EFFECT OF SOIL TEXTURE ON EVAPORATION
WITH IMPLICATIONS FOR PLANTS

by

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INTRODUCTION

Plant geographers and ecologists have observed that vegetation in dry climates is more mesophytic on coarse- than on fine-textured soils (Hillel and Tadmor, 1962). The greater water supply for plants on the coarse-textured soils might result from less evaporation from coarse than from fine soils. However, it also might result from less runoff from the coarse soils as a result of the higher infiltration rates. In addition, the soil on steep slopes is usually coarser than on level areas, and the observation that vegetation is more mesophytic on slopes than on level areas has been attributed by some to a lower incidence of fire on the steep slopes.

It is difficult to know the importance of each of these causes for the greater mesophytism in coarse soils. Surprisingly, little experimental work has been done on the ecological importance of differential evaporation from soils of different texture. This study has been designed to help supply this information.

REVIEW OF LITERATURE

The importance of evaporation of soil moisture has long been recognized. According to one estimate 75 to 80 percent of the precipitation is lost through evaporation from bare fields in the Great Plains areas of the United States (Mathews and Cole, 1938, pp 679-692). Kelley (1961) reported that if evaporation could be reduced by the equivalent of 7.6 cm of precipitation per year (15% in a 51 cm rainfall belt), the ten Great Plains states alone would have an additional 300 million acre-feet of water, enough to fill Lake Mead. He also indicated that the need for supplemental irrigation in much of the eastern part of the United States could be

practically eliminated if evaporation of soil moisture could be reduced
by 20 percent. These and many other reports stress the importance of
evaporation of water from soil. On the other hand, some workers like
Veihmeyer (1938) have criticized the emphasis on evaporation, believing
that transpiration was more important than evaporation in depleting soil
moisture. Most workers believe both transpiration and evaporation are
important, and many have studied soil and meteorological factors affecting
evaporation and implications for plants. Although some have believed that
texture affects evaporation rate, very little experimental evidence has
been produced in support of the conclusions.

Soil Scientists' Views of Evaporation

Mosier and Gustafson (1917, pp 243-244) wrote, "surface soils are
dry in arid regions and this prevents, in a measure at least, a large loss
of water, since the movement of water through dry soil is very slow." They
assumed that coarse soils have more rapid water-vapor movement than fine-
grained ones, but the loss in either case is very small. They provided no
experimental evidence. Lutz and Chandler (1946, pp 234-236) recognized
that rocks in fine-textured soils reduce water loss by evaporation. They
also recognized the favorable conditions for tree growth on sandy soils in
dry regions due to less evaporation but did not prove it experimentally.
In the 1950's, after some work had been done on the role of texture in
evaporation, some writers, like Cocannouer (1954, p 120) did not mention
a single word about the effect of texture on evaporation. Kohnke (1968,
p 35), in his book Soil Physics, included one sentence that coarse-textured
soils had too little capillarity to supply the surface with water.

Some workers have been more specific by separately considering the effects of capillarity, water-holding capacity, and mulches on evaporation.

Effect of Capillarity on Evaporation. As early as 1898, King, in his book The Soil (pp 173-177), reported that more water was evaporated from coarse-textured soils than from fine-textured soils when they were kept in a saturated condition so that flow of water was continuous to the surface of soil columns placed in the laboratory. He attributed this phenomenon to the large size of capillary pores in coarse-textured soils, which conduct water faster to the surface than the smaller pores of other soils. He was so impressed by the part played by capillarity that he almost ignored mentioning the soil texture in his future experiments conducted in the field and concluded that thorough plowing checks the evaporation beneath the stirred portion of soil. It is important to note that he did not mention the place and time of his experiments throughout his lengthy discussion in his book. According to the preface, he purposely avoided technical details in order to encourage more research in this field. Burkett (1912, pp 166-167) emphasized the importance of capillaries when discussing evaporation from soil, but ignored texture. Baver (1956, pp 280-283) emphasized environmental factors affecting the rate of evaporation without much recognition of the effect of texture. On the basis of work done in the late nineteenth century he dealt mostly with the importance of a dry loose layer of soil on the surface in order to break capillary connections with the soil beneath. He cited one example indicating that there was some importance of size of soil particles and then concluded that greater evaporation from the finer fractions was undoubtedly due to their greater capillary capacities. Sykes and Loomis (1967) reported that untreated

structureless loam and sandy soils lost more water by evaporation than those treated with soil-aggregating agent (2% of Krilium) in soil columns 45 cm long. Evaporation remained the same in silty clay loam with good structure when treated and untreated with Krilium. They postulated that because aggregation reduced particle contact, capillarity was reduced, and as a result less water was evaporated from treated loam and sandy soils.

Krilium itself absorbs water, which they did not mention and they did not compare evaporation from different textured soils supplied small amounts of water.

Effect of Moisture-Holding Capacity on Evaporation. In 1907 Briggs and McLane concluded that moisture-retaining power of soil particles was low in sand and high in fine-textured soils, but did not mention evaporation. Russell (1937, p 504) though mainly concerned with differential water-holding capacity of soils, mentioned that the texture of the surface layer was important in affecting evaporation. He wrote that water loss by evaporation was less from "light" than from "heavy" soils. Krynine (1937, pp 30-31) included soil texture as one factor affecting evaporation. Because soils of different texture have different amounts of surface area on the soil particles, they have different capacities to resist evaporation. Veihmeyer and Hendrickson (1955) supported this view with explanations of moisture relationships in surface soils. Because sand holds little water, the upper layer soon dries below the permanent-wilting point but fine-textured soils must lose more water to reach this state.

