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Effect of subsurface drainage on removal of salts from Swell-Shrink soils

SM Jadhao and AS Patil

Abstract
Aim: The present investigation was conducted to assess the removal of salts from swell-shrink soil through subsurface drainage.
Methodology: For assessing the salt removal through drainage water an experiment was conducted with different treatments of sub-surface drainage *viz.*, 15, 30, 45 and 60 m spacing and 60, 90 and 120 cm depth. Monthly the leachate samples were collected from June 2001 to July 2002 and analyzed for different salinity parameters.
Results: The maximum concentration of ions in leachate was recorded with 15 m drain spacing at all three depths i.e. 60, 90 and 120 cm. There was no much effect on pH of leachate but the EC of the leachate increased from July 2001 to January 2002 and again showed decreasing trend thereafter upto July 2002 in all the treatments. The $Ca^{2+}+Mg^{2+}$ content was highest in first five leachates and decreased thereafter. The removal of sodium potassium, chloride, bicarbonate and sulphate showed increasing trend from July 2001 to January 2002 and decreased thereafter.
Interpretation: The 15 m drain spacing at all three depths found effective in removal of salts from swell-shrink soil.

Keywords: Swell-shrink, subsurface, drainage, effluent pH, EC, $Ca^{2+}+Mg^{2+}$, Na^+, Cl^-, HCO_3^-, SO_4^{-2}

Introduction
The introduction of canal irrigation and seepage resulted in rise of water table to the crucial 1 to 1.5 m depth in large areas. Every rise of water table is accompanied by an increase in the mineralization and dissolution of salts from the upper salt rich horizons which are ultimately drawn upto the surface by evaporation. Under perennial irrigation some soils developed salt problems according to the nature and concentration of various salts particularly the chlorides, sulphates and bicarbonates of sodium (Zende and Hapse, 1986) [6].
In the different irrigation commands of Maharashtra state, it is reported that 48 to 68 per cent area have water table within three meter (Zende, 1968) [5] and about 37 thousand hectares are salt affected which is concentrated in the command areas, where high water demanding sugarcane cultivation is being practiced. Introduction of canal irrigation in this area proved beneficial for few decades, it has showed problems of drainability and soil degradation. The ground water table in this area has been rising steadily and thereby bringing the dissolved salts to the surface especially in areas with low topography. These soils having high swell-shrink potential and poor drainability.

Methods and Materials
Laying of subsurface drainage system
The subsurface drains were laid out over 8.1 ha area with different spacing i.e. 15, 30, 45 and 30 m and depth 60, 90, 120 cm.

Lateral drain

Material	:	PVC, corrugated perforated pipe
Perforation size	:	20 x 15 mm
Perforation No.	:	120 per m length
Diameter	:	80 mm OD
Slope given	:	0.2 per cent

Collector/Main drain

Material	:	PVC, corrugated non-perforated pipe

Diameter : 100 mm OD
Slope given : 0.1 per cent

Manholes
Depth of manholes: according to the depth of drain
1. 100 cm for 60 cm depth
2. 130 cm for 90 cm depth
3. 160 cm for 120 cm depth

Diameter of manhole: 1 m (inside)

Results and Discussions

pH of drainage water

The presented data (Table1) revealed that the pH values of drainage water collected from saline sodic soils where the sub-surface drainage system was installed, increased from July 2001 to December 2001 and it decreased from January 2002 to July 2002 in all the four treatment combinations of subsurface drainage.

From this data it is observed that the pH values of leachate increased with 45 m drain spacing at all its three depths i.e. 60, 90 and 120 cm. The removal of soluble salts through drainage water had reflected variation in pH at different depths. Similar results were reported by Bharambe *et al*. (1992) [1].

Electrical conductivity of drainage water

The data presented in Table 2 and Fig. 1showed that the electrical conductivity of the drainage water showed increasing trend from July 2001 to January 2002 and decreased thereafter i.e. from February 2002 to July 2002 in all the treatments of subsurface drainage with respect to spacing and depth. This fluctuation in the electrical conductivity of drainage water might be due to the opening and closing of canal. This reflects that up to the month of January the canal was closed hence the drainage out flow was less and concentration of salt was more and from February to July the canal was open and the drainage outflow was more and the concentration of salt was less.

The removal of salts was more with 15 m drain spacing at all the three depths i.e. 60, 90 and 120 cm followed by 30 m drain spacing. Similar results were reported by Mark and Grismer (1993) [3].

Calcium content in drainage water

It would be seen from the table 3.that there was no specific trend was observed in the calcium content in drainage water from July 2001 to July 2002 with the installation of subsurface drainage for reclamation of saline sodic swell shrink soil. But the removal of calcium was more in the treatment of 15 m drain spacing and 60 cm depth followed by 90 cm depth and least removal of calcium was recorded with 60 m drain spacing. This might be due to the release of native calcium in this calcareous soil.

