COLORADO AGRICULTURAL EXPERIMENT STATION

and

AGRICULTURAL RESEARCH SERVICE

Progress Report No. 4

September 1958

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PROGRESS REPORT NO. 4

Colorado Contributing Project

Study of Evaporation from Soil Surfaces in Terms of Soil and Micrometeorological Factors

of the

Western Regional Research Project W-32

Basic Hydrological Factors Relating to Water Conservation

September 1958

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Agricultural Research Service, U.S.D.A.

Objectives:

The project is a comprehensive study of evaporation from soil surfaces. The objectives are to evaluate the variables known to affect evaporation from soil and to search for relationships among the pertinent variables which will permit quantitative estimates of evaporation from a given soil under prevailing ambient conditions.

Completed Work:

The first phase of the study dealt with steady state evaporation from a soil in contact with a water table. This part of the project has been terminated for the present and the results have been reported elsewhere (1,2,3,4).

In the previous progress report (Report No. 3, 1957) it was shown (in Figs. 4, 5 and 6) that under severe evaporating conditions an inverse relation may exist between the rate of evaporation from soil and the rate of evaporation from a free-water surface. The explanation given in Report No. 3 for this phenomenon was that a downward temperature gradient resulting from high radiation to the surface caused a downward movement of water in the vapor phase.

It was later discovered that the inverse relation between evaporation from soil and evaporation from a free-water surface could be produced with deeper water tables without a high input of radiant engery to the surface. All that is required to produce such an effect is for the evaporation to exceed the maximum rate at which water is supplied to the surface from wetter soil below.

Once the surface dries beyond a critical moisture content, a hysteresis phenomenon apparently causes the rate of upward movement to be reduced still further.

New Experiments:

The phenomenon just described has been produced under carefully controlled conditions in the laboratory where the upward flow from a zero pressure source was produced by a capillary barrier at the top of the column, the liquid in the barrier being under a negative pressure (less than atmospheric). In this experiment, the liquid used was a hydrocarbon rather than water, This column consisted of a fine sand and the temperature was uniform throughout. Consequently there was no possibility that the phenomenon observed could have been caused by temperature gradients. The experimental arrangement is shown in Fig. 1.

It was found that as the tension at the top of the column was increased, the steady state rate of movement increased. The potential gradient producing upward flow likewise was increased throughout the column. When the tension at the top of the column was increased beyond a critical value, however, the rate of upward movement was reduced and the potential gradient existing through most of the column was reduced.

