V. Preharvest Modifiers of Fruit Quality

The development and expression of fruit characters are profoundly influenced through the complex, dynamic interaction of numerous environmental factors upon a tree which represents a given rootstock-scion variety combination. Some general effects of different rootstock-scion variety combinations with respect to cropping and fruit quality were discussed earlier and should be kept in mind in this discussion of other preharvest modifiers. The latter are logically grouped under 2 main categories, geographical (location) influences, which pertain to climate, edaphic and biotic factors, and cultural practices, which include mineral nutrition, sprays, water relations, pruning and tree age. The final section on variation of fruit on a tree provides the key to sound scientific research on bearing trees: where to obtain a representative sample. The literature on geographical influences is both slight and generally lacking in experimental data, most of the conclusions being based upon observation and experience. Scant attention has been paid in the past towards characterizing the microclimates of citrus groves in various locations and relating climatic variables to fruit characters except in the most general way. By contrast, the literature on different aspects of cultural practices is immense, primarily because of the relative ease with which experimental data can be obtained for specic facets of each practice. There are many gaps in the overall body of knowledge on preharvest modifiers but it is becoming clearer every day to those who deal with postharvest problems that the history of the individual fruit while on the tree plays a profound role in all subsequent stages of its life, including whether it will reach the consumer's table in sound edible condition or be tossed into a garbage can somewhere along the line.

A. Geographical (Location) Influences

The combined effects of climate, soil and other location factors are summarized in Fig. 10. where it may be seen that a warm, wet area such as Florida produces sweet, juicy fruit with thin rinds and poor color while an arid, dry region with cool nights like California has tarter, bright colored fruit with thick rinds which hold well on the tree and ship well. Each location in which citrus is grown has its own microclimate and other factors, hence there are an infinite number of variations within these general patterns.

1. Climate:

There are pronounced seasonal variations in most if not all fruit characters as a result of weather conditions (Fig. 11a, b). It is not really known why seasons of high total soluble solids and high solids: acid ratio and low total soluble solids and low solids:acid ratio occur. They result from the complex interaction of temperature, rainfall, humidity, sunshine and wind. Cold weather during the bloom period may delay blooming so that fruit mature later than usual. Dry weather in the summer and warm weather in the fall slow growth of fruit and development of soluble solids. Regreening of 'Valencia oranges is definitely related to temperatures earlier in the season, being most prevalent when winter and early spring months are warmer and wetter than usual. Weather conditions also have direct or indirect effects on fruit shape, rind texture, color, size, pest problems, wind scarring, etc.

Location effects are often substantial, as may be seen in Fig. 12a where curves for Marsh grapefruit on rough lemon from the Ridge (Lake Hamilton), Indian River (Ft. Pierce), West Coast (Bradenton, and Dade County rocklands (Homestead) are presented. Similar differences occur with other varieties (see Appendix).

Numerous strains of a few varieties, navel and 'Valencia' oranges, Marsh grapefruit and 'Eureka and 'Lisbon' lemons, are grown in California and Arizona, with year around harvesting of oranges and grapefruit as a result of several distinct climatic zones. There is a 6 months' difference in season between grapefruit grown in coastal areas and the desert region of California-Arizona. Fruits are noted for their deep uniform color, rather thick rind and lower juice content. They hold we on the tree and ship well.

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Preharvest Modifiers of Fruit Quality (cont.)

'Marsh' and 'Ruby' grapefruit in Texas have much higher total soluble solids and better keeping quality, as well as better retention of red color in 'Ruby', than in Florida.

Florida has numerous varieties to cover a season from late September-early October to May-June. Tree storage and shipping qualities are poorer than in California. External and internal quality is distinctly better in the Indian River, West Coast (Pinellas and Manatee Counties) and northern portion of the interior areas than in the interior area proper. Maturity of navel oranges in California is retarded by high fall and low spring temperatures. In Florida, most strains of navel are shy bearing and erratic in fruit size with poor texture and shape.

2. Soils:

Adaptability to specific soil conditions is a major criterion in the use of a particular rootstock, thus it is difficult to isolate the influence of soils per se. Citrus is grown successfully on a wide range of soil types from sands to moderately heavy clays and rock (as in the Homestead area). Fruit quality is generally higher (and yields lower) on the heavier, well-drained soils, because of higher nutrient reserves and better water-holding capacity. Hodgson (from California) attributed the high quality of fruit from trees on hammock soils in the Indian River area to a low but continuous supply of N from permanent sod cover in the groves (Hilgeman made the same comment with regard to soils under sod cover as compared to those without in Arizona). The influence of soil type on total soluble solids, total acid and solids:acid ratio may be seen in Fig. 12a,b for 'Marsh' grapefruit on rough lemon.

B. Cultural Practices

1. Mineral Nutrition

Decades of research by Camp, Reitz, Sites, Wander, Steward, Koo and others at Lake Alfred (AREC Lake Alfred) and by Reuther, Smith and others at Orlanda (USDA Hort. Field Station) on mineral nutrition of citrus in Florida have led to the evolution of present fertilizer recommendations. There is a general consensus the best fruit quality and yield are obtained with a balanced fertilizer program used at an optimum level for a given variety, stock, soil and locality. (There is considerable evidence, mainly observations, actual rates of fertilization may be sacrificing fruit quality for higher yields.)

General effects of the major nutrients from Reuther and Smith's work, later corroborated by studies at Lake Alfred and Ft. Pierce are:

a. N: A high level of N delays maturity (slows the increase in total soluble solids and decrease in acid) and fruit color is greener (slows degreening). Grierson and Koo found that adverse effects of high nitrogen were accentuated by irrigation or rain (tangerines) Too high N may induce Cu deficiency.

b. P: A high level of P results in lower total soluble solids and solids:acid ratio and slower (later) degreening, otherwise little effect, thus P in excess of tree requirements (which are low) is detrimental to fruit quality. The only area in Florida where P is actually lacking in soil is Davie muck near Ft. Lauderdale.

c. K: High K results in poorer (greener) color, large coarse fruit, less juice and lower solids and solids:acid ratio. Maturity is delayed 2 to 3 weeks with high K as compared to low level.

d. Mg: There was no effect of Mg on fruit characters when applied at rates high enough to control alternate bearing. Mg is part of the regular fertilizer recommendation for citrus, hence Mg deficiency (bronzing) and alternate bearing would occur only in an abandoned grove.

