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Effect of Guar gum polymer treatment on infiltration behaviour of soils

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ABSTRACT

In the present study, Guar gum polymer solution was applied to the soil in concentrations of 0.01, 0.025, 0.05 and 0.1% by weight of water and the infiltration behaviour of soil was observed to assess and quantify the effect of polymer treatment. The inert and biodegradable Guar gum is an indigenous, economical and easily available polymer which does not produce any harmful effect when applied to the soil. The experimentation was carried out under actual field conditions at Pantnagar. The infiltration behaviour of Guar gum treated soils observed with the help of double cylinder infiltrometer indicated in general, that Guar gum polymer treatment to the soils resulted in reduced rate of infiltration. The efficacy of Guar gum treatment in reducing infiltration rate was found to be increasing with the increased concentration of polymer treatment. It was also observed that soils treated with polymer acquired basic infiltration rate earlier as compared to untreated soils.

1. INTRODUCTION

The conservation of natural resources in terms of their quantity and quality by applying proper management and protection techniques is everyone's responsibility. Though everybody should feel concerned and must favourably contribute towards meaningful conservation of natural resources like soil, water and environment in order to ensure sustainability of the entire system but the major part of responsibility lies on researchers and scientists to evolve methodologies for increasing water use efficiency by minimizing its loss.

The control on water loss will help greatly in improved irrigation planning and more area can be brought under irrigation with the existing potential of the available water resources. Puddling has been found to be effective in controlling percolation losses; however, in soils of lateritic belt in eastern zone of the country and other medium and coarse structured soils, in spite of puddling a large percentage of water is lost due to percolation. If soil and water conservation measures are not implemented, the loss of water for crops via soil erosion can amount to as much as 5 m lit $ha^{-1}yr^{-1}$ (Pimentel and Kounang, 1998).

Thus, there has been a need to evolve some better methods for controlling water losses in fields. There has been growing interest over the last two decades in the use of supergel materials to improve soil physical properties and increase water use efficiency. These gel-forming conditioners proved to be effective in increasing water holding capacity and consequently decreasing deep percolation losses in sandy soils (Miller, 1979; Hemyari & Nofziger, 1981; Al-Omran *et al.,* 1987). These materials can thus increase water supply to growing plants and improve water use efficiency (El-Hady *et al.,* 1981; Terry & Nelson, 1986; Al-Harbi *et al.,* 1996). Recently, the use of polymers in agriculture has become quite popular. Polymers are the materials having very high molecular weight, consisting of several structural units called monomers which are bound together by covalent bonds.

In this study, an attempt has been made to apply Guar gum polymer in soils at different concentrations to study infiltration behaviour of soil. Guar gum is one of the outstanding representatives of the new generation of plant gums. Its source is an annual pod-bearing, drought resistant plant originating from India called Guar, or cluster bean (*Cyamopsis tetragonolobus* or *C. psoraloides*), belonging to the family Leguminosae. Guar gum is D-galactose and D-mannose *i.e.,* a galactomannan biodegradable, water soluble, inert, and easily available natural polymer. The viscosity attained in Guar gum is dependent on time, temperature, concentration and pH rate of agitation and practical size of the powdered gum used. India is the major producer of guar in the world and its contribution to the world production is around 80%. In India, Rajasthan and Haryana States contribute 85% of the total production of India.

2. MATERIALS AND METHODS

This study was carried out under actual field conditions at Pantnagar, District U.S. Nagar, Uttarakhand state in India. The soil used for study was sandy loam and its characteristics are given below:

The Guar gum polymer treatments to the soil were applied in four selected concentrations to study infiltration behaviour of soil as described below:

Soil property	Description/range
Texture	Less than 20% clay and 50 to 80% sand
Structure	Granular
Hydraulic conductivity	7.2 cm h^{-1}
Basic infiltration rate	2.886 cm h^{-1}
pH	8.4
EC	240 mmhos
TDS	140 ppm

Preparation of Polymer Solution

The polymer solutions were prepared in four concentrations *i.e.,* 0.01, 0.025, 0.05 and 0.1% by weight of water *i.e.,* 0.1, 0.25, 0.5 and 1g in 1000 ml of water, respectively. The known quantity of polymer was added to the luke warm water (40^{0}C) and manually stirred continuously for 20 minutes to ensure that it gets dissolved completely. The solution was then kept for 24 hours under room temperature so that it forms a thick viscous gel depending on polymer concentration.

