The influence of different soil types and treatments on the loss of moisture from fallowed lysimeters
by Bernard L Brown

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University

Abstract:
Moisture efficiency of four Montana soils and five treatments on one soil type was determined in a lysimeter study between May 3 and October 31, 1957. The effect of soil properties on infiltration and evaporation was studied and an efficiency percentage calculated.

Evaporation, infiltration, and moisture stored in the soil volume are controlling factors in moisture efficiency. High infiltration contributes to high efficiency, whereas high evaporation provides low efficiency. Both evaporation and infiltration were influenced by the moisture stored in the soil.

Seasonal influences were noted among soils and soil treatments. Soil properties which were desirable during one period were frequently undesirable during other periods.

During the experimental period, the Huffine soil evaporated less and infiltrated more water than other soils under study, having an efficiency of 20.5%. This is 41.4% more efficient than the Bridger, 14.3% more than Manhattan, and 300.0% more than Huntley.

High storage capacity and low permeability probably accounted for the low efficiency of the Huntley soil.

Among the soil treatments, the rock mulch was outstanding, having a season-long efficiency of 60.4%. During three weeks of warm, wet weather in June, 79.8% of the moisture passed through the 4-inch layer of soil. Throughout the season, the rock mulch was more than three times as effective in infiltrating moisture as the next best treatment. In comparison, all other treatments were relatively ineffective although coarse aggregates stabilized with VAMA were slightly better than the other treatments.

THE INFLUENCE OF DIFFERENT SOIL TYPES AND TREATMENTS ON THE LOSS OF MOISTURE FROM FALLOWED LYSIMETERS

by

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INTRODUCTION

All life depends on water. In the early white settlement of the New World, major areas of population were along the coast. When these areas became overcrowded, there was a major population influx toward the inland areas. The main path of settlement followed along the rivers, which not only presented an accessible highway but furnished an ever-ready supply of water.

Eventually man was forced to settle in the more arid areas. Again water was a prime factor in settlement. Usually an adequate supply was available for human consumption, but frequently the supply was inadequate for satisfactory crop production.

Moisture is the limiting factor in crop production in most non-irrigated areas of Montana. It has been estimated (16) that 20 to 25% of the moisture that falls is used by crops. Usually less than 5% of the precipitation is lost through runoff in streams and underground reservoirs. Seventy to 75% is returned to the atmosphere through direct evaporation.

Many people have been interested in the moisture utilization in cultivated areas. Attempts to alter moisture efficiency have met with limited success. Moisture changes during a drying cycle have not received much attention, and only very limited attempts have been made to devise soil treatments to increase moisture utilization.

The present study was undertaken to determine the differences in moisture storage efficiency of four Montana soils and five treatments on one of these soil types.

REVIEW OF LITERATURE

Lysimeter studies have been used throughout the world to study many soil properties. While many of these studies have involved some aspect of nutrition, moisture utilization has frequently been included. Kohnke, et al., (21) has discussed the construction and performance of lysimeters.

Three general types of lysimeters have been used, as discussed by Harrold and Dreibelbis (14).

(a) The fill type with vertical walls, open top, and perforated bottom. This type does not retain the original profile as the soil is usually screened and mixed before filling.

(b) The Ebermeyer type in which a pan or funnel is inserted at desired depths in the soil. There is unrestricted lateral flow, as this type has no walls. Water is percolated through the soil into the pan or funnel and measured.

(c) The monolith or undisturbed soil block type. A casing of vertical walls is built around an undisturbed soil block. A perforated pan or sheet is placed under the undisturbed block for water percolation.

Most of the lysimeter work done has been on nutrient balance in the soil. Smith (30) used a lysimeter in a study of nitrogen balance in an irrigated area. The study involved infiltrated moisture. Similarly, Bizzel (6) also was interested in nitrogen balance but under cropping at different fertilizer levels, but again moisture loss was studied.

A 9-year experiment was carried on by Joffe (18), using Ebermeyer-type lysimeters at different levels to trace cation activity throughout the soil profile. Quantity of precipitation was found not to determine the quantity of leaching or translocation of ions in the soil profile.

Lysimeters offer a means by which comparisons can be made under similar field conditions. Kardos (19) compared nutrient status of cultivated and virgin soils in a subhumid area. Bizzel (5) compared the effect of ammonium sulfate and sodium nitrate in removal of the N and Ca from the soils. Kilmar, et al., (20) used a monolith-type lysimeter to study nutrient and water loss from a silt loam. Differences between cropped and fallowed lysimeters were studied. The influence of slope and associated runoff of water and nutrient status were also studied.