Magnesium content in drainage water

The removal of magnesium started from July 2001 but there was no any specific trend in removing of magnesium through drainage water was recorded from July 2001 to July 2002 (Table 4). The maximum removal of magnesium was recorded with 15 m drain spacing and it was total 68.6, 57.4 and 57.3 meL^{-1} at 60, 90 and 120 cm drainage depths respectively.

The minimum removal of magnesium was recorded with 60 m drain spacing. The removal of magnesium through drainage water might be due to the release of more magnesium from soil. Hence the removal of magnesium increased as the drainage spacing decreased.

Sodium content in drainage water

The removal of water soluble sodium in drainage water showed increasing trend from July 2001 to December 2001 and decreased thereafter from January 2002 to July 2002 in all the four sub-surface drainage treatments (Table 5 and Fig. 2). This might be due to the opening and closing of canal.

The maximum removal of sodium through leachate was recorded with 15 m drain spacing i.e. 102.7, 108.2 and 134.4 meL^{-1} in 60, 90 and 120 cm drainage depth respectively but the 120 cm depth found superior over 60 and 90 cm. This maximum removal of sodium in this treatment might be due to the drainage coefficient was found enough in removal of water soluble sodium through leachate. Similar results were reported by Sharma *et al*. (1994) [4]. The removal of sodium in 30 m drain spacing was 69.8, 89.4 and 109.2 meL^{-1} with 60, 90 and 120 cm depth respectively. The minimum removal was recorded with 60 m drain spacing.

In a nutshell it was observed that removal of sodium was more with narrowest spacing and minimum with widest spacings.

Potassium content in drainage water

From the data (Table 6) it is observed that the removal of potassium was more from July 2001 to January 2002 and less from February 2002 onwards but there was no specific trend was observed regarding the potassium content in drainage water with respect to time.

The presented data revealed that the potassium content in leachate was maximum with 15 m drainage spacing and 60 cm depth i.e. 1.76 meL^{-1}, followed by 90 cm depth i.e. 1.15 meL^{-1} and with 120 cm the potassium content was 0.79 meL^{-1}. This might be due to the least solubility of potassium. The minimum removal of potassium was observed with 60 m drain spacing indicating the drainage out flow was decreased as the drain spacing increased.

Chloride content in drainage water

The removal of chloride through drainage water was increased from July 2001 to January 2002 and it showed decreasing trend from February 2002 to July 2002 in all the treatments of subsurface drainage (Table 7 and Fig. 3). This fluctuation in the removal of chloride through drainage water might be due to the outflow of drainage water, when the outflow was smaller the concentration of chloride was highest and lowest with largest outflow.

The removal of chloride was recorded highest with 15 m drain spacing i.e. 66.2, 69.0 and 154.3 meL^{-1} with 60, 90 and 120 cm drainage depths, respectively followed by 30 m drain spacing i.e. 45.4, 59.0 and 83.4 meL^{-1} with 60, 90 and 120 cm drain depths respectively. This might be due to the drain out flow was highest for narrowest spacing and lowest for largest spacing and because of the more solubility of chloride. This findings are in accordance with the findings of Sharma *et al*. (1994) [4].

Bicarbonate content in drainage water

The bicarbonate content in drainage water showed increasing trend from July 2001 to December 2001 and it showed decreasing trend from January 2002 to onward in all the treatments with respect to spacing and depth (Table 8). This fluctuation may be due to the opening and closing of canal.

From this data it is observed that the removal of bicarbonate was more with 15 m drain spacing i.e. 114.2, 106 and 108.7 meL^{-1} with 60, 90 and 120 cm drainage depths respectively, followed by 30 m drain spacing and the removal of bicarbonate in this treatment was 97.4, 95.4 and 79.1 meL^{-1} with 60, 90 and 120 cm drainage depths respectively. Similar observations were reported by Kundu and Singh (2001) [2].

In short the subsurface drainage found beneficial in removing of bicarbonate through drainage water and 15 m drain spacing was superior in this regard.

Sulphate content in drainage water

The sulphate removal was increased from July 2001 to January 2002 and it decreased from February 2002 to July 2002 (Table 9 and Fig. 4).

The removal of sulphate was highest with 15 m drain spacing and the concentration of sulphate was 44.6, 55.4 and 96.4 meL^{-1} at 60, 90 and 120 cm drainage depths respectively during the period of one year and 120 cm depth found superior over all other depths. With 30 m drain spacing the concentration of sulphate was 26.8, 42.4 and 76.4 meL^{-1} at 60, 90 and 120 cm drainage depths respectively. The minimum removal of sulphate was recorded with 60 m drain spacing i.e. 20.8, 23.4 and 26.84 meL^{-1} at 60, 90 and 120 cm drainage depths respectively. This might be due to the more solubility with Na_2SO_4.

In general it was observed that the removal of sulphate through drainage water was increased with decreasing drainage spacing.

Adjusted SAR of drainage water

The adjusted SAR increased from July 2001 to Jan. 2002 in 15 m drain spacing and from July 2001 to Dec. 2001 in rest of the treatments (Table 10). The maximum adj. SAR was recorded with 15 m drain spacing followed by 30 m drain spacing indicating the drainage outflow was maximum for less spacing which was found better in removing of sodium through leachate.