California work by Jones and Embleton has shown a striking increase in regreening of 'Valencia' oranges with a high rate of N applied in late spring or summer (when fruit are being harvested). Too much N lowers fruit quality while high K increases fruit size. There has been a great deal of research on the latter over the years and small sizes are still a problem.

Citrus Maturity and Packinghouse Procedures

Preharvest Modifiers of Fruit Quality (cont.)

Deficiency and toxicity symptoms of nutrients on fruit (now difficult to find in Florida but well known in the past):

N: Few small fruit of good quality.

P: Poor external quality (dull light color, coarse texture), higher total soluble solids and acid than normal, and poor bearing.

Cu: (exanthema or ammoniation): Dark, raised scars on fruit, splitting (transversely or diagonally), premature drop, gumming of albedo or central axis. (Occasionally seen on fruit from young trees, very rarely on that from older ones.)

Zn: Small, woody or ricey, poorly colored fruit (preceded by leaf symptoms).

B: Numerous symptoms, including gum pockets, gumming of albedo and central axis, misshapen fruit, thick rind, spotting of rind, premature fruit drop, low total soluble solids and low juice content.

As (toxicity): Symptoms are similar to B deficiency on grapefruit.

2. Sprays

Citrus trees are sprayed or dusted for 3 main reasons: to prevent or correct minor element deficiencies with nutritional sprays as part of the mineral nutrition program; control diseases (melanose, scab, brown rot), insects (scales, mealybugs, whiteflies, thrips, plant bugs, etc.) and mites (rust mites, purple and other mites) with pesticides; and physiological sprays for maturity, control of preharvest drop and fruit set and abscission aids. Materials with effects on external quality include nutritional sprays and pesticides, the latter for prevention or reduction of discoloration and blemishes, in addition to certain physiological sprays (mostly adverse). Those with effects on internal quality, aside from nutritional sprays discussed earlier under Mineral nutrition, include scalicides and physiological sprays, particularly the latter applied for reduction of acidity.

a. Scalicides: Yothers in the 1930's and Winston in 1942 mentioned that oil emulsion sprays slowed degreening, especially of early oranges and tangerines, and would produce a fruit blotch (oil spotting) if the material was applied to trees when fruits were between 3/4 and 1-1/2 inches in diameter (why fruits should be sensitive at this stage but not earlier or later is unknown). Both workers found increased wood damage and susceptibility of trees to cold (both conducive to increased melanose problems). Sinclair, Bartholomew and Ebeling reported lower total soluble solids and solids:acid ratio in oranges sprayed with oil emulsion as compared to hydrogen cyanide fumigation in California in 1941.

Organo-phosphates, such as parathion, were introduced as scalicides shortly after World War II. Results of an experiment over 2 seasons with oil-emulsion and parathion sprays to 'Hamlin' and 'Parson Brown' orange showed 2 main trends, the lowering of total soluble solids and solids:acid ratio by the oil-emulsion reported earlier and a small increase of total soluble solids and acid with parathion (Table 9). Tests with other organo-phosphates at AREC Lake Alfred have given similar findings, namely small or no effects on total soluble solids or solid: acid ratio.

b. Arsenical and other sprays for reduction of acidity: Webber and Swingle observed about 1893 that acidity of oranges was reduced when trees were sprayed with an insecticide containing arsenate as an impurity. It was reported in 1921 from California that lead arsenate greatly reduced acidity of navel and 'Valencia' oranges. Spraying of trees in Florida became common practice after passage of the 1925 Maturity Law, with the result that a law banning the use of arsenic in any form on bearing citrus was passed in 1927. Enforcement of the Arsenic Law was lifted for the Mediterranean fruit fly campaign in 1929-30 and reimposed in 1931. Potential and actual threats of legal action impelled the Florida Department of Agriculture to investigate the effects of arsenate on all citrus fruits. Their work and that of others showed a drastic lowering of acid with even light doses of arsenate on oranges and tangerines but comparatively little effect on grapefruit. A permanent injunction against enforcement of the Arsenic Law as to grapefruit was handed down in 1933. Experiments in South Africa in the late 1930's and 1940's showed that lead arsenate reduced acidity of Valencia oranges, with a recommendation that trees be sprayed only once every 3 years, preferably in December or January. It was reported that sprays of 1.5 lb superphosphate in 3 gal of water also reduced acidity without affecting total soluble solids. (This curious finding was reported in countless publications but was finally laid to rest when it was discovered the superphosphate contained arsenic as an impurity.)

Harding (USDA Orlando) ran tests on grapefruit over several seasons, the results of which are shown in Fig. 13a, b, c, for total soluble solids, total acid and solids:acid ratios of unsprayed and sprayed Marsh and Duncan on rough lemon and sour orange. These curves show that lead arsenate (1 lb per 100 gal = 1.2 g per liter) sprays had no effect on total soluble solids but a progressive influence on total acids as the season progressed, so that the solids:acid ratio was increased. There was an insignificant reduction in fruit weight and no effect on percentage juice or ascorbic acid. Sprayed fruit became palatable at an earlier date than unsprayed.

