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Avocado Tree Arrangement and Thinning in Relation to Cross-Pollination

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Benefits of cross-pollination

It has now been definitely shown that California avocado production can be increased by the interplanting of two or more varieties (4, 5, 6, 11). Contrary to our earlier conclusions (10), cross-pollination evidently increases avocado fruit-set. The observed average increased set of about 40% may well mean a doubling of the grower's net profit-since fixed costs represent a large proportion of his debits.

However, this does not necessarily mean that it will pay a grower to plant his orchard in such a way as to permit maximum cross-pollination.

If I had a healthy Fuerte grove anyplace in the avocado-growing parts of California, I would make provision for cross-pollination. But one is more hesitant to urge action that requires others to spend their money. And, especially for varieties other than the Fuerte, more data are needed.

In the first place, we do not as yet know how general in Southern California these cross-pollination effects are, nor how great they will prove to be on the average. The grove of John and Helen Best in Pauma Valley (6) is the only grove that I know of planted in such a pattern that cross-pollination effects can readily be measured and statistically analyzed. My measurements of other varieties in other locations (4) have also disclosed significant yield increases associated with the proximity of two or more varieties. But large-scale, better-designed experimental studies are needed in many locations.

A second reason for proceeding cautiously with commercial applications of our cross-pollination findings is uncertainty as to the relationship of costs to benefits. It is one thing to be reasonably certain that having nearby flowers of different varieties will result in more set fruit. It is another matter to be certain that the increased set will pay for the added expense of bringing the different flowers close together. As Kornhauser (15) put it in a different connection, "The basis for decision is always the same. If it brings more income than it costs, do it. If it doesn't, forget it."

Methods of enhancing cross-pollination

In one known case, an isolated seedling avocado tree had never set a fruit in spite of prolific bloom each spring. One year, branches with flowers and buds were cut from a second seedling and placed in the first, which then set a crop of fruit. This method has been used on a commercial scale with other tree crops. But the long flowering season of the avocado makes it of little use to us.

Bee hive pollen inserts have also proven an economically sound way to increase the

fruit-set of some deciduous fruits. But the long avocado bloom period, and especially the unique difficulty of collecting avocado pollen on a large scale, have prevented us from following this approach. It is hoped that research developments will eventually make pollen inserts useful also for avocado pollination.

There are at present 3 practical ways for the avocado grower to give his grove the benefits of cross-pollination.

First, he can plant trees of the two varieties in almost the same planting hole (12). This will result in “half -trees,” each on its own root.

Second, he can graft branches of a pollinating variety into the trees of his major variety. I have done this in the Pauma Valley grove of Doug Anderson on a fairly large scale. A number of varieties and selections have thereby increased Fuerte fruit-set. For some trees in some years the Fuertes with small flowering branches of a second variety have set over twice as much fruit as the check trees. The average increase has been considerably less. There is no evidence of benefits beyond the tree into which the graft has been inserted.

Finally, the grower can alternate trees of different varieties. This method is akin to the first, except that the trees are planted far enough apart for each to develop normally for many years. It is the method that will now be discussed in greater detail. Note that an alternating-tree situation can be achieved either by designing a new planting, or by suitable top-working. In a maturing grove, top-working may be desirable for other reasons (18, 19).

Alternating trees of different varieties

That is the layout of the Best grove (5, 6). Actually, they did not plan the design for cross-pollination. In one section, Topa Topa trees were interset at every tenth Fuerte row simply for windbreaks. As such they have indeed benefited the Fuertes—but the pecuniary gain from cross-pollination has probably been much greater. In another section of the Best grove, Hass and Fuerte trees were planted alternately at 20 feet each way, so that, when the trees began to crowd, the variety that had meanwhile proved less profitable could be removed.

The beneficial results from the Best grove show that this is a sound method for increasing fruit-set by cross-pollination.

Compared with the "combination-tree" and "branch-graft" methods, tree alternation has certain advantages. First, it can be combined with other benefits, such as windbreaks; in some cases, judicious pruning may permit windbreak benefits from the combination-tree type of planting also.

Second, it involves a more normal type of avocado grove, requiring little cultural care that will be new to the grower. In fact, there are some groves that already have this alternating pattern, for other reasons. With either of the other two approaches, careful annual pruning of the main variety, or the pollinator, or both, will be desirable; since the two varieties are in such close juxtaposition, a proper balance between them must be maintained by the grower.

