J. Amer. Soc. Hort. Sci. 102(2):152–155. 1977.

Fertility and Irrigation Effects on 'Temple' Orange. II. Fruit Quality[1]

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Additional index words. nitrogen, phosphorus, potassium, juice quality, external fruit quality, *Citrus* spp.

Abstract. **Increased N and K rates resulted in higher acid content in juice of 'Temple' orange (*Citrus* hybrid). P fertilization lowered both soluble solids and acid contents, but the influence on acid was more pronounced as it was reflected in higher soluble solids-acid ratio. High N vs. low N treatment also caused a small but consistent reduction in juice content. Spring irrigation resulted in higher soluble solids content than fall irrigation. N treatments decreased and K treatments increased both fruit size and weight; irrigation treatments showed no consistent trends. High N and spring irrigation treatments caused increased intensity of orange color in rind. Incidence of creased fruit was increased by high N, low K, and spring irrigation treatments. No consistent trends were found in fruit storage decay with grove treatments and the data were significant only in certain years.**

'Temple' is an excellent eating orange and is produced primarily for fresh fruit market. It has relatively high juice acid content and it usually will not meet minimum maturity standards until Jan. – Feb. Frequently 'Temple' oranges are at their prime externally but the juice will not meet the minimum maturity standard. It would be desirable if maturity can be hastened so fruit can be harvested at their prime both internally and externally and thus extend the season.

Attempts have been made experimentally to reduce the acid content of the juice by arsenate spray (11). Fruit sprayed with arsenate was able to meet the maturity standards sooner than that from the control trees. Since it is illegal to spray arsenate on oranges, attempts were made to determine if juice acidity can be reduced through conventional cultural practices.

A fertilizer and irrigation experiment was initiated in 1969 to study the effects of N, P, K, and irrigation timing on 'Temple' orange. This paper reports the results of fruit quality. A companion paper discusses the effects on yield and leaf analysis (13).

Materials and Methods

Treatments, experimental layout, and design of the investigation have been described in Part I of this paper (13). All plots were harvested when preliminary samples from all treatments reached the minimum legal harvest requirements for 'Temple' in Florida. A 40-fruit sample was collected randomly at harvest time from each plot for juice quality measurements. Methods used in juice analysis have been reported (6). External fruit quality measurements were made in the packinghouse using a 408 kg sample from each plot containing 2,000 to 2,500 fruit depending on individual fruit size. The fruit were washed, sized, and graded for blemishes including russet, scab, green coloration, and creasing (10). Not all blemishes were present in sufficient quantities to be measured every year. Unclassified blemished fruit were grouped as miscellaneous and used to calculate % No. 1 grade fruit. Fruit diam was measured with a standard commercial sizer for oranges. Fruit wt was the average from the 40-fruit sample and expressed as g per fruit. Fruit color evaluation was made with a visual comparison colorimeter (3). This reflects fruit color from the surface of the fruit sample and was compared with a strip of "Munsell" color plates with values ranging from 100 (dark green) to 0 (deep orange) (9). At least 5 readings were made for each sample.

For the storage study, a 100 fruit sample was collected from the 3 predominant sizes found in each plot. These fruit were washed, waxed, and stored in commercial fruit cartons at 21°C for 3 weeks. Fruit were examined at weekly intervals for stem-end rot (*Diplodia natalensis*), green mold (*Penicillium digitatum*), and sour rot (*Geotrichum candidum*), and the decayed fruit were discarded after each examination (8).

Results and Discussion

Data for all measurements were analyzed each year. Only the average values of all years were presented because of the large vol of data. Annual data for certain measurements are presented to show trends and magnitude of treatment effects. Interactions among treatments were not significant for most years and measurements. Significant interactions are discussed where they exist.

Internal fruit quality. Juice content showed a consistent reduction with high N treatment and the difference was significant in 4 of the 6 years. This is contrary to results reported

Table 1. Effects of fertilizer and irrigation treatments on juice quality of 'Temple' (Avg of 6 yr).