Effect of Mulches on Evaporation. Lyon and Buckman (1939, p 158) in their book The Nature and Properties of Soils, mentioned evaporation of water and its reduction by the application of artificial and natural mulches

but did not mention any effect of texture on evaporation. Penman (1941) doubted the value of mulches for reducing the rate of evaporation under warm summer conditions. He reported that the initial rate of evaporation was higher from sandy loam than that from clay loam soil, but that the rate soon becomes the same in the two soils. His observations were based on laboratory experiments in which soils were initially drained freely and no water was added afterwards. Tsiang (1948) found that pebble mulches reduced the rate of evaporation in some of the dry sections of China. Similar results are reported by Hanks and Woodruff (1958) and Benoit and Kirkham (1963). Donahue (1955, p 263) was mainly concerned with application of organic mulches to reduce evaporation, and mentioned that the coarser the texture, the deeper the percolation of water and the lesser the water loss.

Plant Ecologists' Views of Evaporation

The attitude of plant ecologists was similar to that of soil scientists. Early workers emphasized the importance of climatological factors and soil factors other than texture in plant distribution.

Briggs and Belz (1910) believed that the distribution of short grasses in the Great Plains areas was related to evaporation losses of water more than to the amount of precipitation, but they did not consider soil texture. Shreve (1925) attributed the distribution of plants in the deserts of California to the effect of differential precipitation but he also did not consider soil texture. Weaver and Clements (1929, pp 168-180) restricted most of their discussion of plant distribution to the effect of climatological factors. However, they considered total surface area of

soil particles an important soil property. The finer the particles the
more surface is presented for the retention of water and greater is the
absorbing area for plants. But they did not mention the role of texture
in evaporation and its implication for plants.

Dice (1952, pp 83-34) and Woodbury (1954, p 64) did not mention soil
texture but gave much importance to meteorological conditions for plants.
Oosting (1956, p 164) discussed the effect on evaporation of climatic
factors, exposure, cover and color of soil, but did not mention texture.
Hanson and Churchill (1961, p 69) in their book The Plant Communities,
mentioned texture, structure, moisture content and chemical constituents
as factors affecting the grouping of plants without any emphasis on either
of those factors separately. Emphasizing the need to know the water balance
in different textural soils in dry climatic zones of Spain, Tames (1961)
pointed out that more water was stored in sandy soils than in clayey soils
in areas receiving only the water which falls on them through rain, thus
providing better moisture relations for plant growth.

Recognition of effect of texture on evaporation in controlling plant
distribution in dry areas was by Hillel and Tadmor in 1962. Comparing the
moisture regimes of four habitats in the Central Negev Highlands of Israel,
they found that sand had more favorable moisture conditions due to greater
infiltration, lack of surface runoff and less evaporation than fine-
textured soils. They stated that in such dry areas the situation was the
reverse of that found in humid areas where sands were more droughty than
fine-textured soils. Rickard and Murdock (1963) obtained similar results
in a study of desert vegetation mosaic at the Atomic Energy Commission
Test Site in Nevada.

Daubenmire (1965, pp 19-20) stated that surface evaporation removed much of the water which might be utilized by plants without reference to texture. In Plant Communities (1968, p 200) he mentioned that stabilized sand dunes in arid and semi-arid regions formed relatively favorable habitats for plants, because almost all of the water that falls on them is available for plant use.

Experiments on the Effect of Texture on Evaporation

Keen in 1914, 1921, and Keen, Crowther and Coutts in 1926 gave some evidence that soil texture is important in evaporation. They studied evaporation and absorption in thin layers of soils in chambers with controlled humidity, and concluded that rate of evaporation was controlled by clay content and the amount of organic matter present in soil. Gardner and Fireman (1958) supplied moisture to the bottom of soil columns to study the rate of evaporation, in different textured soils, under the influence of wind. The low rate of water loss from quartz sand was attributed to the failure of the relatively large sand particles to remain moist at the surface even at low rates of evaporation. The rate was also related to the depth of water table. The greater the depth, the drier the surface of soil and the lower is the rate of evaporation. Similar results were reported by Hanks, Gardner and Fairbourn (1967) who observed that evaporation under isothermal conditions was slightly less in sand than in silt loam in soil columns 45 cm long initially wet to the bottom.

Review of the literature indicates that most of the early work, which later on greatly influenced the future line of thinking, has been done in humid and subhumid areas where evaporation is not a big problem. However,

some ideas about the role of texture in evaporation have been put forward
by the workers who dealt with the problems of evaporation in drier climates
or compared soils of different textures and their implication for plants.
None of them have experimentally separated the effect of texture on evapo-
ration from effects on runoff and fertility.

In summary, experimental work is inadequate to assess the effect of
texture on evaporation in climates in which precipitation is insufficient
to wet soils below the root zone.

MATERIALS AND METHODS

Experiments were conducted from June 11 through December 3, 1968, in
a greenhouse at Kansas State University, Manhattan. Daily maximum tempera-
ture varied from 20 to 40 C and minimum temperature 10 to 15 C. To reduce
temperatures during the summer the roof was whitewashed and the greenhouse
was evaporative cooled. The exhaust fan was about 5 meters northwest of
these experiments and the evaporative cooling pads about 15 meters south.

