deformation value of 2.3 mm, corresponding to subjective score 3 (soft), is assumed to be the limit of acceptability for fresh tomatoes at the retail level. This, however, needs further evaluation for other cultivars and using a large scale consumer acceptance study before establishing minimum firmness requirements for marketing tomatoes.

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J. Amer. Soc. Hort. Sci. 103(1):73–76. 1978.

Influence of Irrigation and Environmental Factors on Grapefruit Acidity[1]

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Additional index words. Citrus paradisi, water stress, fruit quality, acclimatization

Abstract. **Summer water stress in grapefruit (*Citrus paradisi* Macf.) trees caused high titratable acidity levels during the winter. The after effect of water stress lasted up to 6 months. Brief sudden rises in acidity during the winter were correlated with short durations of relatively high day temperatures. Such episodes did not affect the percentage total soluble solids.**

The concn of juice acidity declines during fruit development and maturation in most citrus fruits, with the possible exception of lemons and limes. This is true for many non-citrus, acid containing fruits. Grapefruit are picked in the Negev Desert (Southern Israel) during the winter, between Nov. and April. The fruit continues to grow and its weight may double during this time. The acid concn delcines until Nov. and remains more or less constant thereafter (2, 3). A similar pattern was described for grapefruit in California (19), Texas (5), and in certain years in Florida (7). Concn of titratable acidity in juice may be stable, but the absolute amount of acid calculated on a per fruit basis actually increases due to fruit growth and accumulation of acid during this time. Sinclair (20) showed the absolute amount of acid per fruit increased under Florida's climatic conditions, even when acid concn in juice decreased during the winter. Grapefruit is very different from the orange in this respect (13, 15).

Acidity levels in desert-grown grapefruit increase in certain years during the winter months, particularly in Jan. (9). The fruit is less palatable when this happens than it was in Nov. There are reports which indicate that acid levels in citrus fruit is related to environmental conditions (4, 5, 13, 15, 16, 19, 20). Rasmussen et al. (15), for example, reported a correlation between high temp and acid content of young orange fruit, and an inverse relationship between mean acid content of 'Ruby Red' grapefruit and rainfall.

This paper is concerned with the relationship between certain environmental factors before and during harvest and acid levels

[1]Received for publication March 14, 1977. Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel, 1976 Series, No. 272-E.

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[4]The authors are indebted to Dr. H. Bielorai of the Institute of Soil and Water for supervision of the irrigation experiment.

in the grapefruit. Major parameters reported herein are temp and water regime.

Materials and Methods

'Marsh Seedless' (old-line) grapefruit trees, budded to sour orange (*Citrus aurantium* L.) rootstocks, were planted in 1959 at the Gilat Experiment Station of the Agricultural Research Organization, situated in the northern Negev, Israel, at 31°N, 34°40'E, 150 m MSL. The soil is a regosolic loess with a sandy loam texture. The climate is semi-arid. Average annual rainfall is about 250 mm during the winter with large fluctuations from year to year. A common practice is to continue irrigation during the "rainy" season, Nov.–April, in the case of a dry spell. Due to low ambient temp, trees are usually dormant during Nov. to Feb.

Irrigation experiment. Trees in the orchard were spaced 6 x 6 m. Design of the experiment was a randomized block with 6 replications, each plot consisting of 16 trees. Three replications were used for the purpose of this investigation. Differential irrigation treatments were begun in 1964. Irrigation intervals were 18 and 40 days. The amount of water per irrigation was determined by soil moisture measurements to a depth of 90 cm with a thermal neutron probe. Irrigation was provided by under-canopy sprinklers. All treatments received identical irrigation treatment during the winter (Nov.–April) months (2, 3). Trees irrigated during the summer every 40 days suffered from the effects of water stress (2, 3). The most pronounced effects being retardation of vegetative growth and low yields. Fruit quality measurements were made during 1968–69 and 1969–70, only the results for the latter being presented here.

Juice quality. Small fruit sampes were used in order to be able to collect fruits frequently from the same trees. Preliminary work indicated that a sample of 10 fruits per repetition was adequate. Increasing the sample size to 40 fruits did not reduce variability significantly. This may be true only for a comparatively young orchard at the planting spacing used. Fruit were sampled every 5 to 10 days from the 4 center trees of each 16-tree plot and juiced about 20 hr after they were picked. Juice was extracted by an electric reamer and strained through 30 mesh Saran netting. Titratable acidity, expressed as anhydrous citric acid %, was determined with 0.1 N NaOH, using phenolphthalein as indicator. Total soluble solids (TSS) percentage, expressed as sucrose, was determined with a Zeiss 'Abbe' refractometer.