Recommendations for spraying lead arsenate, the only form used, were developed following passage of the Florida Citrus Code of 1949, which incorporated Judge Petteway's (Circuit Court of Polk County) injunction barring enforcement of the arsenic law on <u>bearing</u> grapefruit trees. These are to use 0.4 to 2.5 lb per 100 gallons of water (2 to 6.25 lb per 500 gallons = 0.48-1.50 g per liter) applied 1 to 6 weeks after bloom, the higher concentration for early season maturity and a lower one for midseason maturity of white-fleshed varieties. Only 0.4 to 0.6 lb per 100 gallons (= 0.48-0.72 g per liter) are recommended on pink and red varieties. Sprays should be applied about once every 2 or 3 years because of the carryover effect. They should not be expected to correct late bloom, excess potash, overirrigation or a mistimed oil-emulsion spray (one put on too late in the summer). Use of arsenate is universal in Florida grapefruit groves. California prohibits arsenate on all bearing citrus and Arizona and Texas have no regulations on it.

Periodically, there has been agitation to use arsenate on varieties other than grapefruit. Clandestine experiments by private growers and AREC Lake Alfred have shown that very small amounts, such as about 4 ounces (113.4 g), dusted on 'Temple' results in a moderate lowering of acid, hence high total soluble solids:acid ratio. The Fla. Department of Agriculture is adamant, however, against any change in the present law The question may, however, become moot if the current (and illogical) outcry against "poisons" results in banning lead arsenate on grapefruit. The Interior section of the state, where acidity tends to be limiting, will then be hurt far more than the Indian River, where juice tends to be limiting early in the season. (Arsenic is, of course, found in trace amounts in nearly all soils; moreover the quantity used on grapefruit trees is low and that persisting as residue in the peel and juice when fruit are harvested is a fraction of the legal tolerance. This is a completely different situation than in apples, where 6 or 7 arsenate sprays are applied and fruit must be washed to remove residue.)

Work by Vines and others at Lake Alfred as to how arsenate effects the reduction in acidity has shown arsenate partially substitutes for phosphate in the ATP-ADP energy transfer system which results in a blockage of the portion of the Krebs cycle leading to citric acid information. Acidity, thus, is not reduced as the season progresses but the acid was never formed to begin with (if the total amount is static, the % goes down as the fruit enlarges).

c. Physiological sprays for preharvest drop, fruit size and fruit set: Numerous experiments have been conducted in California with sprays of compounds, such as 2,4-D; 2,4,5-T; and 2,4,5-TP; for

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Preharvest Modifiers on Fruit Quality (cont.)

control of preharvest drop and to increase fruit size of oranges, grapefruit and lemons. Similar studies have been made in Florida to control preharvest drop of 'Pineapple' oranges and 'Temple'. Postbloom or later sprays of low concentrations, 2.0 to 20 ppm, were effective in California on oranges and lemons and are used there commercially. Experiments in Florida showed that 2,4,5-T, or better 2,4,5-TP, also in low concentrations gave some control of preharvest drop of 'Pineapple' oranges and a recommendation as to use is still in the Better Fruit Program, although now there is more interest in fruit removal.

GA and other compounds (such as 2,4-D) have been used to induce parthenocarpic fruit set in varieties like 'Orlando' tangelo and navel orange. Generally speaking, concentrations which were effective in promoting better fruit set have resulted in green color, very coarse texture and other undesirable aberrations. Tests on navel oranges have indicated that GA may inhibit formation of the navel, a desirable feature if proper concentrations, timing of sprays, etc., can be worked out. At present, GA is not cleared for general use on citrus.

d. Physiological sprays for abscission: Great interest has developed in recent years in chemicals which will accelerate normal formation of the abscission layer of fruits so that they can be harvested mechanically instead of by hand labor. Hundreds of compounds have been tested, ranging from ascorbic acid, iodoacetic acid, mannitol, etc., to cycloheximide, under laboratory and field conditions. Ethylene, of course, will cause abscission but thus far no practicable method has been developed for its field use. Cycloheximide has proved most practical and has been cleared by Food and Drug for use on citrus as of 1977. Unfortunately, none of the compounds tested thus far are effective on 'Valencia' oranges, where harvesting of mature fruits is done with young fruits of the next crop on the trees. Abscission sprays, currently, cycloheximide, are put on a few weeks before harvest, usually 1 to 3 weeks earlier, on early or midseason oranges where they do an effective job but are useless on 'Valencia' oranges.

Preharvest Modifiers of Fruit Quality (cont.)

3. Water Relations:

A number of studies at AREC Lake Alfred and grower experience have shown that overirrigation or heavy rains resulting in high soil moisture is detrimental to development of good (deep, bright) fruit color and rate of degreening. Deficiency of moisture during the growing season or early part of the harvest season can cause excessive fruit drop and failure of fruits to attain normal size. Irrigation thus is used by many growers to supplement rainfall. Greater care must be exercised in groves on a high N fertilizer program to ensure that timing of irrigation and the amount of water supplied do not slow normal development of color and internal fruit qualities. Certain varieties, such as 'Pineapple' orange or tangerine, are notably sensitive to soil moisture during the season of harvest. Zebra skin of tangerines is caused by letting trees get too dry and then picking fruit 3 to 10 days after a heavy rain or irrigation.

4. Pruning:

Color of citrus and most other fruit is highly correlated with exposure to light, deep bright rind color being obtained only with full exposure. Few studies relating pruning to fruit characters have been made; however, it has been a general observation that hedging, topping or other types of pruning to improve yields have also resulted in better color and higher internal quality (since color and development of sugars acid, etc., are correlated). Effects of pruning have been particularly noticeable in the form of higher packout with tangerines, which do not develop good color if the fruit are partially or fully shaded.

5. Tree Age:

Oranges and grapefruit begin to bear in the second or third year after planting in the field and generally have a sufficient number of fruit for commercial harvesting in the fourth or fifth year. The non-bearing period of tangerines, 'Temple', tangelos and 'Murcott' is shorter by a few years. The nonbearing cultural program is designed to promote rapid healthy vegetative growth, to expand and develop bearing surface, with a transition to the bearing program where the emphasis is on yield and fruit quality. Fruit borne in the nonbearing and early part of the bearing years are typically larger in size, coarser in texture, lighter in rind color, more likely to be misshapen (for the variety) and lower in total soluble solids, total acid, juice content and aromatic constituents than those on trees in mature bearing (10 to 20 years in the case of oranges or grapefruit).