Three soils were collected. About 300 kg of freshly deposited
washed gravelly sand were collected on the east bank of the Kansas River.
This site lies 0.8 km southeast of Manhattan (NW 1/4 NW 1/4 sec 20, T10S,
R8E), Riley County, Kansas. About 500 kg of loam from the A horizon in the
grassland-forest border along the side of a small valley just north of the
Kansas River Valley were collected 6.4 km east of Manhattan, 0.4 km north
of Highway 24 (NW corner sec 12, T10S, R8E), Pottawatomie County, Kansas.
About 300 kg of silt loam, mostly from the A horizon, were collected along
the bank of a temporary stream valley which had been straightened by man.
The soil was high in organic matter and covered with _Bromus inermis_. The

soil was collected 3.2 km north of the KSU campus (NW corner, sec 6, T10S, R8E), Riley County, Kansas. These three soils were collected in April, 1968. The soils were passed through a 6-mm sieve, air dried by spreading on pavement and thoroughly mixed by frequent mixing with a rake and shovel.

The tests were made in 60 plastic sewer pipes, 10 cm inside diameter, 90 cm long with a wall thickness of 0.35 cm. A wooden disc was held in the bottom by two wires inserted through holes drilled about 5 mm from the end.

Soils were uniformly packed in these pipes, using a wooden rod to compact the soils after each addition of about 5 cm of soil. Care was used to prevent sorting of the soil during handling. The soil-filled pipes (soil columns) were held in three wooden frames, ten on each side of each frame. To reduce temperature fluctuation through the sides of the pipes, the covers on the sides were lined with 6-cm thick glass-wool building insulation (Fig. 1, and Fig. 2).

A platform scale was used to weigh the soil columns. The smallest unit on the sliding beam was 10 g. Unfortunately the results of series I indicated that soil-column weights were not reliable. Therefore, the amount of water added and not evaporated was calculated by subtracting the initial water content (air dry moisture) from the water content of the soil at the end of the experiment. Unfortunately the need to use this procedure was not foreseen so moisture content was not obtained for soils at the beginning of experiments, and had to be inferred from the moisture content of the dry soil in the bottom portion of soil columns. This method was used in series I, IV and V but not in series III, in which soil moisture was not ascertained. In series III the soil-column weights were used.

Fig. 1. Soil-filled pipes held in three wooden
frames, oriented east-west.

Fig. 2.   Arrangement of pipes within each frame,
showing insulation.

In spite of great care taken to mix the soils thoroughly, the air-dry
moisture content was not entirely uniform in fine-textured soils. So, for
calculating the total moisture left at different depths in fine-textured
soils, the average moisture content present below the wet layer was used.

At the completion of series I, IV and V (without plants) soil samples
were obtained at various depths in the soil columns with the help of a hand-
made auger and moisture percentages were determined gravimetrically.

The Bouycucos-hydrometer method was used for mechanical analysis of
each soil (Table I). Soil moistures at various atmospheric pressures
(Table II) were obtained by use of pressure membrane apparatus (Richards,
1947). Moisture equivalents were ascertained by the method described by
Briggs and McLane 1907, and the hygroscopic coefficients were determined by
the method described by Baver (1956, p 283) (Table II).

Four of the six series of experiments were conducted without plants
to assess evaporation losses from the three soils when equal amounts of water
were added to each soil. The different watering treatments involved differ-
ent amounts and different intervals between addition of water. When water
was added to the sand care was taken to spread it evenly over the entire
surface. In the other two soils the water flowed over the surface and in
them special care was taken to avoid mechanical packing by pouring the water
gently onto the surface.

The two series with plants were conducted to confirm that the differ-
ences in water evaporated would be important to plants.

The amount of water applied was not intended to wet any soil column
to the bottom. The sand columns in some cases did become wet to the bottom
because of the low water-retaining capacity, but in no case did the other
soils become wet deeply.

Table I. Mechanical analysis of soils (percent by weight).

Soils	Gravel 6-2 mm	Sand 2-0.02 mm	Silt 0.02-0.002 mm	Clay < 0.002 mm
Gravelly sand	10.95	84.20	4.85	0
Loam	0	47.80	40.20	12.00
Silt loam	0	11.80	62.20	26.00

Table II. Characteristics of soils used.

Soils	Saturation	Moisture percentages (oven dry weights)								Moisture equivalent	Hygroscopic coefficient
		Soil moisture tension (atm)									
		1/10	1/3	1	3	7	11	13	15		
Gravelly sand	20.17	1.59	0.77	0.75	0.64	0.50	0.40	0.35	0.30	1.63	0.29
Loam	32.74	30.96	15.85	11.59	9.69	8.18	7.30	6.60	5.80	15.06	4.63
Silt loam	52.14	40.60	29.60	22.49	20.26	16.44	14.30	13.40	12.50	25.63	9.61

Series I. Evaporation When Watered Weekly

To compare evaporation among the three soils without plants, two amounts of water, layers 1.0 cm and 1.5 cm deep (80 ml and 120 ml, respectively), were added at weekly intervals for five weeks, to five replicates of each of the three soils. The weights of the soil columns were obtained initially, just before each weekly watering, and just before obtaining soil samples at the end of the experiment. Sampling the soil for gravimetric determination of soil moisture was done one week after the last watering. The series was begun on June 11 and ended on July 16. The weather was generally sunny and hot.

On July 6, in the fourth week, the greenhouse bed containing the soil columns was accidentally flooded with water 1 to 3 cm deep by someone who forgot to turn the water off after watering in the greenhouse. Due to this flooding, some water was absorbed by the soil columns from below as shown in Fig. 3 and 4, but this water did not move up the soil columns enough to contact water added from above except in the sand. Thereafter, wood boards were placed below the soil columns to reduce the likelihood of such trouble in the rest of the series. These boards raised the top of soil columns 1.5 cm above the insulation at the sides.