Near the top of the column (about a half inch from the surface) there

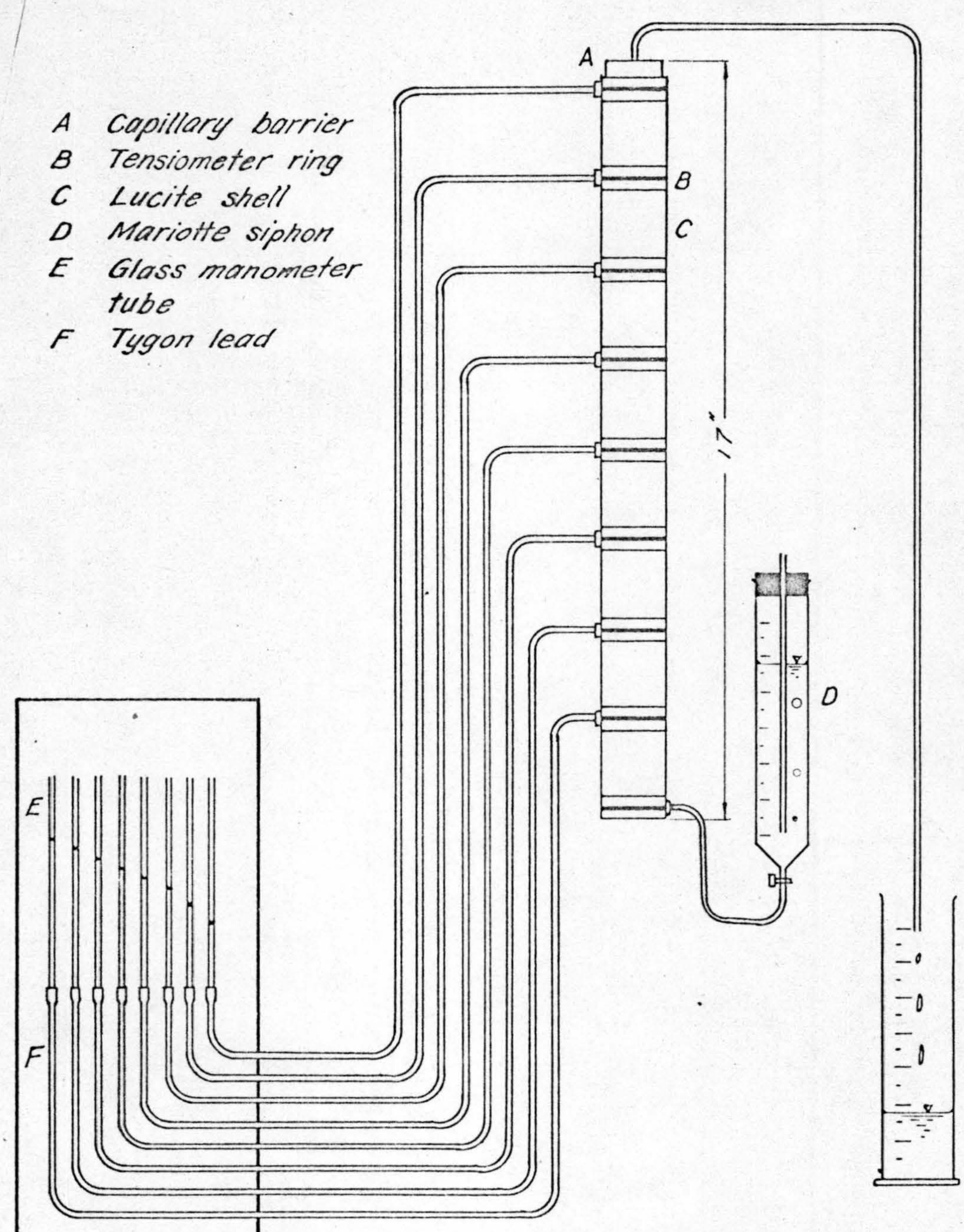


Fig. 1 Schematic of apparatus for producing upward flow in a sand column

appeared to be a sharp discontinuity in liquid content. Across this discontinuity there existed a very great potential difference. This result was in agreement with observations made on soil columns from which evaporation was taking place.

It appears, therefore, that the maximum rate of water movement from a water table takes place before the surface dries. It is possible, moreover, that the soil below the surface may be wetter after the surface dries than before. A detailed description of a theory explaining this phenomenon has been presented in reference 3.

Effect of Surface Treatments:

Recently investigations of evaporation from soils in contact with a water table have been discontinued and a new series of experiments to determine the effect of surface treatments has been undertaken. In these experiments the loss of water as a function of time has been measured using two soil types, a clay loam and a fine sand. The soils were placed in lucite tubes 8 1/2 inches long with an I.D. of 3 1/2 inches. The soils were first saturated with water and then placed on a turntable in a chamber with controlled temperature, humidity, and radiation. The design of the chamber and turntable was described in Report No. 3.

The surfaces of the soil columns were treated in several ways as follows:

1. No special treatment
2. Surface made white with chalk
3. Surface made black with carbon powder
4. Surface was compacted

5. A compacted layer was produced at a depth of 1 inch

6. Surface was roughened by periodic stirring

7. Surface was covered with about 1/4 inch of sawdust

8. Surface was covered with about 1/4 inch of fine gravel

9. A 10°/o solution of Lux detergent was sprayed on surface

10. An undiluted solution of Lux detergent was sprayed on surface

11. Water table was maintained at the surface.

Only the surface of the soil column was exposed to radiation. The sides of the column were insulated by a plastic enclosure and a dead-air space. The rate of water loss as a function of time was determined by periodically weighing the soil columns except in the case of the column in which the water table was maintained at the surface. In the latter case the evaporation rate was determined by periodically weighing a Mariotte-syphon bottle which supplied the water at constant head. There were two columns for each treatment on each of the two soils.

The results for the two soils were qualitatively similar as shown in Figs. 2 and 3. It appears that for the fine sand, there was more spread in the results for several of the treatments than was the case for the clay loam. Except for the gravel and sawdust mulches, it is believed that the differences were not significant. Runs were made using several levels of evaporativity as measured by the evaporation from the soil with the water table at the surface. The differences in evaporation were inconsistent between the several runs except where the surface was covered with a gravel or sawdust mulch. The results of only the first run are shown in Figs. 2 and 3, but subsequent runs produced similar results.

