Table 2. Attributes of woody ornamental plants which determine their ultimate salability according to survey of nurserymen.

<table>
<thead>
<tr>
<th>Age (time in field)</th>
<th>Heaviness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Helfiness</td>
</tr>
<tr>
<td>Balance</td>
<td>Highly finished plant</td>
</tr>
<tr>
<td>Body</td>
<td>Market value</td>
</tr>
<tr>
<td>Buds (applies to broadleaf evergreens)</td>
<td>Overall appearance</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Roots permeated soil</td>
</tr>
<tr>
<td>Color</td>
<td>Root structure</td>
</tr>
<tr>
<td>Demand</td>
<td>Salability</td>
</tr>
<tr>
<td>Density</td>
<td>Shape</td>
</tr>
<tr>
<td>Fibrous roots (liners, seedlings)</td>
<td>Size (height, width, caliper)²</td>
</tr>
<tr>
<td>Form</td>
<td>Structure</td>
</tr>
<tr>
<td>Fullness</td>
<td>Vigor</td>
</tr>
<tr>
<td>Health, thriftiness</td>
<td></td>
</tr>
</tbody>
</table>

²Principal criterion determining salability.

...nutrition by noting that he and other nurserymen were "struggling and attempting to find the best fertilizer combinations; perhaps more of an art than science. Probably stumble and stay locked in some of the shotgun methods we are using."

Literature Cited


PLANT NUTRITION AND DECIDUOUS FRUIT CROP QUALITY

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Physiological problems observed during postharvest handling of deciduous fruit crops often originate during production as a result of climatic, nutritional, or other cultural factors. Sometimes the likelihood of a problem occurring is partially under genetic control. For a postharvest physiologist to be fully effective in evaluating a problem, he must know the cultural history of the commodity with which he is working. Similarly, the researcher studying cultural factors should know the relationships between treatment variables and quality traits. Often this can best be accomplished by collaboration of researchers working in both fields, but one individual with proper background and interest may also acquire relatively complete information. I consider this symposium highly appropriate to point out interrelations between plant nutrition and commodity quality, and the need for adequate information on quality aspects of nutritional research to enable accurate interpretation of results.

It is my intent in this discussion to identify, by problem symptoms, areas of plant nutrition – fruit quality interactions, and to present specific examples to illustrate such symptoms. Comments are not intended to serve as a review.

In this discussion, "quality" will be used to denote attractiveness to the consumer, whether the commodity is to be marketed fresh or in some processed form. Quality factors associated with health and food value will not be considered. Attractiveness to the consumer is associated primarily with appearance, flavor, and texture. However, quality standards applied under state and federal regulations usually relate solely to appearance.

For convenience of discussion, plant nutrition – fruit quality interactions will be segregated into three categories, as follows:

1. Nutrient deficiency, excess, or imbalance resulting in appearance abnormalities and necrotic areas in fruits.
2. Nutrient deficiency or excess affecting fruit quality, but with no necrotic areas in fruits.

Appearance abnormalities with necrotic areas in fruits

This category includes primarily those disorders in which necrosis of limited areas of tissue occurs. If necrotic areas develop while fruit...
enlargement is still taking place, fruit distortion is likely. The degree of visible distortion is related to the time in the life of a fruit when internal symptoms first occur, and the location of the involved areas. Large scale ripening-related edge distortion can be great. However, considerable distortion may occur even during the latter weeks of maturation, if necrotic areas are not too deeply imbedded. Those disorders occurring after fruit enlargement is nearly complete, or during the postharvest period, do not cause distortion; but sunken spots may appear due to desiccation of necrotic areas in surface or nearsurface tissues.

Among deciduous tree fruits, apple disorders have received major attention. Research on so-called “corking” disorders of apples has recently been reviewed (3). The causes of most corking disorders either are not known or are not understood. There is convincing evidence that B deficiency is associated with, or is the basic cause of, drought spot, brown rot, “monkey face,” olives, and malformation, corking, or cracking of stone fruits (2, 3, 4, 10, 11, 16). Symptoms may develop early in the life of a fruit, thus resulting in severe distortion. B deficiency is usually correctable by periodic applications of small amounts of borax to the soil, or by foliar sprays of soluble B compounds.

In recent years, Ca has received considerable attention in relation to corking disorders (3, 6, 9, 10, 18, 16, 17). Several possible roles have been ascribed to Ca, but it is doubtful that sufficient information is yet available to give assurance to any assigned role. In addition to Ca, evidence is also strong that Mg and N, and perhaps other elements, are implicated in bitter pit of apples, and perhaps cork spot of pears. However, the incidence of these disorders has only been lowered, not eliminated, by nutritional manipulations. It is obvious, therefore, that other, unknown factors are important, in addition to known cultural relationships, such as crop load, fruit size, and harvest maturity. Identification of specific corking disorders by symptoms may be highly confusing, particularly if more than one disorder is present. Elimination of conflicting results is unlikely until basic causes of the disorders are better understood.