Results and Discussion

Acid levels in juice were higher in fruits harvested from trees that suffered from summer water stress (Fig. 1). This was true for the entire winter season, despite the fact that differential irrigation treatments were applied during the summer months only. The water regime was essentially similar for both treatments during the winter. Acidity levels were not constant during the winter months (Fig. 1, 2). Some of the variation was associated with short periods of relatively elevated temp.

A linear correlation was established between acidity in total soluble solids and ambient air temp. The best correlation was found with mean air temp during the 3-day period preceding the sampling day (Fig. 3). This correlation was valid for the period from Sept. to March. Titratable acidity decreased rapidly in April, probably due to fruit senescence.

These results do not agree with those reported for oranges. Reuther (16) reported "there is a broad, qualitative relationship between prevailing air temp and the rate of decrease of acid concentration in orange juice." As water content of the juice may vary considerably during fruit growth, Sinclair (20) suggested the possibility of eliminating this variable by expressing titratable acid as a percentage of total soluble solids instead of percentages of fresh wt (Fig. 2).

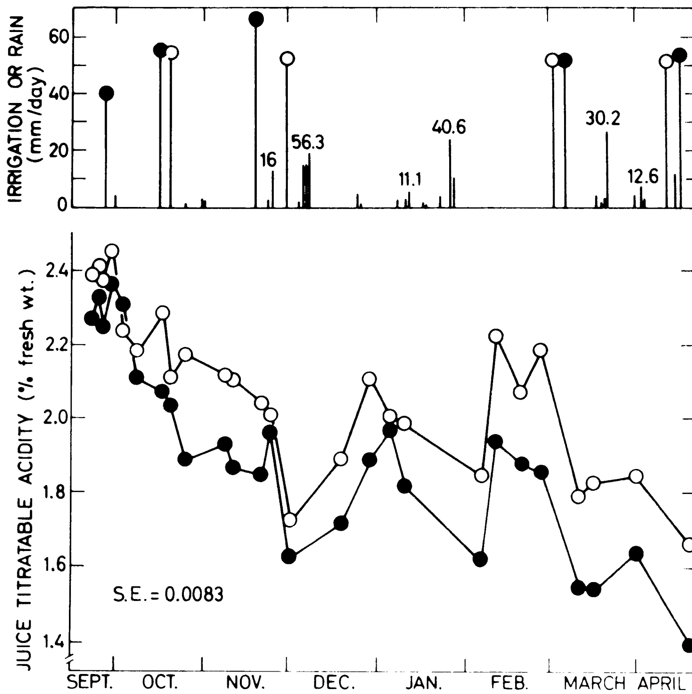

Fig. 1. Precipitation and juice titratable acidity during winter 1968/69 for trees irrigated during summer at 40-day intervals (o) and at 18-day intervals (•).

TSS to acid ratio. This ratio reached the legal standard of 5.5 to 1 in Nov. It did not continue to rise as expected but fluctuated, dropping on at least 3 occasions below the legal standard (Fig. 4). Similar changes have been reported under extreme desert conditions (9). The decline in ratio was more pronounced for fruit harvested from a less frequently irrigated treatment, which showed the after effects of summer water stress.

Most of the knowledge obtained in recent years regarding the response of citrus fruits to climate has been for oranges, particularly 'Valencia', and concerned mainly with long-range effects of different climatic regions on fruit development and quality (13, 16, 17, 18, 19). In general, there is a negative correlation between air temp and orange acidity (16, 17).

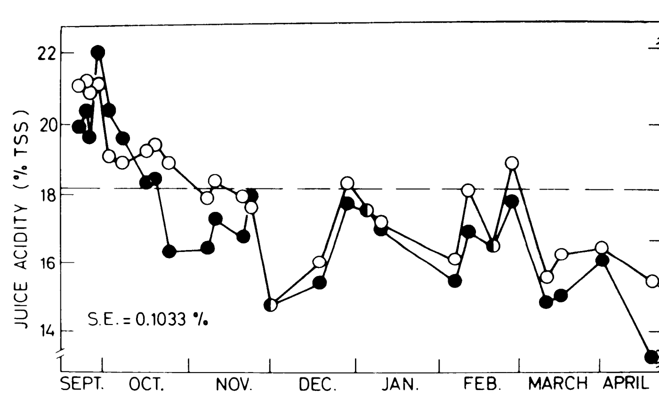

Fig. 2. Percentage juice acid on a total soluble solids basis, for trees irrigated differentially during the summer (treatment described in detail in Fig. 1).