Series III. Rate of Evaporation After One Watering

In this series water was added only at the beginning in order to ascertain the rate of evaporation and the length of time necessary for evaporation of all the added water at least from one type of soil. Two amounts of water, 1 cm and 2 cm, were added to each of three soils, replicated five times. Soil-column weights were obtained daily for the first

4 days and every other day in the following 10 days. The experiment was run from July 22 to August 5. There were several cloudy days in the middle of this experiment, resulting in a reduction in evaporation.

Series IV. Effect of Interval of Watering on Evaporation

Because series I indicated that much less water was lost by evaporation from the gravelly sand than from the two fine-textured soils, it was decided to ascertain the effect of interval of watering on evaporation when the same total amount of water was added per unit of time. In addition, a test was included to assess the effectiveness of a 10 cm layer of sand over loam in reducing evaporation.

The results of this series were erratic due to unknown causes, perhaps from leakage through the greenhouse roof. Therefore, it has been omitted from the results section and series V was run to replace part of it.

Series V. Effect of Interval of Watering on Evaporation

Because loam and silt loam had given similar results, only loam and sand were compared in this series. Three amounts of water; 0.31 cm at 2 day, 0.62 cm at 4 day, and 1.25 cm at 8 day intervals, were replicated four times. Sampling of soil for gravimetric moisture determination was done 2, 4, and 8 days after last watering. The series was run for 32 days beginning from September 22 to October 24, during which the weather was generally sunny. Thus each soil column received 5 cm (400 ml) of water during the 32 days.

Series II.   Germination and Growth of Sorghum
When Watered Weekly

This series was designed to duplicate series I except that sorghum
plants were grown in the soil columns to assess the differences in amount
of water available to plants. As in series I, two watering treatments,
replicated five times, were used in each of three soils, 1.0 cm and 1.5 cm
per week. Five seeds of Sorghum vulgare var. K.S. 14 were sown in each
soil column at a 2 cm depth. Because the seeds did not germinate in the
fine-textured soils watered with 1 cm per week, these columns were covered
with petri dishes at the end of second week to keep the soils moist long
enough for germination. After emergence, the petri dishes and all but one
seedling were removed. To reduce differences in fertility a nutrient
(Hyponex) solution was used instead of pure water. The series was run con-
currently with series I from June 11 to July 30. One week after last
watering the heights and condition of the plants were recorded and dry
weights of the aerial parts of the plants were obtained.

Series VI.   Growth of Sorghum When Watered Weekly

In series II, the effect of texture on growth was confounded by
differences in time of germination in case of the lower water supply.
Therefore, this series was designed to observe growth on plants of the
same size.

In the four replicates of each of the three soils, five seeds of the
same variety of sorghum per soil column were sown at the same depth as in
series II. Enough water was added in the beginning to keep the upper 10 cm
of soil columns favorably moist so that all the seeds germinated at the

same time. After germination, plants were flushed periodically with a nutrient (Hyponex) solution to reduce differences in fertility. After establishment all tubes were thinned to one seedling. The seedlings developed about equally in all soils. When they were 26 to 28 cm tall (October 1) the experimental watering was begun, initially 1 cm of water per week. Because the evaporation rate was reduced as the weather became cooler, on November 5 the amount of water added was reduced to 0.5 cm per week.

The experiment was continued until the plants wilted or died in some of the soils. The experiment was terminated at the end of the 9th week (four weeks after starting the reduced amount of watering). Size, condition and dry weights of tops, depths of roots and water penetration were recorded at the end of the experiment.

RESULTS

Series I. Evaporation When Watered Weekly

More than twice as much water evaporated from fine-textured soils as from sand when a layer of water 1 cm deep was added per week and about three times as much evaporated when 1.5 cm was added. The difference resulted from the fact that in one week about all the water evaporated in all three soils from the upper 10 cm, but in the sand much more water percolated below this evaporation zone in the case of the heavier watering (Table III, Fig. 3 and 4).

Series III. Rate of Evaporation After One Watering

In the 1-cm watering treatment the difference in evaporation between gravelly sand and loams increased till the 6th day, remained constant for

Table III. Average and range in amount of water lost
by evaporation in Series I in 5 weeks
(June 11 – July 16).

Soils	1 cm water/week	1.5 cm water/week
Gravelly sand	% 37 (33 – 41)	% 28 (16 – 35)
Loam	93 (90 – 96)	80 (73 – 86)
Silt loam	87 (85 – 90)	82 (79 – 86)

LSD – 7.8 at 1% level.
5.8 at 5% level.

