PLANT NUTRITION AND CITRUS FRUIT CROP QUALITY AND YIELD

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The effects of plant nutrients on citrus fruit quality cannot be considered independently of their effects on yield. In some cases quality can be improved by sacrificing some yield; however, from the overall economic point of view, it is usually advantageous to sustain maximum fruit yield even though there may be some sacrifice in fruit quality. This report emphasizes the nutrient effects on quality in the ranges in which we expect maximum yield to be sustained. If the deficient ranges for yield are included, the degree of effects on quality is greater. The nutrient ranges and effects discussed are primarily those encountered by the authors under California conditions.

External fruit appearance is of primary importance for the fresh-fruit market, while quality and quantity of juice are of primary importance in fruit for processing. Since the California citrus industry is highly dependent upon fruit for the fresh market, fresh-fruit quality factors will be emphasized.

Studies (6, 10) over the years have shown that within the range of nutrient levels for maximum production only three elements – N, P, and K – have important influences on fruit quality and size. Therefore, the effects discussed will be restricted to these three nutrients. In the deficient range for yield, some of the other nutrients do have highly detrimental effects on quality.

The effects reported here were calibrated against the concentrations of the nutrient in question in 5-to-7-month-old, spring-cycle leaves from nonfruiting shoots on mature trees. The trees were in well-replicated experiments in commercial orchards; there were usually about 20 replications of single-tree plots.

It is estimated that about 75% of California citrus acreage is now fertilized by using leaf analysis as a guide. Tabular leaf analysis guides similar to Table 1 are being used by commercial growers. Such guides, however, are based primarily on yield factors. The effects on yield, size and quality cannot be integrated into one range of guide numbers. Results from leaf analysis can be used most effectively if one is aware of the specific effect on fruit yield, size, and quality as illustrated in Fig. 1 to 4. Tradeoffs among factors may be necessary to obtain best overall results.

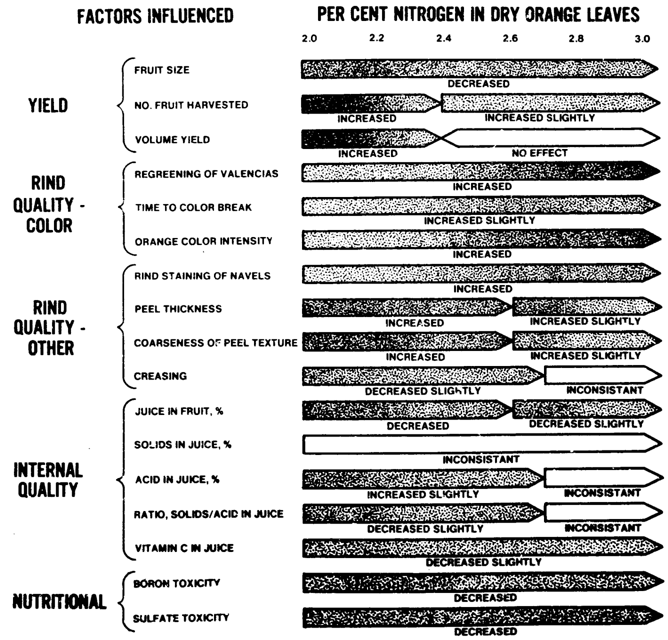

Fig. 1. Influences on yield, quality, and B and S nutrition resulting from changes in the percentage of N in 5-to-7-month-old, spring-cycle orange leaves. (The greater the intensity of stippling, the greater the effect on the factor indicated.) Adapted and updated from Jones, Embleton, and Platt (14).

Nitrogen

Factors of the orange that are influenced by N nutrition are shown in Fig. 1. Of these factors, regreening of 'Valencia' is probably of greatest commercial importance. The most favorable uniform fruit color is likely to occur in the N range that restricts yield; regreening intensifies as leaf N is increased. An increase in N reduces fruit size, and this is a common problem in 'Valencia'. Rind staining of navels, a problem that develops after the fruit is packed and is of particular concern in the San Joaquin Valley of California, is intensified by increasing N levels. Other factors that are adversely affected by increasing N levels are peel thickness, coarseness of peel texture, juice percentage, time-to-color-break, and Vitamin C content in the juice. By increasing N in the lower part of the N range for maximum production, the incidence of the peel problem, creasing, can be reduced; this sometimes can be of practical value. Thus, usually one should strive for an N level in the lower part of the range for maximum production. A major exception to the guide values (Fig. 1) occurs in areas where B and S toxicity occur because of the presence of these two elements in irrigation water. In such cases, B and S accumulation in leaves results in premature defoliation and yield loss. Where this problem exists, increasing leaf N above 2.6% can increase volume yield by reducing the accumulation of B and S in the leaves, and thus reducing premature defoliation. While elevated-N level adversely affects fruit quality, this sacrifice appears to be justified if yields are to be maintained under these specific conditions (13).

