IMPROVING WATER PENETRATION

Terry L. Prichard, Blake Sanden and Allan E. Fulton

One of the most pervasive problems in existing orchards is infiltrating enough water to maximize crop performance. The problem is commonly referred to as poor water penetration. Water penetration relates to both water entry into the surface of the soil and water movement through the root zone. Any barrier to either of these can lead to poor water penetration and associated orchard problems.

Water penetration difficulties result from the inability of the soil to take in enough water in the active root zone to sustain the crop until the next irrigation. The problem is exacerbated by the intense water use of mature trees.

In most areas of California, pistachios average nearly 40 inches per acre of water use per year. Adding some soil storage from winter rainfall and water lost to irrigation system inefficiency, a seasonal irrigation volume of 42 inches and a peak monthly volume (in July) of 9 inches per acre is not uncommon. When poor water penetration occurs, underirrigation is probable.

Ironically, poor water penetration not only leads to inadequate irrigation; it can also be associated with too much water for a temporary period of time. As soil permeability decreases, so does root zone aeration. A saturated soil surface increases the incidence of root diseases such as Phytophthora. Common field and pistachio production problems resulting from poor water penetration include:

SYMPTOMS OF SLOW WATER PENETRATION

- Midseason depletion of deep soil-water and inadequate recharge of subsoil water, even after long irrigations.
- Water that ponds on the soil surface for long periods, disrupting orchard access.
- Reduced vegetative growth and yield.
- Reduced split percentage.
- Higher incidence of root diseases resulting from poor soil aeration.

THE WATER PENETRATION PROCESS

The first step in determining a solution or remedial practice for poor water infiltration is to take a close look at the process of water penetration. At the onset of irrigation, water infiltrates at a high rate. Initially the soil is dry and may have cracks through which water can infiltrate rapidly. After the first few hours, these factors become less important in sustaining infiltration rates. Depending on the soil, as much as 50 to 65% of your total infiltration may occur in the first 3 to 6 hours of a 24-hour set. As the soil becomes wet from the surface into the root zone, the distance from the soil surface to the wetting front of infiltrating water increases. At this point clay particles swell, closing surface cracks and limiting access to small, drier soil pores beneath. Infiltration rates decrease significantly and water moves only by the force of gravity through the larger "macropores" in the soil.

Not only does the rate of infiltration slow down after the first few hours of irrigation, successive irrigations over the season compact the surface and decrease the soil's ability to infiltrate water. Figure 1 shows how cumulative infiltration slows way down after the first 6 hours and decreases with each irrigation over the season. The addition of gypsum to this very low salinity irrigation water did improve infiltration on 8/4.

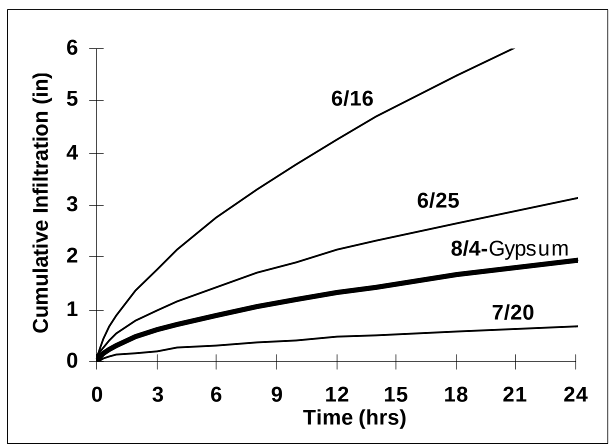

Figure 1. Cumulative depth of infiltration for Wasco sandy loam over the season for the same furrows in furrow irrigated cotton at the Shafter Field Station (Shafter, CA 1995) with low salinity canal water (0.02 dS/m).

The stability of soil "aggregates" and these larger pores depends on the interaction of soil minerals and the salinity of the water in these pores. As the irrigation continues, the salt composition of the soil-water begins to more closely reflect that of the irrigation water, which is generally less saline. This process of chemical change also reduces infiltration rates.

