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EFFECTS OF IRANIAN PETROLEUM MULCHES ON EVAPORATION FROM A CALCAREOUS SOIL[1]

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ABSTRACT

Inadequate moisture supply is one of the important factors limiting crop yields in Iran. Increasing the efficiency of moisture use has an important role on the crop producing capacity of the soils. This experiment was conducted to study the effects of National Iranian Oil Company petroleum mulches (cationic, anionic, and clay emulsions) on the evaporation retardation 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 or incorporated at the rates of 0, 0.1, 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 and incorporation application of these petroleum mulches and also of Krilium Merloam at the rates of 4000 L/ha and 0.10%, respectively, decreased the amount and rates of evaporation from the soil surface significantly. The petroleum mulches, either surface applied at the rate of 4000 L/ha or incorporated at the rate of 10%, equally retarded evaporation. However, cationic emulsions had the least effect with both methods of applications. Moreover, Krilium Merloam was as effective as the petroleum mulches.

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اثرات مالچهای نفتی برروی تبخیر از یک خاک آهکی

سیدعلی اکبر موسوی وعلیرضا سپاسخواه
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خلاصه

کمبود آب خاک یکی ازعوامل مهم محدودکننده تولید محصولات کشاورزی درایران میباشد. افزایش راندمان کاربرد آب نقش عمده ای درظرفیت تولیدی اراضی کشت شده خواهد داشت. اثرات سطح پاشی سه نوع ازمالچهای نفتی ساخته شده درشرکت ملی نفت ایران (امولسیونهای کاتیونی، آنیونی ورسی) با مقادیرپاشش صفر، ۴، ۶و ۱۰ هزار لیتردرهکتار

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وعمق پاشی با مقادیر پاشش صفر، ۰/۱۰، ۰/۱۵ و ۰/۲۵ درصد وزن خاک خشک برروی کاهش تبخیر از یک خاک رس لیمونی در یک آزمایش گلخانه‌ای مورد مطالعه قرار گرفت. ضمناً ماده شیمیائی کریلیوم مرلوم (کوپلیمری از وینیل استات و مالئیک اسید) نیز با مقادیر پاشش مشابه مالچهای نفتی در بررسی های عمق پاشی مورد مطالعه و مقایسه قرار گرفت. سطح پاشی مالچهای نفتی بمیزان ۴ هزار لیتر در هکتار و عمق پاشی آنها و ماده کریلیوم مرلوم بمیزان ۰/۱۰ درصد بطور چشمگیری سبب کاهش مقدار و سرعت تبخیر از سطح خاک گردید. این مالچهای نفتی، چه بصورت سطح پاشی بمیزان ۴ هزار لیتر در هکتار و یا عمق پاشی بمیزان ۰/۱۰ درصد اثرات مشابهی در کاهش تبخیر داشتند ولی امولسیون کاتیونی در کاهش سرعت تبخیر کمترین اثر را داشت. معهذا، مالچهای نفتی باندازه کریلیوم مرلوم موءثر بودند.

INTRODUCTION

The rate of evaporation from sandy loam and silty clay loam soil treated with dimethyl octadecylammonium chloride (DDAC) was significantly reduced due to a negative or repelling capillary force (3). Some experimental studies have mentioned the effect of polyethylene film and petroleum mulches on reducing evaporation from the soil (4, 16, 17). Also Johnson *et al.* (13) showed that the application of 5600 L/ha of liquid asphalt mulch significantly and uniformly reduced the overall soil drying rate. Under high evaporation demand, cumulative evaporation was minimum for the aggregate diameter of 0.5 to 1 mm in the 3-6 cm depth of soil. Hillel and Berliner (11) reported that the presence of water repellent aggregates in the top layer of soil could conserve soil moisture during the evaporation. They stated that a reduction in water content and hydraulic conductivity of the aggregated top layer decreased evaporation.

