providing adequate yields and early maturity in irrigated onions since the N already present in the soil may have been adequate for seedling growth in May and early June. Four topdressings beginning on July 9 provided a satisfactory yield but the maturity was poorer than with treatments starting earlier. Less response was obtained from topdressings starting at times later than July 9. This indicates that only 1 or 2 topdressings in late June or early July may be necessary, but the continuity of the treatments to the end of the season may be important. Some resonse to the late topdressings was obtained which indicates some value in these treatments, but the plants may have suffered from N shortages and a full recovery may not have been possible.

Scheduling N applications according to the amount of water the crop receives offers some promise as a guide to applying N in areas with variable rainfall since soil and plant analysis for N are unreliable under these conditions. Water is related to leaching of N and utilization of N by plants, and correlating N applications with rainfall or irrigation should improve the efficiency of N applications and minimize N losses to the environment.

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Electrical Conductivity of 'Shamouti' Orange Peel during Fruit Growth and Postharvest Senescence[1]

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Abstract. **Electrical conductivity (EC) measurements were carried out in orange (*Citrus sinensis* (L.) Osbeck) peel (with stainless steel electrodes penetrating 2 mm deep), during fruit growth and subsequent prolonged storage on shelf. Values at the equator were quite generally lower than at the stem and especially at the stylar ends. A curve showing two maxima, one at a very young fruitlet stage (late May) and the other two months before maturation was found. The decrease in EC toward maturation continued for some time postharvest while the water content of tissues decreased, but was followed by an increase with progressive tissue senescence. This last part of the curve is tentatively explained by an increased role of symplast conductance due to tissue aging.**

Electrical gradients are probably a major component of many physiological processes occurring in plant tissues (9). Easy-to-measure biophysical parameters for the evaluation of growth stages and viability of citrus fruits are badly needed. It seems therefore logical to test electrical conductivity (EC) of tissues as such a parameter. This has been done with peaches (10), with avocado (2), with pears (1), but no work has been carried out along these lines with oranges. The peculiar structure of a citrus fruit, a hesperidium with clear differentiation between a thick, spongy mesocarp and an endocarp composed of juice vesicles (i.e. not a tissue in the accepted meaning of the term), seems to lend a special interest to such studies with citrus fruits (7).

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Materials and Methods

Twenty-five 'Shamouti' oranges were picked at roughly monthly intervals from May to Dec., 1975 from 20-year-old trees, growing at B, in the coastal plain of Israel about 5 miles from the sea in loamy sand on sweet lime stock but inarched to sour orange.

Mature fruit from 2 existing preharvest experiments were used for the postharvest determinations during the 1974/75 season: a) 18-year-old trees on sweet lime stock on light sandy loam, also in the coastal plain at S, laid out in a randomized factorial layout with 2 regulator treatments × 5 irrigation schedules × 6 blocks with replicates of 1 tree each (Sasson and Monselise, in preparation). Trees were harvested Jan. 14, 1975. b) a randomized block layout with 5 growth regulator treatments × 4 blocks with replicates of 2 trees each at B. Trees were picked on Feb. 24, 1975. Fruits were tested at harvest and at monthly intervals after storage at 17°C. Composite samples of 16 fruits each were obtained from each of the 5 treatments at B and, of 24 fruits each from each of the 5 irrigation schedules at S.

EC was measured with a Conductivity Meter CDM2 of Radiometer N.V., Copenhagen, sensitive between 0 μmhos and

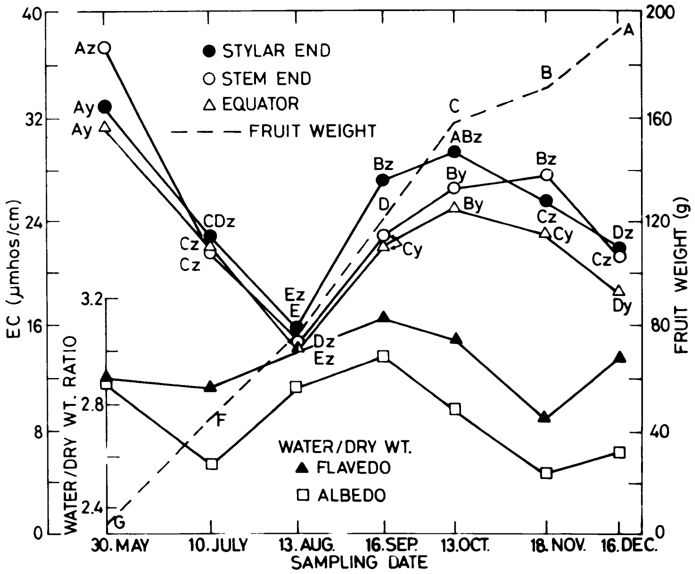

Fig. 1. Seasonal changes in EC at different positions on the fruit, as well as in the ratio of water-to-dry-wt in flavedo and albedo tissues. Upper case letters indicate mean differentiation by multiple range test, within one single curve; lower case letters indicate mean differentiation between positions at each date.