Treatment (kg/ha•yr)	Juice by wt (%)	Soluble solids (%)	Acid (%)	SS/A ratio
Fertilizer				
N: 90	63.3	13.4	1.23	10.98
266	61.2	13.5	1.32	10.30
Significance	**	NS	**	**
yr/6 yr[z]	4	2	5	5
K: 75	62.2	13.5	1.25	10.83
213	62.3	13.4	1.29	10.46
Significance	NS	NS	*	*
yr/6 yr	0	1	3	3
P: 0	63.5	13.4	1.21	11.08
127	63.4	13.1	1.10	11.96
Significance	NS	**	**	**
yr/6 yr	0	3	5	5
Irrigation				
Spring	62.7	13.5	1.24	10.93
Fall	62.3	13.3	1.23	10.89
Significance	NS	*	NS	NS
yr/6 yr	1	3	0	0

[z]No. of yr that showed significant differences at 5 or 1% level in 6 yr.
[NS]Not significant.
*Significant at 5% level.
**Significant at 1% level.

[1]Received for publication September 16, 1976. Florida Agricultural Experiment Stations Journal Series No. 125.
[2]The authors are indebted to Dr. W. Grierson for assistance and advice in conducting the storage study.

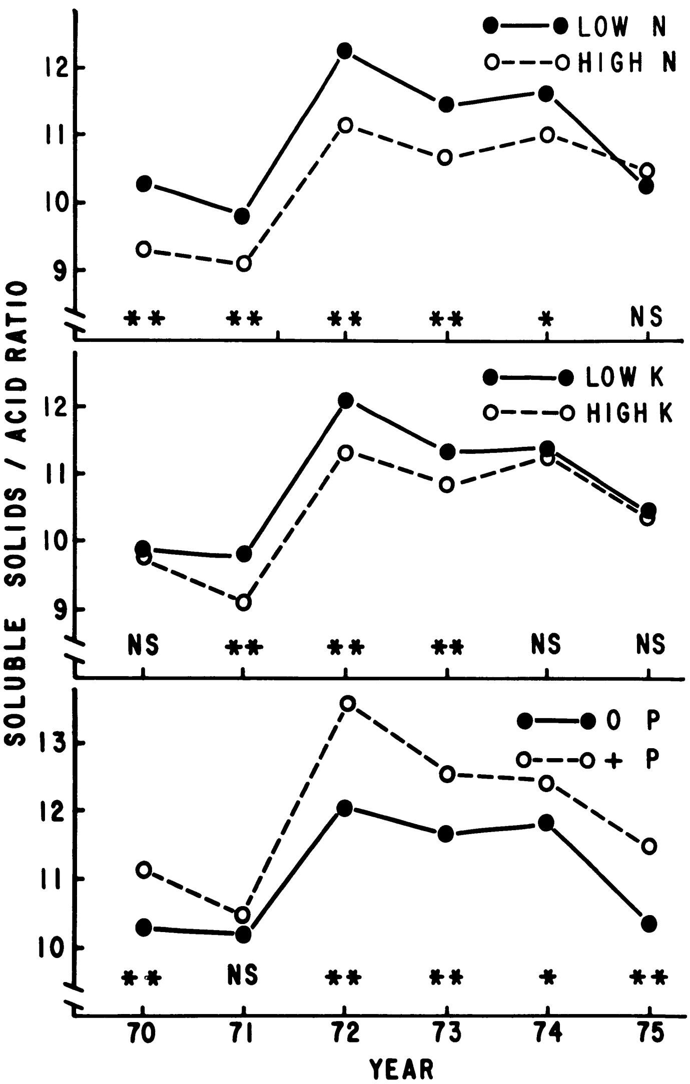

Fig. 1. Effects of N, P, K on soluble solids-acid ratio (1970-1975).

for "round" oranges (a Florida colloquialism for any *C. sinensis* cultivar) (12) and the reasons are not clear (Table 1). It should be further investigated. Spring irrigation resulted in significantly higher juice content in one of the 6 years.

