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EFFECTS OF IRANIAN PETROLEUM MULCHES ON INFILTRATION INTO A CALCAREOUS SOIL[1]

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ABSTRACT

Slow water intake is a problem in most calcareous soils of Iran and causes greater runoff and soil erosion following rainfall or irrigation. An experiment was conducted to study the effects of National Iranian Oil Company petroleum mulches (cationic, anionic and clay emulsions) on infiltration of a Calcixerollic Xerochrept silty clay soil under greenhouse conditions. Mulches were either surface applied at the rates of 0, 4000, 6000 and 10000 L ha^{-1} or incorporated at the rates of 0.10, 0.15 and 0.25% (dry weight basis of soil). Furthermore, Krilium Merloam (a copolymer of vinyl acetate and maleic acid) was incorporated at the same rates of application. Surface application of different petroleum mulches had similar effects on infiltration and on the average, increased cumulative infiltration of soil from 3.9 to 7.6 cm in 90 min. Incorporation applications, on the average, doubled the infiltration of soil. Incorporation application of anionic emulsion was more effective, but that of the cationic, and Krilium showed the least effect on soil infiltration. Minimal required rates of application for petroleum mulches were 4000 L ha^{-1} and 0.10% for surface and incorporation applications, respectively.

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اثرات مالچهای نفتی ایرانی برروی نفوذ پذیری آب دریک خاک آهکی

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خلاصه

کندی نفوذ آب درخاک یکی ازمشکلات خاکهای آهکی درایران میباشد که پس ازبارندگی ویاآبیاری موجب افزایش هرزآب وفرسایش خاک میگردد. برای مطالعه اثرات مالچهای

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نفتی ایران (کاتیونی ،آنیونی وامولسیون رسی)برروی نفوذپذیری یک خاک رسی لائی
آهکی آزمایشاتی درشرائط گلخانه‌ای انجام گردید. مقدار پاشش مالچها عبارت بودند
ازصفر، ۴، ۶ و ۱۰ هزار لیتردرهکتار بصورت سطح پاشی وصفر، ۰/۱۰، ۰/۱۵ و ۰/۲۵ درصد وزن
خاک خشک بصورت عمق پاشی. علاوه براین، ماده کریلیوم مرلوم (کوپلی مری ازوینیل استات
واسیدمالئیک) بامقادیرپاشش مشابه تیمارهای عمق پاشی بکاربرده شد.
سطح‌پاشی مالچهای مختلف اثرات مشابهی برروی نفوذپذیری آب درخاک داشته وبطور
متوسط مقدار آب نفوذیافته درمدت ۹۰ دقیقه را از ۳/۹ به ۷/۶ سانتیمتررسانید. همچنین
عمق پاشی مالچهای نفتی بطورمتوسط نفوذپذیری آب درخاک رادوبرابر کرد. عمق پاشی
امولسیون آنیونی بیشترین اثر وامولسیون کاتیونی وکریلیوم کمترین اثر را دربهبود
نفوذپذیری آب درخاک نشان دادند. حداقل مقادیرکاربردمالچهای نفتی بترتیب
درسطح‌پاشی وعمق پاشی برابر ۴ هزار لیتردرهکتار و ۰/۱ درصدوزن خشک خاک میباشد.

INTRODUCTION

Slow water intake is a problem in most soils of Iran (5). Calcareous soils with low organic matter contents usually from surface crust after irrigation and this reduces infiltration of water into the soil (1). The infiltration rate was increased very effectively in a clay loam soil with 0.1% incorporation application rate of Krilium (8). Blavia *et al.* (2) also reported Krilium to be an effective substance in increasing infiltration. Ahmad and Robins (1) showed surface application of a liquid petroleum mulch (encap) greatly increased infiltration into a loamy soil. Gabriels *et al.* (6) reported that surface application of bitumen emulsion increased infiltration rate, but incorporation application was not effective. In contrast, De Boodt (4) reported that incorporation of a bitumenous emulsion, at a rate of 1.5%, bound soil particles so strongly that their swelling was largely prevented and consequently the infiltration rate was increased 3 times.

The effects of Iranian produced petroleum mulches have not been studied. This experiment was conducted to evaluate the influence of surface and incorporation application of National Iranian Oil Company petroleum mulches (cationic, anionic and clay asphalt emulsions) on infiltration into a calcareous soil under greenhouse conditions. Krilium Merloam, a frequently used soil conditioner , was also compared with the petroleum mulches in the incorporation application study.

