FLOOD IRRIGATION OF CITRUS

H. K. Wutscher[1]

Surface or flood irrigation is the application of water by gravity flow directly onto the soil. Flood irrigation is the oldest irrigation method, and in its uncontrolled form is a natural phenomenon on which many areas still base their crop cycle. The 3 common methods used for citrus are: 1) border irrigation, 2) basin irrigation, and 3) furrow or corrugation irrigation.

Flood irrigation may be the oldest irrigation method, but it is by no means out-of-date. It can be an effective irrigation method under proper conditions:

1) A plentiful and cheap supply of water.
2) Slowly, moderately, or moderately rapidly permeable, deep soil.
3) The land must be relatively level, 0 to 0.3% slope for border and 0 to 3% slope for basin irrigation. Land up to 6% slope can be irrigated with furrow irrigation if special precautions are taken, but 3% or less is preferred.
4) Water quality must be reasonably good because with the large quantities of water applied, large amounts of salt are deposited. On the other hand, if drainage is good, salts can be leached readily with border and basin irrigation. Salt deposits on the leaves are avoided with flood irrigation. Trash, silt, and iron compounds which create difficulties with other irrigation methods are unimportant with flood irrigation.
5) Good drainage is important, more so than with other irrigation methods. All irrigated land must have drainage, no matter how good the water. The land will eventually become unproductive without drainage.

FLOOD IRRIGATION METHODS AND DELIVERY SYSTEMS

Border Irrigation

Border irrigation is the most common and most useful method. A small area, usually 1 but sometimes 2 or more rows of trees, are surrounded with low levees called borders. These borders are put up for each irrigation and are then leveled again in mechanically cultivated orchards. Borders can remain indefinitely with chemical weed control and only need reshaping every 2 or 3 years. Permanent borders must be low enough so as not to interefere with the passage of machinery. Strip watering young trees, *i.e.*, irrigating only a narrow strip along the tree row, saves water and reduces weed growth in the middles. Another water-saving method is to irrigate only alternate middles.

Basin Irrigation

Basin irrigation is very similar to border irrigation except that the areas enclosed by borders are much smaller, usually containing only 1 or 2 trees. This method can be used only with widely spaced trees, like 30 x 30 ft (9.1 x 9.1 m) spacing. Trees planted in hedgerows, *e.g.* 15 x 15 ft (4.6 x 4.6 m), prevent the necessary cross borders between trees in the row after the trees are 5 or 6 years old. Basin irrigation is ideal from the standpoint of applying equal amounts of water to each tree, although it requires much more labor. It can be used on greater slopes than border irrigation. Even distribution of water is no problem. On level land of 0.1% slope or less, about 2 manhours are needed to water an acre with a head of water about 1.5 cubic feet per second. Labor requirements may be 5 to 10 manhours per acre as the slope increases.

Furrow (Corrugation) Irrigation

Furrow irrigation of citrus is used mostly in California, rarely in Texas. It is similar to the method used for field crops in many areas. It can be used on land with steeper slopes than border irrigation, especially when the furrows are run on the contour. Water is diverted into shallow furrows (corrugations) and run down the rows. One furrow may be enough with young trees. Three to 8 furrows are used in older orchards. V-shaped furrows are dug for each irrigation and leveled afterwards in mechanically cultivated orchards as with border irrigation. Permanent furrows are used with chemical weed control,

---

[1] Research Horticulturist, Agricultural Research Service, USDA, Weslaco, Texas (Now at Orlando, Florida).

usually broad, flat furrows which do not interfere with machinery. Furrow irrigation can be done with smaller water delivery systems and requires less attention than the other 2 methods if well laid out. Only about 60% of the root zone is wetted, while border and basin irrigation methods wet 100% of the root zone. Danger of salt accumulation is greater with furrow irrigation than with border irrigation.

Delivery Systems

Systems delivering water from the source to the field are basically the same for all 3 surface irrigation methods, but a good head of water is needed for border and basin irrigation so the area to be watered can be covered quickly. Water movement through the furrows with furrow irrigation has to be fast enough to get even wetting but lower flow rates than with the other 2 methods are sufficient.