Water penetration is influenced by the characteristics of both irrigation water and soil. Those characteristics having the greatest influence are:

Soil

- Dryness at start of irrigation
- Amount and size of soil particles and pores
- Surface access to soil pores
- Cracks
- Level of soil-water salinity
- Composition of soil-water salinity
- Nonuniformity of root zone soil

Irrigation water

- Level of total salinity
- Composition of salinity
- Depth of water applied to the soil surface

MODIFICATIONS TO IMPROVE WATER PENETRATION

Total pore volume, individual pore size, access to pores, and water salinity or sodicity continue to influence the rate of water infiltration for the entire irrigation. By modifying these factors, you can improve water penetration.

Pore volume and pore size

Pores are the voids between soil mineral and organic particles in soils, the spaces through which water and air move. Soils with high sand content (spherical particles) tend to have larger pores. Soils with larger pores generally have higher infiltration rates, with some exceptions. Clay-dominated soils (clays are plate-like particles) tend to have smaller pores. Water usually moves slowly through smaller pores, because smaller pores provide more surface area for water to adhere to. Therefore, water tends to fill a greater number of small pores than it would large pores under the same conditions. But clays also shrink and swell, which helps develop cracks that aid water infiltration.

Individual soil particles can clump together, forming larger structures called aggregates. The small pores within particles remain, and larger pores are formed between the aggregates. The net effect is larger pores, which significantly enhance water penetration and gas exchange. Soil organic matter plays a significant role in stabilizing soil aggregates and increasing pore size.

Soil crusting and access to soil pores

Water from rainfall or irrigation usually enters soil pores from the soil surface. Water also enters pores from subsurface irrigation (active or passive use of a shallow water table), buried drip systems, and through cracks. Formation of soil crusts decreases infiltration by impeding the access to soil pores. The formation of a soil crust or surface seal has been recognized as a contribution to infiltration problems in California as early as 1934. However, the mechanism and effects of corrective actions have not been understood until recently.

In California and other arid and semiarid areas, soil crusts are often the result of sodic soil conditions (soils with excess exchangeable sodium and irrigation water with excess sodium or too little salinity).

Recently, soil-crusting problems have been found in soils that are predominantly light-textured, nonsaline and nonsodic. In these types of soils, researchers have discovered that continuous cultivation of nonsaline, nonsodic orchard soils decreased the distribution of larger pores within the surface profile. Further, reduction in pore size has been related to reduced soil organic matter content. Both conditions occur in a large portion of California orchards.

Soil surface crusts can be formed by two basic methods: (1) reorganization of resident soil particles and (2) covering the soil surface with transported soil particles. In either case, access to soil pores is reduced.

Structural crusts. A structural soil crust is formed by the destruction of soil aggregates and a subsequent reorganization of the resident soil particles. The destruction of soil aggregates can occur as a result of the droplet energy of rain and sprinklers. As droplets hit the soil surface, the disruptive action causes soil aggregates to break down, causing a reduction in pore size and a sorting of soil particles that leaves a film of fine particles on top and clogging larger pores. A similar process occurs in flood and furrow irrigation systems. In these systems, soil wetting causes the particles to reorganize through a process called soil slaking. The crust is made up of a sorted layer at the surface and a compacted layer below. As soil aggregates breakdown, a concurrent physical and chemical dispersion of the fine clay particles allows them to migrate with the water and clog the pores just beneath the compacted layer or washed-in zone

(Figure 2).

Together these factors combine to form a surface seal, or structural crusting, due to the disintegration and recompaction of soil structural components.

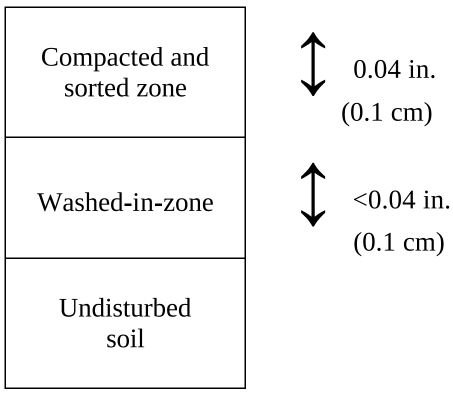

Figure 2. Structural crust

Soil crusts are thin and characterized by higher density, greater strength and smaller pores than the underlying soil. Soil crusts allow less water movement than does underlying soil (Figure 2). The ability of a soil to withstand the destructive force of droplet energy depends largely on the physical and chemical makeup of the soil surface.