Preliminary data indicate that N effects on grapefruit quality are similar but of a lesser degree than those on the orange. Experiments to date have shown little effect of N on lemon fruit quality (12).

Phosphorus

Factors of the orange that are influenced by P nutrition are shown in Fig. 2. In general, the impact of P on quality factors within the range of maximum production is not as great as that for N. An

Table 1. Leaf analysis guide for diagnosing nutrient status of mature 'Valencia' and navel orange trees.[z]

Element	Deficient	Ranges in % (dry matter basis)[y] Low	Optimum	High	Excess
N	<2.2	2.2-2.3	2.4-2.6	2.7-2.8	>2.8
P	<0.09	0.09-0.11	0.12-0.16	0.17-0.29	>0.30
K[x]	<0.40	0.40-0.69	0.70-1.09	1.10-2.00	>2.30

[z]Adapted from Embleton et al. (6). With the exception of N values this guide can be applied for grapefruit, lemon, and probably other commercial citrus varieties.

[y]Based on concentrations of elements in 5-to-7-month-old, spring-cycle leaves from nonfruiting terminals. Leaves selected for analysis should be free of obvious tipburn, insect or disease injury, mechanical damage, etc., and from trees that are not visibly affected by disease or other injury.

[x]K ranges apply specifically for the single quality factor "number of fruit per tree."

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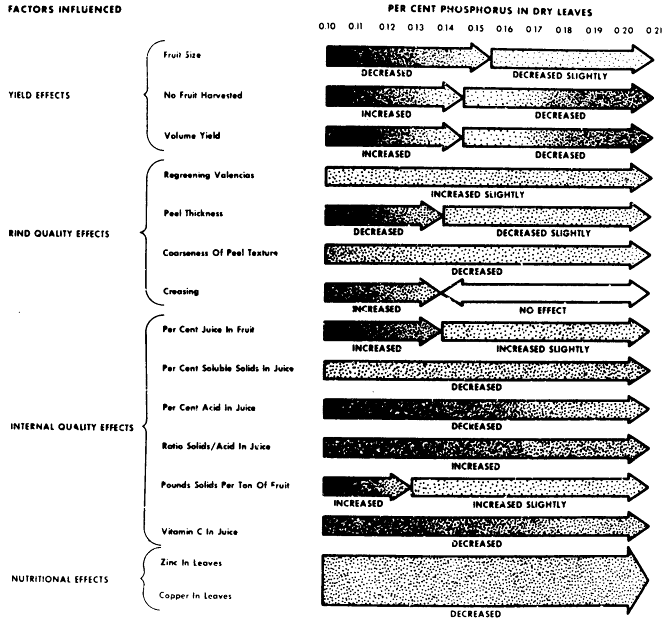

Fig. 2. Influences on yield, quality, and Zn and Cu nutrition resulting from changes in the percentage of P in 5-to-7-month-old, spring-cycle orange leaves. (The greater the intensity of stippling, the greater the effect on the factor indicated.) From Embleton et al. (5).