However, tree alternation also has certain disadvantages. The closer together the

flowers of the two varieties are, the better the opportunity for cross-pollination. Hence, the situation that leads to a need for balancing pruning is the very situation that maximizes fruit-set increase. The fact that an alternating planting permits years of normal growth by each tree implies that the branch contact desirable for cross-pollination will for that period be lacking. Our results indicate that bees will rarely cross a gap of more than a few feet, once they have started working avocado flowers on a particular flight. In the Best grove, when the first Fuerte row from the Topa Topas set two-and-one-half times as much fruit as the check Fuertes, there was no significant increase of set in the second row. And within the first row, it has sometimes been observed that the heaviest Fuerte set was right next to a Topa Topa branch. In a grove with equal spacing of trees, the grower will have to wait some time for appreciable effects from cross-pollination.

A second disadvantage of the alternating-variety method arises when tree thinning becomes necessary. With the branch-graft or even the combination-tree approach, each tree (or tree-pair) is a unit, so that thinning poses no special problem. But complications arise when one has alternated trees so as to produce maximum cross-pollination effects from a proportionately few pollinator trees.

Tree thinning

Optimum avocado tree spacing at planting time is a controversial subject (9, 10, 18). Those who favor an original spacing suitable for mature trees point to the difficulty of having thinning done when it is needed. Most growers find it painful to remove *any* tree that is healthy and producing (10, 13, 15, 19). And crowding reduces fruit production.

This is not always understood by beginning growers and by others who have not actually studied the contours of their trees. They ask how production can possibly be reduced by the trees growing to completely fill the available space. The answer is that when trees have grown solidly together, the surface that they can expose to the sun is essentially a plateau along their tops. Conversely, when their branches did not yet quite meet, their exposed surfaces represented a series of domes, and so a much larger total area for the photosynthesis on which fruit production is based. Hoak (13) stated, "It has been proved conclusively that trees grown under these [crowded] circumstances are producing only a fourth to a third of their potential." This exaggerates the usual yield difference. But crowded avocado trees certainly yield less per acre (7, 10, 15, 19).

Since crowding is detrimental, and since experience has shown that many groves will not be thinned when they should be, plantings are sometimes made at a mature spacing of 40 or so feet either way. If this were the preferred practice, the whole subject of tree thinning could be ignored in a discussion of cross-pollination tree arrangement.

But I do not think that it is good practice. There are a number of advantages for a much closer initial spacing (1, 2, 3, 8, 9, 10, 13, 14, 17, 18, 19):

1. weed-control by shading
2. better use of irrigation water
3. removal of poor-bearing trees
4. uncertainty as to ultimate tree size

5. increased early income.

Points 4) and 5) are especially important.

Ultimate tree size and the time required to attain it will vary with: the variety; the quality of the trees; the soil, especially its depth; the cultural practices, especially fertilization and irrigation; the climatic conditions, such as chilling ocean breezes or frosts. Some of these factors will be unknown or beyond the control of the grower. If his spacing distance eventually proves to be too close, he can always thin. But if his spacing is too wide he can never recoup his financial losses. The time lapse before Fuertes spaced 20 x 20 begin crowding has been estimated as variably as 10 years (13) or 20 (19). And Averrett (1), while suggesting an eventual thinning to 40 feet each way, pointed out that under some conditions the ideal spacing might remain 20 feet "for all time to come."

Even under the reasonably good growing conditions that make thinning eventually necessary, closer initial planting is an excellent investment (1, 8, 10, 14, 19). The per-acre cost of trees, irrigation and fertilization obviously increase with tree number, but overhead costs mean that average tree cost varies inversely with tree number. *See* Todd (17) for an excellent discussion of the financial factors involved. In his hypothetical illustration, a grove planted 36 x 36 would show a net profit only after 16 years, while closer planting and thinning as needed would take the grower out of the red in just half the time.

Therefore, in any new planting it is economically sound to plant the trees much closer than mature size would permit. The psychological barriers that often cause needed thinning to be postponed from year to year, must be overcome by general publicity and by personal encouragement from Farm Advisors, neighbors and other friends. Kornhauser (15) noted that “Many a grower looks at his trees and says to himself that next year he will do something about thinning them out. But next year the crop looks just too good, or the family needs a new car ... and the thinning program is deferred for still another year. It takes courage to apply the axe to good trees.” Mr. Kornhauser explained how he had recently removed one-third of his own trees, and how the results in increased production "are little short of spectacular."