C. Variation of Individual Fruit on a Tree

Sites and Reitz (1949, 1950a, 1950b) conducted the first systematic study of the variation of individual fruit on a citrus tree at the Citrus Experiment Station, Lake Alfred (now AREC Lake Alfred). Purposes of the investigation were to obtain information on accurate sampling of small plots, sampling of large blocks by a packinghouse, and variation of fruit on the tree as a guide for spot-picking. A single 'Valencia' orange tree on rough lemon rootstock about 28 years old and in good condition was harvested in March 1948. Locations of about 1800 individual fruit obtained at the time of picking were classified as to compass direction in 1 of 19 sectors and as to position in relation to shading by the leaf canopy. Five light classes (Fig. 14) were established: "Outside," fruit receiving maximum light available in any sector, "canopy", fruit at least partially shaded at all times, "inside", fruit inside the main part of the canopy and in continuous full shade, "top-outside", fruit in the top of the tree on the outside of the canopy, and "top-inside", fruit in the top of the tree but imbedded in the foliage so that it received intermittent direct light.

Values for total soluble solids, total acid (titratable acid), solids:acid ratio and juice content for the 5 light classes are given in Table 10. There was a definite correlation between rind color and soluble solids, green fruit being much lower in solids than either yellow or orange ones. Trends are shown in Fig. 14.

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Preharvest Modifiers of Fruit Quality (cont.)

Effects of compass direction on total soluble solids, acid, ratio, juice content and vitamin C are shown in Fig. 15 to 19. Values in Fig. 15 to 19 indicate that highest total soluble solids are in the southeast and southwest sectors and the highest acid values are in the same general directions, the net effect being that the highest solids:acid ratios are in the northeast sectors. There were no such trends with juice content although inside fruit had a lower percentage than either canopy or outside fruit as a rule. Vitamin C content was strongly correlated with height and exposure to light. Effects of spot-picking different portions of the tree on soluble solids are apparent in Table 11.

Data in the study show a representative sample (for % total soluble solids) may be obtained from a tree or block by harvesting 20 fruit from the canopy portion at a height of 10 feet (3 meters) or from the outside portion at a height of 3 feet (1 meter). Fruit are collected from the cardinal points to minimize variations caused by exposure. The authors also emphasize large fruit of the same age, variety and from the same position on the tree have lower total soluble solids than small ones, thus all fruit sampled for any given comparison must be of the same size. (Failure to recognize this requirement in sampling fruit has caused endless trouble and controversy in the past.) They also mention sampling procedures must be modified when large blocks, nonsymmetrical trees or nonuniform distribution of fruit on the tree are involved. This study was made on only a single tree but the results have been corroborated over and over in the 30 years since it was made. (Anyone responsible for sampling fruit on the tree for any purpose whatsoever should read and reread the 3 papers with care.)

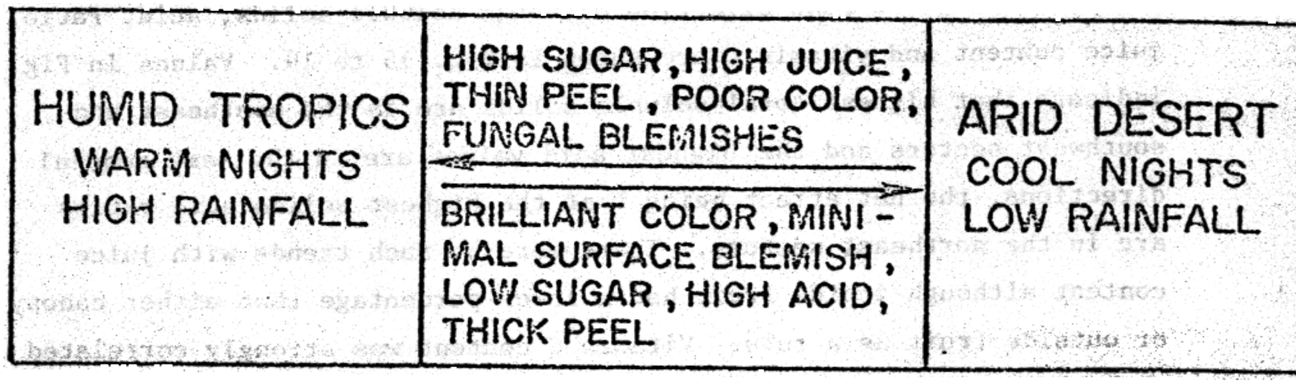


Figure 10. Combined effects of ecological factors on citrus fruit qualities.

