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The Effect of Adjacent Trees of Other Avocado Varieties on Fuerte Fruit-set[1,2]

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Abstract. Fruit-set on trees of the Fuerte avocado in relation to distance from trees of the Hass and Topa Topa varieties in a Southern California grove was analyzed. The presence of adjacent trees of a second variety was associated with an average Fuerte yield increase of about 40%. In certain years there were statistically significant yield decreases on the Fuerte trees adjacent to other varieties. No effects beyond the first row were evident. Cross-pollination appears to be the most probably explanation of the yield increases.

INTRODUCTION

Low and irregular yields are a major problem of avocado *(Persea americana)* production in California (1, 10). Average annual yield per bearing acre has been only about 3,700 Ib (15), in comparison with an estimated Florida average of 6000 Ib/acre (8, 16).

The Fuerte variety accounts for about 60% of California's avocado production. Its bearing habits are notoriously erratic (1). A study was made of Fuerte fruit yields in relation to distance from interplanted trees of 2 other varieties.

MATERIALS AND METHODS

The grove of J. M. Best, in the Pauma Valley of San Diego County, was planted in 1950. One part of the grove had Fuerte trees spaced 28.3 feet each way, with trees of the Topa Topa variety inter-set at every tenth Fuerte row (Fig. 1) for windbreak purposes. Each Topa Topa tree was planted equidistant (20 feet) from each of the 4 Fuerte trees surrounding it. Additional irrigation water and fertilizer have been provided for the Topa Topa interplants. By 1962, a few of the more vigorous Fuerte trees had their branch tips meet; 2 or 3 years earlier, the Topa Topas began to interlace branches with the Fuertes surrounding them. The section selected for yield analysis (Fig. 1) provided a comparison of the 6 Fuerte columns adjacent to Topa Topas ("treated") with the remaining 16 Fuerte columns ("check"). Thus, there were initially 66 treated and 176 check trees. Due to topworking, the number of check columns decreased to 15 in 1958 and to 12 in 1961.

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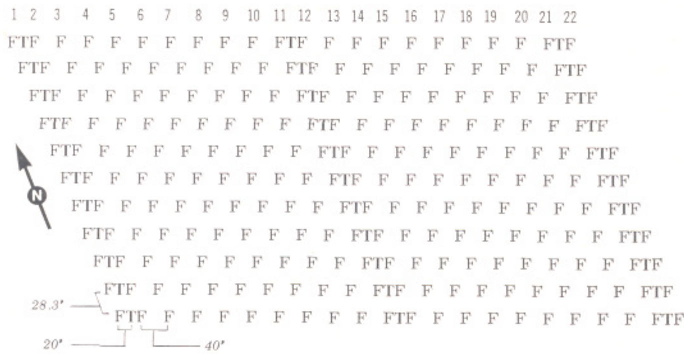

Fig. 1. Grove layout of section analyzed, guard trees not shown. F = Fuerte, T = Topa Topa.

A second section of the grove provided a comparison between 33 check Fuerte trees solidly planted, and 22 treated Fuertes each of which had trees of the Hass variety adjacent on 3 sides. Tree spacing was 20 X 20 feet regardless of variety.

Yields were determined by fruit counts on the tree in autumn prior to the windy season. The necessary precautions in such fruit counting have been discussed elsewhere (2).

This region experiences strong fall and winter winds. Topa Topa trees are upright growers and average considerably taller than the Fuertes in the Best grove. Hence, better fruit set on Fuerte trees adjacent to the Topa Topas might be due to wind-protection. To test this possibility, in 1957 fruit counts were analyzed in terms of the respective tree quadrants, for 36 check and 12 treated random Fuertes.

RESULTS

In this section interplanted to Topa Topa, counts of Fuerte fruits were made each year 1957 through 1961 (Table 1). The test of significance in the analysis of variance is theoretically not valid, since the treatments were obviously not assigned at random. Nevertheless, the balanced nature of the experimental design largely rules out confounding from gradient influences, and we believe that the probability levels as calculated are an accurate reflection of the biological factors involved.

Table 1.—Mean number of fruits on Fuerte trees as influenced by adjacent trees on Topa Topa.

Year	Checks	Adjacent to Topa Topas	Percent increase	Significance of the difference[a]
1957	83.7	203.1	143	***
1958	339.8	299.7	–12	*
1959	322.5	447.9	39	***
1960	112.1	61.5	–45	***
1961	249.3	505.8	103	***
Average	221.4	303.6	37	

[a] * = Probability less than 0.05.
*** = Probability less than 0.001.

In each of the odd-numbered years, Fuerte trees next to Topa Topas yielded highly significantly more fruit than the checks. In the 2 even-numbered years the checks significantly out-yielded the treated.

At least 3 additional influences appeared to be affecting fruit set in this grove: 1) general avocado set in Southern California has fluctuated widely from year to year (15); 2) the trees have become larger each year, and by 1962 had not reached maturity or general crowding; 3) there has usually been a yield gradient, with higher set toward the west side of the grove. This gradient is probably a result of the severe winds that are generally from the east. The eastern boundary of the grove marks the limit of agricultural operations in the area.