Surface irrigation systems are expensive to install. The best way is to put in a large system; the larger the system, the less is the per-unit cost. The usual procedure is to form a water district which sells bonds to pay for the basic parts of an irrigation system.

There are usually only 1 or 2 pumping stations per system in flat areas like South Texas. Distribution from then on is by gravity flow in carefully graded canals. Large capacity pumps lift the water from the source (in South Texas the Rio Grande River) into the main canal. Small streams and wells, where groundwater is usable, can be used as water sources for small systems. The water runs from the main canal directly into smaller branch canals or into a reservoir first. A second lift may be needed at this stage. Systems without any pumping at all are possible, using only the natural slope of the land. The irrigation system on the Mexican side of the lower Rio Grande Valley, designed and built more recently than the systems on the Texas side and according to an area-wide master plan, operates entirely without pumps.

The main canals often have only soil banks, but the smaller canals are usually concrete-lined. Gates from the branch canals lead into underground concrete pipes 15 to 36 inches (38 to 91 cm) in diameter or they are used to discharge the water directly into temporary soil-banked canals, which bring the water to the land to be irrigated. Smaller branch canals or canals originating at discharge valves from underground pipes then convey the water into the orchard. The water is discharged directly into the border strip in well-designed underground pipe systems.

The irrigator, who has to be fairly skillful, blocks the flow of water in the ditch with a piece of canvas or plastic and cuts through the border to flood the basin or the border strip when soil-banked canals are used. Plastic pipe siphons can be used to transfer the water from ditches to basins. The irrigator moves his canvas barrier to the next border strip when the basin is filled to the desired depth and repeats the process. Water is discharged from valves at each border strip with an underground pipe delivery system. Water can be diverted through a length of rubber hose if there is only 1 valve for 2 border strips. Some provision has to be made for the tail water at the end of the row in furrow irrigation. It can either be discharged into a drainage system or returned to the head of the row by pumping.

Six inches (15 cm) is the usual depth to which basins and border strips are flooded in Texas. No extra effort, except time, is required if more water is to be applied for leaching purposes. The water is generally not metered and the charges are made on an area basis within annual allotment limits in Texas. This encourages excessive water use.

FLOOD IRRIGATION CONSIDERATIONS

The Importance of Soil Type

The efficiency of a surface irrigation system, and the usefulness of surface irrigation as such, depends largely on soil type. Water penetration on coarse soils is rapid and deep and large losses result when soil-banked canals are used (Fig. 1). The runs in the orchard have to be kept very short. Losses are much smaller on soils containing more clay, and the runs can be longer, which reduces labor requirements. Water can be applied more rapidly and longer runs can be used with chemical weed control. Penetration becomes a problem in very clayey soils, and leaching is difficult; therefore surface irrigation is not the most desirable method.

The amount and frequency of irrigations is also dependent on soil type. Six inches (15 cm) of water applied on sandy loams in South Texas, which contain 25 to 30%

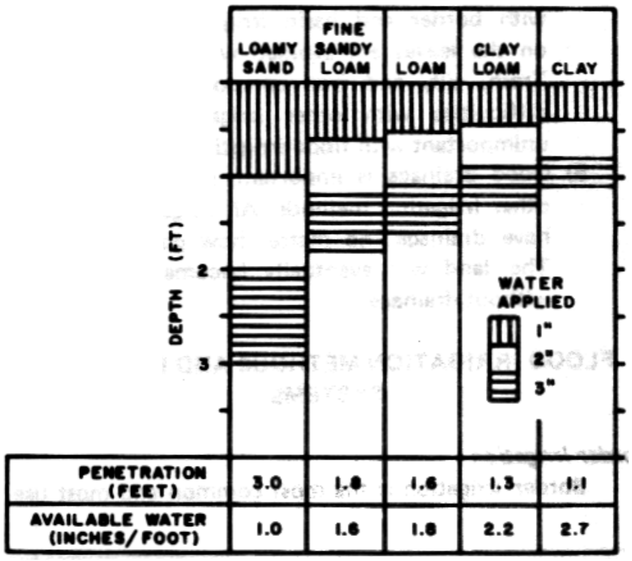

Fig. 1. Depths to which various amounts of surface-applied water will penetrate into dry soil (all available soil moisture has been depleted) and ranges of available moisture per foot of soil in Texas soils of different texture. Source: Bloodworth (1).

silt and clay in the surface soil and more in the subsoil, saturates the top 3 feet (91 cm) of soil, the usual rooting depth of citrus trees. There is less penetration on more clayey soil and lighter and more frequent irrigations are needed if waterlogging is to be avoided and because the trees have shallower root systems.