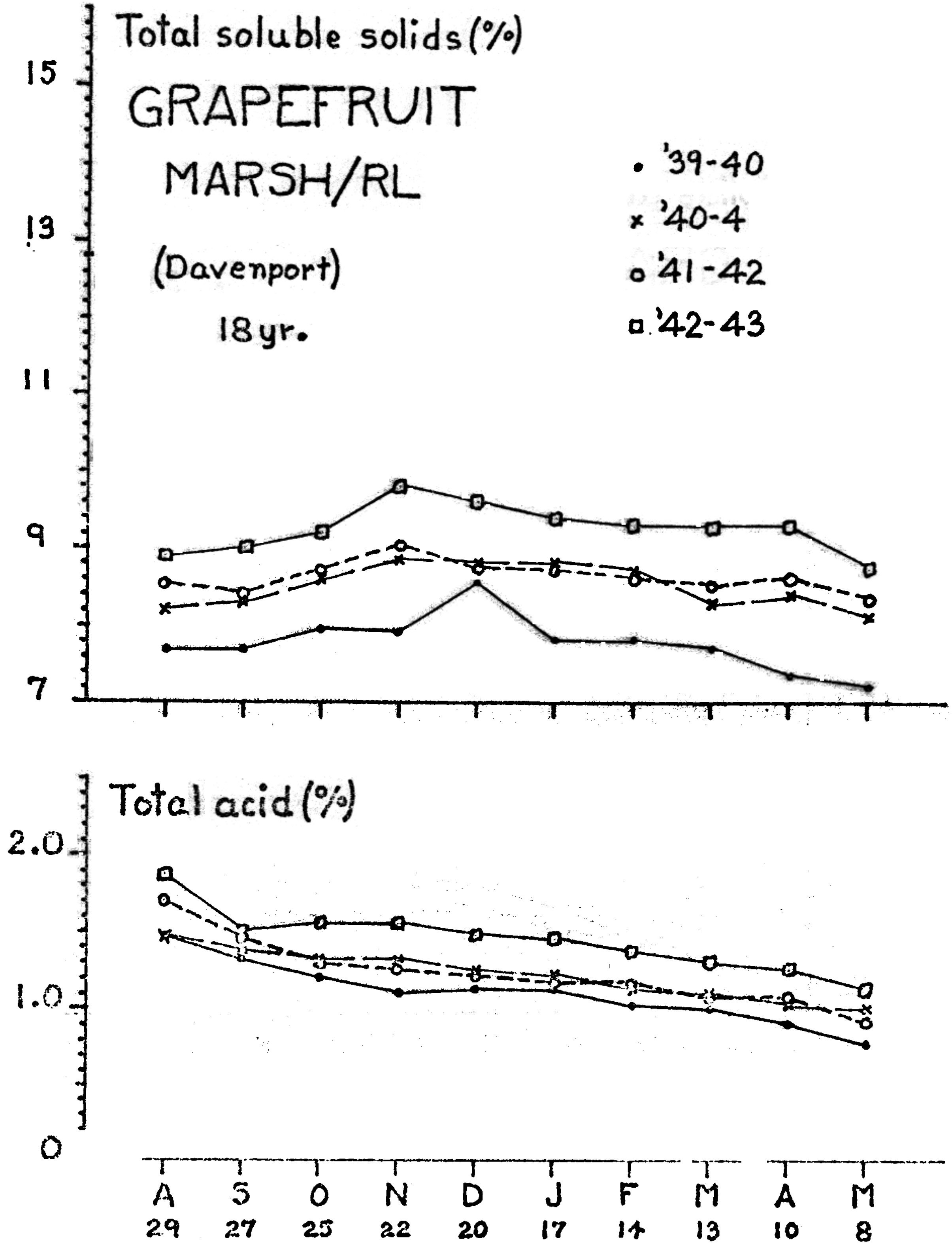


Figure 11a Total soluble solids (%) and total acid (%) of 18-year-old 'Marsh' grapefruit on rough lemon (RL) stock at Davenport in 1939-40, 1940-41, 1941-42 and 1942-43 seasons. (Sample dates are $\pm$ about 4 days.) (Harding and Fisher USDA Tech. Bul. 886. 1945.)