For 1958 and 1960 the analysis of variance showed no significant difference among columns within the 2 groupsof check and treated trees, and the difference was just at the 5% probability level in 1961. But for both 1957 and 1959 the test for homogeneity gave F values indicating highly significant deviations. Thus, the unadjusted 1957 data resulted in an F value for difference between check and treated columns of over 48 times its standard error. When the original data were adjusted for regression on column number, i.e. transformed to compensate for the east-west yield gradient so that greater precision in the analysis is achieved, the F value became over 129 times its standard error. We do not know why this east-west yield gradient should be of appreciable magnitude only during the years when trees adjacent to Topa Topas set more fruit. The indication from the 1961 data that the gradient is decreasing may be a reflection of the fact that the trees are now larger and so better able to provide mutual protection against the winds.

Fig. 2 illustrates the 1961 results. Column averages within both the check and the treated groups varied considerably. Avocado fruit set is notoriously erratic on a tree-to-tree basis (12). The original counts show that the individual tree totals varied from 9 to 609 fruits among the 132 check trees—and these 2 extremes were on consecutive trees in column 14. For the 66 Fuertes next to Topa Topas, the tree totals had a range from 185 to 872. Also, an east-west yield gradient is indicated. In spite of these complications, Fig. 2 shows that the column means of check and treated trees are discrete.

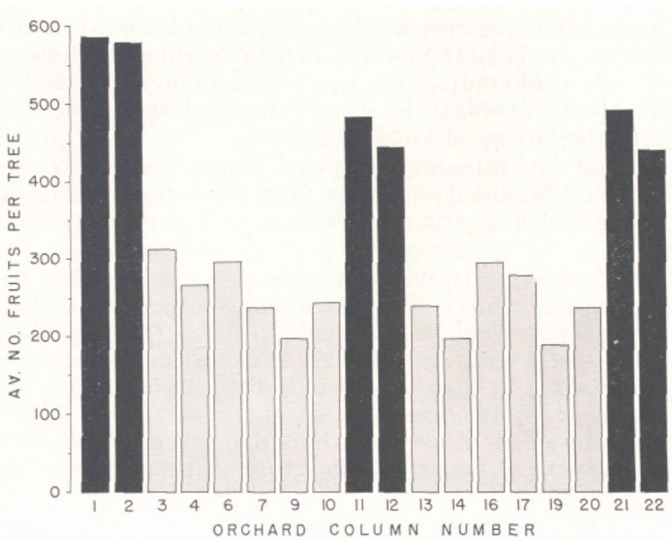

Fig. 2. Fuerte fruit set in relation to Topa Topa interplants, 1961. The dark bars represent yield averages on the Fuerte trees adjacent to Topa Topas.

Similar Fuerte fruit counts were made for 3 years in the Hass-interplant section of the grove (Table 2). The maximum fruit-set increases were smaller than with Topa Topa, but the increases were more consistent with Hass, and all were highly significant.

In the study of possible wind effects, fruit number averages for the respective quadrants were as follows.

Quadrant:	*North*	*East*	*South*	*West*
"Check" trees:	19.6	7.6	18.7	24.3
"Treated" trees:	63.0	36.5	72.6	78.4

In both cases, the east quadrant (the windward side) averaged fewest fruits, and the west quadrant the most. A multiple range test showed that in both cases the east quadrant had significantly fewer fruits (<0.01 for the checks and <0.001 for the treated trees). No differences among the other 3 quadrants were statistically significant. A count of missing main branches in the different quadrants showed that both the check Fuertes and those adjacent to the Topa Topa windbreak had less than 1% of their limbs missing in the north, south, and west quadrants. On the east side, main limbs were absent in 22% of the check trees and 33% of the treated ones.

Table 2.—Comparative mean yields of Fuerte trees alone and interplanted with Hass.

Year	Fuertes only	With Hass interplants	Percent increase	Significance of the difference[a]
1957	102.2	156.5	53	**
1958	225.7	302.1	34	**
1960	21.3	38.2	79	**
Average	116.4	165.6	42	

[a]** = Probability less than 0.01.

DISCUSSION

The data from the Hass-interplant section are less meaningful than those from the Topa Topa section since only one-third as many trees were available; counts were for 3 years instead of 5; and the experimental design involved 2 section-halves corresponding to the 2 treatments, so that that there were no true replications. Soil or other environmental gradients could bring about the indicated treatment differences where none actually existed. However, the compactness and the apparent tree uniformity of this second section makes it unreasonable that differences of the magnitude obtained could result from influences other than the differences in degree of proximity to a second variety.

