20	2.3	4.5	5.1	2.5	12.1	14.2	3.8	11.9	14.0
20-25	10.2	13.5	15.7	3.5	17.0	19.2	7.8	11.3	13.4
25-31	13.6	21.1	23.0	3.7	16.3	18.6	16.3	32.4	31.8

and 778.4 mmol/l to 5.4, 10.5 and 33.5 mmol/l, respectively. Whereas in Paralithic Ustochrept soil the cations reduced from 45.2, 268.4, 608.5 and 1.6 mmol/l to 3.5, 12.0, 40.5 and 0.23 mmol/l,respectively and anions from 9.5, 186.0 and 795.0 mmol/l to 4.8, 9.6 and 41.7 mmol/l, respectively for the same amount of leaching water .The dimensionless leaching curves between EC/EC_0(EC_0 is the initial soil ECe and EC is the ECe of soil after leaching) versus DW/DS (DW is the depth of water and DS is the depth of soil) with respect to desalinization of 0-10, 0-20 and 0-30 cm soil layers for all the three soils have been worked out.The following empirical relationships are drawn from the experimental data for different soils.

Typic Chromustert

EC/EC_0 = 0.1045(DW/DS)-1.7096 r = -0.8486

Vertic Ustochrept:

EC/EC_0 = 0.1450(DW/DS)-1.4551 r = -0.9658

Paralithic Ustochrept:

EC/EC_0 = 0.113(DW/DS)-1.5496 r = -0.9339

These relationships revealed that for 80 per cent reduction in soil salinity,about 0.64,0.80 and 0.69 cm leaching water per cm soil depth should be applied.These equations can be used for prediction of total leaching requirements for a given crop on a given soil type provided the optimum salinity tolerance limit of the crops,its effective root zone and critical water table depth of that particular soil are known.Among all the soils Vertic Ustochrepts need more amount of water per cm of soil.All the soils are clayey in nature and need more time to pass the required quantity of water.Therefore,all possible water conservation measures should be adopted for these soils to conserve the maximum amount of water for a longer duration.

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