The effects of petroleum mulches, being manufactured in Iran, have not been studied on the soil evaporation. This experiment was conducted to evaluate the influence of surface and incorporation applications of National Iranian Oil Company petroleum mulches (cationic, anionic and clay asphalt emulsions) on evaporation from soil under greenhouse conditions. "Krilium Merloam", as 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 experimental site of Bajgah with 5, 50, and 45% of sand, silt and clay, respectively, as described by Moosavi and Sepaskhah (14). Air dried soil passed through a 2-mm sieve and packed uniformly by hand into non-transparent polyvinyl chloride (PVC) tubes of 2.2 mm wall thickness with 10.5 cm internal diameter and 50 cm height and brought to a bulk density of 1.21±0.008 g/cm^2 by tapping the tube on a bench. Bottoms of the tubes were closed by perforated polyethylene plates. Soil columns were immersed in a container of water to a height of about 10 cm to become saturated from the bottom. The saturated soil columns were let drain for 48 h while the soil surfaces were covered by a plastic sheet to prevent evaporation (12). The moisture of each soil column was determined by weighing the column before wetting and after draining the soil. The average water content of the soil column after drainage was 34±0.2% (dry weight).

Petroleum mulches (anionic, cationic and clay emulsion) at the rates of 0, 4000, 6000, and 10000 L/ha were spread on the soil surface to provide film thicknesses of 0, 200, 300 and 500 microns, respectively. Moreover, the petroleum mulches and Krilium Merloam (a copolymer of vinyl acetate and maleic acid) were incorporated into 15-cm top layer of the soil column by means of a mechanical mixer. These were applied at the rates of 0, 0.10, 0.15 and 0.25% (dry weight).

The soil columns were placed in a wooden frame isolated by styrofoam to prevent wall heat exchange. The soil surface was subjected to evaporation under greenhouse conditions with an average daily temperature of 22.2°C. The average maximum and minimum daily temperatures were 34.5 and 11.2°C, respectively.

The amount of evaporation from soil surface was measured by weighing the soil column periodically. The experiments were conducted in a completely randomized design, replicated three times, with 3x4 and 4x4 factorial arrangements in the surface and incorporation experiments, respectively. Three extra columns were used to measure free water surface evaporation.

RESULTS AND DISCUSSION

Surface Application

The cumulative evaporation from the soil surface, as a function of time for surface application of different types and rates of petroleum mulches is depicted in Fig. 1. The treated soil columns showed lower evaporation as compared to the control. The cumulative evaporation decreased as the thickness of the petroleum mulch layer increased. These results also indicated that the rates of evaporation from treated surfaces were lower than that from the free water surface. However, this was not true for the untreated soil. Evaporation from various treatments was not the same throughout the course of study. Differences between cumulative evaporation of treated and control soil columns decreased towards the end of the experiment. Therefore, the surface application of petroleum mulches had short term effects on the soil moisture conservation.

Table 1 indicates the effects of petroleum emulsions on cumulative evaporation after 58 days. The effects of different types of petroleum mulches were not significantly different. All rates of mulch application reduced the total evaporation. The effect of 4000 L/ha was similar to that of 6000 L/ha but it was significantly less effective than 10,000 L/ha (Table 1). Furthermore, the application rates of 6000 and 10,000 L/ha had a similar effect on evaporation. In general, 4000, 6000 and 10,000 L/ha of petroleum mulches resulted in 3.6, 5.2 and 8.8% less cumulative evaporations, respectively, as compared with control. Analysis of variance showed no significant interaction between the types and rates of emulsions.