Both high rates of N and K increased acid (as citric), and decreased SS/A (soluble solids-acid) ratio in juice. The influence of N was stronger than K on juice acid and resultant SS/A ratio. The effects of N rates on these juice characteristics was significant in 5 of the 6 years and 3 out of 6 years for K rates. These trends are in general agreement with results reported for "round" oranges although K usually exerts a stronger influence than N (4, 12, 14). Phosphorus reduced both soluble solids and acid contents of the juice but the influence on acid was much more pronounced than on soluble solids which resulted in higher SS/A ratio. Differences in acid and ratio values were significant in 5 of the 6 years. These trends are similar, but not of the same magnitude, as results reported for "round" oranges (2, 15, 16). The yearly SS/A values for N, P, K treatments are presented in Fig. 1. Irrigation treatments only affected the soluble solids content being higher with spring irrigation than fall irrigation in certain years.

External fruit quality. High N reduced both fruit diam and wt while high K increased both when compared to low rates (Table 2). This is in agreement with results previously reported for 'Temple' and "round" oranges (1, 12, 14). P treatment did not affect fruit diam but did reduce fruit wt. The data were

Table 2. Effects of fertilizer and irrigation treatments on external quality of 'Temple' (Avg 3 to 6 yr).

Treatment (kg/hr•yr)	Fruit diam (cm)	Wt per fruit (g)	Rind[z] color	No. 1 fruit (%)	Fruit blemishes Crease (%)	Russet (%)	Scab (%)	Green (%)
Fertilizer								
N: 90	7.42	196	14.9	66.6	0.4	11.0	18.7	9.2
266	7.32	183	12.5	62.8	1.1	11.0	20.8	6.3
Significance	**	**	**	**	**	NS	NS	**
(yr/yr)[y]	2/6	4/6	3/6	5/6	4/5	0/3	2/3	2/4
K: 75	7.33	186	13.2	65.4	1.1	10.5	19.0	7.0
213	7.43	193	14.1	64.0	0.5	11.3	20.8	8.4
Significance	**	**	NS	NS	**	NS	NS	NS
(yr/yr)	4/6	4/6	0/6	1/6	4/5	0/3	0/3	2/4
P: 0	7.38	194	14.6	65.2	0.6	9.4	18.8	10.7
127	7.37	190	15.3	64.1	0.8	11.8	18.2	13.2
Significance	NS	NS	NS	NS	NS	NS	NS	*
(yr/yr)	0/6	2/6	1/6	2/6	1/5	1/3	1/3	2/4
Irrigation								
Spring	7.41	189	12.1	66.9	0.9	13.4	18.8	12.1
Fall	7.35	191	15.9	62.5	0.5	8.9	20.2	11.8
Significance	**	NS	**	**	*	**	NS	NS
(yr/yr)	4/6	3/6	2/6	3/6	2/5	2/3	1/3	1/4

[z]Scale: 100 (dark green) – 0 (deep orange).
[y]No. of yr showed significant difference over no. of yr measured.
NSNot significant.
*Significant at 5% level.
**Significant at 1% level.

significant for 2 out of 6 years. This should be further investigated. Spring vs. fall irrigation increased fruit diam but reduced the fruit wt slightly. Fruit wt differences due to spring irrigation were inconsistent, showing decreases in fruit wt in 4 years and increases in 2 years. Some of the inconsistencies may be related to the significant interactions between irrigation and K treatments found in 2 of the 6 years. In those 2 years, no difference was found in fruit wt between irrigation treatments at high K rate but at low K rate spring irrigation significantly increased fruit wt. High N and spring irrigation produced fruit with an intensified deep orange rind color when compared to low N and fall irrigation.

