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Full Length Research Paper

Sugarcane plantation effects on the soil hydraulic conductivity in South-West of Iran

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Soil hydraulic conductivity is a crucial parameter in modeling flow process in soils, water management strategies and determining distance between drainage networks. This study aims to investigate and assess hydraulic conductivity and its variation for soil layers under different tillage practices (fallow with non-leaching process, new cultivation with leached soil, first and second Ratoon) in sugarcane fields of "Mirza Kochak Khan" agro-industry unit, Khuzistan, southern province of Iran. Sampling was conducted by Zigzag Method in four different depths, with five replications at each depth. Soil hydraulic conductivity was measured using Guelph permeameter. Analysis of the results indicated that the trend of changes in this parameter was observed from leached soil to the second Ratoon.

Key words: Soil hydraulic conductivity, sugarcane fields, zigzag method, Guelph permeameter.

INTRODUCTION

Soil hydraulic conductivity is one of the most important soil properties controlling water infiltration and surface runoff, as well as leaching of pesticides from contaminated sites to the ground water. Additionally, hydraulic conductivity is a vital parameter used in predictive hydrological models (Vachaud et al., 1988; Braud et al., 1995; Moustafa, 2000). Hydraulic conductivity depends on soil texture and structure and therefore can vary widely in space (Logsdon and Jaynes, 1996). Hydraulic conductivity also shows a temporal variability that depends on different interrelated factors, including soil's physical and chemical characteristics, climate, land use, tillage operations, activity of soil organisms (Fuentes et al., 2004). Many efforts have been made to indirectly predict this parameter from soil variables routinely measured in the laboratory or in the field (Vereecken et al., 1990; van Genuchten and Leij, 1992). Due to changes in location for saturated hydraulic conductivity, it is, however difficult to determine exact quantity to forecast correct water flow in the soil planning for irrigation and drainage system (Moustafa, 2000).

There are different measurement techniques, to study hydraulic conductivity, including the Guelph permeameter (Asare et al., 1993; Jabro, 1996; Kenny et al., 2002; Xu and Mermoud, 2003), the single-ring pressure infiltrometer (PI) (Prieksat et al., 1994; Azevedo et al., 1998; Ciollaro and Lamaddalena, 1998; Creda, 1999; van Es et al., 1999; Xu and Mermoud, 2003; Bagarello and Sgroi, 2004). However, the Guelph permeameter (GP) method is widely applied as an old technique for measuring some of the most important hydraulic properties of soil such as quantifying the size, distribution, and continuity of soil pore network (Elrick and Reynolds, 1992). The technique involves establishment of an infiltration process which attains steady-states flow conditions after a transient phase characterized by decreasing infiltration rates. Steady-state flow rate is the basis for estimating the field-saturated hydraulic conductivity K_{fs} (Reynolds, 1993). In this study, we used Guelph permeameter for evaluation of sugarcane

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Figure 1. Location of Khuzestan Province.

Table 1. Chemical properties in field A.

Hole	Depth	pH	ECe ($dS.m^{-1}$)	SAR
1	0-30	7.29	29.5	20.4
	30-60	7.35	24.1	17.7
	60-90	7.40	16.3	10.4
	90-120	7.5	10.7	8.5
2	0-30	7.44	18.3	11
	30-60	7.39	16.1	10.2
	60-90	7.57	10.4	8.5
	90-120	7.5	12.7	9.3
3	0-30	7.2	36.8	31.2
	30-60	7.15	40.9	22.5
	60-90	7.41	14.5	16.7
	90-120	7.55	18.3	11.4
4	0-30	7.3	30.8	26.5
	30-60	7.33	18.4	14.7
	60-90	7.48	9.5	11.2
	90-120	7.5	15	14.6
5	0-30	7.43	17.4	29.6
	30-60	7.4	23.3	15.8
	60-90	7.62	12	9.5
	90-120	7.58	14.8	7.8

plantation effects on soil hydraulic conductivity in four different fields.