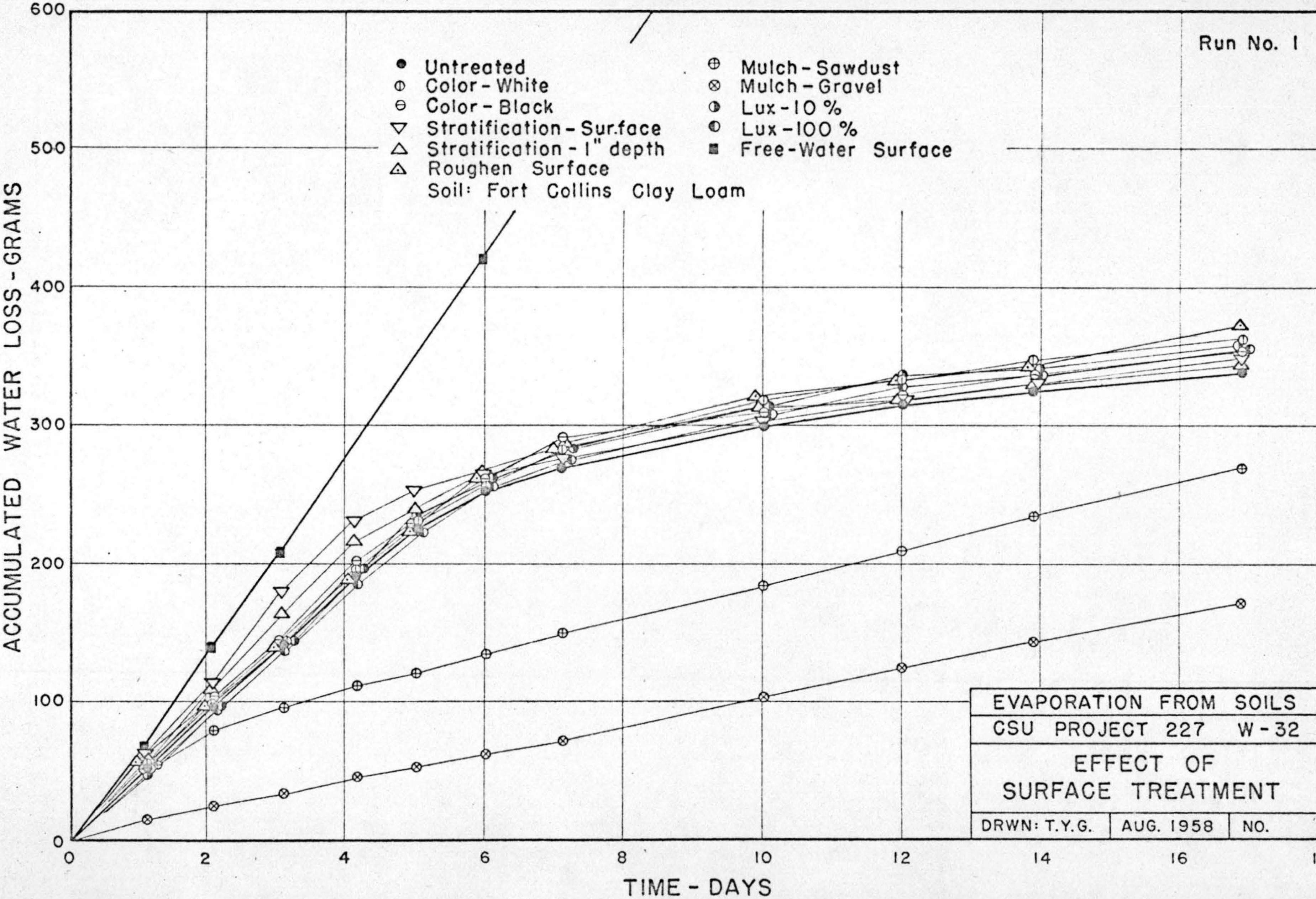