Table 1: Effect of subsurface drainage on pH of drainage water

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02
	15 m drain spacing												
60 cm	7.91	8.12	8.20	7.90	7.79	8.42	8.20	8.01	8.10	8.53	8.20	8.08	8.00
90 cm	8.16	8.11	8.16	7.86	7.76	8.22	8.00	8.10	8.04	8.40	8.10	8.32	8.04
120 cm	8.18	8.16	8.20	7.93	7.94	8.23	8.08	8.00	7.94	8.60	8.05	8.38	8.48
	30 m drain spacing												
60 cm	8.20	8.12	8.25	7.91	8.66	8.20	8.13	8.25	7.96	8.08	8.08	8.36	8.44
90 cm	8.23	7.92	8.30	8.12	8.14	8.23	8.25	8.30	8.06	8.12	8.00	8.35	8.64
120 cm	8.26	8.36	8.36	8.07	7.77	8.30	8.22	8.39	8.02	8.10	8.08	8.42	8.25
	45 m drain spacing												
60 cm	8.16	8.20	8.24	8.19	8.67	8.31	8.30	8.50	8.20	8.12	8.04	8.40	8.62
90 cm	8.29	8.24	8.24	8.23	8.16	8.28	8.32	8.48	7.94	8.02	8.00	8.18	8.65
120 cm	7.94	8.50	8.65	8.27	8.06	8.14	8.22	8.26	8.11	8.20	8.30	8.20	8.37
	60 m drain spacing												
60 cm	8.21	8.20	8.40	8.38	8.52	8.15	8.20	8.11	8.34	8.50	810	8.30	8.04
90 cm	8.20	8.10	8.25	8.29	8.61	8.08	8.20	8.20	8.05	8.30	8.14	8.38	8.10
120 cm	8.15	8.40	8.35	8.24	8.47	8.18	8.15	7.92	8.02	8.40	8.20	8.48	8.30

Table 2: Effect of subsurface drainage on calcium content in drainage water (meL^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	2.4	2.2	2.0	1.4	4.0	2.3	3.0	2.9	2.2	3.0	1.8	1.0	0.6	28.8
90 cm	2.6	2.8	2.5	2.5	3.8	3.2	2.7	3.0	4.0	1.9	1.5	1.4	1.0	32.9
120 cm	2.5	2.4	2.0	1.9	1.4	2.9	1.0	2.5	4.7	5.3	2.0	1.4	1.0	31.0
	30 m drain spacing													
60 cm	1.9	2.6	2.5	2.4	2.2	3.2	2.0	2.0	2.5	2.2	2.0	1.0	0.5	27.0
90 cm	1.9	4.0	4.0	3.2	1.9	6.0	1.7	2.1	2.0	1.9	2.0	1.0	0.9	32.6
120 cm	1.4	1.2	1.2	1.2	3.0	5.2	2.6	2.5	3.0	1.3	2.4	1.4	0.5	26.9
	45 m drain spacing													
60 cm	1.8	1.3	1.5	1.7	1.1	3.3	1.0	1.4	2.1	2.7	1.4	1.3	0.6	21.2
90 cm	5.0	4.8	3.0	2.2	2.1	2.1	1.9	1.0	1.4	1.9	1.2	1.2	0.9	28.7
120 cm	1.6	1.4	1.2	1.0	1.2	1.8	2.2	1.4	1.2	1.0	1.0	0.8	0.6	16.4
	60 m drain spacing													
60 cm	0.8	1.4	0.8	1.1	1.0	2.2	1.1	1.8	2.3	1.8	2.0	2.0	0.7	29.0
90 cm	1.4	2.4	2.3	2.3	2.2	3.1	2.1	1.4	2.5	1.6	2.1	1.1	0.5	25.0
120 cm	2.3	2.2	2.0	1.9	1.3	2.8	1.3	1.6	1.5	1.5	1.3	1.0	0.8	21.5

Table 3: Effect of subsurface drainage on magnesium content drainage water (meL^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	4.0	5.8	4.0	6.7	10.4	5.9	12.9	5.4	3.3	2.8	2.0	3.0	2.4	68.6
90 cm	3.1	4.0	3.9	3.9	5.7	7.0	4.1	7.0	9.2	1.7	2.9	2.7	2.2	57.4
120 cm	2.5	4.8	5.0	4.1	5.4	6.5	5.6	6.7	6.8	2.4	2.4	2.0	3.1	57.3
	30 m drain spacing													
60 cm	2.1	2.4	2.2	4.7	4.7	4.8	4.5	5.7	3.2	2.8	4.2	3.1	3.0	47.4
90 cm	3.6	3.4	2.2	2.2	3.7	5.0	5.2	4.2	2.4	3.0	4.4	3.3	2.6	45.2
120 cm	4.1	3.5	3.1	2.4	4.3	7.3	5.4	5.7	2.5	1.6	2.8	3.1	2.1	47.9
	45 m drain spacing													
60 cm	1.8	1.4	1.6	5.2	3.0	6.3	4.3	2.2	2.7	2.6	2.5	2.5	1.6	37.7
90 cm	3.9	3.8	2.6	3.3	3.4	4.8	4.4	4.6	2.6	2.8	3.0	2.2	2.4	43.8
120 cm	2.5	2.6	2.4	4.4	5.5	5.8	5.5	4.6	3.4	3.2	3.4	2.6	2.2	48.1
	60 m drain spacing													
60 cm	2.4	2.3	2.2	3.7	3.0	6.7	3.1	2.2	2.5	2.0	3.1	2.6	2.4	38.2
90 cm	2.9	2.9	2.3	2.2	3.5	2.9	2.3	4.9	3.2	2.7	2.7	2.8	1.9	40.2
120 cm	1.8	1.6	2.0	4.7	5.1	3.8	3.1	3.8	2.0	3.7	3.0	3.0	2.7	40.3