MATERIALS AND METHODS

This research was carried out in "Mirza Kochak Khan" agro-industry unit, of Khuzestan, Figure 1, a southern province of Iran, which is located at 31°45' to 31°15' N latitude and 48°12' to 48° 40' E longitude. Four sugarcane farms were selected to carry out the study. A fallow field with non leaching process (field A), a field of new cultivation with leached soil (field B), a field which was in the first process of Ratoon (field C), finally the last field was in secondary process of Ratoon (field D). Hydraulic conductivity for each field was measured by using Guelph Permeameter in four different depths (30, 60, 90 and 120 cm) with 5 replications for each depth. Bulk density was measured separately for each layer of the soil with 3 replications each time.

Table 2. Chemical properties in field B.

Hole	Depth	pH	ECe ($dS.m^{-1}$)	SAR
1	0-30	7.41	2.9	7.6
	30-60	8	1.7	11.3
	60-90	7.73	2.4	10.6
	90-120	7.45	3	6
2	0-30	7.6	3.5	9
	30-60	7.91	2.4	12.2
	60-90	7.54	2.9	9.2
	90-120	7.46	4.9	8.8
3	0-30	7.38	4.2	9.3
	30-60	7.43	3	10.5
	60-90	7.8	2.5	10.6
	90-120	7.55	4.8	9.5
4	0-30	8	2.5	11.1
	30-60	8.11	2.8	10.7
	60-90	7.77	3.1	9.8
	90-120	7.52	4.4	9.6
5	0-30	7.91	1.9	8.9
	30-60	7.8	2.8	8.3
	60-90	7.64	3.5	9.4
	90-120	7.57	4.8	8.7

Chemical properties

For each soil sample the following chemical properties were taken as Tables 1, 2, 3 and 4. The amount of acidity (pH), extract electrical conductivity (ECe) and sodium adsorption ratio (SAR). The soil samples taken from the "Mirza Kochak Khan" fields are all considered in Tables 1, 2, 3 and 4.The percentage frequencies of ECe values for each field are shown in Figure 2. As shown in Figure 2, 40 and 60% of ECe in field A are classified as being saline and very saline soil respectively. In field B, 10 and 65% of ECe are classified as non saline and slightly saline soil respectively and 25% as moderately saline soil. In field C, 25 and 65% of ECe are classified as non saline and slightly saline soil respectively and 10% as moderately saline soil. Finally in field D, 20 and 65% of ECe are classified as non saline and slightly saline soil respectively, and 15% as moderately saline soil.

Figure 3 shows the frequency of sodium adsorption ratio (SAR)

Table 3. Chemical properties in field *C*.

Hole	Depth	pH	ECe ($dS.m^{-1}$)	SAR
1	0-30	7.75	2	8.8
	30-60	7.81	2.4	9.4
	60-90	7.65	2.7	10.1
	90-120	7.63	3.5	10.5
2	0-30	8.1	1.8	11.4
	30-60	7.95	2	10.8
	60-90	7.72	3.5	10
	90-120	7.78	4.4	11.2
3	0-30	7.83	2	9.7
	30-60	7.76	2.4	8.9
	60-90	7.75	2.9	8.5
	90-120	7.55	3.5	7.9
4	0-30	8.2	1.9	11
	30-60	7.91	2.4	10.6
	60-90	7.74	3.8	10
	90-120	7.6	3.3	9.4
5	0-30	7.95	2.2	9.4
	30-60	7.86	5.2	10.1
	60-90	7.77	3	10.1
	90-120	7.71	3.6	11

Table 4. Chemical properties in field D.