MATERIALS AND METHODS

A Calcixerollic Xerochrept silty clay soil (Calcic Cambisols) was taken from the top 30-cm depth of the Agricultural Experiment Station of Bajgah (16 km north of Shiraz, Iran) with 5, 50 and 45% of sand, silt and clay, respectively. Air-dried soil was passed through a 2-mm sieve and packed uniformly by hand into non-transparent polyvinyl chloride (PVC) tubes. The tubes were 50 cm long with 2.2 mm wall thickness and 10.5 cm internal diameter. The soil was packed to a bulk density of 1.21±0.008 g cm^{-3} by tapping the tube on the lab bench. The bottoms of the tubes were closed by perforated polyethylene plates. The soil columns were then wetted by immersing the tubes in a container of tap water to a water height of about 10 cm. The saturated soil columns were then removed from the container and allowed to drain for 48 hr while the soil surface was covered by a plastic sheet to prevent evaporation (7). The moisture content of the soil column was determined by weighing the columns before wetting and after draining the soil. After drainage, the average soil water content was 34.0±0.2% (dry weight).

Petroleum mulches (anionic, cationic and clay emulsions) at the rates of 0, 4000, 6000 and 10000 L ha^{-1} were spread on the soil surface of 36 columns to provide an average film thickness of 0, 200, 300 and 500 μm, respectively. Petroleum mulches and Krilium Merloam (a copolymer of vinyl acetate and maleic acid) were incorporated into the 15-cm top layer of 48 soil columns by means of a mechanical mixer. These were applied at the rates of 0, 0.10, 0.15 and 0.25% (dry weight basis). Some general properties of the mulches have been reported by Moosavi and Sepaskhah (11). The prepared soil columns were used in an evaporation study (2). At the end of the evaporation studies, the treated and untreated soil columns were used for determination of the vertical infiltration of water into the soil. The average moisture contents of the surface and incorporation treated soil columns at the beginning of the experiment was 10.5±0.85 and 9.2 ± 0.62%, respectively, on dry weight basis. A cylinder (with 15 cm height and 10.2 cm diameter) made of galvanized iron was attached to the top of each soil column and sealed with paper tape. A hole was drilled through one side of the cylinder 5 cm above the soil surface and a 10 cm long tube of similar material was soldered to the hole to drain excess water.

The soil columns were then placed on a direct reading balance. After an initial weighing, a constant stream of tap water (EC=0.52 mmhos cm^{-1}, SAR=0.35) was directed into the open cylinder. Water was also added to the column a beaker for a rapid establishment of a constant head of 5 cm of water on the soil surface. Deformation of the soil surface was prevented by placing a polyethylene sheet on the soil surface. After about 10 s, the constant head was achieved and the polyethylene sheet was removed. Thus, after water had reached a constant level, any increase in weight as shown by the balance, was due to infiltration. Water in excess of the soil infiltrability was drained out through the hole and collected in a bucket. This procedure was similar to that used by Bowers and Hanks (3). The cumulative depths of infiltrated water after 90 min were used to compare different treatments.

The experimental designs were 3x4 and 4x4 factorial arrangements with 3 replicates for the surface and incorporation experiments, respectively.

RESULTS AND DISCUSSION

Surface Application

The effects of different treatments on the total depth of water (cm) infiltrated after 90 min are shown in Table 1.

Analysis of variance did not show any significant interaction between the type of mulches and the rates of application. However, the highest rate of cationic mulch was much less effective than either its lowest rate or the rates of the other mulches (Table 1). All rates of application increased infiltration significantly as compared with the control.

Table 1. Cumulative infiltration (cm water) after 90 min as affected by surface application of petroleum mulches.

Rate of application L ha^{-1}	Type of mulch			Mean
	Anionic emulsion	Cationic emulsion	Clay emulsion	
0	3.4	4.0	3.8	3.7b*
4000	7.1	8.8	6.6	7.5a
6000	9.4	6.3	7.3	7.7a
10000	9.7	5.3	7.9	7.6a
Mean	7.4a	6.1a	6.4a	

*Overall means followed by the same letter in each column or row are not significantly different at the 5% level of probability (Duncan's multiple range test).