The hydrologic cycle has been of great interest to a number of authors. Colman (8), using a range of tensions, was able to control seepage rates and drainage of a soil column. Richards, et al., (29) working with moisture tensions, found that soil moisture in fallow soils forms a dynamic system which responds rapidly to moisture changes at the soil surface.

Martin and Rich (26), using a monolith-type lysimeter in Arizona, show that most erosion and surface runoff occurred during the summer, while winter precipitation contributed mostly to storage and percolation. Percolation flow data from two soils was studied by Dreibelbis and Harrold (10). Dreibelbis (9), in further studies, determined the soil constituents in drainage water under a 4-year rotation of corn, wheat, and meadows. This rotation was duplicated on two soil types. Losses of both water and nutrients from the two soils were similar, except for magnesium which varied more with the amount of percolation than with cropping practices.

Fisher and Burnett (13) used lysimeters to determine the proportion of the rainfall that penetrated soils varying in texture and depth. Their data suggested the possibility of using mulches and crop residues to increase the amount of moisture penetration. Evaporation work done at the same location indicated that the rate of moisture loss decreases following surface drying. Additional work on small fallowed areas, diked to prevent runoff, has shown that at least 60% of the rain that fell during a 2-year study was not stored in the soil at the end of the period. Even greater losses by evaporation from the soil surface have been reported on the high plains of Texas by Finnell (12).

Not all work of interest to this problem was done with lysimeters. Buckingham (7) undertook laboratory studies on evaporation. He found that intensive evaporating conditions were responsible for moisture loss exceeding the capillary flow. This formed a dry mulch of soil on the surface area which tended to slow down moisture evaporation.

Veihmeyer and Brooks (35) studied the cumulative loss from bare soil during a 1,547-day period. Moisture lost during this period amounted to 3.65 inches, and one-third of this total was lost the first month. It was found that the higher the water table, the greater the loss of moisture by evaporation.

Working with undisturbed cores of soil, Stanhill (31) compared soil moisture evaporation against free-water evaporation and found evaporation was approximately equal from free water and soil as long as the soil surface remained moist.

Evaporation of moisture from a soil surface was subdivided into three distinct stages by Hide (16). The first stage is the brief period while the soil has a moisture content above field capacity, the second stage is after the soil surface has reached field capacity but before the surface dries, and the third stage is when vaporization occurs below the dry soil surface.

Hide and Brown (17), working with three selected soils, found that soil properties altered the amount and nature of water lost during a drying cycle. Even after the moisture content of the upper 3 inches of soil became fairly constant, there was a diurnal redistribution of moisture within the layer.

Major emphasis in moisture conservation has been placed on the control of runoff. Increased emphasis has recently been placed on other methods of conserving moisture. In Texas, Porter, et al., (28) found that leaving crop residues on the soil surface is considerably more favorable to moisture storage than plowing them down. This is true for land being continually cropped or alternately fallowed. These same conclusions were drawn by Aasheim (1) in the north-central Montana area. However, in northeastern Montana, surface residues did not influence moisture storage efficiency.

Crop residues have been used as a conservation practice by Duley and Russell (11), who found that straw mulch increased water penetration and decreased runoff. Bare soils compacted under heavy rainfall lost two to four times more water by runoff than straw mulched plots.

Staple and Lehane (32) studied the effect of shelterbelts on evaporation rates. Differences were found to be very small between the sheltered and unsheltered areas. However, the sheltered areas had a slight effect in cutting down the evaporation rate. Meteorological conditions were found to be the sole controlling factor when the soil surface was moist. Soil moisture content and movement of moisture to the evaporating surface limited evaporation after the soil started to dry.

Lemon, et al., (24) studied energy relationships of evapotranspiration from soils with moisture at various tensions and found that losses could not be predicted solely on the basis of meteorological variables. Soil moisture tension had an effect, but the plant itself exerted, either directly or indirectly, variable restrictions on the transfer of water.

Kolasew (22), as quoted by Lemon (23), made field observations on a soil surface that had been treated with a Naptha soap compound. He found that the treated surface dried much quicker than an untreated soil. This action was attributed to the alteration of the wetting angle between the solid soil particles and the liquid. In the same article, Kolasew quoted Sukhovolshaia's (33) work, which showed that a 2% treatment of Naptha soap reduced evaporation six or seven times.