Most “corking” disorders are sufficiently detectable at harvest to permit elimination of affected fruits. However, bitter pit may develop during storage or transit, and thus affected fruits may enter market channels with results financially disastrous to the owner.

Black-end of pears, a disorder associated with rootstock-stock-clone interaction, seems, in part, to be nutritional in origin. Affected fruits of both ‘Bartlett’ and ‘Anjou’ have been found to be lower in Ca than normal fruits (17). In California, the disorder has been greatly reduced by higher Ca nutritional levels and improved irrigation practices.

**Fruit quality affects but no necrotic areas in fruits**

Significant deficiencies of most essential elements are detectable by leaf symptoms, even when no fruit symptoms are visible. The same may be true where excesses exist, particularly of sodium or chloride ions. Although fruits may have no abnormal features, the partial loss of photosynthetic capacity that usually accompanies such deficiencies or excesses is likely to result in reduced fruit size, lower soluble solids content, and changes in other chemical constituents, depending on the species and variety. These changes may greatly affect the quality of the fresh commodity, as well as of products manufactured from it, such as canned fruits and wines. High flavor is normally associated with high soluble solids, as are also storage and shelf life. The most serious problem may occur when the nutrient deficiency is accompanied by a heavy fruit crop, as has often happened with K-deficient prunes in California. Mn, Zn, K, Fe, Mg, Cu, P and N have all been reported to influence fruit quality.

Some mineral deficiencies lead to visible fruit symptoms, in addition to small size. For example, Zn deficiency may cause peach and cherry fruits to have extended, pointed, stylar ends, and to cause dark cherries to be poorly colored. Iron deficiency may also result in pale spots of color and failure of normal skin color to develop, as in “white” prunes and pale-green nectarines.

Where the seed is the edible portion, as in nuts, nutrient deficiency may also influence quality. For example, Cu deficiency is reported to result in poor kernel development of Persian walnuts (J. G. Brown and E. F. Serr, unpublished).

**Nitrogen nutrition**

Relationships between nitrogen nutrition and fruit quality are of great interest. Considerable evidence has accumulated as to ways in which N may affect quality. Such quality effects may be subtle and indirect. Vegetative symptoms related to nitrogen are generally lacking, except as leaf size and color and tree vigor may be affected. Most fruit symptoms can hardly be classed as abnormalities. Visual effects of color, size, shape, and maturation, and chemical constituent effects, may be correlated with nitrogen levels. High N has also been attributed to contributing to susceptibility of apples to bitter pit (10) because of the stimulatory effect of N on tree vigor and fruit size. For the same reason, some investigators have reported apple scald to be increased by high N; but there are contradictory findings (14). Keeping quality of apples has been associated with N level in the fruit (7, 8, 14).

**Uniformity of maturity**

The frequent observation that high N delays maturity of tree fruits (1) does not mean that time of maturity is a quality factor, but some of the physical characteristics associated with maturation do affect quality. For example, a reduction in pigment of red cultivars is often associated with delayed maturity and high N. Such a loss of color definitely reduces the grade (8) and value of fruits for the fresh market. Therefore, it is useful to relate N to characteristics of fruit maturation.

Uniformity of maturity is an increasing problem as the number of harvests are reduced due to increasing labor costs and decreasing availability of competent pickers. When once-over hand or machine harvest replaces multiple harvests, the problem of uniformity of maturity is even more acute. High N tends to increase the variability of maturity among trees and among fruits on the same tree. As a result, in commercial practice two things may happen — the harvested commodity is likely to be sufficiently variable to lower grade, and recoverable yields of marketable fruits are likely to be reduced. The grower tends to delay harvest to increase the percentage of fruits in the acceptable maturity range; and, while he delays, many fruits may become sufficiently advanced in maturity that they bruise easily. This could result in a severe loss of quality, and reduces the potential to survive the subsequent marketing system, whether the ultimate use is in the fresh or processed state.

Irregular ripening has been a major quality problem in apricot canning. It is aggravated by variability in ripeness among different parts of the same fruit, in addition to variability among fruits. For example, the stem end may be green when the stylar end is ripe for canning. Uriu and Claypool (unpublished) found this situation to be closely correlated with N levels in the leaf or fruit. With very high N, plus applications of 2.4-D or 2.4,5-T, the stylar end of an apricot became overripe while the stem end was still several days from harvest maturity. It is impossible to obtain a high quality canned pack when variability exists between parts of the fruit.

