Water Penetration of Soils

soil and water management practices important in coping with widespread problem of soil penetration by irrigation water

D. W. Henderson and J. A. Vomocil

The slow rate of water penetration into soils during irrigation is a serious problem, affecting—to some degree—a large portion of the major irrigated areas of California. In extreme cases there is a marked loss of production because it is difficult to supply crops with sufficient water even with frequent irrigation.

Slow water penetration is in reality several problems because it can be caused by different soil conditions. Effective means of coping with the problem depend on the cause. For example, one reason for slow water penetration is excessive sodium absorbed on the soil; a condition recognized for many years as alkali or black-alkali. Because sodium soils may be reclaimed by the use of mineral amendments such as gypsum, there is a tendency to attempt the improvement of other kinds of impervious soils by applying similar materials. Such treatments are not effective, because they do not attack the underlying cause of the problem. All too frequently a quick, effective treatment can not be found.

There are three additional causes of poor water penetration now recognized. One of them—high clay content—is well known. The limitations of clay soils in crop production may include slow penetration of water, but farmers have developed special practices which largely overcome this difficulty. One of the major problems remaining is the prevention of waterlogging of the surface soil, which is frequently more open than the subsoil. Good surface drainage is essential, especially for crops susceptible to injury by root-rot diseases.

Two additional causes are soil compaction by traffic or tillage and unstable soils which run together on wetting. These conditions have been recognized comparatively recently, at least to the extent they are now known to occur.

Soil Compaction

Many soils which naturally absorb water readily have been compacted during land grading or farming operations. Two processes are involved—compression of the soil by excessive surface traffic and compression or puddling by tillage implements. Both are more injurious if traffic or tillage occurs when the soil is moist, and both cause destruction of large pores in the soil necessary for rapid infiltration of water. Where compaction is extreme, entry of roots is retarded or even prevented.

Plow pans—compacted layers a few inches thick just below plow depth—have been recognized for years. They have caused no great concern because they can be broken up by increasing the depth of plowing and because they represent a small part of the total depth of the root zone. More intensive farming, heavier machinery, and in some cases deeper tillage have deepened the compact zone so that it may extend from the soil surface or the bottom of the tilled layer to an over-all depth of 18″–24″ below the surface. This greatly increases the seriousness of the problem.

Highly compacted soils can be recognized by experienced observers by digging or probing, especially if the soil lying below the compact zone is otherwise similar. Comparisons with the same soils in uncultivated areas such as fence rows may be helpful. Compacted soils are hard even when moist, and when lifted with a shovel loams and clays tend to fracture in layers with edges parallel to the ground surface. When a clod is broken, the freshly exposed edges are comparatively smooth with few openings visible. Clay soils have the appearance of fine-grained shale, and sandy soils look like sandstone. Lesser degrees of compaction are harder to distinguish visually even though water penetration is seriously impaired, especially in sandy soils.

Soil compaction affects crop growth through water penetration. The dark strips are green, vigorously growing barley; the lighter strips are plants already dead from lack of water.

Compaction may be considered an abuse of the soil, and the best practice is to minimize traffic or tillage, or delay until the soil is dry. However, essential operations may have to be performed when the soil is moist and therefore susceptible to compaction. Shattering by subsoiling through the compact zone when the soil is very dry may substantially improve the soil and increase water and root penetration. The improvement may be very temporary if the soil tends to run back together or if it is soon compacted again.

Under the most favorable conditions shattering allows penetration of water and roots into the fractures formed, but leaves dense clods which roots can not readily grow into. It should be considered the first step only in soil improvement, the rest depending on natural processes such as slow penetration by roots, wetting and drying, and others. In general, soils compacted by traffic or tillage do not respond to application of soil amendments.

Soil management practices such as cover cropping, growing green manure crops, and crop rotation need more study on a long-range basis. One application of manure or growth of a single green manure crop does not in general improve water penetration into soils already made compact by traffic or tillage. It is possible that such practices carried out over a period of years will reduce the susceptibility of soils to compaction, but not to the degree that they will withstand abuse.