Table 4: Effect of subsurface drainage on potassium content in drainage water (meL^{-1})

Depth of drainage	July 01	Aug01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	0.14	1.51	0.06	0.12	0.17	0.12	0.15	0.15	0.23	0.04	0.02	0.02	0.03	1.76
90 cm	0.11	0.23	0.07	0.11	0.14	0.12	0.15	0.08	0.04	0.03	0.02	0.02	0.03	1.15
120 cm	0.05	0.10	0.08	0.09	0.04	0.13	0.13	0.05	0.03	0.04	0.02	0.01	0.02	0.79
	30 m drain spacing													
60 cm	0.07	0.10	0.08	0.07	0.05	0.07	0.05	0.08	0.17	0.01	0.01	0.02	0.01	0.79
90 cm	0.04	0.18	0.08	0.08	0.06	0.07	0.03	0.05	0.02	0.01	0.02	0.02	0.02	0.68
120 cm	0.06	0.15	0.08	0.10	0.17	0.08	0.05	0.08	0.01	0.02	0.03	0.02	0.03	0.88
	45 m drain spacing													
60 cm	0.17	0.08	0.07	0.06	0.07	0.05	0.05	0.02	0.02	0.01	0.01	0.02	0.01	0.64
90 cm	0.04	0.23	0.07	0.07	0.09	0.06	0.07	0.06	0.02	0.01	0.01	0.01	0.01	0.75
120 cm	0.04	0.10	0.07	0.06	0.04	0.06	0.08	0.08	0.02	0.02	0.02	0.02	0.04	0.73
	60 m drain spacing													
60 cm	0.08	0.21	0.06	0.05	0.06	0.04	0.05	0.01	0.01	0.01	0.02	0.01	0.02	0.63
90 cm	0.06	0.20	0.07	0.06	0.07	0.04	0.04	0.03	0.02	0.01	0.01	0.02	0.02	0.65
120 cm	0.06	0.05	0.06	0.06	0.07	0.04	0.07	0.05	0.01	0.01	0.02	0.02	0.03	0.55

Table 5: Effect of subsurface drainage on sulphate content in drainage water (meL^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	1.2	1.8	1.8	2.0	2.2	18.0	22.4	4.2	6.0	2.8	1.0	0.6	0.6	44.6
90 cm	1.6	2.2	3.2	3.4	3.6	17.6	23.4	5.6	6.0	6.0	1.2	0.8	0.8	55.4
120 cm	1.4	8.8	10.0	11.6	16.4	14.4	17.0	9.0	2.8	2.6	1.2	0.8	0.4	96.4
	30 m drain spacing													
60 cm	1.4	1.4	1.8	1.2	1.8	8.6	2.8	1.2	3.0	1.2	0.8	0.8	0.8	26.8
90 cm	2.2	2.2	2.6	5.0	5.6	8.4	3.4	3.6	2.8	2.4	2.0	1.8	0.4	42.4
120 cm	1.6	10.6	8.8	9.0	11.0	11.4	12.0	3.2	2.8	1.8	1.8	1.8	0.6	76.4
	45 m drain spacing													
60 cm	1.6	1.4	1.6	1.9	2.2	12.4	1.6	2.8	2.8	1.4	0.4	0.4	0.4	28.1
90 cm	1.4	0.4	1.0	0.6	1.0	5.8	2.4	5.2	4.0	1.4	1.0	0.4	0.2	24.8
120 cm	1.8	1.4	2.2	2.0	2.2	14.2	2.8	4.8	4.2	1.4	0.6	0.6	0.2	38.4
	60 m drain spacing													
60 cm	1.2	1.0	1.8	1.8	1.8	6.0	2.4	1.0	1.0	1.2	0.6	0.4	0.6	20.8
90 cm	1.6	0.6	0.4	0.6	1.2	7.8	2.2	2.4	3.2	1.6	0.8	0.6	0.4	23.4
120 cm	1.4	1.2	1.4	2.4	2.4	6.2	2.2	6.4	1.0	1.4	0.4	0.4	0.4	26.8