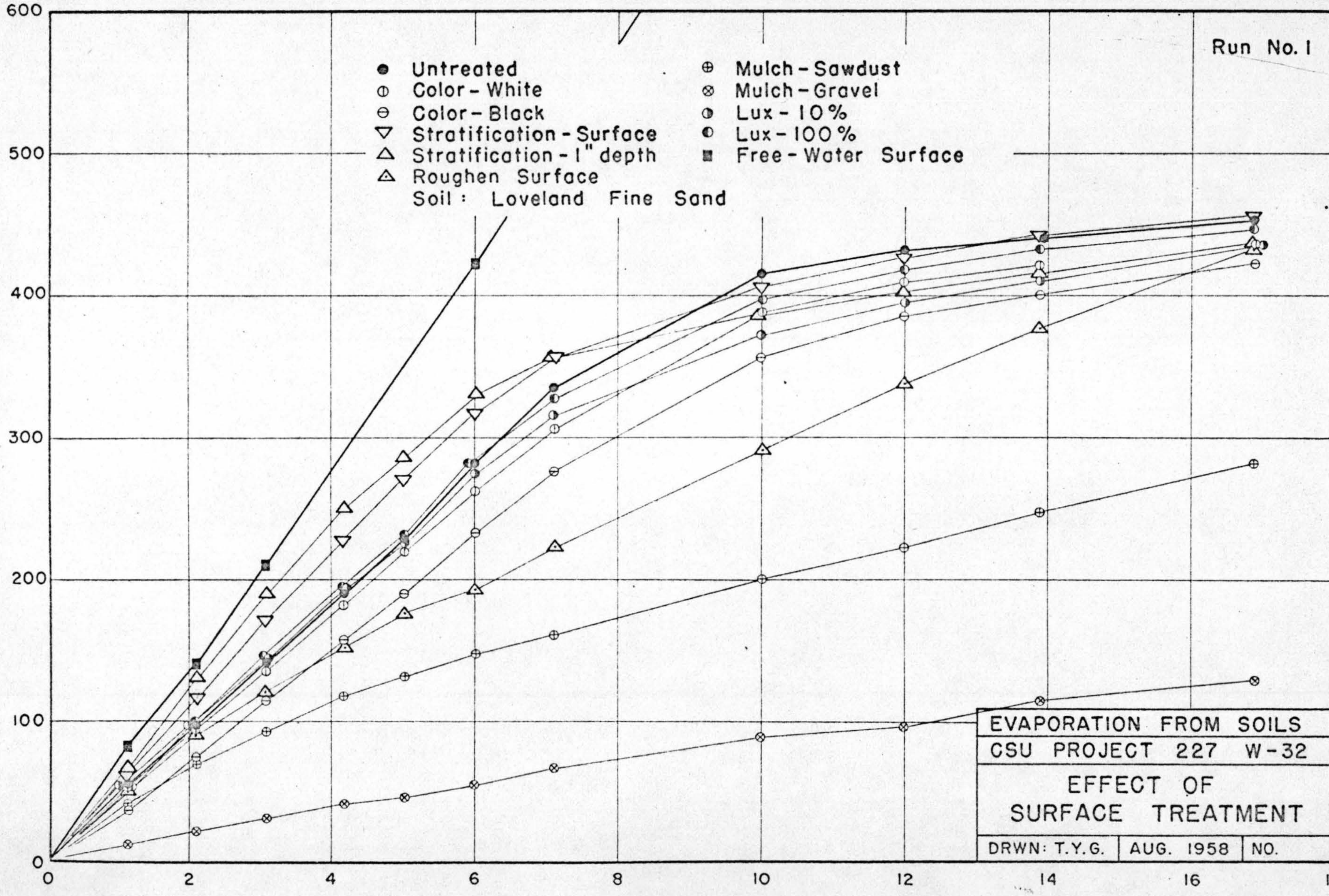