Very little work has been done in the United States with a rock mulch treatment; however, the Chinese (34) have been using such mulches in the more arid areas of China. Whitmore, et al., (36) used a 3-inch gravel mulch and increased plant production by one-third in an area of South Africa. The increase in production was attributed to saving of moisture normally lost by evaporation.

The effect of soil conditioners on structure and water efficiency has been studied. Hedrick and Mowry (15), using these materials, increased water-stable aggregates and infiltration and reduced the loss of moisture by surface evaporation. The soils treated maintained their characteristics over a 32-month period.

Peters, et al., (27) found that soil conditioners had no effect on the permanent wilting point or field capacity. Physical condition was improved, and the increase in available water was probably due to increased infiltration and a deeper, more extensive root system. Martin, et al., (25) also noted improvement in physical condition, but some crops did not respond to the better physical conditions.

Soil conditioners were used by Alderfer (3) on five tobacco seedbeds. They did not produce marked effects on wilting point, total water-holding capacity, or available water-holding capacity. The increases in the total pore space were reflected in a very substantial increase in the aeration pore space.

Lysimeter studies appear to be well adapted to moisture efficiency studies, although most of the available data is for humid areas. Soil treatments are available which affect many physical soil properties, but their influence on moisture storage efficiency has not received much attention.

MATERIALS AND METHODS

This study was undertaken to determine how soils and soil treatments influence the efficiency of moisture storage under summer-fallow conditions. It was believed that the amount of moisture which penetrates beyond a depth of 4 inches was largely stored in the soil profile for future use by plants or for deep percolation. It appeared that the influence of this upper 4-inch layer could best be studied in lysimeters containing 4 inches of soil. This procedure induced boundary conditions at the lower edge of the 4-inch layer which do not prevail in a normal profile. It was believed that the procedure would measure real soil differences which exceeded the error caused by the boundary condition.

Soils and Treatments

The experiment was designed to study how the properties of four soils influenced their efficiency in storing water. In addition, the influence of six treatments on one of the soils was determined.

Four selected Montana soils were used as follows:

1. Bridger clay loam was used as one of the soils for comparison and all soil treatments were imposed on it. It is a dark-colored silty clay loam, well drained, and it belongs to the Chernozem great soil group. It has developed under grass and shrub vegetation on high fans, aprons, benches, and slopes in mountain valleys. It has a well-developed, very fine crumb structure in the surface layer. The sampling site is southeast corner of southwest quarter, Section 15,

Township 2 South, Range 6 East.

2. Huffine silt loam is a Brown soil developed in silty, alluvial materials. It has many properties in common with the Chernozem group but was developed on flat land characterized by imperfect drainage and local accumulations of soluble salts. The structure is somewhat less stable than the Bridger but of a fine crumb nature. The sample was taken from Montana State College Agronomy Field B, Series 1300 at the northeast corner of the block.

3. Manhattan fine sandy loam is a Brown soil, developed in fine sandy lacustrine deposits. The original material consists of windblown, fine or very fine sand which blew into a former lakebed. It is characterized by a high content of fairly-uniform-sized fine sand particles. Samples were taken one mile west of Manhattan, Montana, on the Northern Pacific right-of-way.

4. Huntley alkali soil probably belongs to the Nibbe series which includes slowly permeable Solonchak soils developed in fine-textured, predominantly clay and silty clay alluvium. These occupy stream terraces and valley floors with relatively high water tables. Their parent materials are derived largely from bedrock uplands of late cretaceous shales and sandstones.

The structure is weak, granular, or crumb, except that the surface 1 inch forms a vesicular crust when dry. It is calcareous, including white flakes of free-lime carbonate and other salts. The sample was taken adjacent to the shed on the field used for salinity studies at Worden, Montana, under the supervision of the Huntley Branch Station.

Six treatments as follows were imposed on the Bridger silty clay loam:

5.* Gravel mulch. One inch of gravel ranging in size between 1/4 and 1/2 inch was used. Four kilograms of gravel per 1,060 square centimeters of soil surface gave a mulch approximately 1 inch deep.

6. Straw mulch. This was prepared using chopped wheat straw which was mixed throughout the surface 2 inches of soil. It was applied at a 2-ton-per-acre rate. This left a fairly good surface cover.