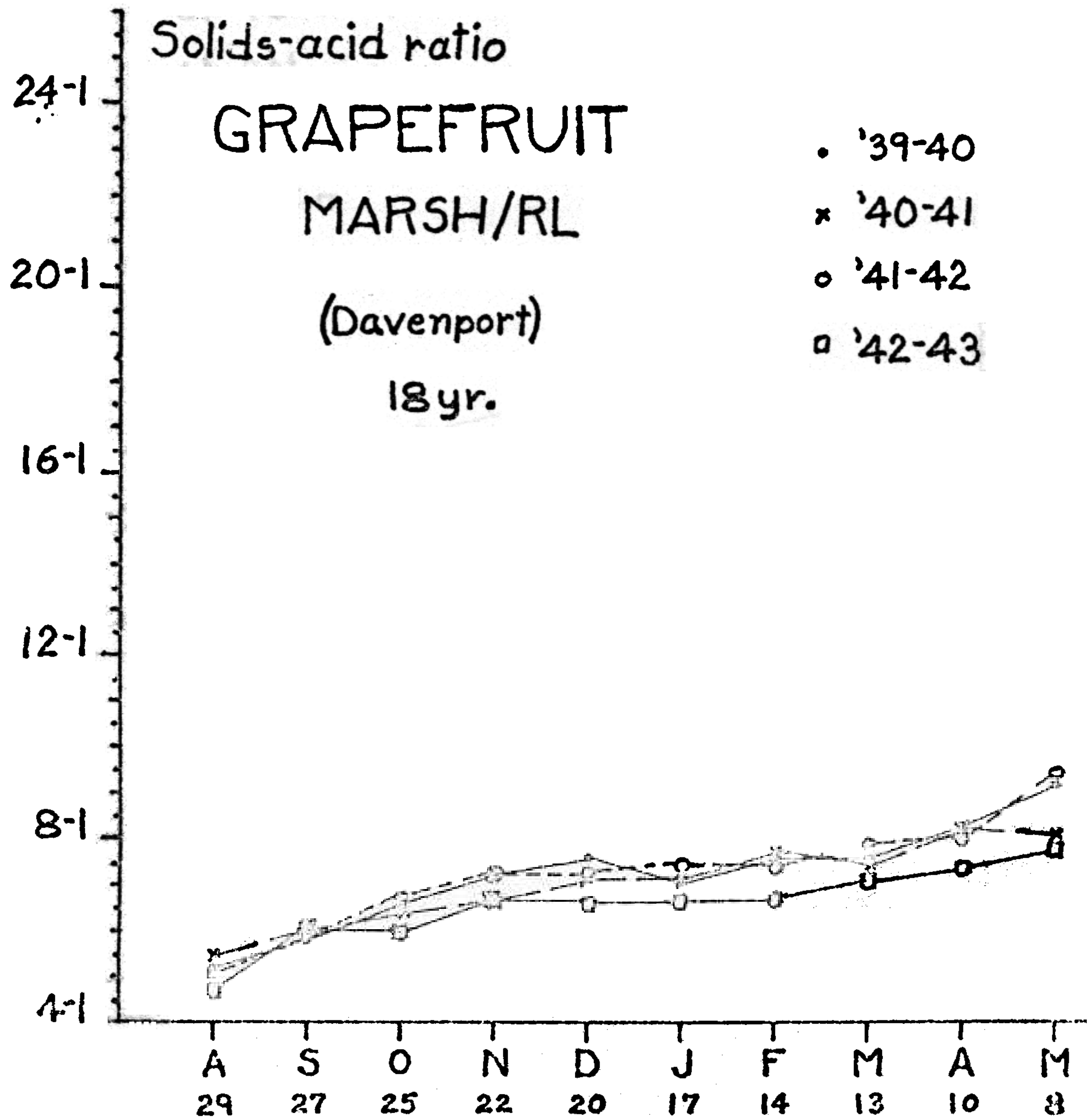


Figure 11b Solids-acid ratios of 18-year-old 'Marsh' grapefruit on rough lemon (RL) stock at Davenport in 1939-40, 1940-41, 1941-42, and 1942-43 seasons. (Sample dates are ± about 4 days.) (Harding and Fisher USDA Tech. Bul. 886. 1945.)

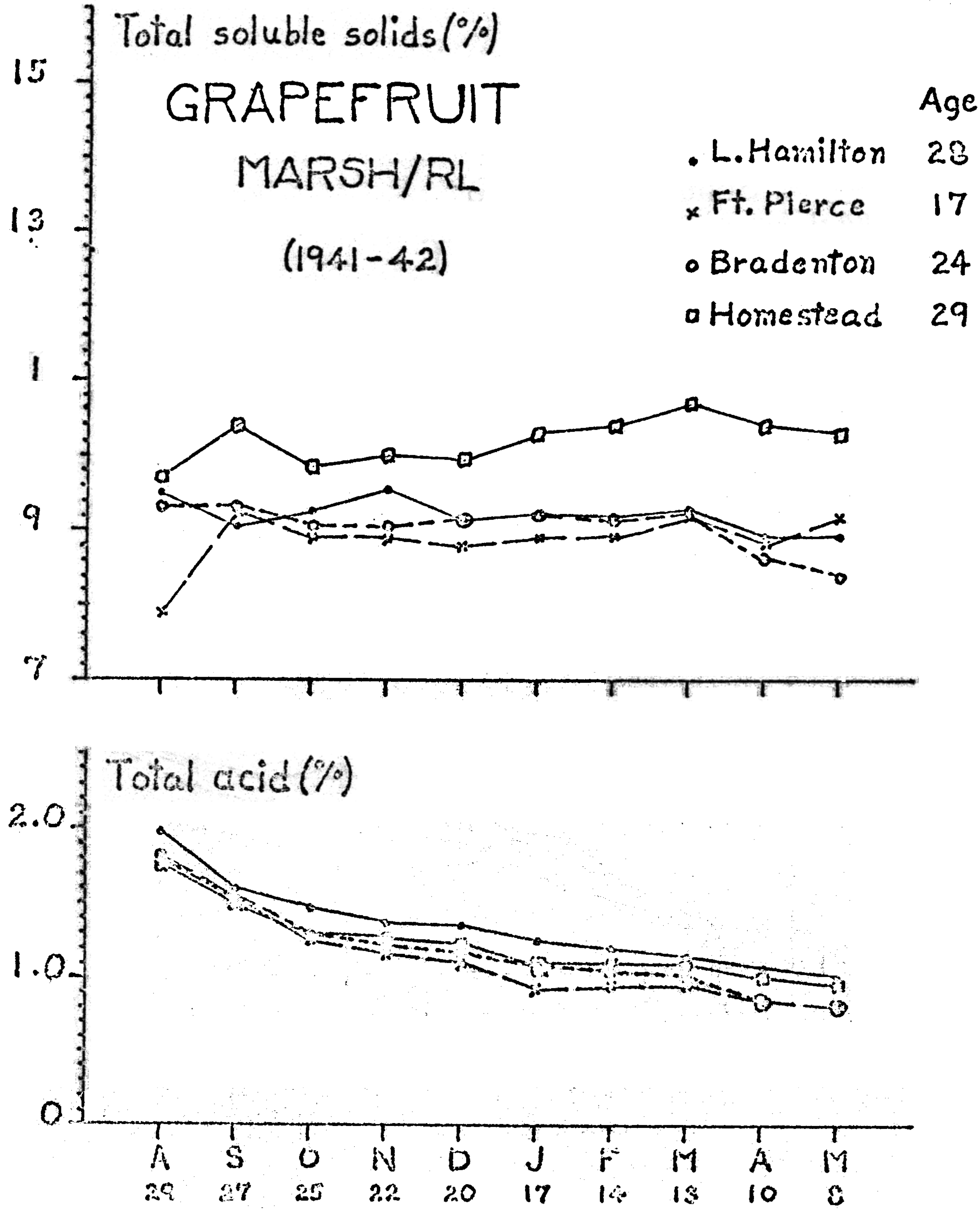
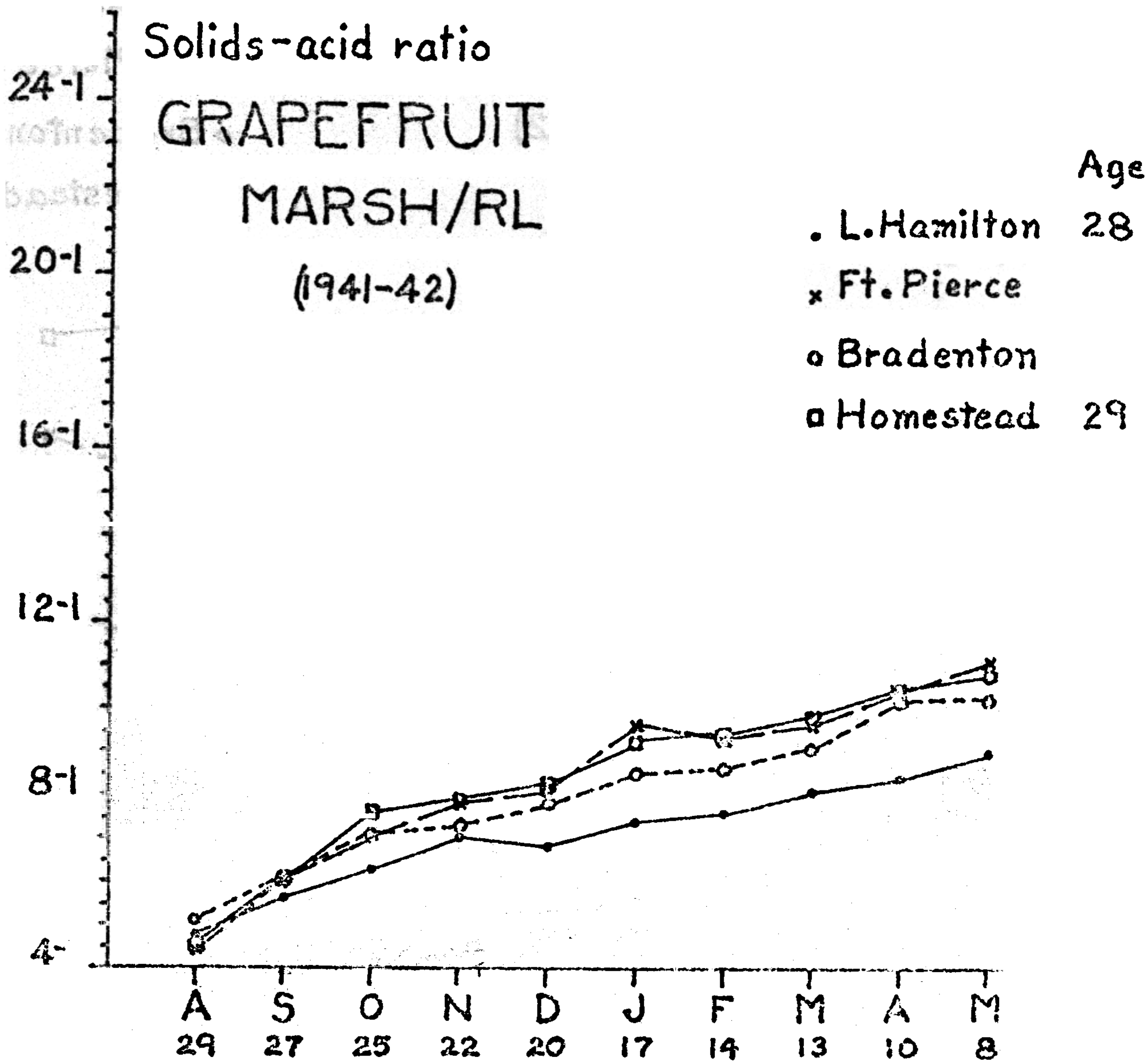


