Journal of the Minnesota Academy of Science

Volume 6 | Number 1 Article 9

4-1938

Infiltration And Capillary Rise In Sandy Soils

Wallace M. Johnson
University of Minnesota

Brother, your grape is better than the Beta Grape (a popular variety of Minnesota); you should call this the 'Alpha Grape'."[6] Father John realized its possibilities and set to work. In a few years he had a fine vineyard of Alpha Grapes, as the variety continued to be called. The vine is of extraordinary hardiness and bears well, and its fruit is of the desirable quality. Shortly Father John had the grape in the hands of nursery men who have spread it far and wide for cultivation; the Jewell Nursery Company sold as many as 20,000 plants in a single year. Its true origin is still the mystery that it was to Brother William.

The Minnesota State Horticultural Society has duly recognized his work. For sixteen years he managed the Trial Station at St. John's; for one year (1907) he was Vice-President of the Society, which in 1923 conferred upon him the signal honor of life membership. Worthily has he been styled the "Burbank of the Northwest."[7]

INFILTRATION AND CAPILLARY RISE IN SANDY SOILS

WALLACE M. JOHNSON
University of Minnesota

Undoubtedly watersheds or drainage basins can be managed for maximum water yields in the same manner as other natural resources. Since the soil is an important natural reservoir, a thorough knowledge of the factors influencing the rate of movement of water through the soil is essential in making management plans for a particular area.

Such factors as texture, porosity, organic content, biologic channels, prevalence of monovalent basic cations, hydration of pores, and resistance of soil air are all generally considered important governing factors for the infiltration of water in soils. Capillary rise may be influenced by organic content, surface tension of the solution, texture and structure, and moisture content. Thus, the combined influence of all of these factors determines the rate of movement of water through soil.

However, in attempting to explain some results secured by the author from previous studies on infiltration capacities of sandy soils in Colorado,[1] it was thought that interfacial tension effects might influence infiltration capacity, although previous investigations by

[6] *Minnesota Horticulturist* — Vol. 46, p. 177ff. 1918.

[7] *Long Prairie Leader,* 1928.

[1] Unpublished data.

Published by permission of the Director of the Minnesota Agricultural Experiment Station as Journal Series Paper No. 1608.

Hilgard[2] and Karraker[3] indicated that soil amendments did not appreciably influence water movement.

The object of these studies, made at the University of Minnesota, was to determine the effect of surface tension agents on the rate of penetration and capillary rise of water in several sandy soils.

Methods

SOILS. Four different soils were used in this experiment, three of decomposed granitic origin from Colorado and one of glacial origin from the University's experimental farm at Coon Creek in Minnesota. Moisture equivalents and organic matter content were determined for each soil, and the results are presented in Table 1.

TABLE I. ANALYSIS OF FOUR SOILS USED IN PRESENT INVESTIGATIONS

Source	Class	Moisture Equivalent	Percentage Organic Matter
Mountain Slope, Colorado	Coarse Sandy Loam	21.02	9.7
Mountain Valley, Colorado	Coarse Sandy Loam	10.45	2.8
Abandoned Field, Colorado	Very Fine Sandy Loam	17.66	2.8
Coon Creek Sand, Minnesota	Loamy Sand	4.52	1.6

The mountain-slope soil from Colorado was classed texturally as a coarse sandy loam but, because of its high organic content, the moisture equivalent is very high. This soil was taken from a 40 per cent slope with a vegetative cover of bunchgrasses (Festuca and Muhlenbergia). In its natural state the soil contains a very high percentage of skeletal material.

The mountain-valley soil from Colorado was of the same texture as that from the mountain slope, but has a much lower organic content and a correspondingly lower moisture equivalent. The slopes were more gentle, ranging from 5 to 12 per cent, and the vegetative cover was of the same type. The amount of skeletal material was high but lower than in the mountain-slope soil.

The abandoned-field soil was obtained from the same vicinity as the valley soil, but from areas that had been cultivated. The texture was a very fine sandy loam. Because of the finer texture, the moisture equivalent was higher than that of the valley soil. The vegetative cover was comprised of a sparce growth of annual and perennial grasses and weeds.

The Coon Creek soil is a loamy sand. The values for moisture equivalent and the percentage of organic matter were much lower than those of the Colorado soils.

SOIL TREATMENT. After collection, the soils were allowed to remain in the laboratory until they had reached an air dry condi-

[2] Hilgard, E. W. Soils. Macmillan Company. 1914.

