Citrus Yield and Quality as Affected by Subsurface Irrigation[1]

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Abstract. Supplemental subsurface irrigation resulted in increased yield and fruit size of 'Washington' navel and 'Owari' satsuma oranges. The larger fruit size, as a result of irrigation, induced a slight but significant increase in peel thickness. Supplemental moisture resulted in a reduction in juice content of 'Owari' satsuma. With 'Washington' navels irrigation increased juice content, or was equal to the control, in 4 out of 6 years. Irrigation did not greatly influence pH, percent soluble solids or solids/acid ratio of the juice. Two years results showed that irrigation did not affect peel color of 'Washington' navels. In 1973 irrigation had no effect on juice color of both types of oranges.

Citrus is grown in south Louisiana on fertile alluvial silt loam soils. Annual rainfall is high, averaging approximately 1.7 m (67 in.)/year. Distribution of rainfall is not always adequate, with 2 periods of limiting moisture occurring usually from mid-May to mid-June and from mid-October to mid-November (Fig. 1). These periods correspond to fruit setting and fruit maturation periods, respectively. The water table in the area varies from approximately .9 to 1.2 m.

Several investigators in other areas, in more arid regions, have demonstrated the effects of irrigation on citrus (2, 3, 4, 5, 6). In Arizona, with 'Valencia' oranges, the total soluble solids, acid, ascorbic acid and peel thickness increased and fruit size decreased when lack of soil water in August produced moderate to severe water stress in the trees (3). Depth of the water table influenced the yields of 'Washington' navel oranges in the United Arab Republic (5). Yields decreased sharply as the water table became closer to the soil surface accompanied by reduced fruit size. High soil water was found to lower soluble solids in Florida (6).

In California it was found that frequently irrigated 'Valencia' trees produced about 20% more fruit in 4 out of 6 years (2). Irrigation increased the size of 'Bearss' limes in Florida and lowered acid in 2 out of 4 years, but did not influence juice content or soluble solids (4).

This study was conducted to determine the influence of supplemental subsurface irrigation on fruit quality and yield of 'Washington' navel and 'Owari' satsuma at the Plaquemines Parish Experiment Station, Port Sulphur, LA.

Materials and Methods

Two .405 ha (1-acre) orchard plots were utilized, one planted to 'Washington' navel and the other to 'Owari' satsuma trees, both budded on *Poncirus trifoliata* (L.) Raf. rootstock. Alternate rows in both plantings were irrigated by an experimental subsurface trickle irrigation system (1), which allowed irrigation of alternate rows without influencing the control or non-irrigated rows. Six replications were utilized per cultivar, with 10 trees per replication, spaced 4.6 m apart on 8.7 m wide rows.

In 1963 prior to planting, 2.5 cm polyethylene plastic pipe laterals (110 m long) with 1.3 cm knife-made slits on 30.5 cm centers were embedded with a subsoiler 46 cm below each row to be irrigated. Longitudinal slits were flexible and self-cleaning when pressurized. Each lateral was connected to a 3.8 cm plastic underground supply line. The system utilized filtered pond water, fairly free of minerals and salts. The system was capable of operation at 350–1055 gs/cm^2 (5–15 p.s.i.) for water injection into the root zone and was designed to apply a volume equal to 2.54 cm of water on a 6.1 m × 6.1 m area per tree in approximately 4 hours. Each lateral of the entire system was flushed at each irrigation for a period of about 5 minutes.

During the first 2 years soil moisture need was determined by irrometers in an attempt to maintain 50% available moisture at the 30 cm soil depth. Irrometers did not function properly in the heavier silt loam soil, so in the following years water was applied for 4 hours when trees showed symptoms of wilting at mid-day. This technique appeared to be a better indicator of moisture stress than the irrometers. Supplemental water was applied 2–4 times per year, depending on rainfall.

Random samples of 30 fruit were collected from each plot between November 5–15 for satsumas (1971–74) and between December 10–20 for navels (1968–74) and between December 10–20 for navels (1968–74) in all years and brought to Baton Rouge for analysis. Average wt per fruit was determined on fruits from all plots. Peel thickness was measured at the equator with calipers. The juice from the 30-fruit sample from each replication was extracted with a Sunkist juicer, strained and percent juice calculated.

The pH of the juice was determined by using a glass electrode pH meter and percent soluble solids was determined with an Abbe' refractometer and recorded as sucrose. Percent titratable acidity was determined by titration of a 10 ml juice sample in 100 ml of distilled water using 0.1 N NaOH to a pH of 7.0 using a pH meter as reference. Solids/acid ratios were then calculated.