Soil crusting is influenced by many soil and water properties. These include:

Soil

- Salinity
- Sodicity
- Presence of iron and aluminum oxides
- Presence of organic stabilizing compounds

Water

- Salinity
- Sodicity
- Ionic valence

The salinity of the surface soil is determined by measuring its electrical conductivity (EC). The EC is an important factor in determining crusting. However, the water around soil particles (that is, soil-water) is strongly influenced and rapidly modified by the constituents of irrigation water. Reduced EC in the soil-water causes clay swelling to increase, reducing the size of soil pores. Irrigation water with an EC of less than 0.3 decisieman per meter (dS/m) can cause problems. Each soil has a unique amount of soil-water salinity (flocculation threshold) at which dispersion of the particles occurs.

As the sodicity of soil-water increases, aggregate stability decreases. The severity of the problem is also influenced by the total salinity of the irrigation water, as shown below in Table 1 and Figure 3. (See the chapter on *Understanding and Managing Salinity* for a discussion of the sodium adsorption ratio, SAR.)

Table 1. Potential for a water infiltration problem.

SAR*	Problem Unlikely EC_e[1] or EC_w[2]	Problem Unlikely EC_e or EC_w
0.0—3.0	> 0.7	< 0.3
3.1—6.0	> 1.0	< 0.4
6.1—12.0	> 2.0	< 0.5

Source: Ayers and Westcost (1985).
*Sodium Adsorption ratio.
[1] Electrical conductivity of extract indicates that soil is saturated past soil salinity.
[2] Electrical conductivity of water indicates irrigation water salinity.

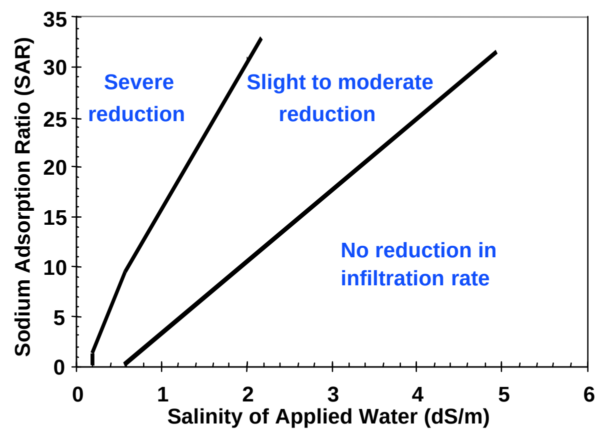

Figure 3. Interaction of total salinity as EC with the sodium adsorption ratio of applied water for causing potential infiltration problems. (Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. United Nations FAO Irrig & Drainage Paper No. 29.)

Although soil sodium (Na) content is important, calcium (Ca) and magnesium (Mg) also play an important role. Increased Ca content in the soil or irrigation water decreases the dispersing effect of the Na and acts to stabilize the soil surface.

These sodium-based guidelines will not necessarily work for all soils. Some California soils outside of the San Joaquin Valley contain a large amount of serpentine clays (some areas of Napa Valley, for example). As a result, they are rich in Mg and relatively low in Ca. In such an environment, Mg may behave like Na, and the result is unstable soil that tends to disperse and become impermeable. Although the diagnostic criteria for such conditions have not been extensively tested, some professional consultants suggest that when the Mg to Ca ratio exceeds 1:1 then serpentine soils may develop infiltration problems. Soils rich in exchangeable K may also have infiltration problems. Some reports maintain that when K is the predominant cation, it has the same effect on soil stability and porosity as does Na: the soil becomes less stable, disperses at the surface and seals over. Soils with a predominance of montmorillonite and illite clays are most easily dispersed by excess Mg.

Hydrous oxides of aluminum (Al) and iron (Fe) and organic matter components, however, exert a stabilizing force on clay—a force that acts against the dispersing effect of sodic water or waters with very low salinity.

Depositional crusts. The effects of structural crusts are most pronounced in medium to light-textured soils. Formed by the sedimentation of fine soil materials on the native soil surface, a depositional crust limits access to the larger resident soil pores (Figure 3). This type of soil crust is most often the result of high-velocity water collecting sediment that settles out when the waters slow. The size of the particles in suspension is small (the particles are usually clays); their plate-like structure forms a very effective barrier to soil pores.

