FLATWOODS CITRUS IRRIGATION

BRIAN J. BOMAN
Agricultural Engineer
University of Florida, IFAS
Ft. Pierce, FL 34954

Introduction

Citrus production in Florida historically has been centered in the deep sandy soils of the southern part of the Central Florida Ridge. The last several years, however, have brought a dramatic switch in the citrus distribution throughout the state. Factors such as increased consumer demand, urban expansion, and the recent severe freezes have brought significant increases in citrus acreage to the South Florida Flatwoods. Along with the influx of large new citrus plantings, there has been a rapid expansion in the urbanization of the coastal Flatwoods soils areas. The resulting conflict between urban and agricultural users of the water resource has made water allocation one of the most pressing regional issues.

Water shortages along with water quality issues have caused the general public, environmental groups, and regulatory agencies to focus on agricultural practices and, most assuredly, growers will be required to make operational changes in the near future to accommodate environmental concerns. Irrigation, made necessary by the recurring drought periods throughout the winter and spring months, has made agriculture the single largest user of water in the state. Some of the most pressing regional issues facing citrus growers in the Indian River District deal directly with ensuring that sufficient quantities and quality of water remain available for irrigation of citrus. Much of the water used for irrigation in Flatwoods areas comes from aquifers with high salinity levels.

Irrigation Research

Irrigation research in Florida has been conducted mainly on the deep sandy soils of the southern part of the Central Florida Ridge where the rooting depth is typically 6 to 12 feet. Irrigation during flowering and fruit set in the spring has been found to increase yields of Hamlin, Pineapple, and Valencia sweet oranges (Koo and Sites, 1955). Subsequent studies showed that irrigating at one-third depletion from January through June and two-thirds depletion the remainder of the year provided the most efficient use of water while still maintaining yields near the magnitude of the continuous one-third depletion level (Koo, 1963).

Myers and Harrison (1975) investigated a variety of overhead and drip systems along with placement of emitters with different outputs. They found no significant differences in yield during three years of near-average rainfall. However, they found that all irrigation systems and amounts gave significant increases in yield during a drought year. In one experiment, Koo and Hurner (1969) suggested that increases in yield response to irrigation may be related to increases in crown growth response. Zekri and Parsons (1988) reported on water relations of Marsh grapefruit at two application levels and found greater water stress (as measured by stomatal conductance and leaf water potential) occurring in the drip irrigated trees, even though the same volume was applied with overhead or microsprinkler irrigation.

In Florida, Koo (1978, 1985) showed that increased irrigation coverage of the orchard floor resulted in greater fruit yield for large grapefruit under Ridge conditions. Smajstrla and Koo (1984) compared microsprinkler and drip systems on sandy soils of the Ridge, determining that about 50% coverage of the root zone is necessary for adequate growth and yield. Zekri and Parsons (1989) also reported that irrigation systems providing greater coverage area gave better leaf and fruit growth than systems providing less coverage.

Koo (1961) studied the distribution and uptake of soil moisture in mature citrus groves at Lake Wales and Lake Alfred and found that soil water extraction was more extensive away from the trees during low rainfall periods. On the typical sandy textured soils used for citrus production, drip irrigation generally wets a small diameter column of 2-5 feet on both Ridge and Flatwoods soils (Koo and Tucker, 1974). This small volume of wetted soil may limit the usefulness of drip irrigation for Florida citrus.

Citrus is very sensitive to water and nutrition (especially nitrogen) deficits during the flowering period (Doorenbos and Kassam, 1979). Deficits during this period are directly related to reduced fruit set. Deficits during the fruit set period will increase fruit drop while deficits during the early yield formation period can reduce fruit growth. The main objective of irrigation is to provide plants with sufficient water to minimize stress that may cause reduced yield or poor quality fruit. The required timing and amount of applied water is governed by the prevailing climatic conditions, stage of growth, soil moisture holding capacity, and root development. Smajstrla et al. (1985) determined that microsprinkler irrigation of young 'Valencia' orange trees in Florida was most effective (in terms of growth) when irrigations were initiated at tensions of 20 cbar. Irrigation and fertilization are known to be linked together. Recent fertilization studies on young trees have shown similar tree growth between slow release fertilizer and traditional dry broadcast fertilization 5-6 times per year (Marler et al., 1987, and Ferguson et al., 1988).