On the average, three rates of application (4000, 6000 and 10000 L ha^{-1}) increased cumulative infiltration of soil from 3.7 to 7.6 cm in 90 min. Similar results were reported by other investigators (1, 4, 13). Table 1 shows that increasing rate of application from 4000 to 10000 L ha^{-1} did not significantly increase infiltration, suggesting that an increase in infiltration is not a function of the thickness of the mulch layer. The least amount of mulches that can prevent crust formation and surface sealing was sufficient to increase infiltration. Swartzendruber and Hillel (14) showed that the presence of a mulch cover over a soil surface did not affect the soil's infiltrability, but its effect was due to protection of the soil surface against the direct impact of water. De Boodt (4) also reported that petroleum mulch on the soil surface prevented crusting and surface sealing and resulted in greater infiltration of water.

Incorporation Application

All rates of incorporation application increased infiltration significantly except for the lowest rate of Krilium (Table 2). Petroleum mulches and Krilium, on the average,

Table 2. Cumulative infiltration (cm water) after 90 min as affected by incorporation application of petroleum mulches and Krilium.

Rate of application %	Type of mulch			Krilium
	Anionic emulsion	Cationic emulsion	Clay emulsion	
0	3.8c*	3.1c	4.9c	3.0b
0.10	12.0a	5.3b	6.0b	4.0b
0.15	11.0a	5.0b	8.7a	5.6a
0.25	8.2b	7.7a	9.4a	5.4a
Mean	8.8(a)	5.3(c)	7.2(b)	4.5(c)

*Means followed by the same letter in each column and means followed by the same letter in parentheses in the last row are not significantly different at the 5% level of probability (Duncan's multiple range test).

doubled the infiltration rate (7.4 vs. 3.6 cm of water in 90 min). However, different types of mulches acted differently upon infiltration of water. The anionic emulsion significantly improved infiltration more than other mulches. The least effective materials were cationic emulsion and Krilium which had similar effects (Table 2). Gabriels *et al.* (6) also observed that incorporation of cationic bitumen emulsion was less effective than anionic bitumen emulsion in improving infiltration. Krilium and cationic petroleum mulches were reported to have greater degree of hydrophobicity (9, 8, 11) and this property might have prevented rapid intake of water by the soil. However, use of Krilium and cationic petroleum mulches stabilized the pores in the soil (10) and increased infiltration rate as compared with the control (8). The results of the analysis of variance showed a positive interaction of the type of mulches with the rates of application. In the case of petroleum mulches, application of 0.1% was sufficient to increase soil infiltration significantly. This is in contrast with a required application rate of at least 0.15% for Krilium. In general, anionic and clay emulsions were more effective than Krilium in increasing soil infiltration rate. This may be due to the lower degree of hydrophobicity of these materials compared with Krilium. Incorporation of anionic mulches, in particular and clay emulsions, in general, seems to be more effective in infiltration improvement than surface application. However, surface application of cationic mulches vs. incorporation application i.e., 4000 vs. 10000 L ha^{-1} changed the effectiveness with treatment levels, L ha^{-1} (Tables 1 and 2). This anomaly might be due to a relatively greater hydrophobicity of the cationic mulch. Our results are consistent with the results of others (2, 4, 6, 9, 13) who have related the ability of petroleum mulches and Krilium in increasing the infiltration, to their aggregating effects. The incorporation of soil conditioners as petroleum mulches and Krilium into the soil, has generally produced larger and more stable aggregates in the soil (10). The relations between the infiltration of water in 90 min and mean weight diameter of aggregates as reported by Moosavi and Sepaskhah (10) for petroleum mulches and Krilium are shown in Fig. 1. Mean weight diameter is a measure of the stability of soil aggregates. Positive and significant correlation coefficients of 0.75 ($P < 0.01$) and 0.93 ($P < 0.05$) were obtained for the petroleum mulches and Krilium, respectively. The infiltration increases as the stability of soil aggregates increases. The regression coefficient for the petroleum mulches was 11 times larger than that for Krilium. Therefore, these results indicate that infiltration enhancement could be related to the effect of aggregate improvement, but other properties of the petroleum mulches and Krilium (like their hydrophobicity) might have influenced the infiltration of water. Furthermore, Krilium might have partially blocked soil pores in the aggregates which have been made by its own application. Improvement of infiltration rate and reduction in the surface runoff of soils is one of the methods of preventing soil erosion. Therefore, Iranian petroleum mulches have the merit to be applied as enhancing factor of soil infiltration and for reducing the surface runoff and erosion. Further research is needed to evaluate their quantitative effects on runoff under different conditions and application methods.