Hole	Depth	pH	ECe ($dS.m^{-1}$)	SAR
1	0-30	7.75	2	9
	30-60	7.7	2.9	8.8
	60-90	7.65	3.5	8.5
	90-120	7.6	3.2	7.9
2	0-30	7.9	1.8	10.5
	30-60	7.79	2.4	8
	60-90	7.66	3.4	9.1
	90-120	7.64	4.6	8.3
3	0-30	8.07	1.9	11.2
	30-60	7.85	2.7	10.7
	60-90	7.69	3.5	9.9
	90-120	7.65	4.2	9
4	0-30	7.89	2.8	8.8
	30-60	7.83	2	8.2
	60-90	7.7	3.3	7.7
	90-120	7.63	3.8	10.4
5	0-30	7.9	2.5	8.5
	30-60	7.81	3.4	12
	60-90	7.77	4	8.3
	90-120	7.68	4.5	9

based on percentage and according to SAR classifications of the four studied fields. In field A, 50 and 25% of the data are classified as slightly and moderately sodic soils respectively. In field B, 65 and 35% of the data are classified as non sodic and slightly sodic soils respectively. In field C, 50% of the data are classified as non sodic soils and 50% of data are classified as slightly sodic soil. Finally 75 and 25% of the data obtained from field D are classified as sodic soil and slightly sodic soil respectively.

Physical properties

These properties include: soil tissue, bulk density and hydraulic conductivity, which were measured in the fields. Soil tissue varies from clay loam to clay, loamy silt to clay, clay loam to clay fluctuates, and loam to clay in fields A, B, C, and D, respectively. The results of the measured bulk density for each field are shown in Table 5. It should be mentioned that these figures are the averages of 5 measurements for each depth at different points of each field. As shown in this Table 5, the least bulk density is 1.3 $kg.m^{-3}$ (layers 0 to 30cm field B), and the maximum is 1.65 $kg.m^{-3}$ (layer 90 to 120 cm in field A). The results of measured hydraulic conductivity for different layers are also shown in Table 6. The least quantity of hydraulic conductivity is 5.63 $cm.day^{-1}$ (layer 60 to 90 cm in field D) and the largest quantity is 17.80 $cm.day^{-1}$ (layer 0 to 30 cm in field A).

Figure 4 shows the comparison made between the values of hydraulic conductivity of different soil layers of the four fields and those quantities proposed by Soil Preservation Organization of USA. As shown in Figure 4, hydraulic conductivity values 5, 40 and 55 for field *A* are classified as very low, low, and approximately low respectively. In field B, 55 and 45% of the data are classified as low and approximately low. In fields C and D, changes in hydraulic conductivity value were similar showing that 5, 50 and 45% of the data are classified as very low, low and approximately low.

RESULTS AND DISCUSSION

LSD[1] test has been used to compare *ECe* for different soil depths in the four farms. The results are in Table 7. There is a significant difference at the 1% level between *ECe* values of different layers in field *A* in comparison with the other three fields. This significant difference is predictable because of the high amount of salt in the soil profiles in the area. After the primary and secondary leaching operations and removal of salt from the soil profile, a significant difference is observed at the 1% level which moves toward a significant difference at the 5% level in fields B, C, and D. Table 8 shows the comparison made between values of bulk density of different soil layers of the four fields, which indicates significant difference in different layers of field A compared to other

1 ***Least significant difference***

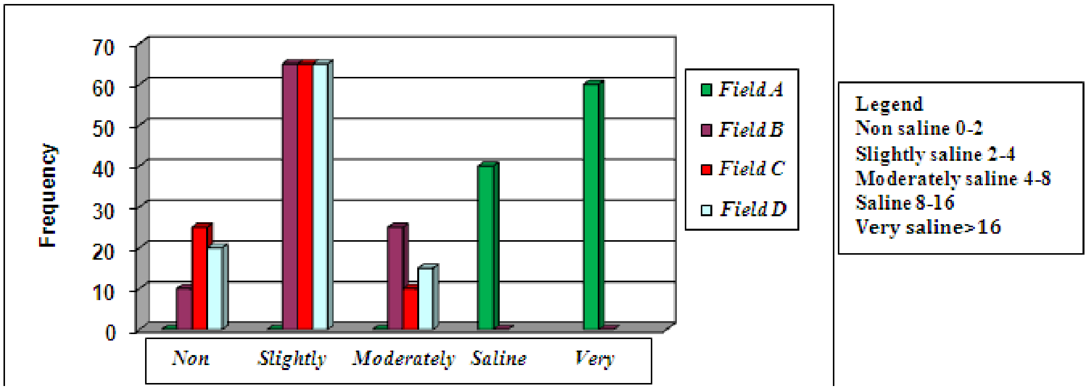

Figure 2. Frequency of ECe in soil fields assessed on the basis of ECe categories.