Results from the Topa Topa section of the grove show that proximity effects were not present every year, and suggest plausible reasons why this should be so. Yields of the Fuertes next to the Topa Topas averaged 2.5 times as great as on the check trees in 1957 (Table 1), and avocados in California are commonly highly alternate in bearing (10). The spring of 1958 was a very good year for Fuerte set, as evidenced by the Fuerte yields throughout southern California (15). So the Fuertes adjoining Topa Topas set well, but slightly less than the check trees, for which the previous season had been an "off" year in terms of yield. The spring of 1959 was the third consecutive year of conditions favorable to Fuerte set (15). The check trees averaged about as much as they had in the previous year while the Fuertes adjacent to Topa Topas set their largest crop to date: about 40% more than the checks. The spring of 1960 was not favorable for Fuerte set (15), and the check trees had a light crop. But the trees near Topa Topas had almost a crop failure: their bloom that spring was very light, indicating that the extremely heavy crop of the previous year had largely exhausted necessary nutrient reserves, perhaps of starch (4). The spring of 1961 was moderately favorable for Fuerte set, and the checks averaged a good crop; the trees next to the Topa Topas yielded even more heavily than in 1959, presumably due to their combined advantages of less set the year before and proximity to a second variety.

Cause of the increased fruit set: The early work of Nirody (14) and of Stout (18) showed that avocado flowering is characterized by synchronous dichogamy: the flowers of a particular variety are normally male during one period of the day and female during a different period. Hence, they postulated a need for cross pollination by a variety with a different flower behavior pattern. But Clark (7) found that trees screened to exclude insects that might bring in pollen of another variety, set fruit abundantly when bees were placed inside the screen to provide intra-tree pollination. Also, large blocks of a single variety frequently set good crops of fruit in California (10). So the need for cross-pollination was discounted in this state (5, 10, 17). A similar conclusion was reached in the Rio Grande Valley (6), but some evidence to the contrary was noted in Florida (16).

There are other possible explanations of our observed fruit set increases. The presence of one variety may result in an environment more conducive to fruit-setting in a different variety. Thus, in the Hass-interplant section, the Hass trees have grown more slowly than the Fuertes. Fuertes in a solid block would fill in and begin to suffer from mutual competition, such as shading, sooner than when interplanted with Hass. However, the additional crowding actually present appears to be too small to explain the yield differences. Moreover, the reverse situation, and to a much more marked degree, was present in the Topa Topa section; increased set was associated with increased tree crowding. One might hypothesize that two adjoining varieties make more efficient use of the available nutrients or other limiting factors, and possibly even have some sort of mutual, or at least unilateral, beneficial effect of one on the other. But no effects of this kind have been reported for avocados, and it appears most unlikely that such factors could account for yield increases of about 40%.

Another possible explanation is wind protection. Windbreaks have been observed to enhance fruit set (13). The Topa Topa windbreaks undoubtedly reduced air movement in nearby Fuertes. This would result in higher temperatures when cool breezes blew during the spring fruit-setting period. Avocado fruit set in California has been shown to vary directly with average spring temperature (10), and to be reduced by chilling breezes (9), especially in Fuerte (11). Windbreaks also lessen injury from hot dry winds, during the blooming period (3, 10, 13). By reducing tree desiccation (16), the windbreak may reduce internal moisture stress at a critical period so as to minimize the abscission of young fruit. Under some conditions, windbreaks promote tree growth and so a larger bearing surface, by protecting against both chilling and drying winds (9, 10). Windbreaks may reduce windfall losses prior to fruit harvest (or count). They may also increase set by permitting greater insect activity, especially of honey bees, as an indirect effect of higher temperature and through reduced air movement *per se* (13). Bees are very important for avocado fruit set in California (7, 10).

The results from the analyses by tree quadrants showed that the windward (east) side of the check Fuertes had a much higher proportion of missing limbs and averaged less than half as many fruits as the other 3 quadrants. Evidently wind has played a major role in determining tree shape and so fruit distribution in this grove. But the trees adjacent to the Topa Topa windbreak were of similar conformation; they had actually a higher proportion of missing east-side limbs than did the checks, and their east quadrants yielded less than the other 3 quadrants to a degree that was statistically more significant than in the case of the check trees. Moreover, the exposed quadrant of the adjacent trees averaged more fruits (36.5) than the most sheltered quadrant of the check trees (24.3). This indication that wind protection is not the dominant factor increasing yields adjacent to the Topa Topas is supported by the fact that in other years, with comparable east winds, the check trees set heavily (Table 1). Also, if wind reduction were a major factor, much greater benefit would be expected on the leeward side of the windbreak. Fig. 2 shows that in 1961, for each of the 3 pairs of Fuerte columns adjacent to the Topa Topas, the leeward column has a slightly greater set. But in 1957, when the check-treatment proportionate difference was even greater (Table 1), the largest leeward-windward difference was in the reverse direction.

It seems likely that the several environmental influences discussed all had some effect upon fruit set in the grove examined. But the evidence, including the need for postulating over-compensating influences for reversed situations of tree crowding, makes it appear unlikely that such indirect environmental effects are the principal cause of the large yield increases frequently found associated with variety interplanting. Rather, cross-pollination would seem to be the most plausible explanation. This also was the tentative conclusion, based on less reliable experimental designs, from avocado yield analyses of various varieties at various locations in Southern California (2).

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