In 1972 and 1973 the Gardner color difference meter was used to determine peel color of navel oranges. During 1973 juice color was also determined in a similar manner for both cultivars. Peel and juice

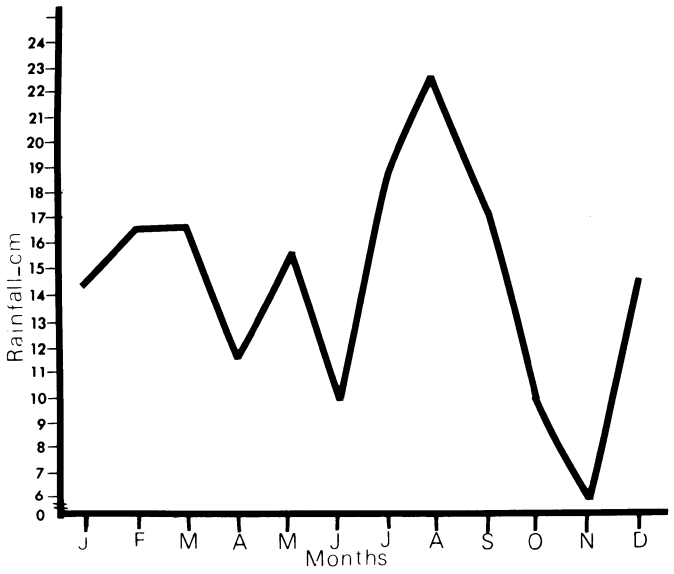

Fig. 1. Average monthly rainfall—Plaquemines Parish Expt. Station, 1964–73.

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Table 1. Effects of supplemental irrigation on quality and yield of 'Washington' navel and 'Owari' satsuma oranges (1968–74).

Treatments	Av. wt/ fruit (g)	Yield[z]	Peel thickness (mm)	Juice		% Soluble solids	% Titratable acidity	Solids/ acid ratio	Peel color[y]				Juice color[y]			
				percent	pH				L	a	b	y	L	a	b	y
Navels[x]																
Control	269	83.7	3.94	56.9**	3.8	11.3	.66*	17.2/1	67.1[w]	21.3	38.0	54.5	55.6[v]	−0.8	31.1	30.0
Irrigated	346**	102.7**	4.29**	53.5	3.8	11.3	.64	17.6/1	67.4	21.3	38.2	56.1	55.7	−1.2	31.1	31.0
Satsumas[u]																
Control	104	105.0	2.98	49.7**	4.0	10.5*	.56	18.8/1	—	—	—	—	47.3[v]	18.9	28.5	22.5
Irrigated	136**	128.0**	3.30**	46.3	4.1	10.2	.56	18.6/1	—	—	—	—	47.5	18.4	28.6	22.7

[z] K/tree; average of 7 years—1968–74
[y] Gardner color difference meter values—standard white tile—L = 91.6, a = −1.3, b = −0.1
[x] Average of 6 years data—1969–74
[w] Average of 2 years data—1972–73
[v] 1 year data—1973
[u] Average of 4 years data—1971–74
* Significantly different at the 5% level
** Significantly different at the 1% level

color were compared to a white standard tile (L = 91.6, a = −1.3, b = −0.1).

Results

Supplemental irrigation resulted in increased fruit size of 'Washington' navel and 'Owari' satsuma oranges (Table 1). Fruit size of navel oranges was increased by 29% over a 6-year period as compared to a 31% increase in fruit size of satsumas over a 4-year period as a result of supplemental irrigation. Associated with this increase in fruit size was a significant increase in peel thickness with both types of oranges, but this increase was not large and considered unobjectionable for fresh market fruit. With increases in fruit size of approximately 30%, peel thickness increased only 9–10%. A significant interaction of low magnitude occurred for peel thickness with navel oranges. Peel thickness of navels decreased as the trees increased in age, but this was not the case with satsuma.

Irrigation resulted in increased yields (total wt of fruit/tree) of 22% and 23% for satsuma and navels, respectively. Yield per tree has increased as the trees increased in age. In all cases, the irrigated plots yielded more fruit than the control; however, increases varied from year to year.

A significant interaction occurred in navel oranges concerning percent juice. The irrigated plots had a slightly higher juice content or equal to the control plots in 4 out of 6 years. However, in 1970 and 1972 the irrigated plots were lower in percent juice. In 1972, the irrigated plots had about 20% less juice than the control due to granulation or drying of juice sacs in the navel oranges which sometimes occurs in larger fruit. As an average, juice percent was reduced. With the satsuma, juice percent was lowered by irrigation during the 4-year period (Table 1). Part of this reduction may be attributed to increased peel thickness as reported by Hilgeman and Sharp (3).

Supplemental irrigation had little affect on juice quality. Juice pH was not altered by supplemental irrigation. Soluble solids were not affected by the additional moisture in navels. Irrigation did affect soluble solids in satsuma, but the difference was small. Percent titratable acidity was lowered in the navel cultivar by irrigation but not with the satsuma. This difference also was extremely small and negligible. Therefore, the solids/acid ratio was not influenced by irrigation.

Peel color of navel oranges was not affected by supplemental moisture in 1972–73. During the 1973 season, juice color of both cultivars was not affected by irrigation. The juice of the satsuma was much darker in color than the juice extracted from the navel cultivar as indicated by larger "a" values (Table 1).

Some significant yearly variation occurred for all factors studied.

The subsurface irrigation system has worked well since installation in 1963. Clogging of slits in the laterals has not created problems, since flushing before irrigation cleans out the slits.

Supplemental irrigation during dry periods resulted in increased yields and fruit size of 'Washington' navel and 'Owari' satsuma in a high rainfall area of south Louisiana. Quality of the juice was not greatly affected by additional moisture.

With an average rainfall of 1.7 m, irrigation 2–4 times per year during low moisture periods appeared to be beneficial for fruit size and increased yields.

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