Unstable Soils

Most soils have a tendency to slake and run together somewhat when dry clods are wetted rapidly, but usually they break down into aggregates consisting of several soil particles, and these aggregates resist further disintegration. But there are some soils which slake to the extent that no aggregates remain, and

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Experimental sections installed during 1956 included: three 8 mil polyethylene, two 4 mil polyethylene, and one section each of a 50 pound and a 90 pound water resistant antifungicidal treated kraft paper coated with 1 mil black polyethylene. These installations were made on three farms in Yuba County. In each case the soil was very sandy and high seepage losses were suspected, vegetative growth was a problem, and considerable time was required for the water to reach the fields to be irrigated.

The linings were installed in all sections after the ditches had been formed with conventional ditching equipment. A minimum of hand labor was necessary to prepare the ditch sides and bottom for lining. A shallow trench—4″–6″—was dug just over the top of the ditch bank. The edges of the lining were laid into this trench and backfilled by hand.

At the end of the season the sections were carefully inspected. All were in good condition. There was little difference between the 4 mil and the 8 mil linings, although some damage was observed in the 4 mil due to either pecking of birds or clawing or gnawing of rodents or small animals. This damage was all above the water line and therefore did not reduce the linings' effectiveness for seepage control.

No difference was detected between the two weights of poly coated papers. Some deterioration of both resulted near the edges where a wicking action of water occurred.

All linings were very effective in controlling vegetative growth beneath the lining.

Siphons were used on one farm to convey the water from the lined sections into furrows for irrigating corn. To prime these siphons some pumping action is required, which oftentimes resulted in the inlet end of the siphon jabbing the lining. None of the linings on this farm were damaged by this action.

In a ponding test—to evaluate the amount of water lost by seepage—the loss through the unlined section was over seven times that of the lined section or approximately 7.7 cubic feet per square foot per 24 hours. Undoubtedly this rate would not be maintained during each irrigation throughout the season. However—assuming the average seepage loss for the entire season was only half of the measured amount—the cost of the lining and installation could be recovered in one average season, based on a total cost of the water alone of approximately $5 per acre foot. Savings in irrigation labor costs also could be realized.

One farmer in Yuba County had to double the number of siphons he had been using because of the amount of water saved by a plastic lining.

Mechanical methods of laying lightweight films—to eliminate some of the installation labor—are being studied. Also rolling the lining up at the end of a season and storing it for use the next year is being investigated.

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Making measurements during a seepage ponding test.

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unless they are very sandy, water penetration is exceedingly slow. Apparently the basic cause is the failure of the clay fraction to cement coarser particles together.

The worst of these soils have certain characteristics by which they may be recognized. The first time a loose seedbed is flooded the soil slakes down until there is no trace of clods remaining. The surface is smooth and becomes hard on drying. Few cracks appear, and these are fine hairline cracks. It is difficult to dig, and yet the soil crumbles readily when a dry clod is crushed in the hand, with formation of an excessive amount of fine dust. Roadways become covered with a thick layer of powdery dust. There is almost no lateral movement of water from furrows even when the bottom and sides of furrows have not been compacted by tillage or traffic. These characteristics may also be determined by laboratory tests, and better tests may be available soon which will aid in the diagnosis of less serious problems.

More and more problems are being investigated which are caused by this condition. It is especially serious because the difficulty lies in an inherent characteristic of the soil which cannot be changed by any economical means known at present.

Diagnosing the cause or causes of slow water penetration into soil is important because there is no other way to determine whether or not a proposed treatment will be effective. Some soil conditions respond to proper treatment, and a marked—if only partial—improvement results. Others have not yielded to any treatment yet developed. Research is in progress on the basic behavior of soils which will point the way in minimizing the problem, and these studies may suggest new, effective, treatments.

In the meantime, careful soil management is essential to keep conditions as favorable as possible. In cases where water penetration rates are not too slow, crop growth can be improved and yields increased by better management of irrigation water. A practice which is effective for deep rooted crops on deep soils is prolonged preirrigation for annuals or winter irrigation of perennials. If the poor physical condition of the soil does not seriously limit root development, a maximum amount of reserve moisture is stored in the subsoil. During the summer months when it is difficult or impossible to replenish the water in the soil as rapidly as it is used by the crop, the reserve subsoil moisture may determine whether or not there is an adequate supply of water.

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MOVEMENT

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phere suction value—about 75% of the available water has been removed from the Fallbrook soil and approximately 60% from the Holtville soil.