7. and 9. Soil conditioners. VAMA** was used at the rate of 0.2% by weight, as suggested by Allison and Moore (4). The material was applied when the soil was sufficiently moist to be easily worked. It was mixed thoroughly and allowed to dry. The soil was sieved into two aggregate size groups--4 to 16 mesh,

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* Treatment numbers are a continuation of soil numbers.

** Provided by Monsanto Chemical Company.

designated "coarse", and less than 16 mesh, designated "fine". These treatments will be referred to in this article as coarse and fine.

8. Surfactant.* This material was applied at the rate of 0.1% by weight. This was applied to the soil in a powdered condition and thoroughly mixed.

10. Check. No treatment.

Table I provides the lysimeter numbers, treatments, and randomization for the experiment.

Lysimeters and Construction

To facilitate the collection of infiltrated water, a trench 60 feet in length, 10 feet deep, and 4 feet wide was dug, shored up, and covered with 6 inches of soil. The 60-foot length allowed 15 four-foot areas on each side of the trench for lysimeter treatments. A door covered the exposed steps leading into the trench to reduce temperature changes within.

In construction of the lysimeters, the bottom of each box was a square, shallow funnel of galvanized sheet metal with the top edge on each side of the funnel perpendicular to the ground level. This made a lip which fitted between two 1/8-inch sheets of asbestos-board which acted as the lysimeter walls. Asbestos was chosen because of its low water-holding capacity and heat conductivity. The corners of each box were tarred as a deterrent to leakage. The sides were held in place by small angle irons bolted in each corner.

* PR-51 provided by Atlantic Refining Company.

Table I. Lysimeter numbers, treatments, and randomization.

Lysimeter No.	Soil	Treatment No.	Treatment
1.	Manhattan	1.	Manhattan
2.	Bridger	7.	VAMA coarse
3.	Huntley	3.	Huntley
4.	Bridger	9.	VAMA fine
5.	Bridger	8.	Surfactant
6.	Bridger	4.	Bridger
7.	Bridger	6.	Straw mulch
8.	Bridger	10.	Bridger
9.	Huffine	2.	Huffine
10.	Bridger	5.	Rock mulch
11.	Bridger	4.	Bridger
12.	Bridger	6.	Straw mulch
13.	Bridger	5.	Rock mulch
14.	Bridger	8.	Surfactant
15.	Huffine	2.	Huffine
16.	Bridger	7.	VAMA coarse
17.	Bridger	10.	Bridger
18.	Huntley	3.	Huntley
19.	Manhattan	1.	Manhattan
20.	Bridger	9.	VAMA fine
21.	Manhattan	1.	Manhattan
22.	Bridger	6.	Straw mulch
23.	Huffine	2.	Huffine
24.	Bridger	8.	Surfactant
25.	Bridger	5.	Rock mulch
26.	Bridger	10.	Bridger
27.	Huntley	3.	Huntley
28.	Bridger	7.	VAMA coarse
29.	Bridger	4.	Bridger
30.	Bridger	9.	VAMA fine

Table I continued.

Treatment No.	Soils under study
1.	Manhattan fine sandy loam soil
2.	Huffine silt loam soil
3.	Huntley alkali soil
4.	Bridger clay loam soil
	Soil treatments under study
5.	Bridger clay loam + rock mulch
6.	Bridger clay loam + straw mulch
7.	Bridger clay loam + VAMA coarse
8.	Bridger clay loam + surfactant
9.	Bridger clay loam + VAMA fine
10.	Bridger clay loam soil

Stretch metal 1/8 inch thick was cut to the dimension of each lysimeter and placed in the bottom. This was covered with a 1-inch layer of glass wool on which the soil rested.

The lysimeter box was approximately 13 inches square, and the depth from stretch metal to top was 7 inches. The top edge of each individual box was placed 2 inches above ground level. It was decided that each box would contain 4 inches of soil. The soil surface in the lysimeter was approximately at ground level.

One-half-inch copper tubing with a 3-inch funnel soldered in one end connected the individual lysimeters with receptacles in the trench below. The lysimeter boxes were centered over the funnels in the copper tubing. Individual cans in the trench collected leachate which drained from the lysimeter boxes through the funnels and copper tubing.