[3] Karraker, P. F. Soil Moisture, Soluble Salts, and Surface Tension. Journal of Agricultural Research *14:* 1915.

tion. Each was then screened through a 2 mm. sieve to remove the coarser particles and was then carefully mixed to secure uniformity. A large portion of each soil was burned in a muffle furnace at red heat to destroy the organic matter. Upon cooling, the soil was again screened and thoroughly mixed.

Four different treatments, together with a nontreated control, were studied and are designated as follows:

1. Original Soil. This consisted of duplicate samples of each soil as described above without additional treatment.
2. Burned Soil. Duplicate samples of the burned soil as described above were used without further treatment.
3. Added Organic. To duplicate samples of burned soil, enough organic matter, in the form of peat, was thoroughly incorporated to bring the organic content back to the original value shown in Table 1. The peat had been dried and ground in a large food chopper equipped with burrs and screened through a 2 mm. sieve.
4. Added Calcium Stearate. Enough calcium stearate to make a 1 per cent concentration, by weight, was thoroughly mixed into duplicate samples of burned soil and screened. Uniformity of mixture was difficult to secure.
5. Added Urea. To duplicate samples of burned soil, enough powdered urea to make a 1 per cent concentration, by weight, was thoroughly mixed and screened in the same manner as the previous treatments.

It is recognized that the addition of organic matter, in the form of peat, to burned soil will not bring such a soil back to its original condition. It was thought, however, that such a reconstructed soil would serve to indicate the influence of organic matter on interfacial tension of the soil particles and subsequently affect the movement of water in the soil.

FACTORS STUDIED. The rate of capillary rise was studied in glass tubes 1½ inches in diameter and approximately five feet long. The bottom end of each tube was covered with cheesecloth held in place by a rubber band. The tube was held in an upright position by means of clamps and ring stands so that the bottom end rested on a Filtros block in a vessel containing distilled water. Soil was then poured into the tubes in a steady and uniform stream until full. This procedure did away with stratification to a considerable extent. After filling, gentle tapping was applied until settling ceased. This gave a very uniform packing, as is evidenced by the close agreement between the duplicates for each soil treatment. Immediately following the filling, the water vessels were filled with distilled water, and a constant level was maintained throughout the experiment. Measurements were taken at periodic intervals up to 120 hours. In some soils, maximum capillary rise was not secured, but continued rise after this time would have been extremely slow.

The rate of penetration was studied by determining the time

TABLE II. INFLUENCE OF CERTAIN TREATMENTS TO FAVOR DIFFERENT SOILS ON CAPILLARY RISE OF WATER

Average Capillary Rise in Inches

Kind of Treatment	Time (hours) ½	1	2	4	8	16	31	55	79	101	120
Mountain-slope Soil											
Original	5.13	7.38	9.5	12.0	15.25	18.25	21.38	23.75	25.25	26.5	27.5*
Burned	8.63	11.75	15.5	20.25	25.5	30.75	35.25	38.63	40.5	42.13	45.5*
Added Organic	7.13	9.63	13.0	17.13	21.63	26.5	30.38	34.75*	37.25*	38.75*	39.75*
Added Calcium Stearate	4.00	6.00	7.38	10.25	13.0	15.88	17.5	18.5	18.88	19.0	24.0*
Added Urea	9.38	12.50	16.25	21.63	27.25	32.88	37.63	41.38	44.0	45.75	50.0*
Mountain-valley Soil											
Original	5.38	7.5	9.63	11.75	14.25	17.88	19.13	21.25	22.38	23.5	24.0*
Burned	8.63	11.75	15.38	20.13	25.88	31.38	36.75	40.38	42.63	44.38	46.0*
Added Organic	5.00	6.63	9.13	12.25	16.5	20.88	26.13	32.0*	34.75*	36.75*	38.0*
Added Calcium Stearate	1.63	1.88	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	3.5*
Added Urea	9.25	12.13	15.75	20.75	24.5	28.63	32.5	35.25	37.13	38.88	42.75*
Abandoned Field Soil											
Original	5.63	7.63	9.75	12.5	16.00	19.13	22.5	25.5	27.38	28.75	29.5*
Burned	10.0	13.5	17.0	21.63	27.25	32.13	36.63	40.38	42.75	44.38	47.0*
Added Organic	8.25	11.25	14.5	18.5	23.38	28.88	32.5	36.25*	38.25*	39.5*	40.25*
Added Calcium Stearate	2.00	2.5	2.75	2.88	3.13	3.25	3.25	3.25	3.25	3.25	3.25
Added Urea	11.25	14.63	18.75	23.25	27.75	32.38	35.88	38.88	41.0	42.88	42.0*
Coon Creek Soil											
Original	5.63	6.38	7.25	8.00	9.00	9.75	10.88	11.88	12.63	13.38	13.5*
Burned	9.00	11.38	13.75	16.25	19.13	22.00	25.13	28.13	30.13	31.63	32.0*
Added Organic	7.00	8.75	10.75	13.25	16.00	18.88	21.38	23.88	25.25	26.0	27.25*
Added Calcium Stearate	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*	1.5*
Added Urea	10.38	11.88	13.38	15.00	16.88	18.88	21.5	23.38	24.88	26.13	29.5*