Fruit blemish data in Table 2 varied from 3 to 5 years for different blemish measurements. All fruit were examined for various blemishes every year but not all blemishes were present in sufficient quantities to be measured annually. These variations are due to year to year differences in environmental conditions in the grove which may influence the degree of success in the control of different insects and diseases.

High N increased and high K decreased the incidence of creasing. Spring irrigation increased the number of creased fruit when compared to fall irrigation. Spring irrigation also produced more russet fruit than fall irrigation. Among fertilizer treatments, only P produced more russet fruit. This difference was significant once in 3 years. Both high N and fall irrigation treatments resulted in more scab fruit. This agrees with results reported for scab in lemon (7). Spring irrigation and high K and P produced a higher percentage of green fruit while the high N produced fewer green fruit than the low N. Data in % green fruit agree with trends reported for rind color for all treatments except irrigation. For rind color interactions between N and irrigation treatments were significant in 2 of the 6 years. In those 2 years, the difference in rind color between spring and fall irrigations was about 2.5 fold for high N as for low N, which may account for part of the inconsistency.

Percentage No. 1 fruit is calculated by subtracting all blemishes, and it varied from less than 50 to over 80% over the 6-year period. Levels of N and irrigation timing produced more

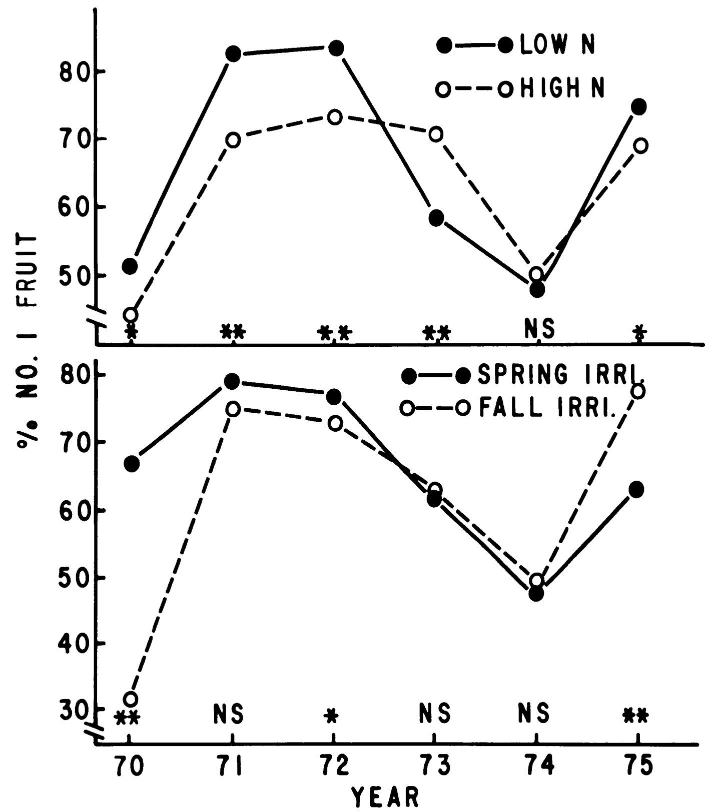

Fig. 2. Effects of N and irrigation treatments on % No. 1 fruit (1970-1975).

significant differences in % No. 1 fruit than did K and P treatments. In general, low N and spring irrigation produced more No. 1 fruit than high N and fall irrigation; but the trends are not consistent for all years. This is because the magnitude of various blemishes varies with treatments and years. Annual data for % No. 1 fruit for N and irrigation treatments are presented in Fig. 2.

Storage decay. Decay measurements in storage are quite variable and are generally not significant (Table 3). Green mold was the predominant decay in storage. N treatments seem to have more influence on decay than other treatments. No consistent trend was found with treatments except for sour rot with N where high N rate reduced the incidence of sour rot in 5 of the 6 years when compared to low N rate and the data were significant in 3 of the 6 years. Spring irrigation had significantly fewer stem-end rot fruit than fall irrigation in 2 of the 6 years.