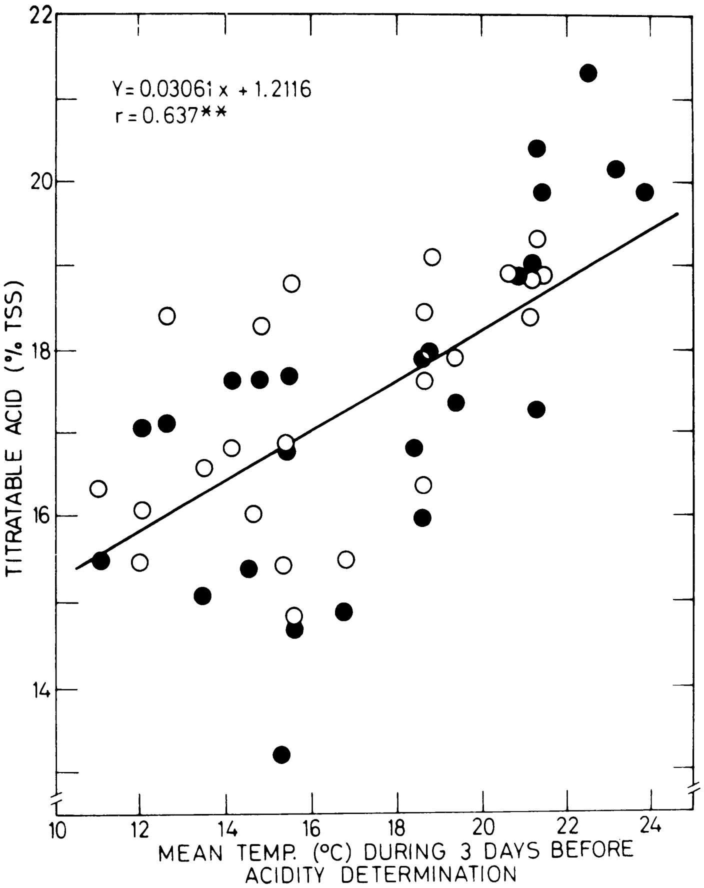

Fig. 3. Percentage juice acid in total soluble solids vs. mean daily temp for 3-day period before sampling date (irrigation regimes as described in Fig. 1).

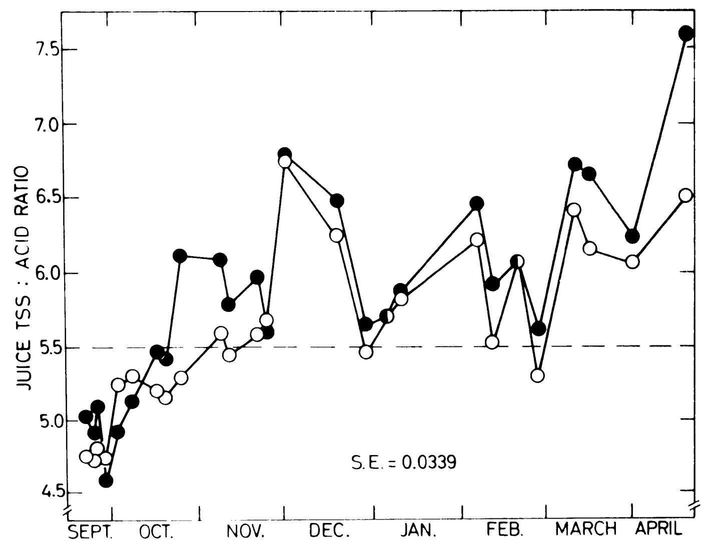

Fig. 4. Changes in total soluble solids: acid ratio during the 1968/69 season are influenced by two irrigation regimes (treatments described in Fig. 1).

This means citrus fruit tend to mature late and retain a high acid content for longer period in cool areas, with the possible exception of oranges at early stages of development (15). An important difference between oranges and grapefruit is in their growth rate during the winter, fruit growth of most orange varieties being negligible (19) in comparison with grapefruit. The fact that the juice content is not changed in growing fruit means fruit growth is accompanied by continuous accumulation of sugars and acids in the fruit during the winter.

The long-term overall effect of temp on fruit development and maturity should be distinguished from the short-term effect of a few warm days during the cold season. The apparent contradiction can be explained by the different role of root and shoot environment. Short-term warming can cause direct changes to fruit and shoot metabolism but did not effect the root environment. Root temp at a depth of 50 cm was below 15°C from mid-Dec. to mid-Feb., soil temp at depth of 20 cm was even lower in Dec., but higher in Feb. No root growth was detected during the Dec.–Feb. period.

Soil temp influences many processes in the upper part of the tree, an example being bud break which may be inhibited by low soil temp (6, 9). This probably occurs through effects on hormonal balance in the shoots and fruits as a result from temp effects on synthesis or translocation of hormones from roots (1, 10). The best known root hormone is obviously cytokinin, which is produced mainly by active root tips. Atkin et al. (1) showed that a warmer maize root system delivers more cytokinins, but Cary (4) observed a reduction in orange juice acidity under high soil temp. A reduction in tomato fruit (citric acid accumulator) acidity was observed with kinetin (benzylamino purine) treatment (12).