Table 6: Effect of subsurface drainage on Bicarbonate content in drainage water (meL^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	10.0	9.3	9.0	10.1	16.8	9.8	18.8	13.1	6.9	6.0	5.2	4.2	5.0	114.2
90 cm	6.0	7.2	8.1	8.1	10.1	11.2	11.0	10.4	13.0	8.0	5.0	4.0	3.9	106.0
120 cm	5.3	7.8	8.0	8.0	8.2	14.1	9.0	7.1	14.0	14.0	5.1	4.2	3.9	108.7
	30 m drain spacing													
60 cm	1.0	3.0	2.0	6.8	4.2	6.9	6.0	3.2	6.0	6.3	5.8	4.1	3.0	97.4
90 cm	5.6	6.0	6.2	9.2	10.2	7.9	8.0	6.4	6.0	5.2	5.2	5.9	3.6	95.4
120 cm	4.9	5.	5.6	6.8	8.0	8.3	7.9	6.8	6.0	5.0	6.0	4.9	3.9	79.1
	45 m drain spacing													
60 cm	4.0	4.8	3.9	5.1	6.0	7.7	6.5	6.4	6.0	5.3	6.2	5.4	3.6	70.9
90 cm	9.0	9.9	7.1	8.2	9.2	9.7	10.0	6.2	4.9	6.2	5.2	4.2	3.8	93.6
120 cm	5.3	5.1	6.2	5.0	7.5	10.3	9.0	6.0	5.0	6.0	5.0	4.0	3.4	77.8
	60 m drain spacing													
60 cm	4.4	5.2	5.9	6.8	6.9	7.2	6.2	5.4	6.2	5.0	5.9	4.9	3.6	73.6
90 cm	5.0	7.8	7.6	6.8	7.2	6.5	6.0	5.3	6.1	6.1	5.3	4.8	4.0	78.5
120 cm	3.6	3.8	4.9	6.0	9.3	6.9	7.5	7.2	6.3	5.0	7.2	6.0	5.0	78.7

Table 7: Effect of subsurface drainage on chloride content in drainage water (meL^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total
	15 m drain spacing													
60 cm	1.38	2.36	2.5	2.91	10.10	13.60	18.75	9.30	7.77	3.05	1.66	1.66	1.25	66.23
90 cm	1.38	1.52	1.66	4.16	8.20	14.20	18.33	9.58	11.40	4.72	1.25	1.11	1.52	69.03
120 cm	1.94	13.80	14.70	16.70	16.80	13.90	20.10	8.33	2.50	1.25	1.66	1.52	2.08	154.36
	30 m drain spacing													
60 cm	2.22	1.25	1.38	2.77	6.00	11.40	13.88	6.25	4.16	1.52	1.66	1.66	1.25	45.4
90 cm	1.60	2.08	2.63	3.61	7.50	12.40	11.94	5.97	2.50	3.33	2.08	1.80	2.63	59.07
120 cm	1.52	7.91	10.40	18.10	9.2	10.80	17.91	6.25	4.16	1.94	1.94	1.94	1.38	83.45
	45 m drain spacing													
60 cm	1.25	1.38	1.52	1.52	4.20	11.70	12.50	2.91	3.88	1.25	2.50	2.08	1.25	37.94
90 cm	1.25	1.38	1.25	1.38	8.00	13.50	16.94	4.44	3.88	1.38	1.25	1.25	1.66	47.56
120 cm	1.66	1.52	1.38	4.86	7.20	12.40	15.69	3.88	3.88	1.80	1.25	1.25	1.25	48.02
	60 m drain spacing													
60 cm	1.52	1.52	1.52	1.38	6.90	12.50	11.52	2.91	5.83	1.38	1.38	1.11	1.66	41.13
90 cm	0.97	1.66	1.94	6.25	7.20	9.44	19.86	3.88	4.30	1.38	2.22	2.08	1.25	52.43
120 cm	1.25	1.38	1.52	1.25	9.30	10.00	15.00	6.66	1.25	1.38	2.08	2.22	1.52	44.81

Table 8: Effect of subsurface drainage on adj.SAR of drainage water

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02
	15 m drain spacing												
60 cm	2.06	4.53	8.47	9.68	9.05	27.00	26.00	16.12	14.54	12.92	5.21	4.20	4.09
90 cm	5.69	3.53	8.90	10.45	10.92	25.25	26.98	17.44	11.84	15.47	4.53	3.98	3.44
120 cm	13.69	10.93	9.80	15.60	26.41	22.82	28.70	20.64	12.00	8.20	6.41	5.94	4.45
	30 m drain spacing												
60 cm	0.82	1.17	2.14	4.62	9.14	22.00	12.22	9.93	10.22	7.90	4.45	5.22	3.92
90 cm	4.87	6.44	6.39	11.90	13.33	24.48	11.25	13.39	9.43	9.26	6.07	6.32	4.92
120 cm	5.35	8.13	15.43	22.81	21.85	17.58	23.87	11.82	9.08	9.94	4.70	3.65	3.42
	45 m drain spacing												
60 cm	1.36	3.86	6.48	3.37	7.01	21.11	8.37	6.14	8.40	5.61	4.83	5.08	4.16
90 cm	1.42	4.47	6.41	5.79	6.83	15.86	14.04	15.64	5.52	6.96	3.43	4.60	4.40
120 cm	3.77	4.41	5.01	6.50	13.65	18.76	11.42	17.27	5.52	6.87	4.62	5.75	5.58
	60 m drain spacing												
60 cm	1.32	0.92	2.36	1.40	6.18	15.08	12.31	5.52	11.25	5.81	6.62	3.63	3.29
90 cm	2.04	2.81	3.09	1.62	6.45	23.85	12.14	14.08	13.07	6.04	3.86	3.92	4.90
120 cm	4.13	3.12	4.62	9.75	14.58	23.47	13.03	12.25	11.33	3.68	3.55	3.89	3.60