Figure 12a Total soluble solids (%) and total acid (%) of 'Marsh' grapefruit on rough lemon (RL) stock at Lake Hamilton, Ft. Pierce, Bradenton and Homestead in 1941-42, (Sample dates are ± about 4 days.) (Harding a Fisher USDA Tech. Bul. 886. 1945.)



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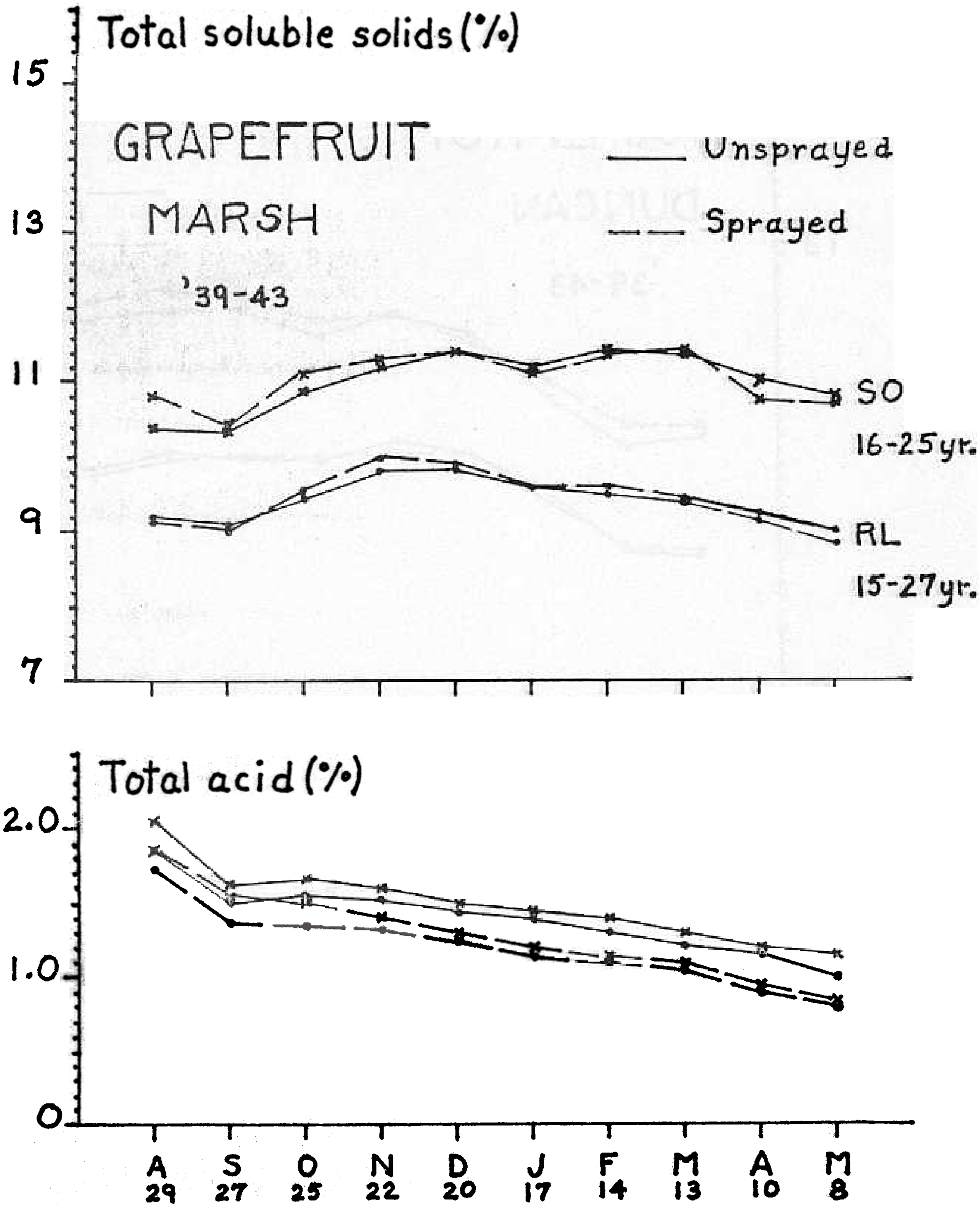