Fig. 3. Soil Moisture, 7 days after last watering, in soil columns to which a layer of water 1 cm deep was added at 7 day intervals for 5 weeks (Series I).
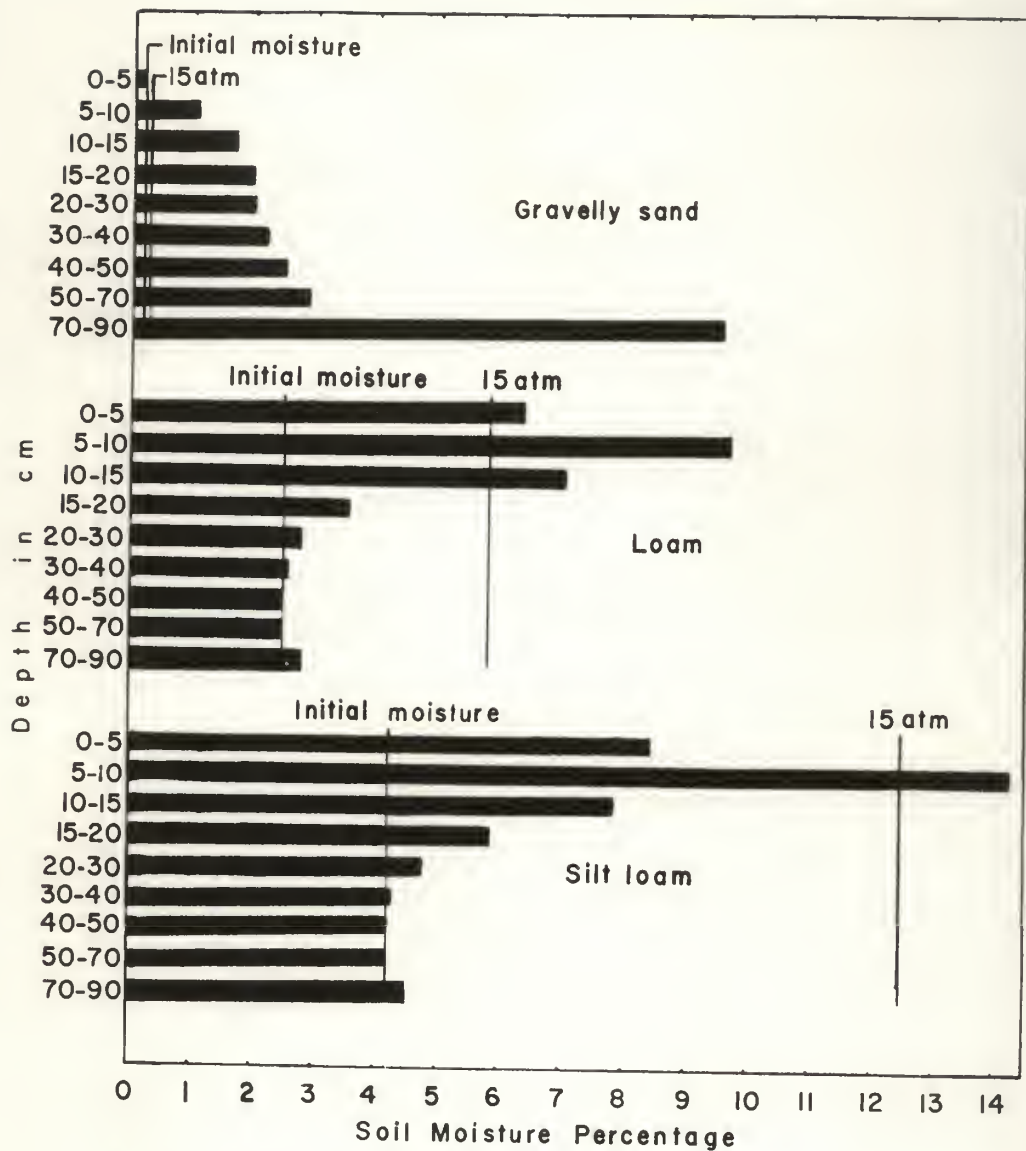
Fig. 4. Soil moisture, 7 days after last watering, in soil columns to which a layer of water 1.5 cm deep was added at 7 day intervals for 5 weeks (Series I).

the next three days and then decreased steadily till the end of experiment.
This difference was significant at the 5% level between silt loam and sand
from the 6th through the 12th day. At the end of 14 days, all of the water
had evaporated from the loams but 10 percent of the water was present in
sand (Fig. 5). In the 2-cm watering treatment the difference in evapo-
ration between gravelly sand and loams was statistically significant after
the first day. The difference increased slowly till the 14th day, when it
was maximum. After 14 days, 90 and 88 percent of the water added was
evaporated from loam and silt loam, respectively, and 50 percent from sand
(Fig. 6).

Series V. Effect of Interval of Watering on Evaporation

Percentage of water loss decreased as the interval and amount of
water added increased. The decrease in evaporation was much greater in
the sand than in loam. The effect of watering interval on evaporation was
statistically highly significant in both soils (Table IV).

When 0.31 cm was added at 2-day intervals, all of the water was con-
fined to the upper 20 cm; when 0.62 cm was added at 4-day intervals it wet
more deeply, and when 1.25 cm was added at 8-day intervals a still deeper
layer was wet. The sand was wet to the bottom in the 8-day interval
watering (Fig. 7).