Furthermore, a crowded grove means that the fruit-set averages higher in the tree. Hence picking costs per fruit are also higher.

Some owners of smaller avocado groves beside their homes, may deliberately prefer a situation of crowded trees. I have been in groves so crowded that all the lower limbs had died and been removed—one could walk upright anywhere. This creates a "private park" that is fully shaded and thus pleasantly cool all summer. The effect can be delightful. But in such a case the grower is choosing to take part of his grove earnings in the form of non-pecuniary benefits.

To earn the most money from an avocado grove, plant close and thin when necessary.

Tree thinning is quite simple when a regular pattern is followed (1). When this pattern is modified as needed in order to remove a larger proportion of the poor-producing trees, the procedure becomes somewhat complicated (2).

But in a grove with varieties planted alternately for cross-pollination purposes, tree thinning can be much more complicated. This is not true of groves with such a simple

layout as half the trees of each variety, completely alternated, and equally spaced. One can then thin simply be removing every other row and so an equal number of trees of each variety. The remaining trees are as well cross-pollinated as ever.

Such an equally-spaced layout has the drawback that many years elapse before the flowers of the two varieties are close enough together for appreciable cross-pollination. Also, the requirement of about equal tree numbers introduces a rigidity that may not fit in with demands of the avocado fruit market, or with the grower's interests.

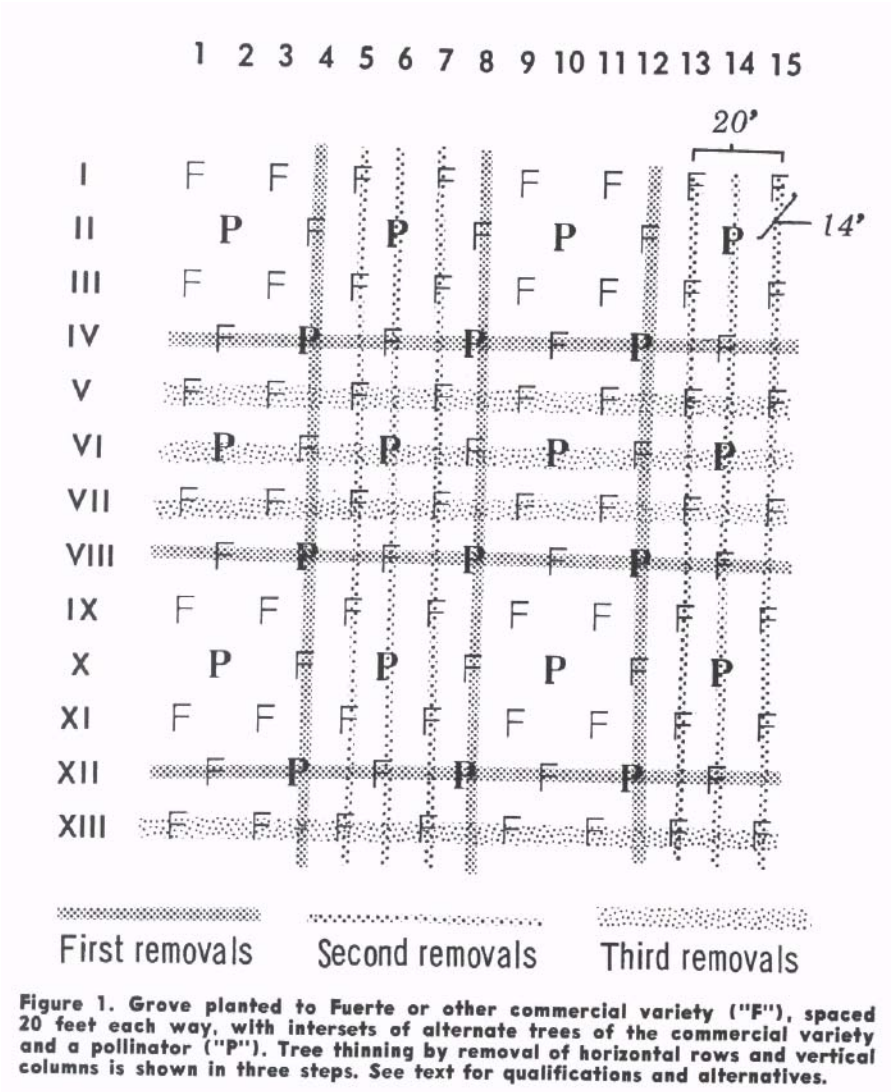

Figure 1. Grove planted to Fuerte or other commercial variety ("F"), spaced 20 feet each way, with intersets of alternate trees of the commercial variety and a pollinator ("P"). Tree thinning by removal of horizontal rows and vertical columns is shown in three steps. See text for qualifications and alternatives.