500 mmhos, test voltage of 0.25 V, measuring frequency in our experimental range, 70 c.p.s. Electrodes were stainless steel needles, one cm apart, embedded in a rubber stopper and protruding 2 mm.

EC was tested in peel 3 times at each of 3 positions, equator, stem and stylar ends, with determinations averaged for each position. Fresh matter was dried at 60°C in a ventilated oven for 48 hr.

Internal ethylene concentration of fruit was tested on 2.5 ml of air extracted from the fruit axis at the stylar end by a syringe and injected into a Packard 7400 Chromatograph provided with an hydrogen flame ionising detector and fitted with a glass column packed with active alumina 4% water, v/w).

Results

EC measured was probably a weighed average of values obtaining in the peel to the depth penetrated by the electrodes. They penetrated 2 mm, hence flavedo and albedo shared about 1:1 and the pulp was not involved in the readings.

Effect of position on fruit. A clear differentiation in values between positions is evident from all of the data. The general tendency was for the highest values to be found at the stylar end, the lowest at the equator, while values at the stem end, were generally intermediate. Relative ranks varied somewhat during fruit development (Fig. 1), but were more or less constant after harvest (Fig. 2).

Seasonal trends. Fig. 1 shows seasonal trends of EC in 'Shamouti' oranges from control trees in the B grove beginning with small 4 g fruitlets up to mature 193 g oranges sampled at roughly monthly intervals. It also shows the progress of fruit growth and the values of the water-to-dry-wt ratio for albedo and flavedo tissues. A steep initial decrease in EC is evident from June to August, down to values similar to those found in mature orange peel. However, later, this trend is reversed and values attain a new peak in Oct., which is only slightly lower than the early maximum. Values decrease thereafter toward the period of maturity. The initial decrease in EC is partly matched by a corresponding decrease in the ratio of water-to-dry-wt (albedo) which also corresponds to the period of most rapid growth of peel (4). The subsequent fluctuations of this ratio are out of phase with regard to the curve of EC, except perhaps in the latter part of autumn, when peel thickness usually increases again. The ratio of water-to-dry-wt in the flavedo is a somewhat distorted picture of the curve concerning albedo.

Postharvest changes. Fruit was stored for a period of 3 months, while 3 to 4 weeks is the usual period elapsing between picking and retailing for fruit shipped from Israel to European markets. The EC curves are presented separately for the B and the S fruit beginning at the picking date of each and continuing for three months, in Fig. 2. Curves are also shown for the water-to-dry-wt ratio of albedo and for internal ethylene concn of fruits of the 2 lots separately. Significance was tested in all cases, however, over 8 sampling dates for the pooled data of S and B to assess the general changes occurring, not only after picking of both lots but also with the period elapsed since anthesis in the spring of 1974. It should be noted that picking occurred for S fruit in the first third of the usual picking season, and for B fruit at the end of the second third.

Clear trends of increase with aging were detected at later dates for both lots of fruits when the EC data are considered, apart from the effects of position on the fruit already noted. This is especially marked for the B fruit which is comparable to the S fruit as to the period spent in storage, but is six weeks older in terms of total fruit age. Similar age trends can be seen also with ethylene concn, although in this case the effects of both storage period and fruit age seem operative. A parallel trend also exists between EC and water-to-dry-weight ratios.