Polymer Treatment to the Soil

The Guar gum being water soluble was applied to the soil in solution form to treat the soil. The polymer solution was applied in the soil at the pre-decided concentration after installing the infiltrometer. One litre solution for each concentration of polymers was prepared separately. In proportion of the area occupied, 700 ml polymer solution was applied in the inner cylinder and 300 ml in outer cylinder. The thick viscous polymer solution was spread uniformly over the entire soil surface with the help of a 50 mm soft painting brush. To protect from direct sun shine the entire area was shaded with a dark polythene sheet. It was then left for 24 hours to get dry and form a fine layer over the soil surface. Protection from direct sunshine helped to prevent any cracks in the polymer sheet.

Observation of Soil Infiltration

Once the polymer solution applied to the soil became completely dry in the form of very thin layer, the experimentation to observe infiltration rates of the soil was started. The infiltration behaviour of polymer treated and untreated soil was observed by recording infiltration rates and cumulated infiltration with the help of double cylinder infiltrometer. The infiltrometer was inserted about 10 cm deep in the soil and care was taken to keep the installation depth of the cylinders the same in all the experiments and also to keep the disturbance to the soil minimum possible. To observe infiltration behaviour of the polymer treated soils and to assess the effect of polymer treatments T1, T2, T3 and T4 at 0.01, 0.025, 0.05 and 0.1% concentrations of polymer, respectively on infiltration rate of soils was measured and compared with the control C1 *i.e.,* untreated soil. The experiments were conducted under constant head conditions and continued till the basic infiltration rate is achieved.

3. RESULTS AND DISCUSSION

The observed infiltration rate and cumulated infiltration for control *i.e.,* untreated soil and Guar gum polymer treated soils (Table 1) were compared to quantify the effect of polymer treatment on infiltration behaviour of soils. For visual comparison, the observations are shown

Table: 1
Comparison of infiltration rate and cumulative infiltration for Guar gum polymer treated soils at selected concentration

Sl.No.	Cum. time t, min	Cumulated depth of infiltration for control and polymer treated soils, cm					Infiltration rate, cm h^{-1}				
		C1	T1	T2	T3	T4	C1	T1	T2	T3	T4
1	1	0.580	0.509	0.495	0.467	0.453	34.80	30.54	29.7	28.02	27.18
2	2	1.117	0.99	0.948	0.905	0.849	32.22	28.86	27.18	26.28	23.76
3	4	1.754	1.556	1.485	1.386	1.273	19.11	16.98	16.11	14.43	12.72
4	6	2.306	2.037	1.966	1.839	1.627	16.56	14.43	14.43	13.59	10.62
5	8	2.801	2.461	2.39	2.249	1.924	14.85	12.72	12.72	12.3	8.91
6	10	3.268	2.843	2.772	2.603	2.179	14.01	11.46	11.46	10.67	7.65
7	13	3.820	3.324	3.225	3.027	2.476	11.04	9.62	9.06	8.48	5.94
8	16	4.301	3.748	3.649	3.395	2.688	09.62	8.48	8.48	7.36	4.24
9	20	4.867	4.215	4.144	3.805	2.928	08.49	7.005	7.425	6.15	3.6
10	25	5.518	4.752	4.71	4.258	3.211	07.81	6.444	6.792	5.436	3.396
11	30	6.112	5.243	5.233	4.682	3.466	07.13	5.892	6.276	5.088	3.06
12	40	6.961	5.851	5.813	5.163	3.777	5.094	3.648	3.48	2.886	1.866
13	50	7.711	6.459	6.393	5.644	4.088	4.500	3.648	3.48	2.886	1.866
14	60	8.391	7.067	6.973	6.125	4.399	4.080	3.648	3.48	2.886	1.866
15	70	8.999					3.648				
16	80	9.480					2.886				
17	90	9.961					2.886				
18	100	10.44					2.886				