Figure 1 illustrates a design that has certain advantages. This layout has Fuertes initially 20 feet each way with alternate Fuertes and pollinators interset. The trees are equally spaced, but the basic distance apart is only 14 feet. Two-thirds of the Fuertes have two pollinator trees that distance from each of them; the remaining Fuertes have four pollinators each 20 feet away. Hence, when the trees are young the cross-pollination benefits are greater than in the case of the usual 20 foot or so initial spacings. The closer spacing is acceptable because few other varieties spread as vigorously as the Fuerte, and so the pollinator trees provide extra space before

crowding occurs. Moreover, cross-pollinated trees will be expected to set more fruit and therefore to grow a bit more slowly.

A second advantage of this design is the fact that the pollinator trees originally comprise only one-quarter of the total, the proportion declining to one-fifth of the total after the first thinning. Once the trees are large enough to overlap, a proportion of one pollinator to four trees of the main variety should be quite adequate.

The initial spacing in Figure 1 means 218 trees per acre. This seems like a large number. But it is probably financially sound, for the reasons cited above. Todd's (17) plan began with 269 trees per acre. His conjectural data, however, suggest almost no pecuniary advantage of this spacing over one involving only half the tree density. But there are two additional considerations that favor close planting. First, Southern California population pressures make it very difficult to predict the situation in any avocado area 10 or 20 years from now; this adds emphasis to short- and middle-term considerations. Second, even where the trees are initially so close that some must be removed before they have more than paid for themselves, these still might be a good long-range investment; in our humus-poor soils, their roots would be valuable and if the tops were shredded and left on the ground there would be further benefit.

The first thinning reduces the number of trees by three-eights, from 218 to 136. As shown in Figure 1, this is done by removing every fourth row, IV, VIII, XIII, XVI, etc.; and by removing the remaining trees in every fourth column, 4, 8, 12, 16, etc. One-third of those removed are pollinators. Depending upon the environment, and the length of time that the grove is retained, this could be the only thinning necessary.

The interset plants marked F, removed in this first thinning, might actually he of a more precocious third variety.

After the first thinning, the remaining trees form units of five; a pollinator with four Fuertes (or other variety) around it. Subsequent thinning should treat these units as if each were a complex tree. This means removing three rows (or columns) simultaneously. So the second thinning involves columns 5, 6, and 7, then 13, 14, and 15, etc. Similarly, the third thinning takes out V, VI, and VII, then XIII, XIV, XV, etc. The second and third thinnings could, of course, be reversed.

A weakness becomes evident. Removing three adjacent rows at the same time could leave large gaps in the grove. This weakness is inherent in any planting scheme that seeks to make the most effective use of a minimum of pollinators. But it can be greatly ameliorated by proper pruning.

Avocado pruning should be kept to a minimum, primarily limited to keeping branches from interfering with irrigation or other orchard operations. But it has a major usefulness, which pertains to tree crowding. Whether or not the planting is in solid blocks of one variety, prune to prevent crowding at the tree peripheries. Instead of beginning to decline, fruit production will keep on increasing, as the pruning maintains an orchard of ever taller domes. Even as the wise planter chose the very best trees for the ones placed where they would be permanent, so also he limits his pruning (to alleviate crowding) to the trees that will be removed in the next tree-thinning. Thus the permanent trees are allowed to develop normally. By the time that a row of trees is

ready to come out, they will be reduced to the upright form of the Lombardy poplar— or a crowded Zutano. This means much better production than when either of the two alternative procedures are followed: letting the adjoining trees just grow together and eventually removing whole trees; or removing the trees when crowding begins.

The problem isn't quite as simple when a cross-pollination design makes it desirable to remove tree rows in groups of three. But the arrangement is such that the distance between rows one and three is only 20 feet. By regular pruning as described above, one can reduce the width occupied by each temporary group of three rows to a minimum. This may be all that proves necessary; the first thinning and subsequent pruning may keep the grove in good production for its lifetime.