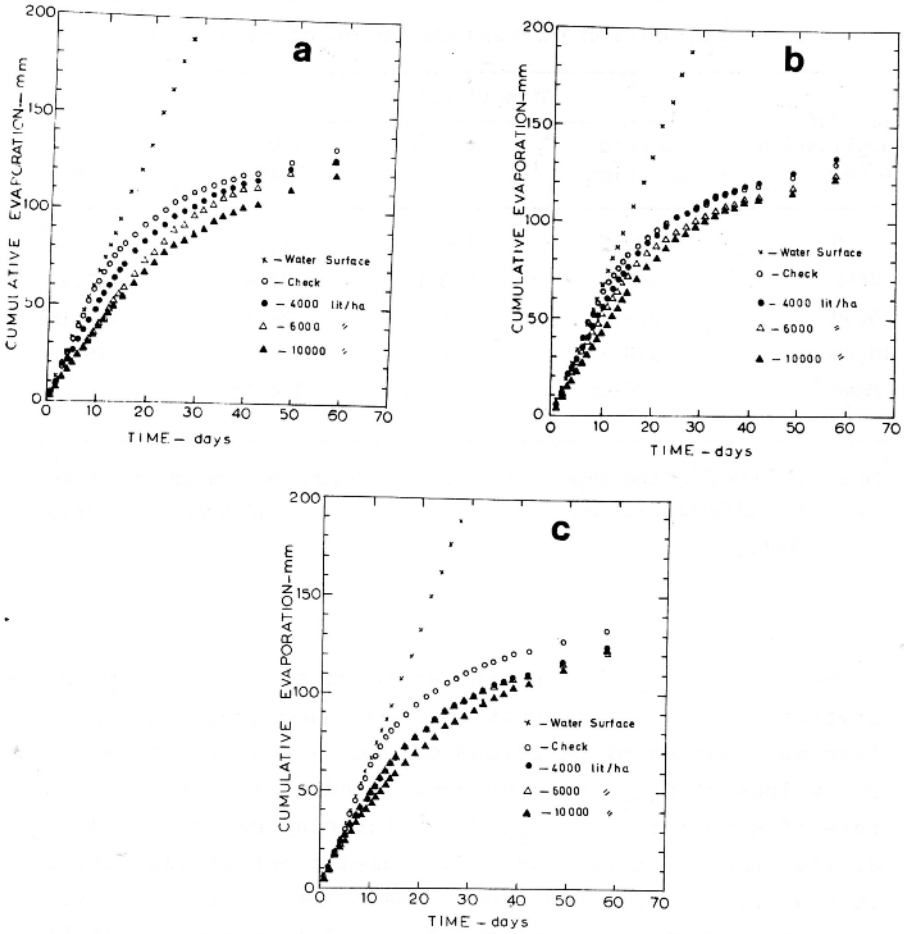

Fig 1. Cumulative evaporation from the soil columns as a function of time for the surface application at different rates of anionic (a), cationic (b) and clay emulsion (c).

Table 1. Cumulative evaporation (mm of water) of a 58-day period from soil columns as affected by surface application of various rates of petroleum mulches.

Rate of application L/ha	Type of mulch: Anionic emulsion	Cationic emulsion	Clay emulsion	Mean
0	132.5	130.1	133.4	132.0a*
4000	127.8	133.1	120.6	127.2b
6000	126.6	124.8	124.1	125.1bc
10,000	118.3	122.1	120.7	125.1bc
Mean	126.3a	127.5a	124.7a	

*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).

The time requirement, expressed in days, for 100 mm of evaporation (D_{100}) with respect to different rates of surface application of petroleum mulches is shown in Table 2. The values of D_{100} could be considered as a measure of the rate of evaporation, D_{100} value for clay emulsion was greater than that for cationic emulsion but it was similar to that for anionic emulsion. The effects of the anionic and cationic emulsions on the D_{100} value were not significantly different. All rates of application reduced the rate of evaporation significantly. The comparison between the petroleum mulch treatments and the control showed that 21.2, 31.8 and 50.4% increases were obtained in D_{100} values for 4000, 6000 and 10,000 L/ha of the petroleum mulches application, respectively. There was no significant interaction between the petroleum mulches and the application rates. The effect of petroleum mulches on decreasing

Table 2. Days required for 100 mm cumulative evaporation of water (D_{100}) from soil columns after surface application of various rates of petroleum mulches.