Flatwoods Soils

The shallow soils and high water table conditions typifying the Flatwoods soils make proper water management essential for maximized production and efficient use of the water resource. The South Florida Flatwoods contains Alfisol and Spodosol soils which may have impermeable horizons near the surface. Surface horizons are typically sandy in texture with low water holding capacity. Subsurface horizons generally have poor internal drainage resulting from a significant clay content or an organic hardpan (spodic) material. The rooting depth of citrus on Spodosols is typically limited to about 18 inches (Reitz and Long, 1955). Citrus trees grown on these soils are very susceptible to moisture stress during periods of low rainfall since there is such a small volume of soil (and water) in the root zone.

Yields per unit of land area on Flatwoods soils have been equivalent to about one-half to two-thirds of the production obtained on the upland sand Ridge in the center of the state (Calvert, 1978) due largely to problems with water management on these soils.

The natural Flatwoods soil profiles are modified during the bedding process. The water holding capacity (WHC) can change dramatically on some soil types with shallow clay layers. Boman (1987) reported substantially increased WHC on bedded groves with Winder, Oldsmar, and EauGallie series soils as compared to natural soil conditions.

Irrigation System Considerations

Nearly all groves in the east coast Flatwoods soils areas are planted on beds raised from 18-48 inches above the water furrow. Irrigation of these areas has traditionally been by flooding methods where large volumes of water are pumped into a grove. Water is ponded in the water furrow and held for approximately 24 hours, allowing water to seep into the bed. It is then drained quickly from the grove before waterlogging can occur.

Calvert, Koo, and Ford (1967) compared crown flood, perforated pipe sprinkler, and furrow flood irrigation systems. Utilization of crown flood irrigation requires grove preparation and quantities of water such that water can be raised above the bed tops and completely flood the block being irrigated. More common is furrow irrigation, which is accomplished by increasing the water level in the water furrows and allowing seepage to move the water into the beds. Furrow irrigation was shown to supply less water to 24-inch beds than crown flood or sprinkling methods. Capillary rise was up to 12 inches above the free water surface in Felda loamy fine sand, but less than 6 inches in an Immokalee fine sand. Smajstrla et al. (1982) reported on the application efficiency of a flooded grove. On a block basis, individual irrigations averaged only 24% efficiency. However, when water reuse of tailwater was considered, irrigation efficiencies as high as 87% were reported.

The recent expansion of irrigated acreage and the uncertainty about available water has led to most new citrus plantings having provisions for alternate methods of irrigation. Microirrigation systems using microsprinkler or drip applicators have been the predominant among these alternatives. The microsprinkler systems, which provide more freeze protection for young trees than drip systems, are the most popular among South Florida citrus growers. Microsprinklers normally spray 10 to 20 gallons of water per hour, and often the systems are designed to allow injection of fertilizer and chemicals with the water.

Several microirrigation spinner and spray emitters were evaluated by Boman (1989a) to determine their distribution patterns and the relationship between their operating pressure and the resulting discharge flow rate. Emitter flow rate, pattern distribution and uniformity were measured for each type of emitter at pressures of 15, 20, and 25 psi. The spinner types of emitters had higher uniformity of water application than spray types under the no-wind conditions. Most spray emitters had 50 to 75 percent of the wetted area receiving insignificant water applications while 10 to 15 percent of the wetted area received more than three times the average application. Spinner emitters, however, had 30 to 80 percent of the wetted area receiving applications in the range of 50 to 150 percent of the average. None of the spinner models had areas of application greater than four times the mean application depth of the emitter.

Microsprinkler assembly discharge variations were examined by Boman (1989b) to partition contributions from the spaghetti tubing and the emitter. The coefficients of variation (CV) of the emitters alone were found to be excellent (less than 2%) for the two models tested. Variations in 2-foot lengths of spaghetti tubing ranged from 2.0% to 7.6%. Spaghetti tubing diameter was found to significantly affect discharge rate at 20 psi system operating pressure. A 12% increase in discharge rate from Micro-Bird II Spinners resulted when spaghetti tube diameter increased from 4 mm to 6 mm. The discharge rate increased 60% for Microsprinkler III emitters when 10 mm tubing was used instead of 4 mm tubing. Spaghetti tubing was found to be an important factor to consider in the overall uniformity of microsprinkler systems.