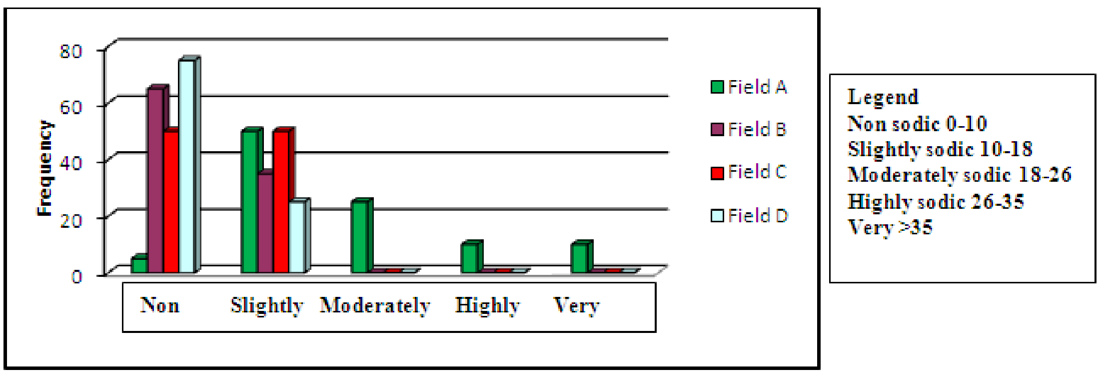

Figure 3. Comparison of sodication of the fields based on SAR classifications.

Table 5. Soil tissue and average bulk density of different soil layers.

Fields	Depth(cm)	Bulk density (kg.m^{-3})	Tissue	Fields	Depth(cm)	Bulk density (kg.m^{-3})	Tissue
Field A	0-30	1.46	C	Field C	0-30	1.35	C
	30-60	1.49	C		30-60	1.37	C
	60-90	1.58	C-L		60-90	1.47	Si- C
	90-120	1.65	C-L		90-120	1.57	C-L
Field B	0-30	1.3	C	Field D	0-30	1.4	C
	30-60	1.38	C-L		30-60	1.46	C-L
	60-90	1.49	C-L		60-90	1.54	L
	90-120	1.56	L		90-120	1.6	C-L

Table 6. Hydraulic conductivity for different layers of soil (cm.day^{-1}).

Fields / Depth	Field A	Field B	Field C	Field D
0-30	17.8	9.27	10.72	8.46
30-60	13.69	12.83	13.3	7.96
60-90	9.37	17.44	14.26	5.63
90-120	12.53	11.4	8.78	10.68

fields. Such statistical differences are due to removal of salt in the soil profiles, compaction of the soil because of cultivation and variation of soil tissue. Table 9 shows the final comparison made between the hydraulic conductivity at different layers in the four fields. Based on these data, we understand that hydraulic conductivity of soil in field A in comparison with other fields shows a significant difference in all layers. Such differences are due to a great deal of salts in particles of the soil and

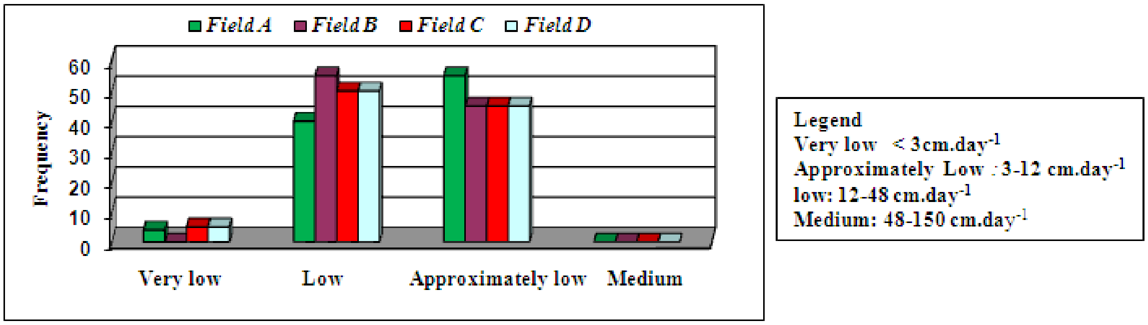

Figure 4. Comparison of hydraulic conductivity of soil samples in the fields.