Discoloration of canned freestone peaches in California, although primarily a maturity problem, is also associated with high N. Maturity indices may be influenced differently by high N. For example, loss of chlorophyll is retarded, as may also be filling of the cheeks, causing the peaches to appear immature, but fruit softening and development of anthocyanin pigment in the inner flesh and adjacent to the pit cavities may be little affected. A delay in hardening of stone fruits to “mature” actually results in high anthocyanin, which, after forming a metallic complex in the can, is readily oxidized to a brown product (5). Reduction of nitrogen levels and better control of harvest maturity solves the problem.

Some apricot cultivars, e.g., ‘Blenheim’ (‘Royal’), are susceptible to “pit-burn,” a disorder associated with high field temperatures. Susceptibility increases as maturity advances. If ambient temperatures reach 38-40°C, pit-burn is likely to occur. Cells in tissues near the pit die, and in time lose their liquid, leaving a void partly surrounded by brown dead tissue. However, if the tree is in a low N status, fruits exposed to the sun may exceed air temperature by almost 10°C, but with no heat injury occurring. On the other hand, if a tree has high N status, it is common to find heat-killed fruit (solar sunburn) of fruits whose temperatures do not exceed 35°C. Whether the actual cause of pit-burn is related to membrane permeability, enzyme activity, oxygen stress, or other factors is not known, but N is involved.

**Soluble solids and flavor**

Yields of tree fruits per acre increased dramatically in California between the mid-1920’s and mid-1950’s. Since these increases have been modest, with the greater part attributed to improved nutrition, primarily involving N and water. Concurrently, the soluble solids content of the juice has considerably diminished (Table 1). Since high flavor is normally associated with high soluble solids of the fruit (Fig. 1), the indications are that flavor quality diminished between the two periods.

N levels in the tree may greatly influence fruit bud formation and fruit-set. With favorable cultural practices and climatic conditions, it may be possible to increase yields to the point of overcropping and still produce fruits of satisfactory size and appearance, but low in soluble solids and flavor potential. When N is deficient, its application has increased both yield and soluble solids in fruits. However, when N
is further increased to excessively high levels, soluble solids may diminish (Fig. 2). Observations of orchards with very high N levels have indicated that vigorous vegetative growth may occur during the period of fruit maturation. Competition between fruits and new shoot growth for photosynthetic capacity could readily account for reduced soluble solids under normal crop loads. Supporting observations have been made both on 'Bartlett' pears and cling peaches. The vigorous second flush of new shoot growth has not been observed on pears from all climatic zones.

It does seem clear that N nutrition can affect fruit quality by the influence it may have on crop load, photosynthetic efficiency, and new shoot-fruit competition for carbohydrates.

While high N has been reported to lower soluble solids in a number of instances, flavor information has been contradictory. Both improved flavor and poorer flavor have been reported for peaches having high leaf N (13, 15). It seems likely that differences in soluble, nonsugar constituents account for such results. Tannin-type compounds are often sufficiently high in low N fruits to detract from flavor. Under a high N regime, however, tannins may be at a level that enhances flavor. In studies with cling peaches a moderate N level gave significantly better flavor than did very low or very high levels, although correlation coefficients were not high.

Another area of interest relates to the subtle chemical effects N may have that influence the quality of canned fruits. Apricots, particularly 'Blenheim', are subject to softening in the can, which involves degradation of cell walls. One type of softening is significantly correlated with low pH and high acidity. Claypool and Uriu (unpublished) found that increasing N increases pH and lowers acidity of the fruit. Therefore, increasing the N level may have a desirable effect in reducing softening of the canned fruit; but at high N levels, irregular ripening may be a problem. There is a climatic override that may mask the N effect, as warm temperatures during final maturation also increase pH and lower acidity.

The examples I have mentioned, which implicate N directly or indirectly with specific aspects of fruit quality, are of value in pointing out the need for more complete information on fruit tree nutrition as it affects fruit quality. Such information is needed not only for N, but for other elements as well. Where possible, observations should carry through the distribution system. A coordinated effort by specialists in fruit tree nutrition, postharvest physiology, and food science could be worthwhile in this important area.

### Table 1. Approximate changes in soluble solids content and yield of selected cultivars over extended time period.

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Years</th>
<th>Low</th>
<th>High</th>
<th>Yield/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peach (Elberta)</td>
<td>1925-26</td>
<td>11.6</td>
<td>13.6</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>1958-59</td>
<td>9.4</td>
<td>13.0</td>
<td>8.4</td>
</tr>
<tr>
<td>Plum (Duarte)</td>
<td>1925-26</td>
<td>12.8</td>
<td>14.6</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>1958-59</td>
<td>9.6</td>
<td>12.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Pear (Bartlett)</td>
<td>1925-26</td>
<td>11.6</td>
<td>16.6</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>1953-55</td>
<td>9.9</td>
<td>13.1</td>
<td>8.8</td>
</tr>
</tbody>
</table>

3Adapted from reports of California Crop and Livestock Reporting Service.

### Literature Cited