Formulas are available for calculating the length of run for different soil types. There is no substitute, however, for detailed knowledge of local conditions and designing a surface irrigation system strictly on the basis of published formulas can lead to problems. Runs are ideally from 200 to 600 feet (61 to 183 m) long, but occasionally runs up to 1,600 feet (488 m) long are used, depending on soil type, slope, the shape of the orchard, and the cultural system. The Soil Conservation Service gives advice and assistance in planning irrigation layouts.

The losses in getting the water into the field from branch canals can be minimized by lining the canals with concrete, but this creates permanent structures which obstruct field operations. Underground pipelines with valves are the most desirable. Aluminum pipe and rubber hoses are often used and offer advantages because they are easily moved.

Land Leveling and Cost of Establishing Flood Irrigation Systems

Land leveling has become a widespread practice in the last 30 years, as machinery became available to do the job rapidly and economically. Leveling to a slope of 6 inches (15 cm) per 1,000 feet (305 m) is common in South Texas. There is no question that land leveling makes field operations, especially irrigation, easier than on sloping land and that the danger of erosion is decreased. Rainfall is utilized more efficiently because there is less run-off.

Leveling can easily be overdone. Deep cuts create large areas where the subsoil becomes the surface soil, which causes fertility and infiltration problems which often reduce yields for many years. The advantages of a level soil surface are thus outweighed by poor growth and yield, and it often takes years to restore cut areas to normal productivity. Problems associated with deep cuts can be avoided by leveling in contour benches.

Installation of a new surface irrigation system in South Texas costs about $500 per acre ($1,250 per hectare), $100 for clearing the land, $200 for leveling, and $200 for installation of drainage pipes. Installing a drip irrigation system costs about the same. Land leveling is usually not necessary with drip irrigation and smaller pipes can be used, but savings are offset by the need for powerlines, pumps, filters and emitters. The main components already exist in most of the irrigable areas of the Rio Grande Valley, hence surface irrigation systems are usually cheaper and easier to operate than other irrigation systems. There is little that can go wrong in a well-designed surface irrigation system.

The water districts are strongly in favor of surface irrigation. This is what they are used to, and they object to keeping branch canals constantly full of water as they would have to for drip irrigation. The current charges vary from water district to water district, but typical figures are $5.30 per acre-foot (12 ha-cm), plus 25% for evaporation and seepage losses, and $0.50 per acre per month service charge when drip irrigation is used. The user has to install a meter. There is an annual $4.00 per acre flat fee and $3.50 per irrigation or 0.6 acre-foot (7 ha-cm) of water but no service charge or the 25% charge for losses with flood irrigation.

Water Quality

The concern with water quality is primarily confined to arid areas where evaporation exceeds rainfall. South Texas, for instance, has an average annual rainfall of 25 inches (635 mm) but pan evaporation is in the 50-inch (1,270-mm) range. Dissolved salts in the groundwater are concentrated because of the high evaporation rate and reach levels damaging to plant and soil. Groundwater is, therefore, sometimes unsuitable for irrigation in arid areas. Rivers and streams originating in more humid areas are the usual irrigation water sources, but the quality of their water is often adversely affected by drainage from saline areas.

Both the total salt content and the nature of the salts present must be kept in mind when judging water quality. The type of soil, drainage, climate and the rootstock of the trees in addition to the salt content of the water determine whether water of a given quality can be used or not.