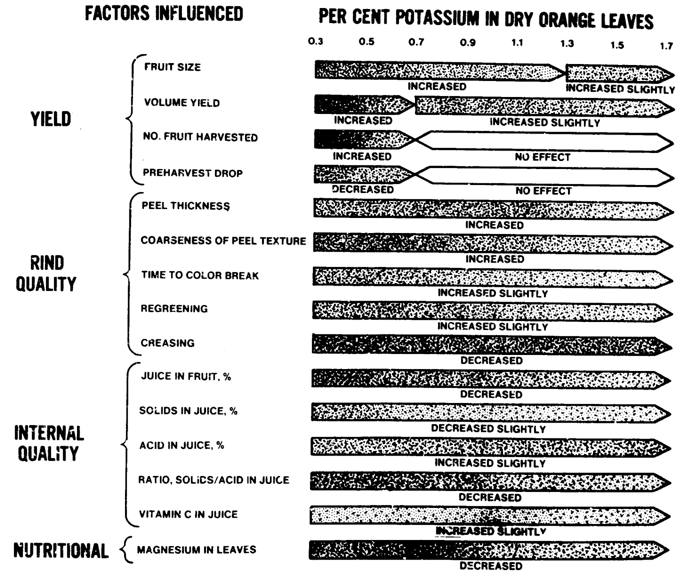

Fig. 3. Influences on yield, quality, and Mg nutrition resulting from changes in the percentage of K in 5-to-7-month-old, spring-cycle orange leaves. (The greater the intensity of stippling, the greater the effect on the factor indicated.) Adapted and updated from Embleton, Jones, and Platt (8).

increase in P is associated with some reduction in fruit size, peel thickness, and coarseness of peel texture, and an increase in juice percentage and regreening. Solids and acid in the juice are decreased, but the ratio of solids to acid is increased. This latter effect could be of importance where early maturity is desired.

Little data are available on P effects on California grapefruit quality, but other data (1, 11) suggest responses similar to those for the orange. Varying P levels have had no practical effect on lemon fruit quality, even in the deficient range for yield (7).

Potassium

Factors of the orange that are influenced by K nutrition are illustrated in Fig. 3. Most of the effects of K on fruit quality are unfavorable. In general, K need not be much above 0.7% in the leaves except when small fruit or creasing or both are problems. To date, the most effective method of reducing the incidence of creasing is to increase the K level in leaves. Soil applications of K are frequently not effective in increasing leaf K. We therefore resort to foliar sprays of KNO_3, which are effective. The increases in N and K in leaves with use of these sprays accentuates the regreening problem while reducing the incidence of creasing. When both regreening and creasing are problems one is limited to attacking the most serious of the two problems and aggravating the other (4).

The effects of K nutrition on grapefruit quality are similar to those on the orange (3).

The effects of K nutrition on lemon factors appear in Fig. 4. Practically all the effects of increasing K leaf levels in lemons are favorable for fresh or processing fruit. Fruit yield, size and some of the quality effects associated with an increase in K in leaves are similar to those for orange and grapefruit, but the economic impact of the fruit quality effects is not the same. For example, a delay in time-to-color-break of the orange may not be desirable or may be of little consequence, however, a delay in time-to-color-break of lemon permits the fruit to remain on the tree longer and attain a larger size before harvest. (Harvesting of the lemon fruit is determined by both fruit size and color.) Also, an increase in acid concentration in lemon juice is usually desirable, particularly for processing fruit; in the orange an increase in acid concentration delays the time to attain legal maturity.

Some lemon and orange quality factors are affected in opposite directions by an elevation in the K level. An increase in K level increases orange peel thickness and reduces orange juice percentage, while it decreases lemon peel thickness and increases lemon juice percentage (2). The increase in juice percentage in conjunction with an increase in the acid concentration in the juice, both of which are associated with increasing K levels, results in a marked increase in pounds of acid per ton of fresh lemon fruit. This is of particular advantage in fruit for processing.

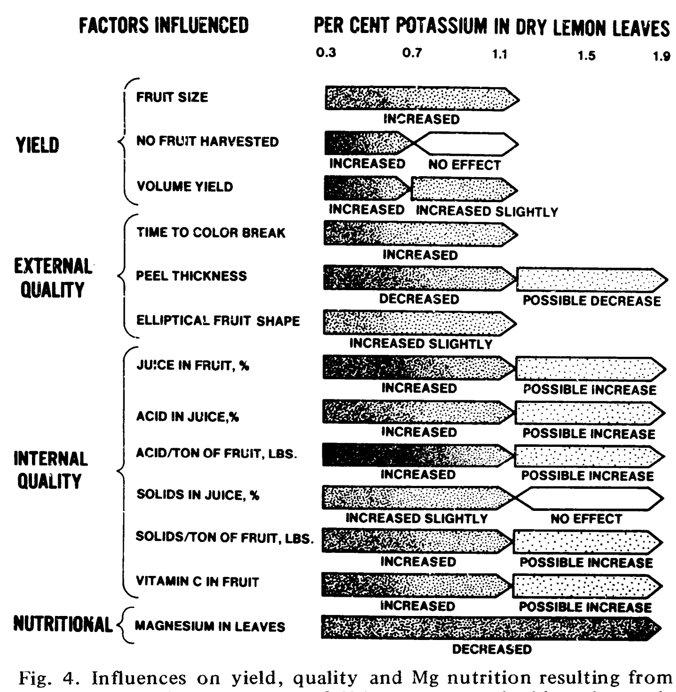

Fig. 4. Influences on yield, quality and Mg nutrition resulting from changes in the percentage of K in 5-to-7-month-old, spring-cycle lemon leaves. (Absence of arrow indicates no valid data. The greater the intensity of stippling, the greater the effect on the factor indicated.) From Embleton, Jones, and Platt (9).