Run No. 1
Untreated
Color - White
Color - Black
Stratification - Surface
Stratification - 1" depth
Roughen Surface
Mulch - Sawdust
Mulch - Gravel
Lux - 10 %
Lux - 100 %
Free-Water Surface
Soil: Fort Collins Clay Loam
ACCUMULATED WATER LOSS - GRAMS
TIME - DAYS
0
100
200
300
400
500
600
2
4
6
8
10
12
14
16
18
EVAPORATION FROM SOILS
CSU PROJECT 227 W-32
EFFECT OF SURFACE TREATMENT
DRWN: T.Y.G.
AUG. 1958
NO.

FIG. 2



Run No. 1
Untreated
Color - White
Color - Black
Stratification - Surface
Stratification - 1" depth
Roughen Surface
Soil : Loveland Fine Sand
Mulch - Sawdust
Mulch - Gravel
Lux - 10%
Lux - 100%
Free - Water Surface
ACCUMULATED WATER LOSS - GRAMS
TIME - DAYS
0
100
200
300
400
500
600
2
4
6
8
10
12
14
16
18
EVAPORATION FROM SOILS
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FIG. 3

In every case the most effective treatment was the gravel mulch. The other treatments including the Lux detergent produced no substantial reduction in evaporation. More recently, other surfactants* (Triton GR-5 and GR-7) were tried on the fine sand. Both of these surfactants produced a very substantial reduction in evaporation, the larger concentrations being even more effective in this respect than the fine-gravel mulch. The results of one of the runs (GR-7 in various concentrations) are shown in Fig. 4.

Both of the Triton surfactants are of the anionic type whereas Lux is a non-ionic surfactant. The reason for the greater effectiveness of Triton as compared to Lux is not known at present. In any case, it would appear that the quantities of surfactant required for an effective treatment and its cost (about \$.35/lb.) would preclude its use of agricultural purposes -- unless a much more efficient method of using the surfactant can be found.

It is apparent from the experiments conducted to date that any treatment which can maintain at the surface a layer through which flow cannot take place in the liquid phase will greatly reduce the evaporation from the surface. Such a layer need not be very thick, a layer of 1/4 inch being very effective. The use of gravel mulch or of surfactants are two methods of creating such a layer. The gravel mulch is effective because of the low capillarity of its large pores, and the surfactants are effective because they reduce the capillarity by decreasing the surface tension of water in the surface layers.

Other treatments such as compacting the surface or loosening the surface by stirring (as in cultivation) produced no significant effect on evaporation.

*Manufactured by Rohm and Haas Co., Washington Square, Phila. 5, Pa.