Water Table Considerations

Water table levels fluctuate widely in Flatwoods soils in the summer rainy season due to the effects of non-uniform rainfall and high intensity rainstorms. Rainfall intensities of 4 inches per day are not uncommon in the summer. Drainage of the soil-water is especially important in the wet season since several studies have shown that citrus root damage may occur under prolonged conditions of high water table (Calvert et al., 1967, Ford, 1968, 1972). Effective water management, which includes both irrigation and drainage, on these poorly-drained soils is essential for profitable citrus production.

The rate of water table recession following heavy rainfall is dependant upon the antecedent conditions, soil series, bed height, drainage structures, and gradient of the water table. Boman (1987) reported times ranging from 20-76 hours for the water table to drop 6 inches. The major Indian River District soils all had 6-inch drawdown rates of 48 hours or less.

Obreza and Admire (1985) concluded that shallow water tables in the Flatwoods soils could significantly augment water available for root uptake. Current irrigation scheduling models fail to take this into account. Graser and Allen (1987) suggest that water table management by controlling at above-normal water tables in the winter and spring could help provide a year around optimum water table for citrus. High water tables permit upflux of water from the water table into the root zone and may thus decrease the need for supplemental irrigations.

Citrus Water Use

Annual rates of evapotranspiration (ET) for 1972-1980 have been calculated from water balances on the SWAP project citrus grove with a Bahia grass cover (Rogers et al., 1983). The ET values were presented for a developing bedded citrus grove (years 2-8). ET values were greater for the deep-tilled and deep-tilled with lime plots than for the shallow tilled plots. During 1973 when the rainfall was 54.1, the average annual ET rates were 44.4, 40.6, and 29.8 inches per year, respectively, for the DTL, DT, and ST plots. Differences in ET for these plots were inversely related to differences in the quantities of water discharged through the subsurface drains.

Estimates of daily citrus water requirements by month were presented by Tucker (1985) for 15 and 24 year-old grapefruit and 20 year-old orange trees. Tree water use estimate range from about 20-30 gal/day for Dec.-Feb. to 60-70 gal/day in July and August.

Water Quality

Water quality is an important factor in citrus production since citrus trees are more sensitive than many other crops to soil and water salinity (Doorenbos and Kassam, 1979). Excess salinity in Florida's irrigation has been known to cause damage to citrus since the late 1800's (Robinson, 1900). Literature on field studies of rootstock salinity tolerance, all from arid areas, have shown that many of the common citrus rootstocks differ in their tolerance to soil salinity. Studies in Texas (Cooper, 1962 and Chapman, 1968) and California (Newcomb, 1979) have shown the general order of salinity tolerance to be: Rangpur lime = Cleopatra mandarin > sour orange > sweet orange = Swingle citrumelo > rough lemon.

The method of application of irrigation water contributes to a tree's ability to tolerate excess salinity (Calvert, 1982). Irrigation water that is applied through overhead or high volume sprinklers must generally contain less than 1000-1250 ppm TDS. Salt-injury symptoms on leaves can occur even with better quality water (800-1000 ppm TDS) on hot, dry windy days if sprinklers allow only intermittent wetting of leaves. Irrigation water sprayed onto leaves evaporates, leaving behind relatively high concentrations of salts. Temperature, relative humidity and wind each affect the rate of evaporation and, thus, of salt deposition on leaves. Night-time irrigation reduces evaporative losses and the resulting salt-concentrating effects. This tends to decrease salt injury on leaves.

Irrigation scheduling becomes of prime importance when using saline irrigation water. Once salts are in the root zone, the only way to remove the salts is through leaching. As the soil dries, the salt are concentrated in the remaining soil water. Soil organic matter, water content and leachabilty all contribute to a need for appropriate management practices until adequate rains leach out accumulated salts. Soils that are poorly drained pose a more serious potential salinity problem than soils that are easily leached. Maintaining a high soil water content and applying irrigation depths great enough to provide a downward movement of salts through the root zone will help to minimize salt damage. Care should be taken to prevent or minimize leaching nutrients and other applied chemicals into the groundwater.