Terms commonly used to express water quality are 1) electrical conductivity (EC), 2) parts per million (ppm), 3) milligram equivalents or milliequivalents (meq/1), 4) soluble sodium percentage and 5) sodium adsorption ratio (SAR). Electrical conductivity is expressed in millimhos or micromhos/cm and gives a measure of the amount of salt dissolved in the water. Parts per million can be used to express the total salt concentration or the concentration of individual elements, especially boron. Milliequivalents per liter expresses the quality of elements present in terms of chemical reactivity. The soluble sodium percentage gives the amount of sodium in relation to the total amount of cations (calcium, magnesium and sodium). The SAR also compares the concentration of sodium (meq/l) to the concentrations of calcium and magnesium but the relationship is:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The SAR can be used to express the sodium hazard of a water. The interrelationship of salinity and sodium hazard is summarized in Fig. 2, which classifies water according to both conductivity and the SAR.

Table 1 is a general guide to irrigation water quality. The salt tolerance of citrus is relatively low and water with an EC of 2 mmhos/cm (1,280 ppm total salts) is about the upper limit citrus will tolerate, depending on soil type, climate, and rootstock as mentioned earlier.

The most important ions affecting citrus are chloride, boron and sodium. Chloride and sodium commonly occur at high levels (over 100 ppm) in irrigation water, but it takes very little boron to cause high boron levels in the leaves. Leaf levels, with sour orange rootstock, are 1,000 to 2,000 ppm chloride, 1,000 ppm sodium and 200 to 300 ppm boron with 100 to 200 ppm chloride and sodium and 0.2 to 0.3 ppm boron in the irrigation water in South Texas. This shows, of course, that the elements in the irrigation water are not taken up in the same proportion as they occur in the water, and that the tendency of the plant to accumulate certain ions also must be taken into account.

The combination of ions is also important. Irrigation will be more damaging if both sodium and chloride are high than when chloride occurs with calcium. Chlorides are easily leached from the soil by rainfall or heavy applications of irrigation water. Boron is held on the exchange complex and is very difficult to remove.

Scheduling of Irrigations

Tensiometers and electrical resistance blocks are widely used in California and can be used to determine the need for irrigation. They are almost never used in Texas because they are unreliable. Colloid material fills the pores and erroneous readings result. Irrigation in Texas is scheduled mostly on the basis of visual observation. Experienced growers can do a good job that way. USDA-ARS scientists are using measurements of solar radiation and temperature on an experimental basis to schedule irrigations on 5,000 acres (2,000 ha) of commercial orchards. The water districts' favorite method is scheduling by calendar, *i.e.*, to plan in advance, at the beginning of the season, when to irrigate. This makes it easy to have the necessary supply of water on hand, but it doesn't take into account the weather and the needs of the trees and is, therefore, undesirable from the production standpoint.

Unnecessary irrigations can be very damaging. The greatest danger lies in raising the groundwater table as roots will not live long in waterlogged soil. The groundwater is usually very salty in arid areas. Salt becomes concentrated if the water tables rises into the root zone or to the surface.

Flood Irrigation as a Cold Protection Measure

Flood irrigation is becoming more important in cold protection with rising oil prices and the environmental protection laws, especially in California. Flooding is the most promising water application method because sprinklers cause ice formation on the trees which results in limb breakage, while fog, mist and drip irrigation are ineffective. Recent experience has shown that mist actually increases frost damage when the dew point is very low because the water evaporates and actually cools the area it is supposed to warm.

Five thousand gallons of water running between the tree rows release 1,126,500 BTU's as it cools from 60°F to 35°F. Over 6,000,000 BTU's are released per 5,000