Series II. Germination and Growth of Sorghum When Watered Weekly

When 1.5 cm of water was added per week, all soils had sufficient
water to support the sorghum plants for the 7 weeks of the experiment.
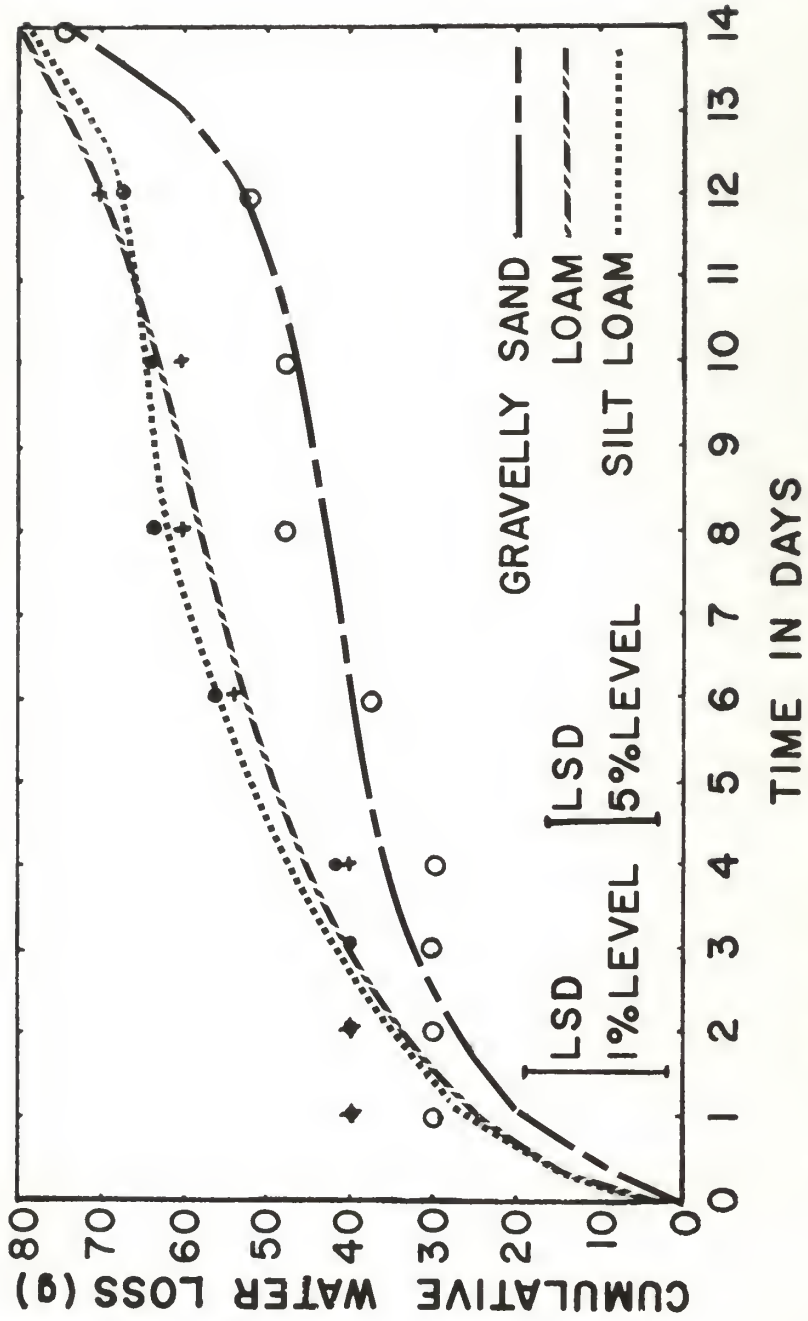Emergence of seedlings occurred in each soil in 2 to 4 days. The plants

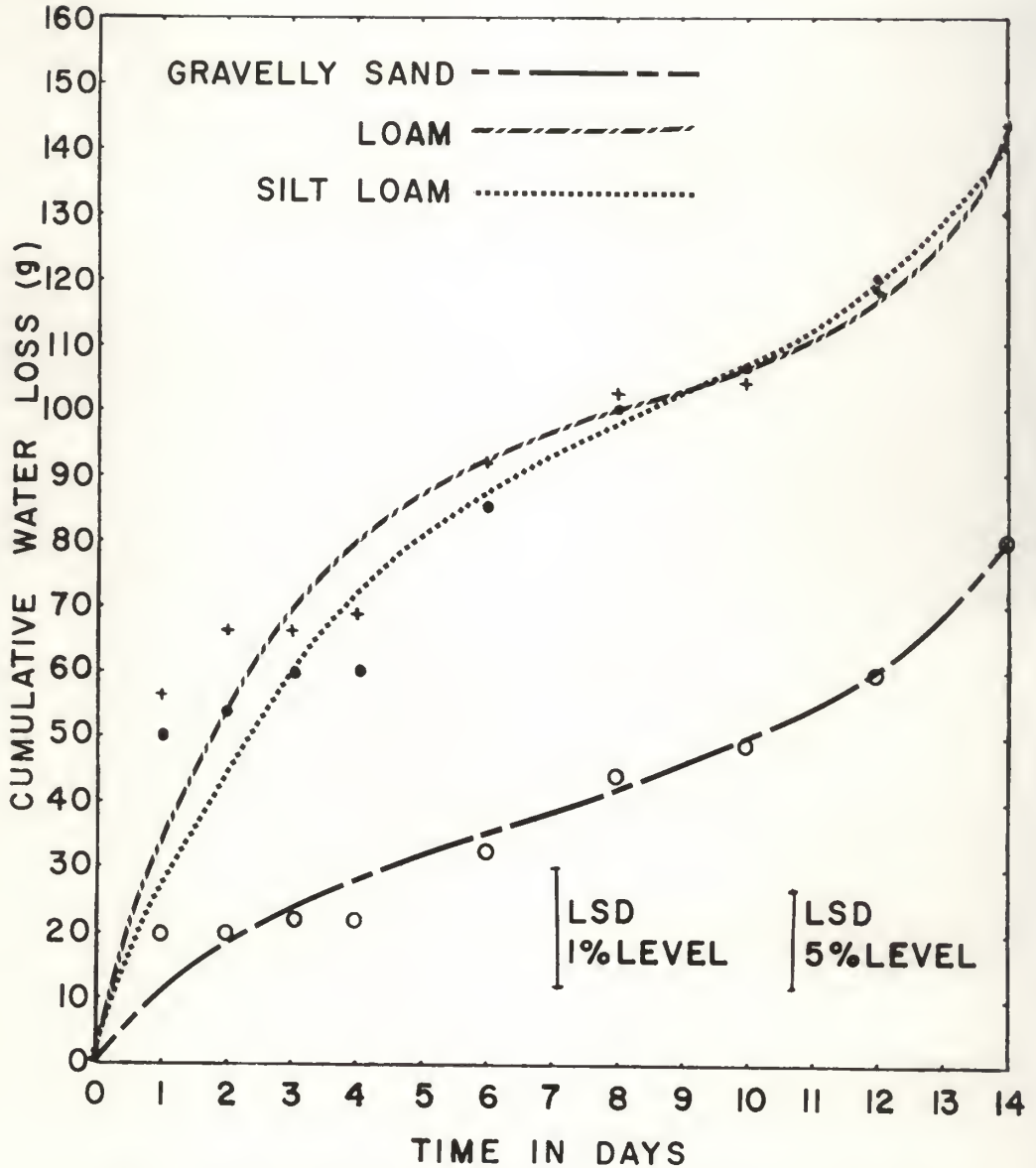Fig. 5. Water lost by evaporation in 2 weeks after one watering (1 cm deep) on July 22 (Series III).