Summary

Most Flatwoods soils have less than 2.5 inches total water holding capacity in the tree's root zone. Irrigations should begin before a third to half of this total is depleted. Most of the water in the soil is released at low tensions. Irrigations should therefore be scheduled accordingly. When the water table drops more than 12-15 inches below the root zone, little upflux is possible in sandy soils.

Application depths of microirrigation emitters are governed by the flow rate, pressure, diameter of coverage, hours run, and the application efficiency. In most cases, the actual emitter discharge will be less than that specified by the manufacturer. It is a good practice to measure application rates of the emitters as installed in the field. Longer duration or night irrigations may be required when hot, dry, windy conditions exist.

The TDS of irrigation water should be routinely evaluated with an EC meter. If excess salts accumulate in the soil, it is best to the keep the soil moist to prevent further concentration of the salts. Periodic leaching may become necessary. However, excessive leaching can waste valuable nutrient salts and thus contribute to groundwater contamination. Compacted soils or those with poor drainage are of particular concern when dealing with poor quality water.

Poor quality water should be kept off of leaves, especially under conditions of high evaporative demand. Irrigate at night whenever possible to minimize evaporative concentration of salts. Choose fertilizer formulations that have the lowest salt index per unit of plant nutrients. Maintain optimum but not excessive nutrient levels in the soil and leaves. Relatively frequent (and more dilute) fertigations make it possible to reduce the salt content of each application and aid in preventing excess salt accumulation in the root zone.

Irrigations applications should be enough to wet the entire depth of the root zone. Applications should be made every 2 to 4 days during peak water use times. Adjust irrigation durations to compensate for low application efficiencies due to wind, low humidity, and evaporation. Remember that the daily tree water requirements in June-August can be twice that of March-April. If summer rains are inadequate and water table levels are low, frequent summer irrigations may be required. One of the most important aspects of good irrigation practice is to make frequent field checks of the soil moisture. Use a shovel or auger to dig down into the root zone to assure yourself that your irrigation program is supplying the required amount of water to the trees, without over-watering.