Further studies of moisture extraction from soils are being made under controlled conditions without using plants. Soil columns are positioned horizontally and brought to equilibrium with water at approximately 30 millibars. This is often a value read on tensiometers following an irrigation in the field. A constant suction is then applied at one end of a soil column, by applying a controlled vacuum to one side of a porous ceramic disc the other side of which is in direct contact with the soil. The lower left graph on page 24 shows the accumulated water extracted from soil columns when the suction of 900 millibars was maintained constant. The extracted water was measured in surface inches in relation to the area of the soil column.

In the same length of time, 80% more water was extracted from a column of soil 14″ long compared with the same column when it was cut down to 7″ in length. This would indicate that, for this Fallbrook sandy loam, root-free portions of the soil 7″ away from roots can make substantial contributions to water extracted by roots.

Soils vary greatly in their ability to conduct water. A comparison of three soil types shows that under the same controlled laboratory conditions the water extracted from a Ramona sandy loam soil was approximately twice as much as from a Fallbrook sandy loam and threefold that from a Yolo loam. The curves comparing various soils were all obtained using 14″ soil columns.

For these studies of soil moisture movement, fragmented soil samples were screened and compacted in the columns. Further studies will be made on undisturbed cores.

If only moisture flow rates are measured—to compare the ability of various soils to conduct water—the size and shape of the soil sample and suction equipment would need to be standardized. However, when continuous records of the moisture suction values are obtained at various locations along the soil column, as well as moisture extraction rates, computations can be made expressing the conductivity values of a soil as a function of the moisture suction. These values are characteristic of the soil and independent of the methods of measurement. They can be used to characterize different soils or study the effects of soil management practices on the same soil. Also, when suction values in the field are measured by tensiometers, flow rates can be estimated.

Studies of moisture movement in soils in the liquid phase are made under constant temperature conditions. Thermal gradients within the soil column, which result in water vapor diffusion, can cause significant disturbances to the measured liquid flow.

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In most cases not enough water can be stored in the soil to last throughout the season. Where water penetration is slow, more water can be applied by irrigating more frequently or by increasing the time the water is on the land surface at each irrigation. Both approaches have advantages and limitations. More frequent irrigation may be accomplished without any other change in the system or in practice, but has the disadvantage of higher labor costs. It may be an inadequate measure for the more difficult problems. Prolonged irrigation may require substantial changes such as converting from furrows to basins in which water can be ponded for long periods or using small furrows to insure better coverage of border strips with small streams. Irrigation of crops susceptible to injury or disease under prolonged irrigation can not be managed in this way, and the practice may encourage growth of water-loving weeds. However, such methods may be the only means of increasing the productivity of soils with very slow water penetration even though changes in cropping pattern or farming operations are required.

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TEMPERATURE

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ing facility must provide for maximum energy capture, discharge water at a temperature giving maximum rice yields, occupy a minimum land area, with reasonable installation and maintenance costs.

From experience in rice irrigation, water temperature may be expected to influence the growth of other crops. However, it is difficult to predict the influence of water temperature on yields because of its numerous direct and indirect effects on the plant. In addition to the cold water damage reported here, crop injury is sometimes associated with warm water.

As more is learned about its effects on irrigated crops, water temperature may become a factor of considerable importance in the selection of crops and their management for maximum yield and minimum unit cost.

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MEASUREMENT

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grove was on a two week irrigation schedule. The irrigation water applied July 19 and August 3 reached the 12″ soil depth but did not wet the soil at the 18″ depth to field capacity.

The time and place to use either tensiometers or blocks depends to a large extent on climatic conditions and soil types and to a lesser extent on the nature of the crop. In inland areas of southern California where high water losses may cause stress conditions in plants, timing of irrigations becomes very important. Tensiometers have proved to be valuable tools for timing irrigations in citrus and avocado groves. However, in the more humid areas where irrigations are intermittent, along with rainfall, resistance blocks are used with satisfactory results. Resistance blocks made of gypsum rather than fiberglass or nylon are generally preferred in agricultural soils.

The neutron method is still a research tool although it might be valuable on large agricultural acreages.

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QUALITY

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in the Imperial Valley. Here Colorado River water is used for irrigation and contains large quantities of sulfate, which produces this toxic symptom.

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