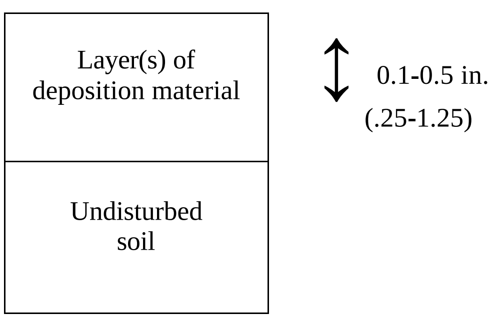

Figure 3. Depositional soil crusting

Nonuniform soils in the root zone

Soil layers below the soil surface, hardened or different in texture, can limit water penetration and root extension. Layers can include indurated hardpans, calcified pans, claypans, or layers of soil with significantly different texture.

These conditions should be modified before planting. They are more easily corrected before trees are planted, when injury to the root systems of trees is not a concern. However, many established California orchards can benefit from additional physical modification. Most often these are orchards where minimal soil modification was implemented before planting, sometimes as the result of financial constraints, lack of site investigation, or the inability to recognize the problem.

IRRIGATION MANAGEMENT

The depth of applied water on the soil surface has a temporary and minimal effect on the water penetration process. In other words, increasing the depth of applied water per irrigation event is unlikely to improve water penetration. Instead, longer irrigations (also known as set times) that apply more water will result in more water ponding on the soil surface for longer periods of time. More ponding could reduce root zone aeration, cause diseases and restrict access to the orchard. For this reason, we again emphasize the importance of irrigation management as a factor in water penetration problems.

Modifying irrigation practices can lessen the adverse effects of irrigating orchard soils that do not take in water adequately. Increasing the frequency of irrigation (i.e. irrigating every 7 days instead of every 14), decreasing set duration and using tailwater return systems can often increase the total water available to the crop and decrease water logging. But without cultural practices that increase and stabilize soil porosity, correct unwanted soil crusts, or modify nonuniform soils in the root zone, a change in irrigation practice by itself will not improve the infiltration rate. However, even with added amendments and cultivation, modifying irrigation practices and using an auger to check soil moisture is the starting point to manage poor infiltration.

PREVENTION OF SOIL CRUSTS

Where soil permeability is low, prevention of soil crusting is often the best course of action and usually the most economical. Prevention includes the application of amendments, use of soil surface covers, soil organic matter management, and improved irrigation management. However, once a crust has formed, tillage may be required before other options can be effective.

Tillage

Shallow tillage can disrupt both structural and depositional crusts. In cases of moderate crusting problems, one tillage per season can restore infiltration rates. However, in soils with severely reduced infiltration, tilling before each irrigation is common.

Shallow tillage to disturb the surface crust is accomplished using a harrow, rolling cultivator, or one of the new types of tillage instruments that loosen soil to a depth of about 6 inches (15 cm). These new instruments create macro-pores without mixing the soil.

Surface protection

Since droplet energy is a mechanical force that breaks aggregates apart, it follows that protection of the surface is highly effective in reducing the effects of structural crusting. Cover crops (either live or dead) can protect the surface from the impact of rain and sprinkler irrigation.

The adequacy of soil surface cover is more important than the type of cover. Cover crops can be resident vegetation, annuals or perennials. Annual crops allowed to die in place or mowed, and left as mulch, continue to protect the surface during the irrigation season while not competing with the crop for moisture.

Organic matter management

All soils contain a small component of organic matter, from 0.5 to 2% in the San Joaquin Valley. Uncultivated soils contain more organic matter than those cultivated under typical orchard conditions. With this reduction in organic matter comes reduction of the stability of soil surface aggregates.

The major stabilizing material that holds soil aggregates together comes from the decomposition of organic matter. The application of soil organic mixtures can increase porosity, percentage of macropores, aggregate stability, and thus increase the infiltration rate. However, the organic matter content of soils in arid or semiarid areas does not increase because of the rapid rate at which the organic matter decomposes. In a 10-year study conducted at the University of California, Davis, researchers incorporated cover crops into the soil. The percentage of organic matter in the soil did not increase over that time. The infiltration rate, however, did increase.