Results indicate N is the dominant factor on fruit quality with K, P, and irrigation treatments having lesser effects except in certain parameters. Trends are in general agreement with results reported for "round" orange varieties (4, 12, 16), except K usually has more effect on "round" orange qualities than N (14). This could be due to inherent differences among citrus species. Fruit quality responses to N and K in this study more closely resemble the responses of mandarins and lemons to N-K and irrigation treatments (5, 7).

The present study showed that the high juice acid content of 'Temple' can be reduced through fertilizer practices. The use of liberal quantities of phosphorus fertilizer would reduce the acid content of the juice (2, 4, 15). In this study, whole P fertilization reduced both soluble solids and acid, the effect on acid was much stronger, thus giving a higher SS/A ratio. The difference in SS/A ratio was almost one unit higher for P treated trees vs. no P trees over a 6-year period. Differences in ratio for individual years varied from 0.25 to 1.50 higher for P treated trees than the no. P trees (Fig. 1). It is estimated that

Table 3. Effects of fertilizer and irrigation treatments on fruit decay during 3 wk at 21°C storage (Avg of 6 yr).

Treatment (kg/hr•yr)	Green mold (%)	Stem-end rot (%)	Sour rot (%)	Total decay (%)
Fertilizer				
N: 90	21.3	3.9	2.9	28.2
266	22.2	4.7	2.3	29.5
Significance	NS	NS	**	*
(yr/yr)[z]	2	0	3	2
K: 75	22.7	4.4	2.9	29.6
213	21.4	4.4	2.4	28.4
Significance	NS	NS	*	NS
(yr/yr)	0	0	1	0
P: 0	21.0	3.5	2.9	27.4
127	21.8	3.7	2.8	28.5
Significance	NS	NS	NS	NS
(yr/yr)	2	1	0	0
Irrigation				
Spring	22.1	4.0	2.5	28.9
Fall	21.4	4.4	2.7	28.8
Significance	NS	*	NS	NS
(yr/yr)	1	2	0	1

[z]No. of yr that showed significant difference in 6 yr.

the use of low N and high P can advance the maturity 10 days to 2 weeks (5). This can be beneficial because frequently, when 'Temple' fruits are at their prime externally, the juice will not meet the min maturity standard. The use of low N and high P may partially synchronize harvest of this variety when both internal and external quality approach optimum.

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J. Amer. Soc. Hort. Sci. 102(2):155–158. 1977.

Mineral Element Changes in Pistachio Leaves[1]

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Additional index words. plant nutrition, leaf sampling, bearing, nonbearing, *Pistacia vera*

Abstract. **Concentrations of several mineral elements in leaflets of *Pistacia vera* L. cv. Kerman, did not differ significantly with leaflet position. Thus, leaflets may be used instead of whole leaves in leaf sampling. Analyses of leaflets indicated that N, P, and Zn concn were relatively high initially. They then dropped rapidly during leaf expansion, reaching a steady state in early summer. Manganese increased from an initially low level and then remained fairly constant. Potassium, Mg, Cl, and B behaved similarly to Mn, but reached constant levels later in the season. Leaves from bearing branches were lower in N and P, but higher in K than leaves from nonbearing branches. It is recommended, in determining mineral element status, that leaves from nonbearing branches be sampled during the month prior to harvest, as most elements are then at a steady state.**

Pistachio acreage in California has expanded over 10 times since 1970 to approximately 30,000 acres. This acreage, composed exclusively of the 'Kerman' (pistillate) and 'Peters' (staminate) cultivars, extends into widely different soil types; and mineral nutrition problems are likely to appear in the future.