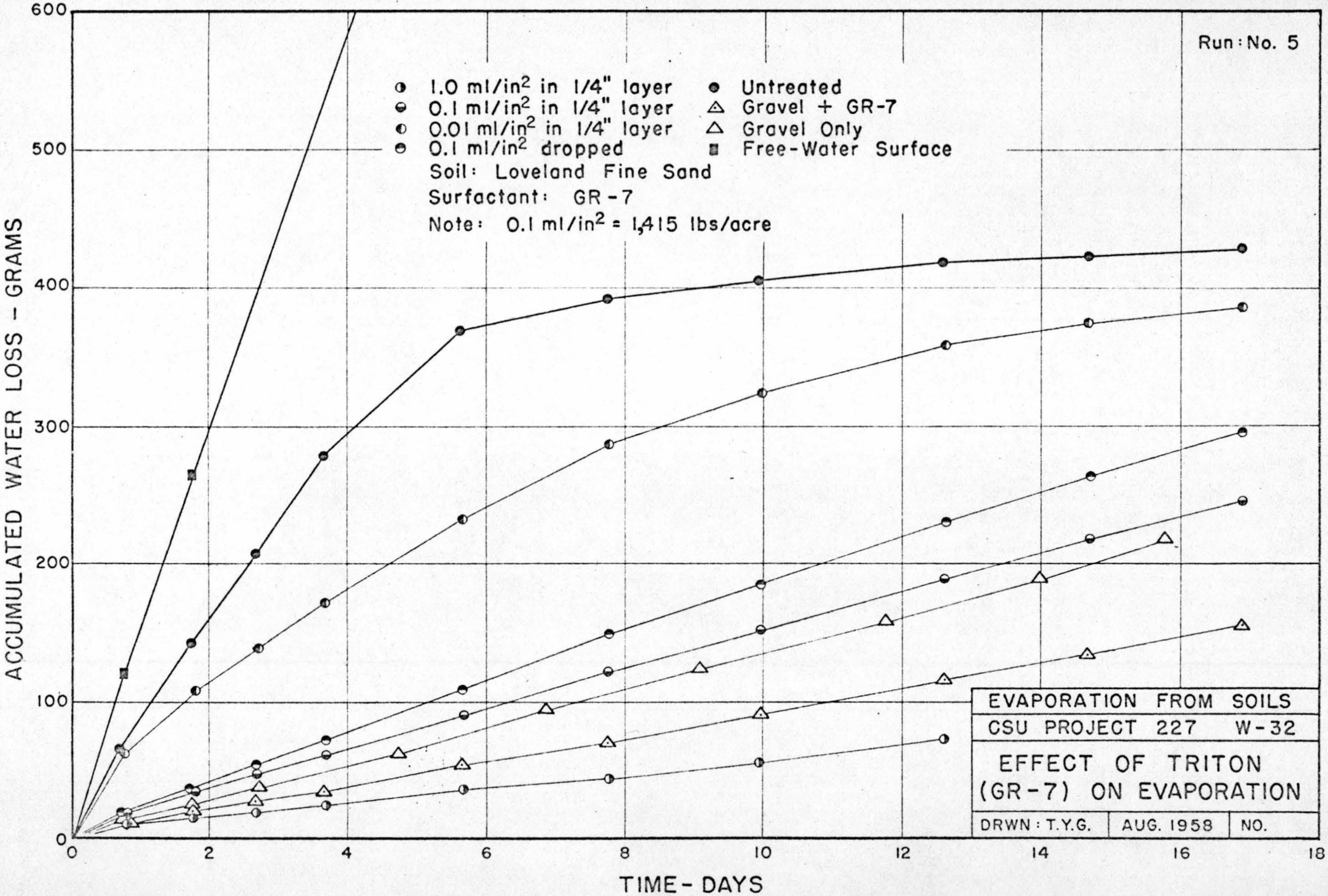
Run: No. 5
1.0 ml/in² in 1/4" layer
0.1 ml/in² in 1/4" layer
0.01 ml/in² in 1/4" layer
0.1 ml/in² dropped
Untreated
Gravel + GR-7
Gravel Only
Free-Water Surface
Soil: Loveland Fine Sand
Surfactant: GR-7
Note: 0.1 ml/in² = 1,415 lbs/acre
ACCUMULATED WATER LOSS - GRAMS
TIME - DAYS
0
100
200
300
400
500
600
2
4
6
8
10
12
14
16
18
EVAPORATION FROM SOILS
CSU PROJECT 227 W-32
EFFECT OF TRITON (GR-7) ON EVAPORATION
DRWN: T.Y.G.
AUG. 1958
NO.

FIG. 4

Changing the color of the surface likewise had negligible effect. Probably the reason that stirring the surface produces no substantial result is that it does not actually loosen the soil unless the surface is fairly dry, and when the surface is dry the rate of evaporation is very small in any case.

Except for soils in contact with shallow water tables, a large proportion of the water lost by surface evaporation is undoubtedly lost in a short period following rains or irrigation when the surface is still moist. Protection from evaporation during this period is needed and cultivation is apparently not effective in this regard.

Plans for Future Experiments:

In order to make quantitative estimates of evaporation from soils under prevailing ambient conditions, which is one of the primary objectives of this project, it will be necessary to conduct some additional basic research. It has been found that under some conditions an inverse relationship between evaporation from soils and evaporation from a free-water surface may exist under steady evaporating conditions. It would be desirable to determine whether or not such a phenomenon exists under conditions simulating those found in the field. In the field, the severe evaporating conditions produced in the laboratory exist for only a short portion of the day. It is planned to modify the control equipment so that the temperature, humidity, and radiation in the chamber will automatically undergo a diurnal cyclic change simulating field conditions.

This experiment is expected to provide some of the information necessary for correlating evaporation from soils in the field with evaporation from free-water surfaces.

Additional experiments will be conducted in an attempt to find an economical method of retarding evaporation. Further studies of the behavior of surfactants will be made in the hope that a more efficient use of this material can be found.

Publications Cited:

1. Progress Report No. 3, Colorado Contributing project for W-32. Study of evaporation from soil surfaces. November, 1957.
2. Schleusener, R. A. Factors affecting evaporation from soils in contact with a water table. Ph.D. Dissertation, Colorado State University, 1958.
3. Schleusener, R. A. and Corey, A. T. The role of hysteresis in reducing evaporation from soils in contact with a water table. A paper prepared for publication in A.G.U.
4. Staley, R. W. Effect of depth of water table on evaporation from fine sand. M.S. Thesis, Colorado State University, 1957.