However, let us consider the case of good growing conditions and of no "subdivision-itis." Sooner or later a second thinning is necessary, which is carried out as shown in Figure 1. There is a mechanical advantage to having three adjoining rows removed at the same time; at least the smaller branches add their organic matter to the soil surface; and grove access roads are provided. (A modification, in which the middle row of the three is left in place much longer than the other two rows, is discussed under a second grove design, below).

The second thinning reduces the number of trees per acre from 136 to 68. A third thinning, if and when needed, reduces the tree number by half again, to 34. Seven of these would be pollinators.

Under superior conditions, still further thinning can eventually be carried out, each time by removing alternate 3-row tree units. Hoak (13) reported a grove that yielded over 20 thousand pounds per acre, in which the tree spacing was 90 feet each way—only five trees per acre. After our third hypothetical thinning described above, we have what is essentially tree-units spaced 60 feet each way; the tree units correspond to single trees, each on 5 trunks spread over 400 square feet, and each with pollinating-branches in the center.

Should not a thinning program aim at removal of the poor-setting trees? Such a practice involves complications and uneven tree spacing (2). In some cases the poor trees will be distributed unevenly enough that advantage can be gained by switching the row groups to be removed. Thus, in Figure 1, it might prove desirable to remove columns 1, 2, 3; 9, 10, 11, etc., instead of 5, 6, 7; 13, 14, 15, etc. But the desirable procedure is to keep yield records of at least the permanent trees. Any substandard tree is then promptly replaced.

The pruning needed to maintain a proper balance between main variety and pollinator trees will vary with the growth rate and habit of each. It will also vary with the relative commercial usefulness of the two varieties.

Figure 2 illustrates a somewhat different planting plan. It has Fuertes (or trees of another primary variety) initially spaced 20 feet each way. But in this case the pollinator trees are placed between column Fuertes, instead of in the center of four Fuertes.

A possible disadvantage here is the fact that the pollinating trees constitute one-third of the total. Pruning can greatly reduce their actual proportion of the total bearing surface. But it would be highly advantageous if they had real commercial usefulness on their

own. Hence the design would be suitable for the grower who might wish to go into the production of Topa Topa seeds for rootstocks. More generally, it would be suitable for the grower who wishes to produce fruit of both the Fuerte and a variety with "A" type flowers, perhaps the Hass. Indeed, if he wished he could reverse the F's and the P's in Figure 2 and so have twice as many Hass as Fuertes. This would provide abundant Hass cross-pollination for the Fuertes. In our experimental groves, Hass has given less dramatic Fuerte yield increases than the Topa Topa or Jalna varieties. But the yield increase has, in more limited tests, averaged nearly as great (4,5).

Another possible disadvantage of this second design is the unequal tree spacing. This must be regarded as a minor nuisance in comparison with the cross-pollination benefits that it makes possible.