Deficiency symptoms, critical levels of mineral elements in leaves, changes in levels during the growing season, and leaf sampling techniques have been established for many fruit and nut tree species (7). The pistachio has been grown commercially in several Middle Eastern countries for many years, but there is nothing in the literature concerning its nutritional requirements other than the fact that it responds "... to applications of nitrogen the same as most other trees" (13).

Materials and Methods

This study was made in 1970 on 'Kerman' grafted on *Pistacia atlantica* Desf. seedling rootstocks at the University of California Wolfskill Experimental Orchards (WEO) in Winters (Sacramento Valley) and the West Side Field Station (WSFS) at Five Points (San Joaquin Valley).

Leaves from the basal portions were used in the early part of the season while the shoots were elongating, as this growth was the most nearly mature. Leaf samples were collected at random from the shoots after shoot elongation had stopped and leaf expansion was completed in mid-May. Leaves were washed in a weak detergent solution, rinsed in tap water several times, given a final rinse in distilled water, dried in a forced-air dehydrator at about 65°C, and ground in a Wiley mill to pass a 40-mesh screen. Nitrogen was detemined by the Kjeldahl procedure, K, Ca, Mg, and Na by flame photometry, Mn and Zn by atomic absorption spectrophotometry. Cl by titrimetry, P by the amino naphthol sulfonic acid method (6), and B by the curcumin method (10).

Sampling. Pistachio leaves are imparipinnate, or occasionally spuriously paripinnate. Leaflets occupying different positions in the leaf were sampled separately to determine if a leaflet was as satisfactory for mineral analyses as an entire leaf. Each leaf held in abaxial (dorsal) view was divided into 4 parts, terminal leaflet, first subterminal leaflet on the right, first subterminal leaflet on the left, and the remaining leaflets (usually 2-4 small sized leaflets). Each sample consisted of leaflets from 30 leaves from nonbearing branches on each of 5 trees.

Seasonal levels. Seasonal levels of mineral nutrients were studied with 25-30 terminal leaflets per tree sampled at intervals from nonfruiting limbs. Five trees at WEO were sampled at 2- to 4-week intervals beginning April 17 when the leaves were about half expanded and continuing until leaf fall. The number of leaflets in each sample was recorded, and the weight was determined after drying. This was done to determine the actual weight of an element in each leaflet, in addition to its concn.

Sampling began May 14 at WSWF and was done infrequently throughout the summer. Eight trees were individually sampled on each date.

Bearing vs. nonbearing shoots. Terminal leaflet samples at WEO were taken from both bearing and nonbearing shoots on 2 trees with moderate crops. Sampling was done on the same dates as those in the study of seasonal levels.

Results and Discussion

Sampling. The pistachio leaf of 'Kerman' is large and bulky. A single leaf may have a dry wt of over 2 g, nearly enough for mineral analysis; however, more than one leaf should be used to assess the nutritional status of any tree. Many leaves could be included in each sample by sampling a single leaflet. The question is: Can any leaflet be used? There were no statistically significant differences in concn of the several minerals in leaflets from various positions of the leaf (Table 1). The nonsignificance was found whether the samples were taken early in the season (April 17), in late summer (August 25), or near leaf fall (Oct. 7). The terminal and the 2 oppositely positioned subterminal leaflets are of about equal size and would be convenient to sample; or just the 2 subterminal leaflets could be used if the terminal was missing.

Seasonal levels (concn basis). Changes in concn of the elements during the season (Fig. 1) were similar to those reported for peach (1) and apple (12). Levels of N, P, and Zn initially were high when leaves were about half expanded. Subsequently, the levels dropped very rapidly during further expansion. The levels reached steady states about the end of shoot elongation (mid-May), when the leaves were fully expanded. All other elements were at low levels in April, but increased steadily thereafter. Potassium, Mg, Cl, and B increased until the first of August, when they levelled off somewhat. Manganese reached a steady state much earlier, i.e., in June. In contrast, Ca in-

[1]Received for publication July 30, 1976.

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