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Curvilinear Relationship between Leaf Nitrogen and Yield of Fuerte Avocados[1]

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There is little experimental evidence relating nitrogen nutrition to fruit yields of avocados. One of the major reasons for this lack of information is the extremely high variability in yields (5). In a progress report in 1955, Embleton, Jones, and Kirkpatrick (3) presented evidence that, in California, production of Fuerte avocados may be greater when the nitrogen level in leaves that expand in the April-June period and are sampled in the August—September period, is maintained at approximately 1.8 per cent than when the nitrogen level is maintained above 2.0.

In a 1958 progress report Embleton *et al.* (2) presented results from experiments with several avocado varieties indicating that fruit yields resulting from very high rates of nitrogen were lower than those from moderate rates of nitrogen. The same rate of nitrogen applied to three different avocado varieties in the same location resulted in different nitrogen levels in the leaves (3). The present report presents results from an experiment on Fuerte avocados indicating that a moderate level of nitrogen in the leaves resulted in higher fruit yields than either a high or a low level.

MATERIALS AND METHODS

The experimental orchard has been described by Labanauskas *et al.* (8). The Fuerte avocado trees were planted in northern San Diego County in 1939 on Ramona sandy loam (stony phase), a light-textured, well-drained, shallow, acid alluvial soil having a cation exchange capacity of less than 4 me per 100 grams. The soil was nontilled; irrigation was by individual under-tree sprinklers; and weeds under the trees were controlled by herbicides. Prior to the establishment of the experiment in 1951, the avocado trees received 3 pounds of nitrogen per tree annually in three applications of sulfate of ammonia broadcast under the trees. The last general application was 1 pound of nitrogen per tree in the spring of 1950.

In 1951, 19 fertilizer treatments were established in single-tree plots replicated five times in a randomized block design. Thus 95 trees were used in the study. The fertilizer treatments included various rates and combinations of nitrogen, phosphate, potash, dolomite, and steer manure. Plots of 6 treatments (30 trees) received no nitrogen from the spring of 1950 through 1954; they then received ½, ½, and ¾ of a pound of nitrogen per tree in 1955, 1956, and 1957, respectively. The 5 trees of one treatment received no nitrogen from the spring of 1950 through 1957. The 60 trees of the remaining 12 treatments received 2 pounds of nitrogen per tree annually, from 1951 through 1957,

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from chemical sources or from steer manure mulch. Two pounds of nitrogen applied in manure mulch did not result in as high a level of nitrogen in the leaves as 2 pounds of nitrogen applied from chemical sources (1). Thus the fertilizer treatments resulted in a wide range of nitrogen levels in the leaves.

Yield in pounds of fruit per tree were recorded every year, starting in 1953. Annual single-tree samples of 20 leaves that had expanded in the April—June period were taken in the August—October period from non-fruiting shoots from all trees, starting in 1952. The leaves were washed in distilled water and dried in a forced-draft oven at 55° C; the blades and petioles were then ground together in a Wiley Mill. Nitrogen was determined by the micro-Kjeldahl method and expressed on a dry-weight basis.

The Fuerte avocados in the area of the experiment are generally harvested in the spring about 12 months after bloom. The yields for 1956 and the nitrogen levels in the leaves for 1955 were not included in the study because the 30 trees that received no nitrogen from 1950 through 1954 were by then so deficient in nitrogen that they had to be fertilized with nitrogen in the spring of 1955. Thus during bloom arid fruit set in 1955 these treatments were not under the Cull influence of the new nitrogen program, but by October, 1955, when the leaf samples were obtained the nitrogen applications had a marked effect on the nitrogen levels in the leaves.

A statistical study was made of the influence of nitrogen in the leaves 011 fruit yield. A second degree equation was fitted as outlined in Snedecor (9). Nitrogen levels in the leaves for each of die 95 trees for each of the five years were related to fruit yields that were obtained in the spring following each of the leaf-sampling dates. This gave 475 pairs of observations for the calculation of the curvilinear regression of fruit yield on the percentage of nitrogen in the leaves. The curvilinear regression of fruit yield on nitrogen concentration in the leaves was calculated on a "pooled within-years" basis without regard to fertilizer treatment *per se.*

RESULTS

The curve in Fig. 1 shows the calculated curvilinear regression of fruit yield on the percentage of nitrogen in the leaves. The multiple correlation coefficient (R) is small, indicating that a large portion of the variability in yield is still unaccounted for. This is not surprising since avocado yields have been found to be extremely variable (5). However, the approach presented in this paper offers one method of handling such variable data and does show that nitrogen is one of the controlling factors in avocado production. The curvature in Fig. 1 is statistically significant at the 1 per cent level of probability. Nitrogen levels in the leaves ranged from 1.26 to 2.49 per cent on a dry-weight basis.

As might be expected, the lower values of nitrogen in the leaves were associated with lower fruit yields. The predicted peak of the curve (Fig. 1) occurred at 1.79 per cent nitrogen. With nitrogen in the leaves ranging from 1.79 to 2.49 per cent, predicted yields of fruit progressively decreased.