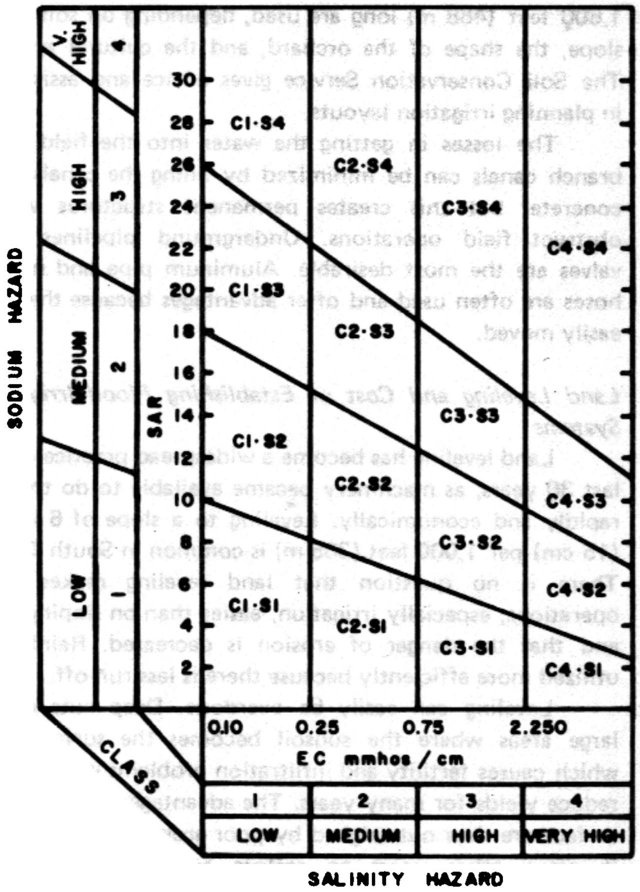

Fig. 2. Guide to quality of irrigation waters (After Richards, ed., USDA Agr. Handb. 60, 1954, p. 80).

Table 1. Guide to quality of irrigation water.

Specific conductance (mmho/cm)	Sodium (%)	Boron (ppm)	Residual sodium carbonate (meq/l)	Quality of irrigation water
0.75	65	0.3-1	1.25	Excellent to good
0.75-2.0	50-65	0.7-2	1.25	Good to permissible
2.0 -3.0	92	1-3	.25-2.5	Doubtful to unsuitable
3.0	92	1.2-3.8	2.5	Unsuitable

Source: Jackson (4).

gals when the water actually freezes. Some very good results have been obtained in combination with wind machines in California. The limitations of using water for cold protection are 1) availability (the conveying systems can't hold enough water to flood all orchards in a given area, and in some cases the water districts refuse to fill pipelines on freeze nights because of the danger of cracking pipes) and 2) flooding cannot be done repeatedly within short periods of time because of waterlogging. Flooding is however, a simple, low cost, and efficient frost protection measure within these limitations.

Effect of Irrigation Method on Mineral Nutrition

It is only logical that the moisture status of the soil affects the nutrient uptake of the plants growing in it. Some work showing this was done as early as 1930. I was interested in how the lack of wet-dry cycles and the constant water saturation of part of the root zone under drip irrigation would affect leaf nutrient levels as compared to flood irrigation. Claims had been made that very saline water could be used on vegetables with drip irrigation.

We grew young grapefruit trees on 15 rootstocks under flood and drip irrigation in field plots as part of our work to find salt-tolerant rootstocks. We applied solutions high in chlorine and boron separately, and then analyzed the leaves for these elements. Trees on 13 of the 15 rootstocks tested took up the same amount of chlorides under both flood and drip irrigation. Trees on only 1 rootstock took up less chloride under drip irrigation than under flood irrigation. Leaf boron levels were the same under drip and flood irrigation on 12 of the 15 rootstocks when irrigated with a 6-ppm boron solution. Boron was lower under drip than flood irrigation with 2 rootstocks. Surprisingly, trees on *Citrus macrophylla*, a rootstock known as boron-tolerant, took up much more boron under drip than under flood irrigation (8).

We converted part of a 7-year-old avocado grove from flood to drip irrigation and then followed the levels of 12 elements at 2-month intervals for 2 years and found that manganese and chlorine were consistently higher under drip than under flood irrigation (6). The explanation seems to be that the salt accumulated around the wetted zones under the drippers in soil containing many feeder roots. There is enough rainfall in South Texas to keep root systems alive in unirrigated soil. The higher manganese levels were probably due to the wetter soil with drip irrigation, as manganese is more available in wet soil (6).