*Data obtained only from one experiment.

required for 15 cc. of water to be collected after penetration through a 7 inch column of soil in a glass tube. A constant flow of distilled water was maintained throughout the experiment.

Results

The results of the studies of the capillary rise of water in the soil are shown in Table 2.

In one experiment where peat (added organic) had been incorporated, the water reached the top of the soil column at the end of 31 hours with all soils except that from Coon Creek. Therefore, in the other experiment, longer tubes were used.

The average height of the water column at the time of each measurement was determined for each of the treatments in each soil. It is clear that the initial rise is much more rapid than at any subsequent time. This is in accordance with previous investigations. It is also clear that the different soil treatments affect the movement of capillary water. In all soils the addition of calcium stearate produced a definite depressing influence on the capillary rise, the total rise being much less than in the original soil. The influence of calcium stearate is not so pronounced in the case of the mountain-slope soil as in any of the others.

The removal from the soil of the organic material by burning greatly increased the capillary rise. The addition of organic matter to burned soils had a depressing effect as compared with the burned soils but was greater than that of the original soils. This indicates that the results on the burned soil were not entirely due to chemical or physical changes produced by burning and that the presence of organic matter in the soil does have some repellent effects. It is recognized that the addition of the peat to the burned soil will not bring about exactly the same conditions as were present in the original soil, but it does show that there is this repellent effect due to organic matter.

The addition of urea to the burned soil showed a slightly higher rise than that in the added organic treatment. This difference is not as distinct as was found for the other treatments, but it appears that the presence of urea has much the same effect as organic matter.

The results of the studies on the rate of percolation are summarized in Table 3.

The rate of percolation is affected by the various soil treatments in the same manner as the movement of water by capillarity. The data, however, are less consistent and the differences are not as great as in the study of capillarity.

Discussion

To determine if the observed differences in the capillary rise of water in the soil columns as a result of the three treatments, origi-

TABLE III. INFLUENCE OF CERTAIN TREATMENTS TO FOUR DIFFERENT SOILS ON AVERAGE PERCOLATION RATE OF WATER

Average Time of Percolation in Minutes

Kind of Treatment	Kind of Soil			
	Mountain-slope	Mountain-valley	Abandoned Fields	Coon Creek
Original	65.49	44.76	64.65	9.53
Burned	27.85	45.29	25.33	8.78
Added Organic	50.43	137.18	31.07	39.47
Added Calcium Stearate	63.60	271.03	46.14	42.03
Added Urea	54.20	34.48	22.73	5.43

Difference required for significance between general treatment means = 21.26.
Difference required for significance between general soil means = 11.02.
Difference required for significance between any two treatments or soil means = 42.52.

nal, burned, and added organic, were real and significant, the data were subjected to a statistical analysis by the variance method. Because of limitations in equipment for conducting the capillary tests it was only possible to study three treatments on all soils at one time. The three treatments which were most important were the comparisons between the original soil, the burned soil, and the burned soil with added organic matter; therefore the tests were designed to measure these differences.

From Table 2 the mean average rate of capillary rise for each treatment and each soil has been calculated, and these results are presented in Table 4.

Analysis of the data showed that highly significant differences (value of "F" greater than the 1 per cent point) exist between treatments, soils, and the interaction of treatments and soils. The difference required for significance between treatment means is 0.11 and that for soil differences is 0.13.