References

1. Boman, B. J. 1989a. Distribution patterns of microirrigation spinner and spray emitters. Applied Engr. Agr. 5(1):50-56.
2. Boman, B. J. 1989b. Emitter and spaghetti tubing effects on microsprinkler flow uniformity. Trans. ASAE. 32(1):168-172.
3. Boman, B. J. 1987. Effects of soil series on shallow water table fluctuations in bedded citrus. Proc. Fla. State Hort. Soc. 100:137-141.
4. Butson and Prine, 1968. Circ. S-187, Agr. Exp. Sta., IFAS, University of Fla., 41 pp.
5. Calvert, D. V. 1982. Effect of ground water quality on crops in Florida. Proc. Environ. Sound Water Soil Manage. Amer. Soc. Chem. Engr. (ASCE). Orlando, FL. p. 440-444.
6. Calvert, D. V. 1978. Comparison of costs and returns from citrus production on deep and shallow soils in Florida. The Citrus Industry, June, p. 7-14.
7. Calvert, D. V., R. C. Koo, and H. W. Ford. 1967. Flood irrigation studies with citrus. Proc. Fl. St. Hort. Soc. 80:79-85.
8. Chapman, H. D. 1968. Salinity and alkali. In: The Citrus Industry. II. Univ. of Calif. Press, Berkeley. p. 243-266.
9. Cooper, W. C. 1962. Toxicity and accumulation of salts in citrus trees on various rootstocks in Texas. Proc. Fla. State Hort. Soc. 74:95-104.
10. Doorenbos and Kassam. 1979. Yield response to water. FAO Irrig. and Drain. Paper No. 33.
11. Ferguson, J. J., F. S. Davies, C. H. Matthews, R. M. Davis. 1988. Controlled-release fertilizers and growth of young 'Hamlin' orange trees. Proc. Fla. State Hort. Soc. 101:17-20.
12. Ford, H.W. 1968. Fluctuations of the water table in drained Flatwoods groves. Proc. Fla. State Hort. Soc. 81:75-79.
13. Ford, H.W. 1972. Eight years of root injury from water table fluctuations. Proc. Fla. State Hort. Soc. 85:65-68.
14. Graser, E.A. and L.H. Allen. 1987. Water management for citrus production in the Florida flatwoods. Proc. Fla. State Hort. Soc. 100:126-136.
15. Koo, R. C. J. 1985. Response of 'Marsh' grapefruit to drip, under tree spray and sprinkler irrigation. Proc. Fla. St. Hort. Soc. 98:29-32.
16. Koo, R. C. J. 1978. Response of densely planted hamlin orange on two rootstocks to low volume irrigation. Proc. Fla. St. Hort. Soc. 91:8-10.
17. Koo, R. C. J. 1963. Effects of frequency of irrigations on yield of orange and grapefruit. Proc. Fla. St. Hort. Soc. 76:1-5.
18. Koo, R. C. J. 1961. The distribution and uptake of soil moisture in citrus groves. Proc. Fla. St. Hort. Soc. 74:86-90.
19. Koo, R. C. J. and G. T. Hurner. 1969. Irrigation requirements of citrus grown on lakewood fine sand. Proc. Fla. St. Hort Soc.:69-72.
20. Koo, R. C. J. and J. W. Sites. 1955. Results of research and response of citrus to supplemental irrigation. Soil and Crop Sci. Soc. Fla. 15:180-190.
21. Koo, R. C. J. and D. P. T. Tucker. 1974. Soil moisture distribution in citrus groves under drip irrigation. Proc. Fla. St. Hort. Soc. 77:61-65.
22. Myers, J. M. and D. S. Harrison. 1975. Drip and overhead sprinkler irrigation effect on soil moisture in a citrus grove. Proc. Fla. St. Hort. Soc. 78:10-16.
23. Marler, T. E., J. J. Jackson, and F. S. Davies. 1987. Growth of young 'Hamlin' orange trees using standard and controlled-release fertilizers. Proc. Fla. State Hort. Soc. 100:61-64.
24. Newcomb, D. A. 1978. Selection of rootstocks for salinity and disease resistance. Proc. Intern. Soc. Citriculture 1:117-120.
25. Obreza, T.A. and K.E. Admire. 1985. Shallow water table fluctuation in response rainfall, irrigation, and evapotranspiration in Flatwoods citrus. Proc. Fla. State Hort. Soc. 98:32-37.

26. Reitz, H. J. and W.T. Long. 1955. Water table fluctuations and depth of rooting of citrus trees in the Indian River area. Proc. Fla. State Hort. Soc. 68:24-29.
27. Rogers, J.S. 1983. Evapotranspiration from a humid-region developing citrus grove with grass cover. Trans. ASAE 26:1778-1783 and 1792.
28. Robinson, M. R. 1900. Report on fertilizers and irrigation. Proc. Fla. State Hort. Soc. 13:140-145.
29. Smajstrla, A. G., and R. C. J. Koo. 1984. Effects of trickle irrigation methods and amounts of water applied on citrus yield. Proc. Fla. St. Hort. Soc. 97:3-7.
30. Smajstrla, A. G., D. S. Harrison, C. Tai, and D. Clapp. 1982. Water budget of crown flood irrigated citrus. Proc. Fla. State Hort. Soc., 95:11-14.
31. Smajstrla, A. G., L. R. Parsons, K. Aribi, and G. Vellidis. 1985. Response of young citrus trees to irrigation. Proc. Fla. St. Hort. Soc. 98:25-28.
32. Tucker, D.P.H. 1985. Citrus irrigation management, Circ. 444, Agr. Exp. Sta., IFAS, University of Fla., 26 pp.
33. Zekri, M. and L. R. Parsons. 1988. Water relations of grapefruit trees in response to drip, microsprinkler, and overhead sprinkler irrigation. J. Amer. Soc. Hort. Sci. 113(6):819-823.
34. Zekri, M. and L. R. Parsons. 1989. Grapefruit leaf and fruit growth in response to drip, microsprinkler, and overhead sprinkler irrigation. J. Amer. Soc. Hort. Sci. 114(1):25-29.