Each lysimeter was centered within a 4-foot square area on which the soil treatment was similar to that in the lysimeter. Thus each lysimeter was surrounded by a 16.7-inch band of soil similar to that within the lysimeter. This was used to reduce mixing of soil within the lysimeter with untreated surrounding soil due to splash. Treatment of soil within the 4-foot square areas was identical to that in the appropriate lysimeter except where surfactant was used. A water solution of surfactant was sprinkled on the area surrounding the lysimeter, whereas dry surfactant was mixed with the soil in the lysimeter.

A solution balance was placed in a balance house on the north side of the experimental area. A window and hole in the balance house door allowed accurate weighings during windy weather.

An 8-day recording rain gauge was also placed at the experimental area. This assured accurate readings during the small thundershower season.

With this experimental setup, precipitation, infiltration, and increase or decrease in weight of each individual box could be determined. By knowing these factors, evaporation could easily be determined, and with all four factors, efficiency of each soil and treatment could be calculated.

Weighings were made at approximately 3-day intervals when weather permitted.

Figures 1 and 2 show experimental diagram and design.

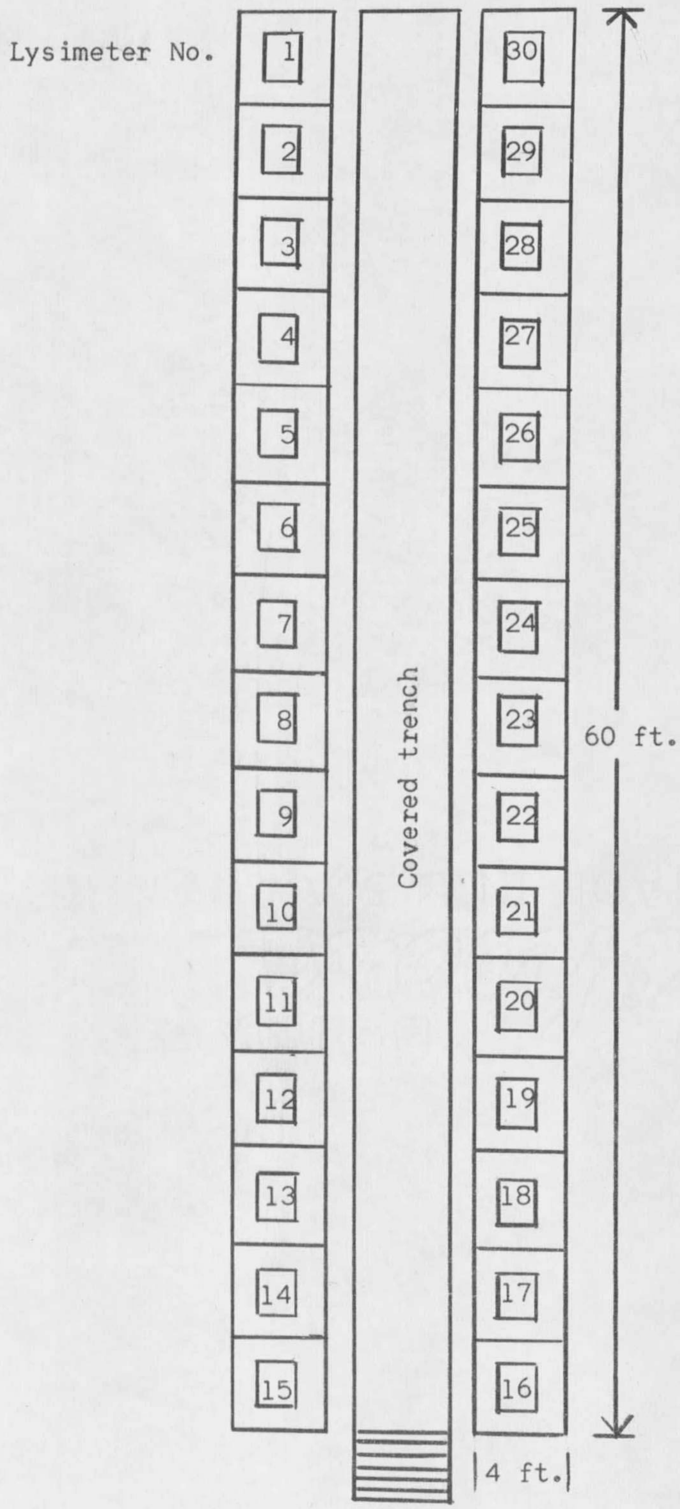

Figure 1. Lysimeter experimental design.