Fig. 6.   Water lost by evaporation in 2 weeks after one watering
(2 cm deep) on July 22 (Series III).

Table IV.   Average and range in amount of water lost by evaporation
in 32 days in Series V (September 22-October 24).

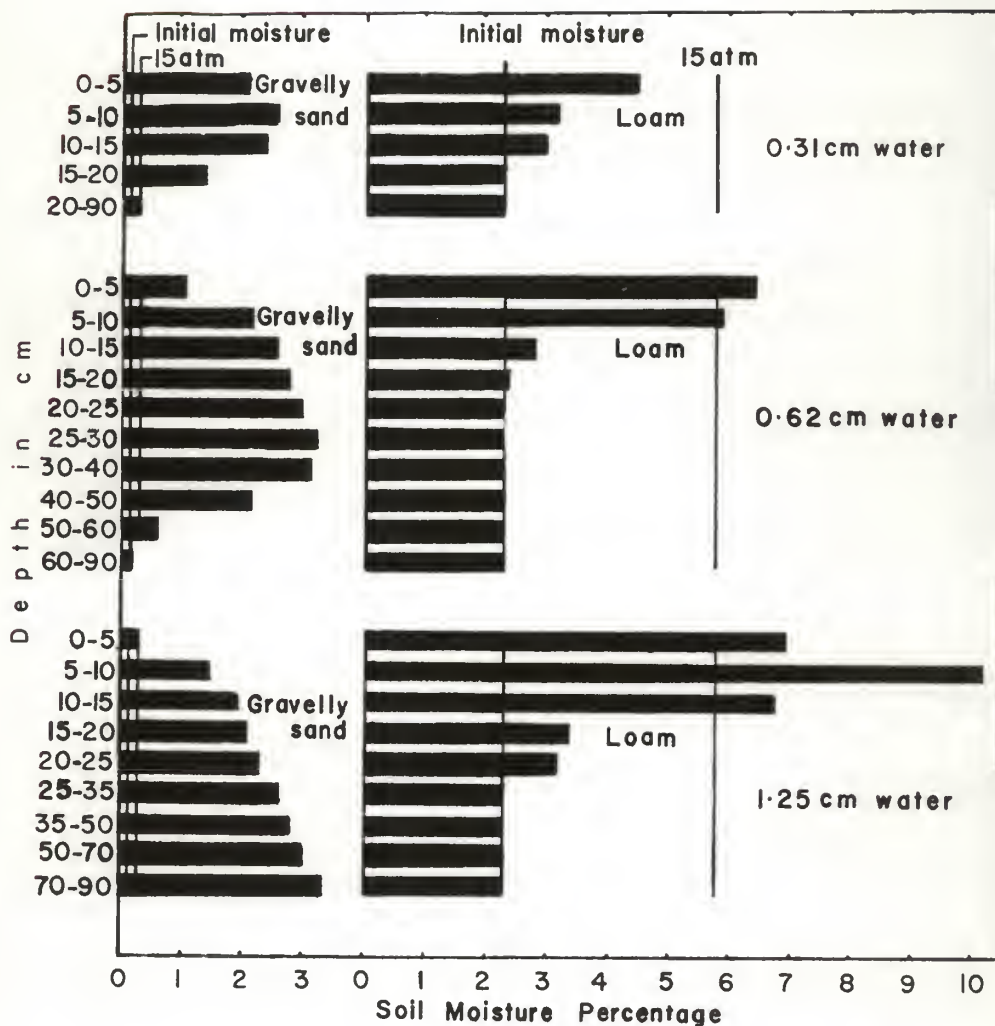| Soils	0.31 cm water added at 2 day intervals	0.62 cm water added at 4 day intervals	1.25 cm water added at 8 day intervals
	%	%	%
Gravelly sand	87	59	27
	(83 - 90)	(54 - 69)	(24 - 31)
Loam	95	89	75
	(94 - 96)	(88 - 91)	(73 - 78)

LSD - 7.6 at 1% level.
5.5 at 5% level.

Fig. 7.   Soil moisture, 2 days, 4 days and 8 days after last
watering in soil columns, to which layers of water
0.31 cm, 0.62 cm and 1.25 cm deep was added at 2, 4
and 8 day intervals, respectively, for 32 days
(Series V).

grew a little better in the loams than sand, probably because the fertility was better in the loams, even though a nutrient solution had been added.