igure 3a. Comparison of total soluble solids (%) and total acid (%) of lead arsenat -sprayed (1 lb per100 gal) and unsprayed 'Marsh' grapefruit on rough lemon (RL) and sour orange (SO) stocks at 27 locations. (Values are averages of 1939-40 through 1942-43 seasons.) (Sample dates are ± about 4 days.) (Harding FSHS 58. 1945.)

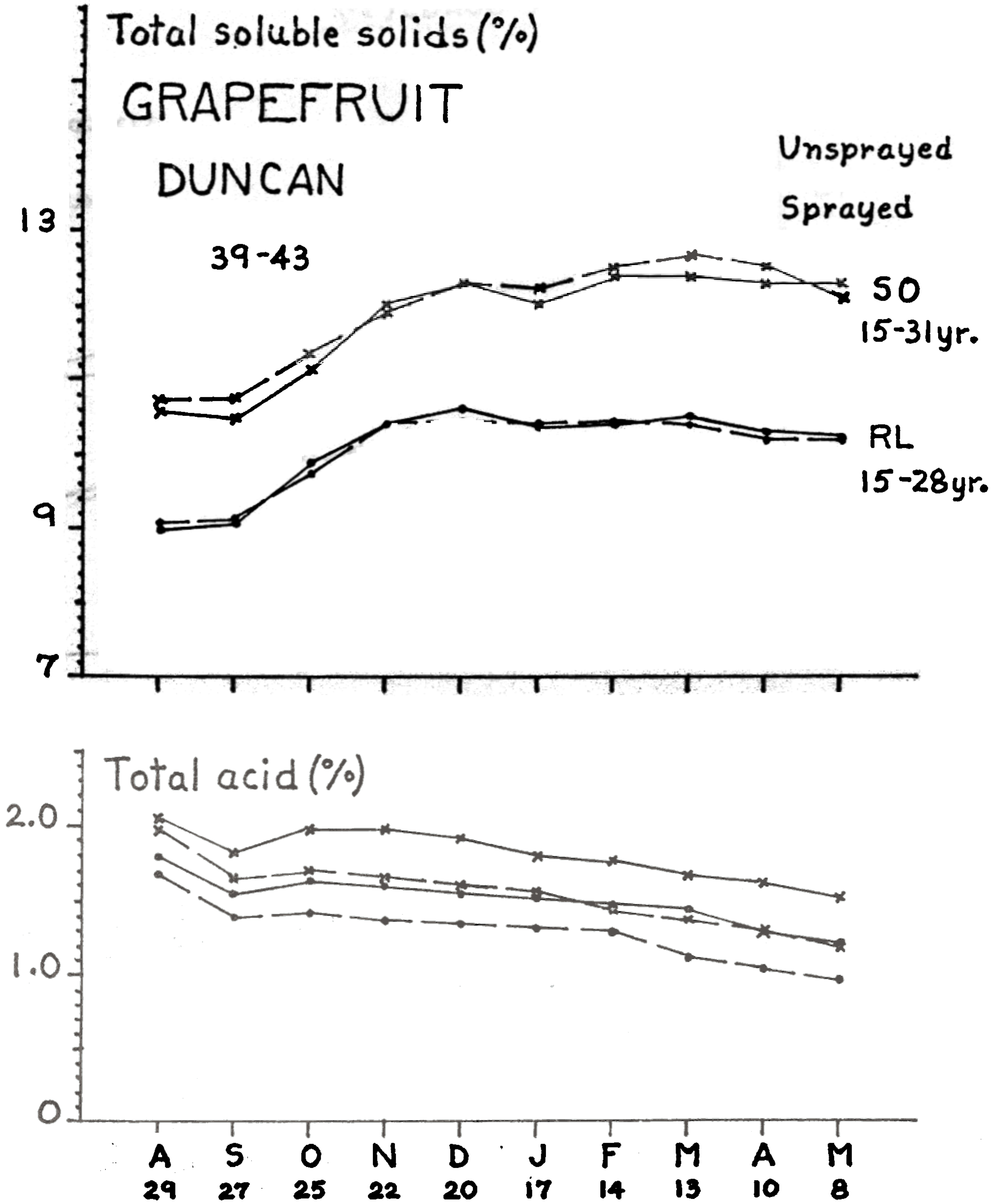

Figure 3b Comparison of total soluble solids (%) and total acid (%) of lead arsenate -sprayed (1 lb per 100 gal) and unsprayed 'Duncan' grapefruit on rough lemon (RL) and sour orange (SO) stocks at 27 locations. (Values are averages for 1939-40 through 1942-43 seasons. Sample dates are ± about 4 days.) (Harding FSHS 58. 1945.)