TABLE IV. INFLUENCE OF CERTAIN SOIL TREATMENTS ON RATE OF CAPILLARY RISE OF WATER IN FOUR DIFFERENT SOILS

Capillary Rise in Inches per Hour

Kind of Soil	Kind of Treatment		
	Original	Burned	Added Organic
Mountain Slope	2.79	4.56	3.81
Mountain Valley	2.76	4.57	2.75
Abandoned Field	2.89	5.02	4.21
Coon Creek	2.06	3.95	3.14

Difference required for significance between general treatment means = 0.11.
Difference required for significance between general soil means = 0.13.
Difference required for significance between any two treatments or soil means = 0.22.

The removal of the organic matter from the soil by burning increased the rate of capillary rise. The addition of organic material, in the form of peat, to the burned soil decreased the rate of rise but not down to the same extent as in the unburned soil. It should be further noted that the treatments affect soils in a differential manner, which probably depends upon the physical properties of the soil.

It is thought that the presence of organic matter reduced the adhesive force between the soil particle and water, and thus the capillary rise is not so rapid as with the organic matter removed. The fact that the addition of organic matter to burned soil has a distinct inhibiting effect further substantiates this conclusion. The strong absorbing properties of organic colloids to attract and hold water probably accounts for some of the retardation of capillary rise. However, this same force should operate to produce a higher final rise in the soil. Data are not available in these tests to provide definite evidence on this point, but they do not indicate that the total capillary rise in the original soil would ever equal that of the burned soil.

The addition of calcium stearate has a similar but more pronounced effect on the capillary rise than the presence of organic matter. The water repellent characteristics of calcium stearate are well known. Apparently the soil particles when coated with this substance lose their absorptive capacity almost entirely. Calcium stearate may be found in nature from the decomposition of animal bodies and soil-inhabiting organisms.

By the addition of urea it appears that the absorbing properties of the burned soil may be somewhat decreased, and thus capillary rise may be diminished. Whether or not the difference is a significant one can not be determined by these tests. Urea is also a substance which might be found in the soil under natural conditions.

PERCOLATION. To determine if the same factors affecting capillary rise had a similar effect on the rate of percolation, the data from these tests were subjected to an analysis of variance of the same type as was used for the studies of capillarity.

Analysis of the data showed that highly significant differences exist between treatments, soils, and the interaction of soils and treatments. In this case the difference required for significance between treatment means is 21.26 and between soil means is 11.02.

Percolation through soil treated with calcium stearate was significantly slower than all other treatments, which corresponds with the strong depressing effect observed in the studies of capillary rise. This treatment was the only one which showed a significant departure from the original soil.

The mountain-valley soil is significantly different from other soils, and the Coon Creek soil from Minnesota is also significantly different from the mountain-slope soil. No other differences were significant. Here, again, the wide variations which occurred in the original data will account for the differences not proving to be significant.

Conclusions

1. The presence of organic material in sandy soils slows down the rate of capillary rise in soil columns.

2. Calcium stearate in the soil has a similar but more pronounced effect on capillary rise than the presence of organic matter.

3. Urea shows a slight tendency to decrease the capillary rise of water in burned soil.

4. In general, the same properties which affect the movement of water in soils by capillarity also affect the rate of percolation.

5. The interfacial tension between the soil particles and the soil water is an important factor in the movement of water in soils.

HIEMENZ'S STUDY OF THE HERON LAKE FRANKLIN'S GULL COLONY

AS REPORTED BY NESTOR M. HIEMENZ

GEORGE W. FRIEDRICH
St. Cloud Teachers College

The Franklin's Gull has been rather extensively studied by Roberts, father of Minnesota Ornithology and reported in the Auk in 1900 and more recently in his *Birds of Minnesota*. Report of a study of this bird was also made by Bent in the U. S. Natural Museum Bulletin, 1921.

This study was made in the hope of adding to the knowledge already obtained by Roberts and Bent. Much of it will be found to be in the nature of verification of these works but additional information was also obtained as will be developed later.

A research grant was given to Hiemenz by the Minnesota Academy of Science which made possible this study of the Heron Lake colony.

I quote Hiemenz extensively throughout most of the paper.

LOCATION AND SIZE OF COLONY. The Franklin's Gulls were nesting in the area known variously as "the marsh," "Mallard Bay," and "Hanson's Bay" just east of the town of Heron Lake. In reality it was a marsh covered with sedges over much of the area, with dense stands of "white cane" (Pharagmites) in some places, and fringed along the shore with bulrushes. There was very little open water, and what there was extended a few feet outward from the