Young grapefruit trees on 20 rootstocks and watered with river water by drip and flood irrigation had higher concentrations of nitrogen, phosphorous, sodium, iron, zinc, and copper in the leaves with drip than with flood irrigation. Calcium and boron were lower with drip than with flood irrigation. Potassium, magnesium and chlorine were the same with both irrigation methods. Rootstock response was not uniform as in the test for chloride and boron uptake mentioned earlier. 'Iran' lemon and 'Rusk' citrange tended especially to react contrary to other stocks in the test and to take up more phosphorous, zinc and copper under flood irrigation (7). Differences found were statistically significant but they were small numerically, except those in chloride uptake by long-established avocado trees. There was not enough difference from a practical point of view to recommend drip irrigation over flood irrigation on the basis of better nutrient uptake. The high chloride levels in avocado trees with drip irrigation show, however, that converting older trees from one irrigation method to another can cause unexpected problems.

SUMMARY

Flood irrigation is not the method to use for all citrus in Florida, but it will remain in use in Texas, Arizona, and some areas of California for some time to come. There are some disadvantages to flood irrigation. Large amounts of water must be available and applied at high flow rates. Skilled labor is needed to flood irrigate properly. Overwatering is a constant and often unavoidable danger. Rain falling on recently irrigated land often causes waterlogging. Flood irrigation is a reliable, cheap, and with proper management, relatively trouble-free method of irrigation with moderately permeable soil, an ample source of cheap water, and the basic canal network and drainage system in place. Unfiltered water, even sewage effluent, can be used. Water distribution by gravity flow keeps energy costs at a minimum. Salt problems can be overcome by leaching and the irrigation system can double as a cold protection system. Surface irrigation should be considered first in countries where lack of technology makes the use of more sophisticated methods questionable. Newer methods will probably reduce the use of surface irrigation in the United States as water becomes scarcer and more expensive.

SELECTED REFERENCES

1. Bloodworth, M. E. 1959. Some principles and practices in the irrigation of Texas soils. Texas Agr. Exp. Sta. Bul. 937.
2. Hagan, R. M., H. R. Haise, and T. W. Edminster, ed. 1967. Irrigation of agricultural lands. Amer. Soc. Agron. Monograph 11. Madison, WI.
3. Isrealsen, O. W., and V. E. Hansen. 1962. Irrigation Principles and Practices, 3rd ed. John Wiley & Sons, Inc. New York.
4. Jackson, M. L. 1962. Soil Chemical Analysis. Prentice Hall, Inc. Englewood Cliffs, NJ.
5. Marsh, A. W. 1973. Irrigation. *In*: The citrus industry, W. Reuther, ed. Div. of Agr. Sciences, Univ. of Calif., Berkeley, CA. Vol. 3, Chap. 8, p. 704-718.

6. Wutscher, H. K. and N. P. Maxwell. 1975. Seasonal changes in 12 leaf nutrients of 'Lula' avocado with drip and flood irrigation. *HortScience* 10(5). (In press).
7. _____________, A. Peynado, and H. Hill. 1975. Effect of drip and flood irrigation on mineral nutrition of young grapefruit trees. *Jour. Rio Grande Valley Hort. Soc.* 29. (In press).
8. _____________, _____________, W. C. Cooper, and H. Hill. 1973. Method of irrigation and salt tolerance of citrus rootstocks. *Proc. Intl. Citrus Congress,* Murcia, Spain, 1973. Vol. 1:299-306.
9. Zimmerman, J. D. 1966. Irrigation. John Wiley & Sons, New York, NY.

QUESTIONS

Q: What does the EPA say about the saline water you're dumping into the Gulf? Are they going to allow it to continue forever?

Wutscher: The only thing they're worried about is pesticide residues in it. They are checking it for pesticides, nitrates, and phosphates.

Lyons: You might point out that that is standard ground water. The drainage water coming out of those groves is the same as any well water in the Rio Grande Valley.

Wutscher: That is a good point. It isn't any worse than the ground water in general, so they really can't object to it.

Q: Why did you conclude that flood irrigation wouldn't be any good for Florida?

Wutscher: Because the soil is so sandy.

Q: Have you ever been in the Indian River Area? (Yes). I can show you a few groves that get up to 800 boxes per acre (80 tons per ha) using flood irrigation, which I think is quite good. So I think you would have to conclude that there are a few groves in Florida in which flood irrigation will work.

Wutscher: Yes, but my impression of the Indian River Area is that you're trying to get rid of water instead of applying it, and I had not thought of flood irrigation being used there.