Generally, when the observed value of nitrogen in the leaves was less than 1.5 per cent, trees were obviously deficient in nitrogen. The leaves were small and pale-green or yellow in color, and the trees produced very little new growth. Yet this severe stress for nitrogen was not associated with as low a yield as was the very high level of nitrogen in the leaves.

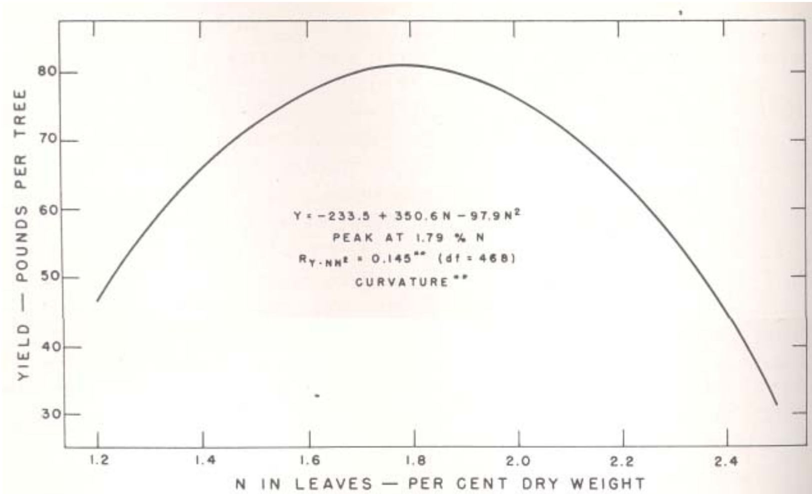

Fig. 1. Curve showing, for five effective years, the curvilinear regression of fruit yield (ordinate) on the percentage of nitrogen in the leaves (abscissa) of Fuerte avocado on a "pooled within-year" basis without regard to fertilizer treatment *per se*. The association of fruit yield in this manner with leaf nitrogen obtained in the August–October period prior to fruit harvest is supported by statistical odds of more than 99 to 1.

DISCUSSION

In spite of the extreme variability in avocado fruit yields we may conclude from the results of this study that maximum production of Fuerte avocados occurs at a moderate level of nitrogen in the leaves and that reduced fruit yields occur at nitrogen concentrations above and below this moderate level.

The lower yield with nitrogen deficiency needs no explanation. The reduced yield associated with the higher levels of leaf nitrogen satisfies the Kraus and Kraybill hypothesis (6) concerning the inverse relation between vegetativeness and fruitfulness. The avocado trees that had less than 1.5 per cent nitrogen in the leaves were relatively low in production, and the small amount of vegetative growth that was produced was light green or yellow in color and the leaves were small. The trees that had nitrogen leaf values near the predicted peak of the curve (1.79 per cent nitrogen) produced the most fruit, were moderately vegetative, and produced leaves that were darker green in color than those with a lower nitrogen content. Trees that had the highest percentages of nitrogen in the leaves were the least productive trees, were very highly vegetative, and had large, dark-green leaves.

Interactions of nitrogen with other elements such as zinc, copper, or boron (4, 7, 8) may play a part in determining the shape of the curve in Fig. 1. Work is underway to determine the importance of such interactions.

Regardless of the explanation of the observed results, the fact that lower yields were associated with high leaf values for nitrogen is important. The high leaf values for nitrogen were produced with a maximum of 2 pounds of nitrogen per tree per year.

Many Fuerte avocado growers in California use more than 2 pounds of nitrogen annually on trees of similar size under similar cultural practices. These results indicate that, on Fuerte avocado, a grower who uses high rates of nitrogen to produce dark-green, highly vegetative trees may not only be spending more money on fertilizer than is necessary, but may also be reducing his total production.

At or near the peak of the curve in Fig. 1 there is a rather wide range of nitrogen percentages in the leaves that was associated with only slight differences in yield. This suggests that for Fuerte avocado an arbitrary range of from about 1.6 to 2.0 per cent nitrogen in the leaves in the latter part of the summer would be a desirable level to strive for to maintain high production.

The authors are not aware of any other report showing a curvilinear relationship between nitrogen in the leaves and fruit yield of tree crops.

SUMMARY AND CONCLUSIONS

Yields and percentages of nitrogen in Fuerte avocado leaves were obtained on an individual tree basis from 95 trees for five production years from an experiment in which differential levels of nitrogen in the leaves were created by various fertilizer treatments.

The curvilinear regression of yield on the percentage of nitrogen in the leaves on a "pooled within-year" basis without regard to fertilizer treatment *per se* was significant statistically at the 1 per cent level of probability.

The highest predicted production was associated with 1.79 percent nitrogen in leaves that expanded in the period April-June and were sampled in the period August-October.

The highest nitrogen values in the leaves were associated with lower yields than were nitrogen values obviously in the deficient range for vegetative growth and fruit production.

The highest nitrogen values in the leaves were obtained with a maximum annual rate of 2 pounds of nitrogen per tree. Many Fuerte avocado growers in California apply higher rates of nitrogen than were used in this experiment.

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