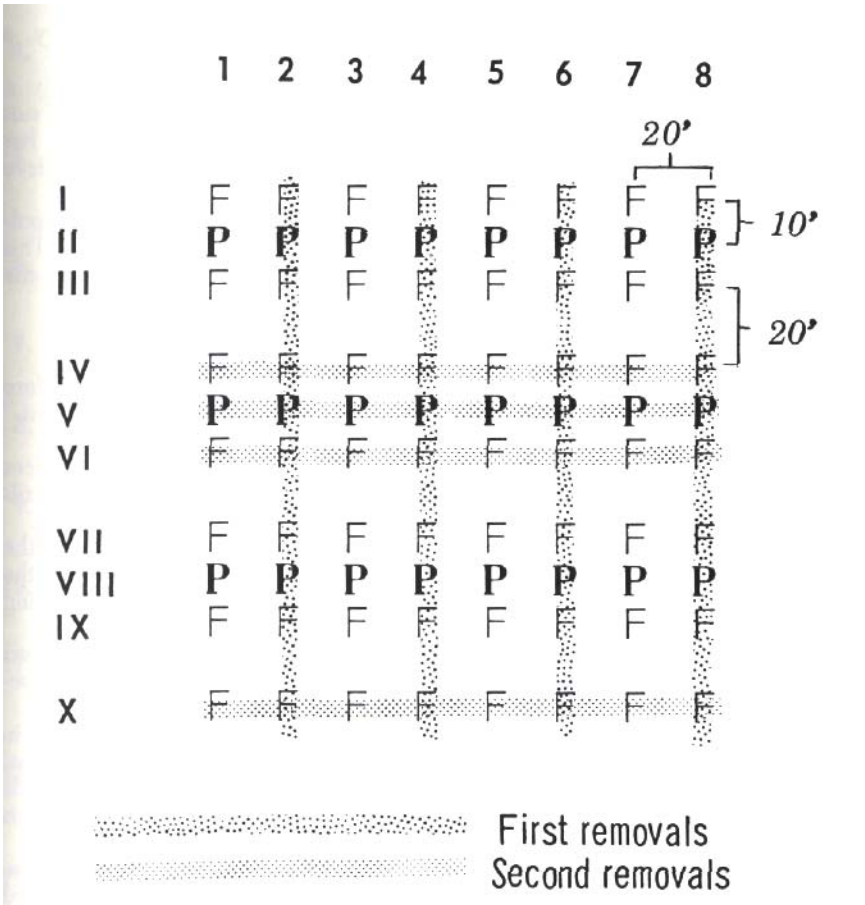

Figure 2. The symbols have the same meaning as in Figure 1. Thinning is shown in two steps, but could involve as many as four steps (see text).

An advantage is the fact that trees of the two varieties are planted only 10 feet apart. Hence there will be cross-pollination about as soon as the trees begin to set fruit.

The original planting is at 150 trees per acre. If thinning proves desirable, it removes every other column, 2, 4, 6, 8, etc., and so cuts tree density by half. This leaves tree-units again, now in clusters of three instead of five, with the centers spaced 40 feet each

way.

If a second thinning becomes necessary, this again involves the removal of rows in groups of three: IV, V, and VI; X, XI, and XII; etc. But the commercial value of both varieties, a probable Prerequisite of this second design, means that the rows marked "P" might well be left in longer. That is, at the second thinning rows IV, VI; X, XII; etc., might be the only ones removed. In this way large thinning gaps would be avoided. (Actually, this modification could be followed with the first design also, if the pollinator variety had sufficient commercial value).

When the latter procedure is followed, rows V, XI, etc., could be removed if a third thinning became necessary. And if the trees were still to eventually crowd beyond what peripheral pruning could rectify, a fourth thinning could be made: columns 3, 7, 11, etc.

The two plans that have been illustrated are, of course, only a sample of what might be designed. The grower can modify them to suit his own situation and his own inclinations. While the discussion has assumed new plantings, a grove with close original planting can achieve similar cross-pollination benefits by appropriate top-working.

If the spacing distance is too great for individual trees to cross-pollinate efficiently, branches of the second variety can be grafted in. This approach is also best when the proportion of the grove devoted to the pollinator is to be kept to a minimum.

Conclusions

Cross-pollination will increase average avocado fruit-set. But before deciding to make provision for such, the grower must "count the cost." These costs and inconveniences may be summarized as follows.

1. *Establishment.* Grafting-in the pollinator branches, or extra trees for the combination-tree method, or extra planning and planting details for the alternating-variety method.
2. *Maintenance.* Additional, consistent pruning to maintain the optimum proportion of pollinating foliage in maximum contact with the trees to be pollinated; with the alternate-variety method, tree thinning is a complex procedure.
3. *Culture.* Different growth habits produce problems for orchard roads and for irrigation and other general grove care; fruit picking be comes more complicated and time-consuming *(see* 8, 9, 10).

The grower who wishes to test possible cross-pollination effects in his own grove must bear in mind the unique, extreme variability of avocado fruit-set. On a tree-to-tree and year-to-year basis, avocado yields are far more irregular than citrus or most other tree fruit yields. This variability has two corollaries.

First, a large number of trees are required for a safe comparison. Using the Best grove as an example, in 1961 the Fuerte trees pollinated by Topa Topas yielded an average of over twice as many fruits as the check trees; but certain of the check trees had about three times as many fruits as certain of the cross-pollinated ones. There should be a minimum of about 20 trees in the smallest group being compared with another group. Whatever approach to cross-pollination a grower may take, he should leave part of his grove untreated, for comparison.

Second, several years' results are required for a safe comparison. In the Best grove, in certain years the cross-pollinated Fuertes actually averaged less fruit than the check trees to a statistically significant degree. Only a year-after-year analysis of relative yield (5) showed why this should in fact be expected even though in the long run cross-pollination averaged highly beneficial.

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