When 1.0 cm of water was added per week, emergence occurred in 9 to 12 days in the sand, but no emergence had occurred in the loams by 14 days, so at that time the tubes were covered. Emergence then occurred 2 to 4 days after covering the loam and 9 to 14 days after covering the silt loam. Within 2 to 3 weeks after uncovering the columns, one seedling died and four wilted in the loam and three died and two wilted in the silt loam. All remained alive and active in the sand. The plants were larger in the sand than in the loams, partly due to age and partly to water supply.

Series VI. Growth of Sorghum When Watered Weekly

When the water supply was 1.0 cm per week, all plants grew well, but after the amount of water supply was reduced to 0.5 cm per week, the condition of plants started deteriorating in loam and silt loam. Most of the plants in the loams were dead at the end of the 9th week (four weeks after the amount was reduced to 0.5 cm per week), but those in the sand were still actively growing to the end of the experiment (Fig. 8). The depth of root and water penetration was greater in sand than in loams (Table V). In sand, the difference in water percolation among the replicates was high, perhaps due to differences in watering during germination, before starting the experimental watering.

DISCUSSION

The results of these experiments confirm that less water evaporates after a given watering in coarse than in fine soils. Obviously less water

Fig. 8.   Sorghum plants, grown in three soils; silt loam (left),
loam (middle) and sand (right), at the end of series VI,
after four weeks of watering with 0.5 cm/week.

Table V. Sorghum-plant growth in 3 soils supplied, after establishment, with 1.0 cm water per week for 5 weeks and 0.5 cm per week for 4 more weeks. Averages and ranges of four replications shown (Oct. 1 to Dec. 3) (Series VI).

Soils	Height of plants	Number of leaves	Size of leaf	Depth of root penetration	Dry weights of top	Depth of water percolation
Gravelly sand	43.5 cm (37-50)	7 (6-7)	25 cm (20-30)	39 cm (30-50)	1.00 g (0.60-1.40)	71.5 cm (50-85)
Loam	38 cm (36-40)	6 (6-6)	22 cm (21-23)	16 cm (12-20)	0.42 g (0.34-0.48)	20 cm (18-21)
Silt loam	40 cm (39-41)	6 (6-6)	22 cm (20-24)	15.5 cm (11-16)	0.45 g (0.34-0.52)	18.5 cm (16-20)

is held in a given depth of sand than of loam, so this means that the depth
to which water is removed by evaporation is not inversely proportional to
the water retaining capacity. Instead, the thickness of the surface layer
dried by evaporation in these experiments was less than twice as great in
gravelly sand as in loams, yet the water-holding capacity of the gravelly
sand is 1/10 and 1/15 that of the loams.

Obviously, then, the depth of wetting is of great importance to
evaporation. Even in coarse sands, if the wetting is shallow enough it
will all evaporate in a day or two, and even in loams or clays, if the
wetting is deep, only a small proportion will evaporate. Thus in series V,
much more water evaporated when a total of 5 cm of water was added at 2-day
intervals, than when the same total amount of water was applied at 4- or
8-day intervals.

In these experiments little difference in evaporation was found be-
tween loam and silt loam. It would be helpful to know whether sands must
be as coarse as in these experiments to have appreciably less evaporation
than loams, or whether fine sands also lose less water than loams. These
experiments, including those with plants, confirm the findings of Hillel
and Tadmor (1962), who stated that sand had more favorable water relations
than loams in dry climates. These experiments show that the difference
between sands and loams is not only due to less runoff, but also due to
less evaporation from the coarse soils.

SUMMARY

These greenhouse experiments were conducted to test the hypothesis that coarse-textured soils lose less water by evaporation and therefore support more mesophytic vegetation in dry climates than do fine-textured soils.

In all the experiments without plants, gravelly sand lost less water by evaporation than loams. The amounts of water added seldom wet the loams more than 20 cm deep, yet usually wet the sand more than 3 to many times as deep. Evaporation was increased in all soils when the interval of watering was decreased. Sorghum plants grew well in gravelly sand but wilted and died in loams supplied with small amounts of water.

These experiments confirm that sand provides more favorable water relation for plant growth than do fine-textured soils in dry climates. The difference is not only due to less runoff, but also due to less evaporation from sand.

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EFFECT OF SOIL TEXTURE ON EVAPORATION
WITH IMPLICATIONS FOR PLANTS

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Six series of greenhouse experiments were conducted to test the hypothesis that coarse-textured soils lose less water by evaporation than do fine-textured soils, and therefore support more mesophytic vegetation in dry climates.

The experiments were conducted on a gravelly sand, loam, and silt loam in insulated plastic pipes 90 cm long and 10 cm inside diameter. In the first series five replicates of each of the three soils were watered at weekly intervals for five weeks with a layer of water 1.0 cm deep and another set with 1.5 cm. The gravelly sand lost 37 and 28 percent of the added water, the loams about 90 and 80 percent of the water, respectively.

All of the water evaporated from loams but some water remained in sand after 1 cm of water was added. The difference in evaporation was statistically significant at 5% level only between sand and silt loam after 6 days. When 2 cm of water was added about 90 percent of the water was evaporated from loams and only 50 percent from sand. The difference in evaporation was statistically significant between sand and loams after the first day.

In another series 5 cm of water was added to the soils in a 32-day period at three different intervals; 2, 4 and 8 days. The sand lost 87, 59 and 27 percent and the loam 95, 89 and 75 percent of the water in the 2, 4 and 8 day interval tests, respectively. In one test with sorghum, germination did not occur in the loams until evaporation was reduced by covering the surface, but with the sand germination was prompt. In another test each soil was kept moist until the plants were 26-28 cm tall. Subsequently, when soils were watered equally, the sorghum in the sand grew well but the sorghum in the loams soon wilted and in some cases died.