Rate of application L/ha	Type of mulch			
	Anionic emulsion	Cationic emulsion	Clay emulsion	Mean
0	24.0	24.0	22.7	23.6c*
4000	27.8	24.3	33.8	28.6b
6000	31.8	29.7	31.8	31.1b
10,000	37.8	31.0	37.6	35.5a
Mean	30.4ab	27.2b	31.5a	

*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).

evaporation in the present experiment is in agreement with the results reported by Hatchett and Bloodworth (8). They observed that soil moisture can be conserved by surface application of petroleum mulches. Wilson and Hedden (19) reported a 1.5% higher soil water content under a layer of petroleum mulch as compared with the bare soil. When petroleum mulch is applied on the soil surface it leaves a layer of petroleum resins on the soil surface and dries out. This layer forms a relatively impermeable vapor barrier and controls evaporation of water from the soil surface.

Incorporation Application:

The effects of different rates of petroleum mulches and Krilium incorporation on the evaporation are shown in Fig. 2. Straight line and curved sections of this Figure are known as constant rate and falling rate stages, respectively.

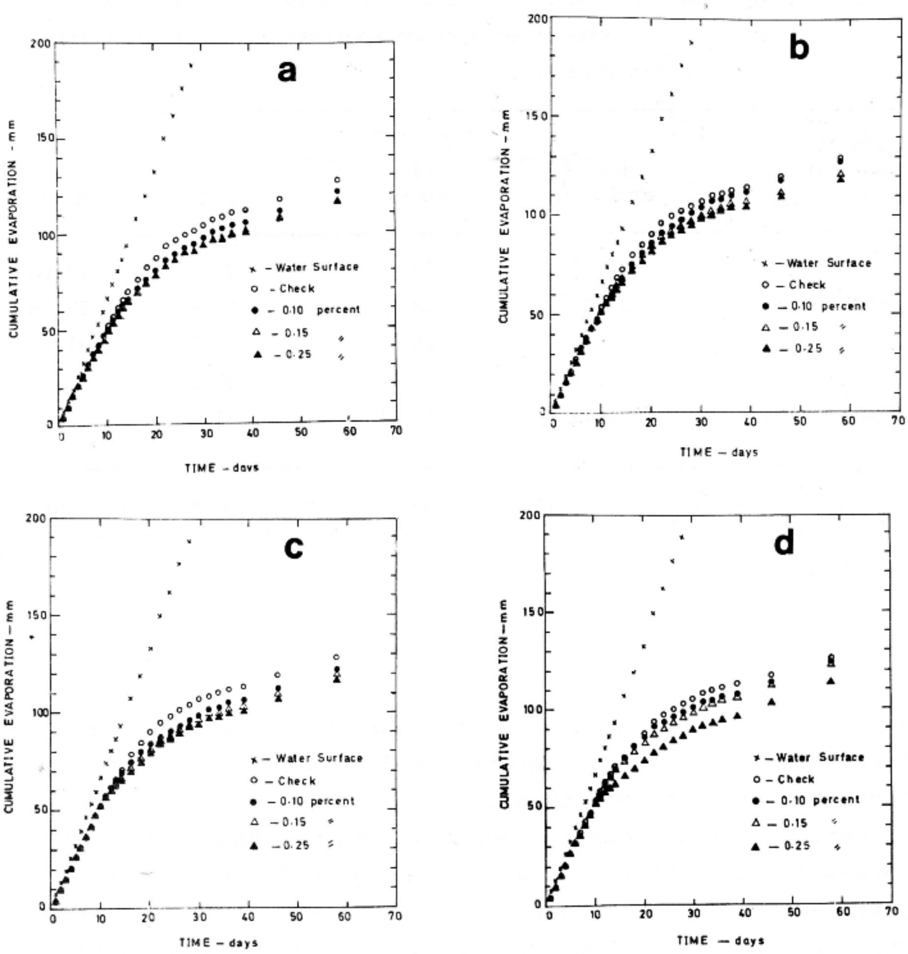

Fig. 2. Cumulative evaporation from the soil columns as a function of time for the incorporation application at different rates of anionic (a), cationic (b), clay emulsion (c) and Krilium Merloam (d).