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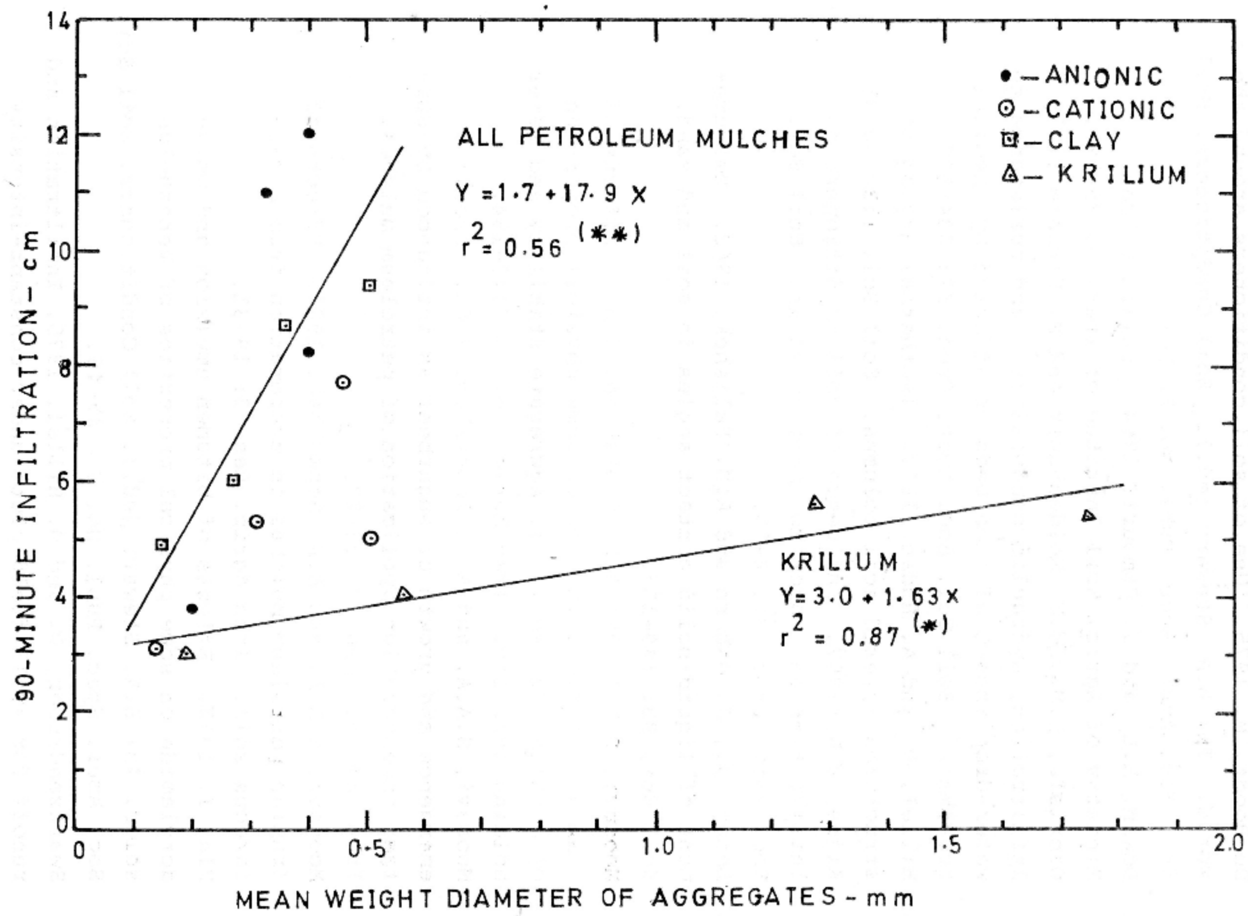

Fig. 1. The relationships between 90-min infiltration and the mean weight diameter of soil aggregates for all petroleum mulches and Krilium.

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