Table 9: Effect of subsurface drainage on Electrical conductivity of drainage water (dSm^{-1})

Depth of drainage	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total	Mean	S.D. ±	CV%
	15 m drain spacing																
60 cm	0.80	1.44	1.53	1.83	2.18	4.20	4.90	3.10	1.80	1.50	0.89	0.85	0.83	25.85	1.98	1.26	63.63
90 cm	0.91	1.22	1.32	1.40	2.17	3.40	2.57	2.50	2.50	2.36	0.68	0.66	0.65	24.34	1.87	1.23	65.99
120 cm	0.78	0.91	1.19	1.41	1.56	3.90	2.30	2.30	2.29	2.20	0.77	0.62	0.66	27.54	2.11	1.13	53.84
	30 m drain spacing																
60 cm	0.48	0.50	0.59	0.83	0.91	1.42	1.45	1.42	1.30	0.87	0.89	0.67	0.46	11.79	0.90	0.35	39.67
90 cm	1.20	2.80	2.98	3.78	3.89	1.71	3.00	1.63	1.10	0.96	0.76	0.72	0.53	15.47	1.19	0.83	70.53
120 cm	0.89	1.02	1.07	1.30	1.78	1.62	1.90	1.41	1.00	1.10	0.82	0.80	0.76	25.05	1.92	1.15	60.25
	45 m drain spacing																
60 cm	0.59	0.78	0.85	0.89	0.92	1.92	0.92	0.90	1.10	0.83	0.78	0.68	0.43	11.59	0.89	0.33	37.78
90 cm	0.61	1.06	1.09	1.68	1.73	1.68	1.97	1.63	0.99	0.88	0.81	0.78	0.50	14.95	1.15	0.42	36.89
120 cm	0.50	0.58	0.66	0.70	1.65	1.91	1.99	1.84	1.40	0.93	0.86	0.80	0.73	15.41	1.18	0.48	60.25
	60 m drain spacing																
60 cm	0.40	0.42	0.50	0.71	0.84	1.82	0.94	0.88	1.20	0.80	0.98	0.72	0.42	10.55	0.81	0.38	47.59
90 cm	0.58	0.81	0.87	1.48	1.68	2.01	1.74	1.66	1.40	0.81	0.69	0.60	0.47	14.41	1.10	0.51	47.23
120 cm	0.64	0.69	0.74	0.76	1.19	2.16	1.88	1.72	1.60	0.96	0.74	0.72	0.61	14.80	1.13	0.50	45.12

Table 10: Effect of subsurface drainage on sodium content in drainage water (meL^{-1})

Depth of drainage(cm)	July 01	Aug. 01	Sep. 01	Oct. 01	Nov. 01	Dec. 01	Jan. 02	Feb. 02	Mar. 02	Apr. 02	May 02	June 02	July 02	Total	Mean	S.D. ±	CV%
	15 m drain spacing																
60	1.36	3.36	5.65	6.73	7.60	20.90	17.80	11.30	10.00	9.56	3.26	2.82	2.39	102.7	7.90	5.70	73.00
90	3.69	3.47	6.34	7.17	8.47	19.60	19.10	13.90	9.78	9.02	2.93	2.60	2.17	108.2	8.32	5.73	68.87
120	9.60	8.30	7.06	10.80	18.70	17.00	20.00	17.00	9.56	5.56	4.13	3.69	3.04	134.4	10.34	5.73	55.43
	30 m drain spacing																
60	0.98	0.98	1.73	3.36	7.06	17.6	8.47	8.47	7.17	5.00	3.15	3.26	2.60	69.83	5.37	4.36	81.29
90	3.36	4.78	4.34	7.82	8.26	19.10	8.69	9.13	6.08	6.3	4.34	4.02	3.26	89.48	6.88	3.99	58.04
120	3.69	5.20	4.67	13.90	16.70	15.70	19.10	10.4	6.52	5.97	3.04	2.39	1.95	109.2	8.40	5.77	68.70
	45 m drain spacing																
60	0.87	1.95	4.02	2.50	4.67	17.80	5.43	3.58	5.43	3.80	2.93	3.04	2.17	58.19	4.47	4.05	90.60
90	1.08	3.58	4.67	3.69	4.34	11.30	9.56	10.90	3.58	4.45	2.26	2.60	2.82	64.83	4.98	3.22	64.75
120	2.17	2.60	2.93	4.45	10.00	13.50	9.34	13.00	3.80	4.34	3.26	3.26	3.47	76.12	5.85	3.91	66.90
	60 m drain spacing																
60	0.76	0.54	1.95	0.87	3.80	12.20	7.39	2.93	7.28	3.80	4.45	2.39	1.95	50.31	3.87	3.15	81.26
90	1.30	1.84	1.95	0.98	4.34	17.20	7.82	10.40	8.80	3.69	2.6	2.60	2.82	75.19	5.78	3.63	62.81
120	2.82	1.95	4.34	7.06	10.00	17.00	8.04	8.04	6.52	2.58	2.17	2.50	2.17	66.34	5.10	5.00	98.03