The implication of this and other research is that organic additions are beneficial by virtue of the products of their decomposition. These products consist of polysaccharides and polyuronides, which act as binders to stabilize aggregates. To be effective, organic matter additions or cover cropping should be continual, because decomposition products are short-lived, especially in California's climate.

Crop residues. Trees provide leaves and prunings that can be left in the orchard for decomposition or incorporation. Interest in chipping or shredding brush is growing as a result of restrictions on burning. Correctly prepared brush can add a significant quantity of organic matter. Be sure to prepare brush properly. Chip prunings into small pieces, and shred brush more than once, or disc to incorporate material.

Manure and green waste. Animal manures have long been applied to orchards to supply nutrients and improve water infiltration. If you use manure, be aware of the potential effects of salinity and sodicity and have a plan for preventing them. Manure often contains weed seeds, so be prepared to handle unwanted vegetation as well.

Green waste is a term used for a mixture of lawn clippings, prunings and garden materials. The mixture is increasingly available for agricultural use. Currently it is available in raw form and in various states of decomposition. The composted materials offer a high ratio of organic materials per unit volume. Green waste is easily spread, and its viable weed seed content is low.

Cover crops. To protect the soil surface from droplet impact as well as provide significant biomass for decomposition, grow cover crops in orchard middles. In addition, cover crops can slow the velocity of surface water, reducing erosion and subsequent depositional crusting.

However, cover crops can compete with trees for nutrients and water. If an orchard contains clover as a perennial cover crop or actively growing winter and summer resident vegetation, water use can increase by 10 to 20 percent (Table 2). The orchard manager must supply additional water or crop stress will occur. The use of winter annual cover crops and vegetation control strategies during summer months, such as chemical mowing, can reduce the water requirement. Another successful strategy is to apply organic matter amendments on a seasonal basis, but have a clean orchard floor at harvest time.

Cover crops can be planted as annuals or perennials, or be resident vegetation. Mature trees with full canopies may shade out cover crops by mid season. Each acre of annual cover crops or

Table 2. Water use by a mature almond orchard with cover crops and bare soil.

Treatment	Increase in water use (%)

Resident vegetation	120
Clover	110
Bromegrass	98
Bare soil	100
Chemical mowing	100

*Water use is relative to that of bare soil.

resident vegetation consisting of winter and summer annuals can produce from 2 to 4 tons of aboveground dry matter. The ratio of top portion to underground dry matter (roots) has been estimated at 1 ½ : 1. Thus, a cover crop that yields 6,000 pounds (2,715 kg) biomass per acre above ground yields about 4,000 pounds (1,810 kg) per acre below ground, in the form of roots. Total biomass from the cover crop is 10,000 pounds per acre (5 tons/acre or 11,000 kg/ha).

Cover crops can increase infiltration rates (Table 3). Increases are attributed to physical factors, such as channels created by roots; surface protection; and increased soil aggregation. Compared to bare ground, soil with cover crop has greater aggregate stability and more macropores.

Table 3. Accumulated infiltration at 120 minutes through various cover crops and bare soils in a mature almond orchard.

	Early season (mm)	Late season (mm)
Clover	66.8 a	63.2 a
Resident vegetation	52.3 a	54.9 a
Bromegrass	52.8 a	65.3 a
Chemical mowing	63.0 a	39.1 b
Bare soil	53.3 a	32.5 b

Numbers followed by different letters are significantly different @ 0.05 level.

Chemical amendments

The addition of chemical amendments to water or soil can improve water infiltration by improving the chemical makeup of the water or soil. Chemical amendments usually increase the total salt concentration and decrease the sodium adsorption ratio (SAR) of the soil-water. Both of these actions enhance aggregate stability and decrease soil crusting and pore blockage.

Four types of materials are used to ameliorate water penetration problems: salts, calcium materials, acids or acid forming materials, and soil conditioners, including polymers and surfactants.

Salts. Any fertilizer salt or amendment that contains salts when applied to the soil surface or when the amendment is dissolved in irrigation water increases the salinity of the irrigation water and ultimately influences the soil-water. Whether the increased salinity is advantageous depends on the SAR of the irrigation water. In terms of the effects of salt alone, increasing the salinity above the levels shown in Table 1 or Figure 3 has little effect on infiltration.