Conclusions

The effects of N, P, and K on citrus fruit quality are important commercially. Problems of fruit yield, size, and quality should not be approached independently; in some cases tradeoffs are necessary for best overall results. Leaf analysis guides calibrated against fruit yield, size and quality have practical value in improving fruit quality. To use leaf analysis results most effectively one should know, for the orchard in question, what specific problems can be influenced by nutrition. One should also have a continuing record of fertilizer applications and leaf analyses. With this information a nutritional program can be planned for the specific orchard in question.

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ORGANIC VS. INORGANIC NUTRITION AND HORTICULTURAL CROP QUALITY[1]

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Until the development of modern chemical fertilizers began in about 1840, natural and organic materials supplied virtually all the plant nutrients to the soil. The use of chemical fertilizers increased gradually until about 1940. Since then the total consumption of chemical fertilizers in the United States has increased nearly fivefold to about 40,000,000 tons annually (28). The development and use of modern chemical fertilizers has decreased the relative importance of organic fertilizers. Today, organic materials account for less than 1% of the N fertilizers sold in this country (27). Phosphate rock materials account for about 20% of the present P fertilizer consumption in the United States, and over 85% of these materials are consumed in Illinois and Missouri (4). Natural potassic fertilizers, such as seaweed, greensand, and granite dust, apparently account for an insignificant fraction of the K fertilizer materials sold in this country, since muriate of potash alone accounts for nearly 90% of the commercial K fertilizers consumed here (4).

Composts and farm manures are important fertilizers to the present-day organic or home gardener, but these materials are of much lesser importance on a national scale. If all of the farm manure in this country were equally distributed and spread without loss, nearly 5 tons of this waste could be applied per acre of cropland. This amount is enough to provide about 25% of the primary nutrient requirement by crops. However, due to the concentration of the livestock industry in specific regions of the country and due to losses of manure during storage and handling, only a fraction of the farm manure may actually reach commercial cropland. Probably no more than 2 to 4% of the manure is used on vegetable crops, assuming that its use is proportional to the consumption of commercial fertilizers on vegetable crops (18).

Impact of organic fertilizers

When one considers the above statistics, it is obvious that the impact of the use of organic fertilizers in the vegetable crop industry is insignificant with respect to the total consumption of fertilizers on vegetable crops in this country. Organic gardening gains potential importance, however, when the statement is made that crops grow better, taste better, and are more nutritious when grown organically than when grown chemically. The advocates of organic gardening have been successful in taking their case to consumers and have gained their confidence. They have presented their case in a language which the layman understands by simply stating that nature knows best and that chemicals merely stimulate the plant and poison the soil (7, 22, 30). Foods are said to lose their wholeness if they are grown in soils enriched with chemical fertilizers (13).

Influence of fertilizers on nutritional quality of plants

Undoubtedly, a relationship exists between crop husbandry (30) or soil fertility (14) and the nutrient content of vegetables. It is clear that varying the mineral content of a nutritional medium for plants will have an effect on their mineral contents (1, 9). Often, however, this relationship is never simple and direct, and other environmental factors may override the effects of nutrient supply (26). The effect of mineral nutrition on the vitamin, protein, and carbohydrate content of vegetables is very complex and few generalizations can be made (10, 26). It has been difficult to associate fertilization practices with nutritional value of vegetables. The general conclusion has been that field and climatic conditions and plant species or cultivar may have more marked and more practical effects on nutritional quality than fertilization practices (10, 12, 15, 16). Another general conclusion is that well-nourished, green plants will have a higher total vitamin content than undernourished chlorotic ones but that contents of specific vitamins will vary (26).

The validity of the hypothesis that organic farming yields vegetables of superior nutritional value has never been adequately tested in human or animal feeding trials. Such a study would be

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