C1 = control plot, T1 = plot with 0.01% Guar gum, T2 = plot with 0.025% Guar gum, T3 = plot with 0.05% Guar gum and T4 = plot with 0.1% Guar gum graphically in Fig. 1 for cumulative infiltration and Fig. 2 for infiltration rate for different concentrations of polymer treatments. It was observed that infiltration attained a constant rate after 40 minutes in all polymer treated soils while in case of untreated soil, it attained constant rate after a lapse of 80 minutes from the start of experimentation.

It was further observed that the cumulative infiltration in first 10 minutes for untreated plot was 3.268 cm while it decreased to 2.843, 2.772, 2.603 and 2.179 cm for polymer treated plots at 0.01% (T1), 0.025% (T2), 0.05% (T3) and 0.1% (T4) concentration of Guar gum, respectively. The maximum and minimum basic infiltration rate was found to be 3.648 and 1.866 cm h^{-1} for 0.01 and 0.1% concentrations of Guar gum, respectively as shown in Table 1.

The observations recorded in Table 2 indicate that the maximum reduction in infiltrated water volume as compared to Control was found to be 28.33, 31.66, 32.00 and 63.33% in the time interval between 30-40 min in Guar gum treated soils at 0.01, 0.025, 0.05 and 0.1% concentration, respectively (Fig 3). The reason for the reduction in infiltration in Guar gum treated soil may be due to choking of soil pores by viscous Guar gum solution. Also the spreading of Guar gum solution makes a thin layer at the soil surface which checks the movement of water in to the soil profile. At lower concentration of polymer; however, the treatment was not found effective because of the fact that it does not make the solution so much viscous.

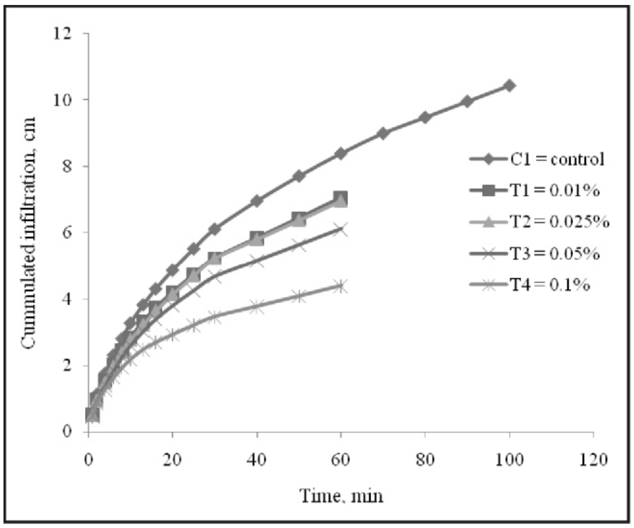

Fig. 1. Cumulative infiltration of soil treated with different concentrations of Guar gum polymer

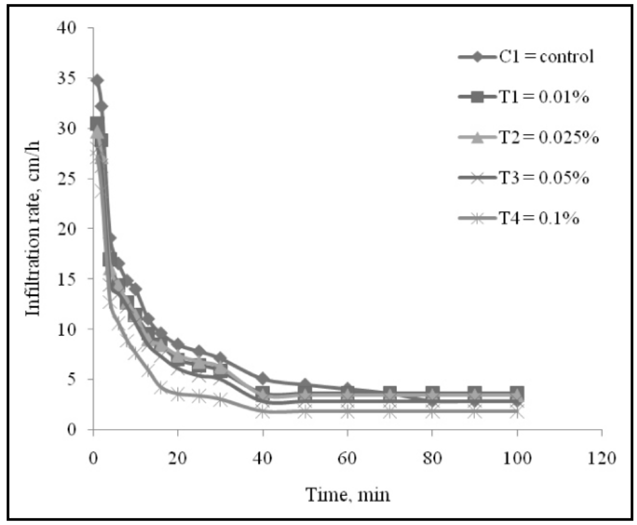

Fig. 2. Infiltration rate of soil treated with different concentrations of Guar gum polymer