Calcium materials. Adding calcium salts to soils and water increases the salinity as well as the soluble Ca content of the irrigation water and soil-water. Calcium salts commonly used include gypsum, lime, dolomite, calcium chloride (CaC1), and calcium nitrate ($CaNO_3$). Each salt has a specific solubility rate in water. CaC1 and $CaNO_3$ are highly soluble; gypsum, moderately soluble; and dolomite and lime, very insoluble. Applying the highly soluble salts directly to irrigation water is convenient but typically more expensive than applying them to soil.

Adding gypsum to irrigation water is reasonably simple and typically less expensive than adding CaC1 or $CaNO_3$. Lime and dolomite are relatively insoluble in water unless the water is acidic (has a pH less than 7.0). Gypsum, CaC1, and $CaNO_3$ have negligible effects on soil pH, whereas lime and dolomite can increase the soil pH of acidic soils.

Acids and acid-forming materials. Commonly applied acid or acid-forming amendments include sulfuric acid (H_2SO_4) products, soil sulfur, ammonium polysulfide, and calcium polysulfide. Since these materials (with the exception of calcium polysulfide) all contain sulfur (S) or H_2SO_4. The acid dissolves soil-lime to form a Ca salt (gypsum), which then dissolves in the irrigation water to provide exchangeable CA. The acid materials do not have to undergo the biological reactions. Instead, they immediately react with soil-lime. Since these materials form an acid in the soil reaction, they all can reduce soil, pH if applied at sufficiently high rates.

Soil conditioners. Amendments in this category are usually organic polymers or surfactants. Organic polymers, mainly water-soluble polyacrylamides (PAMs) and polysaccharides, have been used to stabilize the soil surface by binding aggregates together and resisting the disruptive forces of droplet impact. They also work very effectively in furrow systems by decreasing soil erosion and sediment in the water. They can improve infiltration on soils with illite and kaolinitic clays common in the northwest US, but USDA researchers in Fresno have found that infiltration is not improved in soils with mostly montmorillinite clays (typical of soils in the San Joaquin Valley). Water-soluble PAM is not to be confused with the crystal-like, cross-linked PAMs that expand when exposed to water. They do not influence water penetration; rather they enhance the water-holding capacity of soils.

Organic polymers are long-chain organic molecules that can have different effects on infiltration. The effect depends on polymer properties—such as molecular weight, structure, and electrical charge—and salinity of the irrigation water. Interactions between a polymer and a water molecule also affect the flocculation threshold of shrink-swell clays.

For example, applying a nonionic polymer to water with an EC of 0.05 dS/m promoted flocculation. The effectiveness of the polymer increased with increased polymer concentration. However, the use of anionic polymers improved infiltration in solutions of 0.7 dS/m and reduce infiltration in solutions of 0.05 dS/m.

Researchers have noted a correlation between polymer effectiveness and sprinkler irrigation or rain. Polymers have been shown to work best when sprayed on the soil surface at a rate of about 4 pounds per acre, and then followed with an application of gypsum in soil or water delivered in the form of high-energy droplets.

Other amendments include synthetic and natural soil conditioners. Although there is a long history of soil conditioner development and testing, not enough data exists on the materials to conclude they are uniformly effective.

Surfactants, amendments that reduce the surface tension of water, have been most effective in soils that contain a high percentage of organic matter or that are covered with mulch. Such soils include turf soils, forest soils and burned range land.

(*See the chapter on* ***Understanding and Managing Salinity*** *for more discussion on the chemistry and calculation of rates for water and soil application of calcium supplying and acidifying amendments.)*

OPTIMIZING IRRIGATION IN ORCHARDS WITH POOR PENETRATION

This section will briefly highlight the three basic objectives of irrigation management in orchards with water penetration problems:

- Maximize the amount of water stored, in the root zone, from the winter rains and winter irrigations.
- Develop a thorough understanding of the seasonal water-use patterns of pistachio and incorporate that understanding into irrigation scheduling.
- Assess the existing irrigation method for compatibility with infiltration constraints. If necessary, consider modifying the existing system or changing to another irrigation method.