Table 7. Comparison of depths among all fields considered (LSD).

Fields	0-30 (cm)	30-60 (cm)	60-90 (cm)	90-120 (cm)
A-B	0.14 **	0.11 **	0.06 **	0.05**[2]
A-C	** 0.15	0.1 **	0.05 **	0.06 **
A-D	0.11 **	0.09 **	0.07 **	0.06 **
B-C	0.04 *	0.01 NS	0.01 NS	0.03*[3]
B-D	0.01 *	0.01 NS	0.02 NS	0.02NS[4]
C-D	0.01 NS	0.02 NS	0.01 NS	0.02 *

[2]**Significant difference at a level of 0.01; [3]* significant difference at a level of 0.05; [4] NS: There is no significant difference.

Table 8. Comparison of bulk density among depths in fields considered (LSD).

Depth / Fields	0-30 (cm)	30-60 (cm)	60-90 (cm)	90-120 (cm)
A-B	0.16**	0.11**	0.09*	0.09NS
A-C	0.11**	0.12**	0.11*	0.08NS
A-D	0.06**	0.03**	0.04 NS	0.05NS
B-C	0.05 *	0.01NS	0.02 *	0.01*
B-D	0.1*	0.08*	0.05*	0.04 *
C-D	0.01NS	0.09*	0.07NS	0.03NS

Table 9. Comparison between hydraulic conductivity in depths of soil in tested fields (LSD).

Depth / Fields	0-30 (cm)	30-60 (cm)	60-90 (cm)	90-120 (cm)
A-B	0.18 **	0.08 **	0.16 *	0.04 *
A-C	** 0.16	0.06 **	0.11 *	0.05 *
A-D	0.1 **	0.11 *	0.08 *	0.03 NS
B-C	0.05 NS	0.05 NS	0.05 *	0.07 *
B-D	0.02 NS	0.09 *	0.1 *	0.01 **
C-D	0.04 NS	0.09 *	*0.07	0.03 **

space voids between soil particles.

In such a situation, the high concentration of salts can reduce the diameter of the diffuse double layer (DDL), as a result of soil particle flocculation, the hydraulic conductivity increases. The diameter of diffuse double layers can increase the flocculation of the particles, which can be reduced if we carry out the first and second leaching and removing salt from the soil column. As a result, we will have some reduction in hydraulic conductivity. In addition, if we compare hydraulic conductivity, then we will never show any significant difference among soil layers of the fields C and D.

Conclusion

Based on the results of this study, the following were concluded:

1) An important factor that causes decrease in the growth of sugarcane is salinity and sodication. So, if *ECe* reaches 21.7 and *SAR* is 20, yield will be reduced 100 and 50% respectively (Reynolds, 1985). Thus, in regions such as Khuzestan, leaching salts from the soil is necessary for cultivation of sugarcane.
2) To design a drainage system, soil hydraulic conductivity measurement is essential. This issue of Mirza Kochak Khan fields which are layer-shaped and also there are tissues, which have sudden changes of more importance.
3) There are some factors which decrease the infiltration of water and salt in the soil profile of the "Mirza Kochak Khan", these factors include: lack of organic materials, instability of the structure of the soil, sodic soil, overlapped soil, long-term leaching soil and filling the trenches with soft soil or disturbed soil.
4) It is suggested to incorporate green manure and crop residue within the soil, to provide suitable conditions to increase endurance, decrease the soil compact, and enhance the reserves of water in soil.
5) It is suggested to design the distance between drainage systems based on Guelph permeameter.

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