One of the main locations of cytokinin production in the tree is without doubt the root system. It appears reasonable to postulate that soil temp influences fruit acid accumulation through effects on hormonal balance in the leaves and fruit, mainly cytokinins. Usually, the after-effect of water stress on citrus, as can be seen from stomatal response, lasts only a few days (8, 11), possibly due to changes in ABA-like inhibitors (10, 11). The long duration of the after-effect of summer water stress on citrus fruit acidity during the winter can be explained by the hypothesis that any changes in hormonal balance in water stressed trees brought about by damaged root system during the summer (1, 10) will not be corrected during the winter. Soil temp remained below 15°C during the Dec.–Feb. period in this experiment, resulting in root growth inhibition similar to that was reported by Girton (6) and North (14). A drastic change in fruit metabolism, mainly acidity decline, occurs in March. This can be associated with soil temp increase, the soil at a depth of 50 cm reaching 20°C in March. This temp increase triggers root growth (14), and change in root hormonal production and both bud break and flowering occur at this time (9, 14).

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J. Amer. Soc. Hort. Sci. 103(1):76–77. 1978.

Ethylene in Fruits of Blackberry and Rabbiteye Blueberry[1]

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Additional index words. climacteric, ethephon, *Rubus arvenis, Vaccinium ashei*

Abstract. **'Humble' blackberry (*Rubus arvenis* Bailey) extractable ethylene content reached more than 7.0 mg/liter shortly after full bloom and dropped to well under 1.0 mg/liter for the remainder of fruit development. The low ethylene levels during the latter stages of fruit development suggests that blackberries are nonclimacteric. 'Tifblue' rabbiteye blueberry (*Vaccinium ashei* Reade) extractable ethylene was more than 5.0 mg/liter approximately 2 weeks after bloom, declined to near 1.0 mg/liter during green fruit development and peaked at 3.7 mg/liter in reddish-green (ripening) berries. The increased level of ethylene in ripening fruits suggests that rabbiteye blueberries are climacteric.**

Ethylene has been associated with developmental stages of many fruits (8). The purpose of this research was to determine whether a relationship exists between endogenous ethylene and developmental stages of blackberry (*Rubus arvenis*) and rabbiteye blueberry (*Vaccinium ashei*) fruits.

Materials and Methods

Samples of 25 fruits were collected periodically from field plots of 3 year old 'Humble' blackberry and 3 year old 'Tifblue' blueberry. 'Humble' is an upright self-fruitful blackberry cultivar. 'Tifblue' blueberry is not self-fruitful, but was in a planting with 9 potential pollinator cultivars. Fruit set in 'Humble' and 'Tifblue' was essentially 100% as young fruit abscission does not normally occur. Pollination was accomplished entirely by native insect populations.

About 20 blackberry flowers were tagged to visibly monitor fruit development and samples of comparable untagged fruits were collected at weekly intervals from bloom to maturity. Blueberries were collected biweekly beginning an estimated 2 weeks after the completion of bloom and at shorter intervals during the ripening stages. Samples were immediately transported to a laboratory for analysis. Ethylene analyses were completed within a maximum of 2 hr after sampling. The internal atmosphere of fruits was extracted by a technique similar to that of Beyer and Morgan (2). Fruits were submerged in a chamber filled with saturated sodium chloride solution and placed under a partial vacuum of 185 mm for 10 min.

A 2cc sample of the extracted atmosphere was injected into an F&M Model 5750 gas chromatograph equipped with a flame ionization detector and a 1.8m activated alumina column. The gas chromatograph had an ethylene sensitivity of 0.02 mg/liter. Ethylene levels are expressed as the concentrations (mg/liter) in the extracted tissue atmospheres.

Results and Discussion

The peak ethylene level in blackberries (untreated) was 7.1 mg/liter 1 week after full bloom (Fig. 1). Pollination and subsequent shedding of flower parts occurred during the period from full bloom to 1 week after full bloom. The high levels of ethylene were probably associated with these early developmental stages (1, 4, 7). The young fruit abscission associated with an increase in ethylene production following bloom in several fruits (1, 7) does not normally occur in blackberry.

Blackberry full bloom was April 15, 1976. Ethephon (2000 mg/liter) sprayed on blackberries 5 days after full bloom increased endogenous ethylene to more than 38 mg/liter 2 days after application (Fig. 1); no abscission of young fruits was induced. Ethephon was applied to young blackberry fruits at concentrations of 250 to 6000 mg/liter without causing fruit abscission. This suggests that a mechanism for ethylene induced young fruit abscission is not present in blackberries. Ten days

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