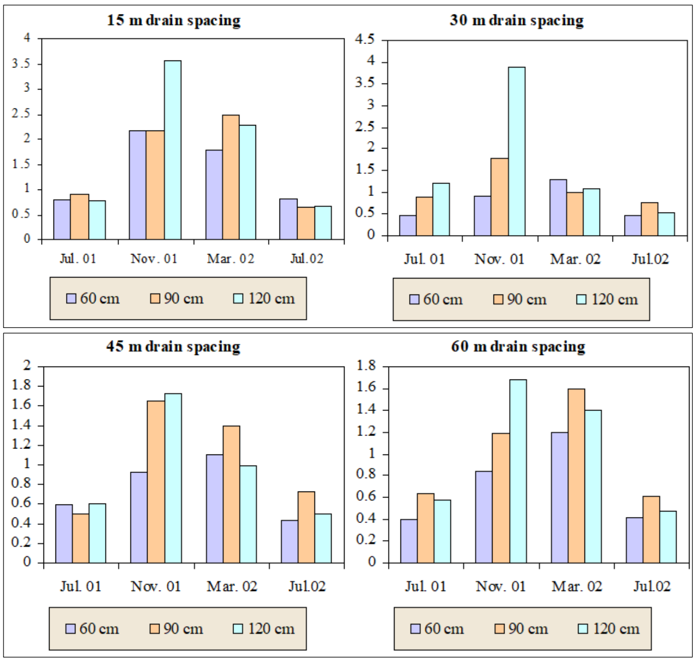

Fig 1: Effect of sub-surface drainage on Electrical conductivity of drainage water (dSm^{-1})
X = Month
Y = EC dSm^{-1}

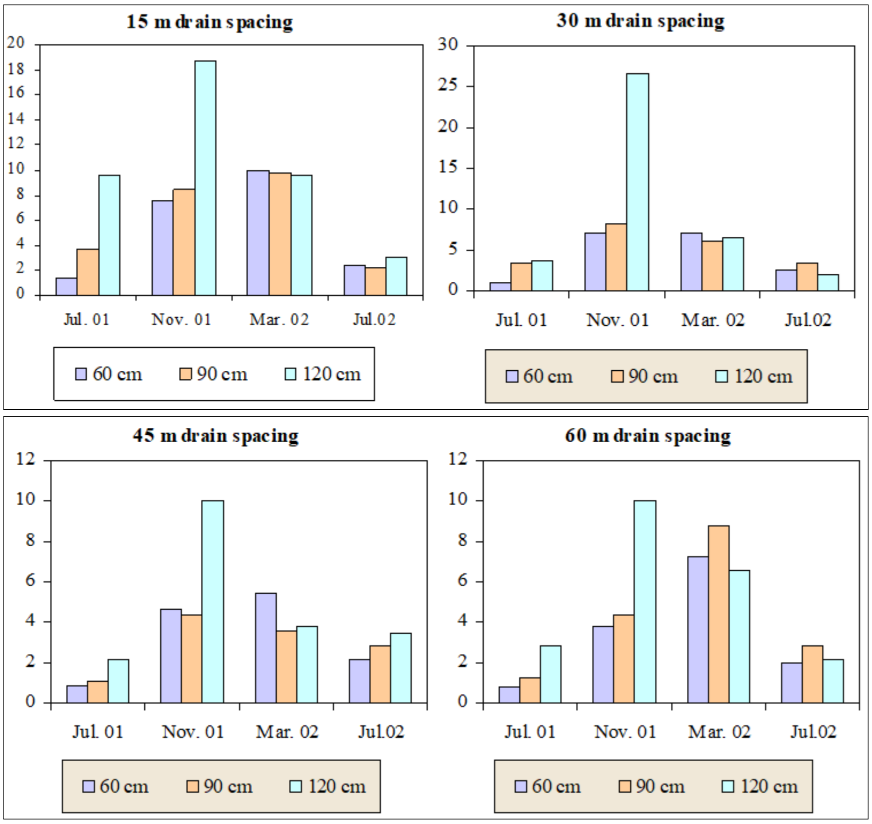

Fig 2: Effect of sub-surface drainage on sodium content (me L^{-1}) in drainage water