Table: 2
Percent volume reduction in infiltrated water for Guar gum polymer treated soils at selected concentration

Sl.No.	Cum. time t, min	Volume of water infiltrated, ml					Percent volume reduction in infiltrated water as compared to control, %			
		Untreated plot	Guar gum treated plot							
		C1	T1	T2	T3	T4	T1	T2	T3	T4
1	1	410	360	350	330	320	12.19	14.63	19.51	21.95
2	2	380	340	320	310	280	10.53	15.79	18.42	26.31
3	4	450	400	380	340	300	11.11	15.55	24.44	33.33
4	6	390	340	340	320	250	12.82	12.82	17.95	35.89
5	8	350	300	300	290	210	14.28	14.28	17.14	40.00
6	10	330	270	270	250	180	18.18	18.18	24.24	45.45
7	13	390	340	320	300	210	12.82	17.95	23.08	46.15
8	16	340	300	300	260	150	11.76	11.76	23.53	55.88
9	20	400	330	350	290	170	17.50	12.50	27.50	57.50
10	25	460	380	400	320	200	17.39	13.04	30.43	56.52
11	30	420	350	370	300	180	16.66	11.90	28.57	57.14
12	40	600	430	410	340	220	28.33	31.66	32.00	63.33
13	50	530	430	410	340	220	18.87	22.64	20.93	58.49
14	60	480	430	410	340	220	10.42	14.58	12.82	54.17
15	70	430								
16	80	400								
17	90	400								
18	100	400								

C1 = Control plot, T1 = Plot with 0.01% Guar gum, T2 = Plot with 0.025% Guar gum, T3 = Plot with 0.05% Guar gum and T4 = Plot with 0.1% Guar gum

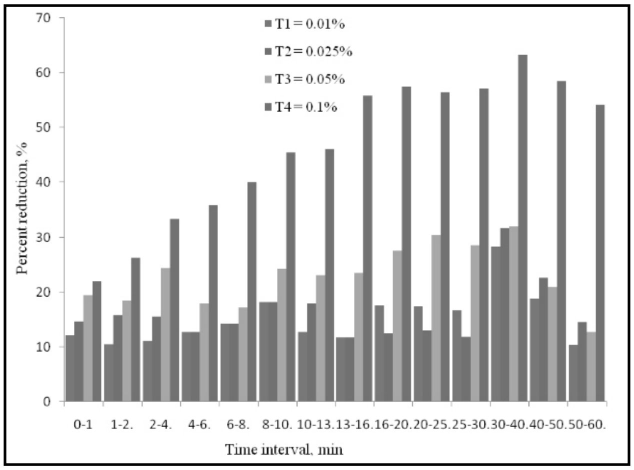

Fig. 3. Comparison of percent volume reduction in infiltrated water as compared to control at different concentrations of Guar gum polymer

4. CONCLUSIONS

Application of Guar gum polymer treatment in soil is found to be effective in reducing infiltration rate of soil. Also, in polymer treated soils, the basic infiltration rate is achieved early as compared to untreated soil. There was a volume reduction in infiltrated water 28.33, 31.66, 32.00 and 63.33%, respectively for 0.01, 0.025, 0.05 and 0.1% Guar gum concentration as compared to untreated soil in the time interval of 30-40 minutes. The percent volume reduction in infiltrated water was found to be increasing with increase in concentration of Guar gum polymer treatment. This may be due to the reason that Guar gum polymer forms a viscous layer and chokes soil pores which leads to reduction in infiltration rate of the soil.

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