Beginning each growing season with a full water profile in the root zone is critical to managing orchards with water penetration problems. Simply stated, the more water stored in the root zone prior to leafout, the less water must infiltrate later, when the crop is growing. The amount of water that can be stored from rainfall and winter irrigation is variable because it depends on soil texture and depth of root zone.

Water storage in sands and sandy loam soils ranges from 3.0 to 7.5 inches (7.5-18.8 cm), or only about 7 to 18 percent of the total water consumption by mature trees. In finer loam to silt-loam soils, water storage ranges from 7.l5 to 14.0 inches (18.8-35 cm), about 18 to 33 percent of the total seasonal water use.

During drought years and in low-rainfall areas, such as the southern San Joaquin Valley, rainfall alone may be insufficient to completely refill the root zone with stored water. Past studies assessing the effective storage of rainfall suggest that during winter the soil stores about 50 percent of total rainfall. Evaporation, transpiration by resident vegetation, and runoff account for the rainfall that is not stored in the soil.

In situations where rainfall is insufficient to refill the water profile in the root zone, winter irrigations may be needed. In severely dry winters, one, or at most two, irrigations should be sufficient or supplement rainfall and refill the root zone with stored water.

Timing of these irrigations is important. Irrigating too early in the winter (November through January) may result in unnecessary irrigations if rainfall is abundant in later winter months (January through March). Waiting until early spring (March or April) to irrigate, after most of the rainfall has occurred, may be risky too. Root systems are actively growing before the trees actually leaf out; irrigation during this period cools the soil, which may enhance disease and deprive the new roots of oxygen.

Given these considerations, and the fact that January and February are the two wettest months in California, the best time to plan your winter irrigation is in mid to late February.

Understanding the seasonal fluctuations in water use is as important as managing infiltration problems. Understanding how water use increases from leafout to early summer (early June), knowing that water use peaks during midsummer, and understanding the water requirements during the harvest season are key to managing water penetration problems.

Crop water use by a mature orchard steadily increases from 0.03 inch (.075 cm) per day in March to about 0.30 inch (.75 cm) per day by mid-June. (**See the chapter on *Irrigation Management.)*** Knowing this will help prevent you from irrigating too frequently in the spring and too infrequently as mid-summer approaches. Furthermore, understanding that maximum water use by mature pistachios in July and August may exceed 0.30 inch (.75 cm) per day will help you determine the proper irrigation interval during the period of highest water demand, when the orchard soil limits water infiltration. Well-watered, productive orchards use considerable quantities of water during late August through September.

The third objective of irrigation optimization is to assess the existing operation system and design, and if possible, improve it to provide the cumulative depth of water that can infiltrate the problem soil. An orchard with an infiltration problem usually can infiltrate 1.0 to 3.0 inches. (2.5-7.5 cm) per irrigation.

In your assessment, determine whether the existing irrigation system is designed and operated in a manner that can uniformly and completely apply small amounts of well-controlled water. If you do not know the depth of applied water per irrigation, begin by determining irrigation on-flow rates, irrigation set times, and the acreage irrigated per set. Then calculate the average depth of applied water.

If you have a reliable estimate of water applied per irrigation and it greatly exceeds typical depths of infiltrated water, consider whether you can improve irrigation system performance. The performance of border flood systems is most likely to be improved by increasing flow rates, leveling land and reducing run lengths. In the case of pressurized irrigation systems, give further attention to management and design. Sprinkler and microsprinkler systems should be more suitable for soils that pose infiltration problems since they can apply water more uniformly and can easily be operated more frequently.

REMEDIAL POSTPLANTING MEASURES

Tillage of orchard middles to disrupt limiting soil layers in a closely spaced orchard is most commonly done using a rip shank in a single pass, and in two passes in a well-spaced orchard. The depth of the shank is often limited by the tractor, though a 4-foot (1.2 m) from the trunk.

CAUTION: Using either a multiple or single rip shank can damage existing roots. However, over time, the improved soil characteristics and root pruning will encourage new root growth. Roots take time to begin growing and regrowth varies with the season and the carbohydrate status of the tree. In any event, do not till all the middles at once. Modifying alternate middles each year produces the best results. Ripping or backhoeing seem most effective in the fall, after harvest when soils are dry and easy to break up and mix. In addition, tree water use is low at that time, and you can take help encourage postharvest root initiation.