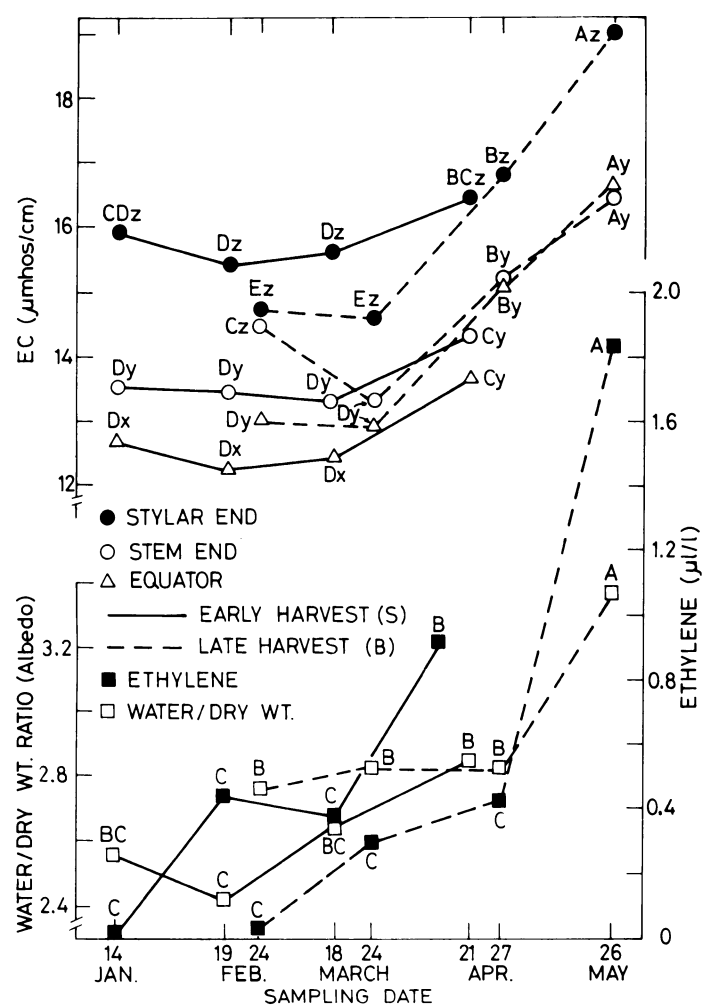

Fig. 2. Postharvest behavior as to EC, water-to-dry-wt ratio in albedo, ethylene concentration in internal fruit atmosphere. Upper case letters indicate mean differentiation for each parameter between dates (fruit groups B and S pooled for statistical analysis), lower case letters, between positions at each date.

Correlation of the data in Fig. 2 give highly significant positive coefficients ranging between 0.638 and 0.677 for S and between 0.692 and 0.753 for B, according to different positions on the fruit.

Discussion

The curves of EC determinations follow roughly parallel patterns at different positions on the fruit which adds confidence in their meaningfulness. The low overall coefficient of variation during the postharvest period of 3.45% (92 dF for error) is indicative of satisfactory reproducibility.

A remarkable feature of EC data lies in the relative constancy of relationships between different positions. These features can not be explained but differences in the concn of several ions among positions on the fruit have been frequently observed, since the extensive investigations of Haas and Klotz in 1935 (5). Such differences have often been suspected as responsible for differential physiological behavior, as in the case of the more severe peel damage caused by gamma radiation (8) to the stem end or of the stem-end rind breakdown of oranges (6).

A general resemblance can be seen between the data of Weaver and Jackson (10) on peaches and our own, notwithstanding the large differences in fruit structure and texture of tissues. They found an increase from 10^4 to 1.4×10^4 ohms (corresponding to a decrease from 100 to 71 μmhos) during the 4 weeks preceding maturity, using quite different procedures, as impedance was measured with an alternating current at 250 c.p.s., while impedance values decreased (i.e., conductivity increased) later with progressive ripening. Similar changes with ripening have been found with pears (1) and avocado (2). Trends are about the same as in the descending latter portion of curves in Fig. 1 and the ascending latter portion in Fig. 2, apart from the absolute values which cannot be compared (3).

An interesting point, which may throw some light on the causes of the fluctuations in EC, is the parallel trend with the ratios of water-to-dry-wt in albedo. This ratio may change initially in storage because of water loss. This is a possible cause for a slight tendency of EC values to decrease during the first month in storage. However, it is fairly clear that a change in hydration in the opposite direction does not occur during later stages of storage. There is a decrease in water loss with fruit aging (Monselise, unpublished data), but there is certainly no net gain in water content. The increase in water-to-dry-wt ratio values must be due to a decrease in dry wt, the denominator of the ratio. A decrease in dry wt is probably due to tissue senescence and progressive depletion of reserves becoming conspicuous, because the numerator remains more or less constant. It seems logical to explain the parallelism between EC and water-to-dry-wt ratios with the senescence of tissues because loss of dry wt in itself can hardly justify an increase in EC. A tentative explanation of EC changes during aging and senescence might be as follows: Conductance occurs mainly through the apoplast while peel tissues are relatively turgid. A water loss would then be responsible for the decrease in EC values, because of increased impedance of drying cell walls (3). Cell permeability would increase later on with the onset of senescence; also electrolyte leakage, a typical behavior of senescing membranes would then occur. Conductance would then increase, while the apoplast contribution would remain more or less unchanged. Then, the higher the permeability of membranes, the larger the EC values which would be recorded. The latter portion of EC curves after a storage 3 times as long as the average time in transit and for retailing would hence be a reflection of increasing senescence and a measure of this process. Additional studies on these lines are under way.

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