X = Month
Y = Na, me L^{-1}

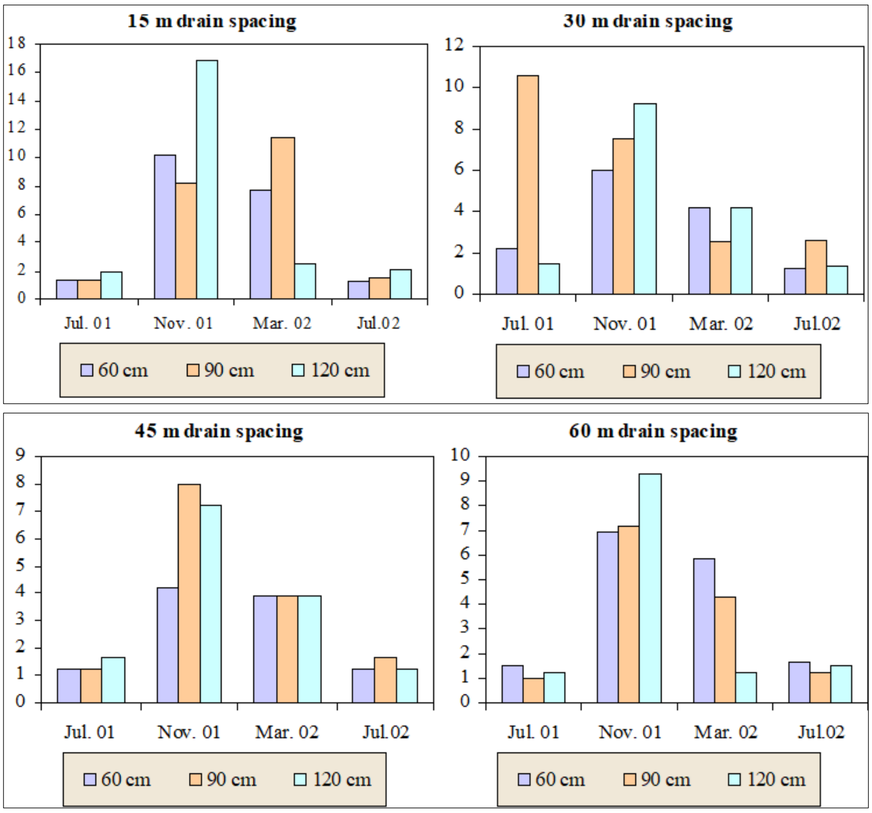

Fig 3: Effect of sub-surface drainage on chloride content (me L^{-1}) in drainage water
X = Month
Y = Chloride content (me L^{-1})

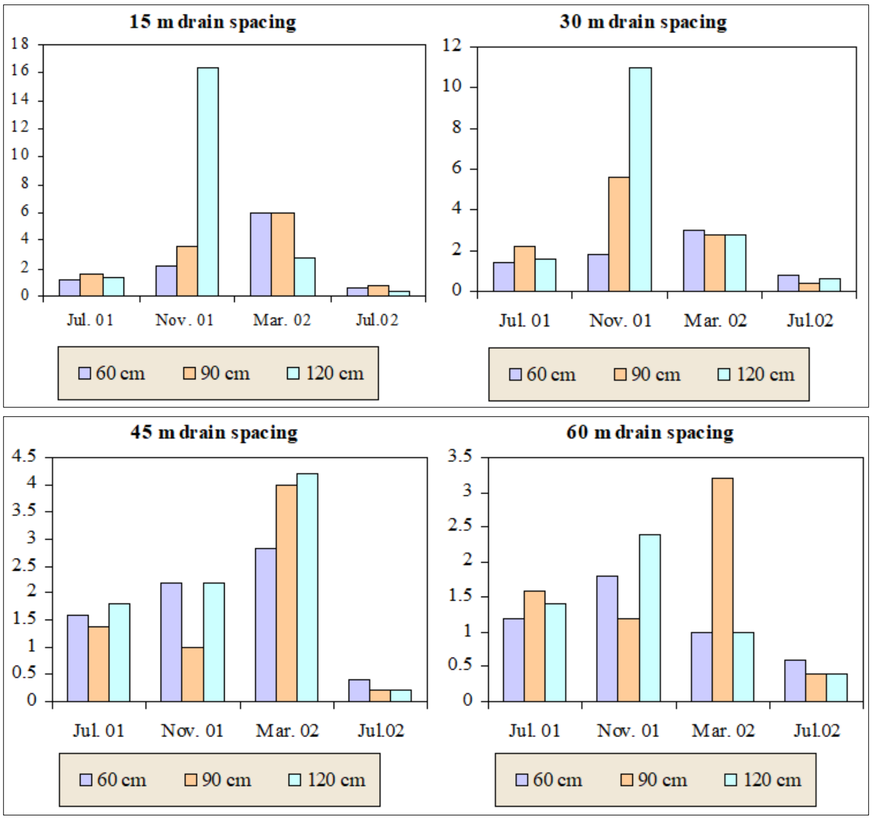

Fig 4: Effect of sub-surface drainage on sulphate content in drainage water (me L^{-1})

X = Month
Y = SO_4^{--} meL^{-1}

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