All rates of petroleum emulsions and Krilium decreased evaporation from the soil surface. The rates of evaporation at the constant rate stage were approximately the same for control and the treated soil columns but the differences started at the beginning of the falling rate stage.

The 58- days evaporation for different treatments is given in Table 3. The types of petroleum mulches and Krilium had similar effects on evaporation (after 58 days) (Table 3).

Table 3. Cumulative evaporation (mm of water) of a 58-day period from soil columns as affected by incorporation application of various rates of petroleum mulches and Krilium.

Rate of application %	Type of mulch				
	Anionic emulsion	Cationic emulsion	Clay emulsion	Krilium	Mean
0	133.4	137.6	135.8	138.0	136.7a*
0.10	124.1	124.9	129.3	131.0	127.3bc
0.15	128.6	134.2	126.3	131.1	130.0b
0.25	121.3	127.2	123.5	122.3	123.6c
Mean	127.3a	130.9a	128.7a	130.6a	

*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).

All rates of application reduced evaporation significantly. Average decreases of 6.9, 4.9 and 9.6% in evaporation were obtained with 0.10, 0.15 and 0.25% of mulches and Krilium, respectively. However, application rates of

0.10 and 0.15% were not significantly different. There was no significant interaction between the types of treatments and the application rates. The values of D_{100} for different mulches and application rates are given in Table 4.

Table 4. Days required for 100 mm cumulative evaporation of water (D_{100}) from soil columns after incorporation application of various rates of petroleum mulches and Krilium.

Rate of application %	Type of mulch				
	Anionic emulsion	Cationic emulsion	Clay emulsion	Krilium	Mean
0	24.2	22.8	23.8	22.3	23.3c*
0.10	33.3	29.8	28.3	26.0	29.4b
0.15	29.8	26.7	31.0	29.3	29.1b
0.25	32.5	29.7	32.5	35.0	32.4a
Mean	30.0a	27.3b	28.9ab	28.1ab	

*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).

Various types of emulsions and Krilium had approximately the same effects on the rate of evaporation from the soil surface. Moreover, application rates decreased the rate of evaporation significantly, relative to the check. Although, 0.10 and 0.15% mulches had similar effects on the rate of evaporation but these were significantly less effective than 0.25% rate. Average decreases of 26.1, 24.9 and 39% in the rate of evaporation were obtained from application of 0.10, 0.15 and 0.25% of mulches and Krilium, respectively.

Similar results have been reported by other investigators concerning the effects of incorporation application of different kinds of soil conditioners and petroleum emulsions on the evaporation of water from the soil surface (1, 2, 12). The effect of incorporation of petroleum emulsions and Kirilium on reducing evaporation from the soil surface was mainly due to their aggregating effects (11). Hillel and Berliner (11) showed that a layer of water repellent aggregates conserved soil moisture during the evaporation phase. Increasing aggregation of the soil particles on the soil surface restricts the upward unsaturated flow of water into this so called repllent layer (6, 7, 10, 11, 12). Water flowup to or near the immediate surface layer must occur before evaporation commences (9). Therefore, evaporation of the soil water is intimately related to soil water transmission properties. Robins (15) concluded that evaporation is slower from soil with low hydraulic conductivity than from soil with high hydraulic conductivity at tensions between 100 to 400 millibars. Aggregated soils have lower conductivity in this range of tension than untreated fine soils. Decreased evaporation in treated soils may also be due to the soil profile discontinuities which influence water transmission upward to the surface (5, 18). Incorporation of petroleum emulsions and Krilium to a depth of 15 cm in the soil columns produces discontinuity in the capillary pores through aggregation of the soil and this may decrease flow of water to the surface layer.

Although the application of these petroleum mulches proved to reduce the evaporation from bare soil surface, their degree of effectiveness in field application and their economic feasibility remain to be studied.

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