SOME RELATIONS BETWEEN LEAF AREA AND FRUIT SIZE IN TOMATOES[1]

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(WITH FOUR FIGURES)

Introduction

Some years ago, when the senior writer was studying growth in tomato fruits, it was noticed that the later developed fruits in a cluster were always smaller than the first ones set (**1**); that in tomatoes the setting progresses from the base of the cluster and the apical flowers may produce no fruits. There seemed also to be a relation between the size, or perhaps age, of the plant at the time of setting of a fruit and the final size of that fruit. The fruits in the first cluster were invariably small and the setting was poor, only one or two fruits being produced. The size of the individual fruits as well as the number per cluster increased until the third or fourth cluster, when the maximum was reached. The later developed fruits were distinctly smaller. At the time it seemed reasonable to assume that these differences in size of fruits were due to the food supply of the plant. It seemed desirable therefore to find out to what extent the fruit size was dependent upon the available food supply. In order to do this a study was made of the relation between leaf area and fruit size in an experiment first conducted during the summer of 1932.

Before 1932, experiments had been conducted with apples, pears, grapes, peaches, and filberts (**2, 6, 7, 8, 9, 10, 12, 13, 14**), and a relation had been found to exist between the leaf area and fruit size. In 1911 HARRIS (**3**) found, in *Cladrastis,* that the heaviest seed in a pod was located next to the proximal (basal) end, and that there was a progressive decrease in the weight of the seeds toward the distal end. In beans, the same investigator (**4**) also found a correlation between the position of a seed in the pod and its weight, but in this plant the lightest seed was at the proximal end, with a progressive increase in weight toward the distal end, although the heaviest seed was usually not at the end but second or third from the distal end. Just which seed was heaviest depended upon the number of seeds in the pod; with few seeds in a pod the heaviest seed was at the end, but in pods with many seeds it was located several seeds from the distal end. HARRIS had observed in *Cladrastis* and in beans the same phenomenon that had been observed in the tomatoes, that the size varied with the position in the fruiting structure. He offered no explanation, however. SINNOTT (**11**), from his work on the bean and *Acer saccharum,* concluded that there was no correlation between

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the size of the body of a plant and the organs produced by it, such as leaves and fruits, but that these are correlated with the size of the growing point from which they were formed.

Experimentation

In the summer of 1932, several hundred tomato plants were set out in the field. The plants were divided into four groups having one, two, three, or four leaves per plant. Each plant was permitted to produce fruits in only one cluster. Within each group of plants the clusters bore one, two, three, or four fruits. In this way there were obtained plants ranging from four leaves and four fruits to plants with one leaf and one fruit. The fruits were produced in either the second or third cluster.

The plants were not pruned to the desired number of leaves until the flowers had opened and at least one or two fruits had set. Consequently, the reduction in leaf area was operative only after the fruits had already been formed. Early fruit development was brought about by a plant with many leaves. In this way only one factor in the fruit growth was subjected to the experimental treatment, namely, its increase in size. According to SINNOTT the final fruit size had been determined by the time the leaves were removed and no effect of increasing or decreasing the leaf area per fruit could be obtained.

The experiments during this summer came to nought for two reasons. Crows, which had never done any damage before, destroyed many fruits, and thereby greatly reduced the number of plants that could be used. It was also found that when only a few leaves were left per plant the intense radiation of heat from the soil caused the leaves to curl, and, in some instances, to roll up. From this summer's work it became evident that the experiment must be conducted with a reduced light intensity, either in the field under shade or in the greenhouse.

In 1933 about 200 plants were grown in the greenhouse in 9-inch pots. Some plants were also placed out-of-doors for comparison but these were soon destroyed by the drought. The plants were pruned to one stem. Fruits were permitted to develop in the first, second, or third cluster and the leaves left were one, two, three, or four per plant. As in the preceding summer, they were not removed until some fruits had set. Only one, two, three, or four fruits were left on each plant. When only a few leaves were left on a plant there was a constant proliferation of new shoots, but these were removed as fast as they were formed. It would seem that considerable food material must have been used in the formation of these shoots. At the end of the experiment, the fruits were removed only as they matured. In some instances this reduced the number of fruits per leaf for some time, but by this time the fruits left were usually full grown, although not ripe, and

they probably did not derive any special benefit from the support of an increased leaf area. Blueprints were made of the leaves and the area determined with a planimeter. The area as given is for only one side of the leaf. When the final calculations had been made only 122 of the original 200 plants were left; the others had died during the summer, or had been discarded because of the loss of some of the fruits.

In analyzing the data, those plants that produced fruits in their first cluster have been omitted because there were too few of them. For the remaining plants, the efficiency (fruit-weight/leaf-area ratio) has been calculated and is represented in figure 1. For one plant with one leaf and

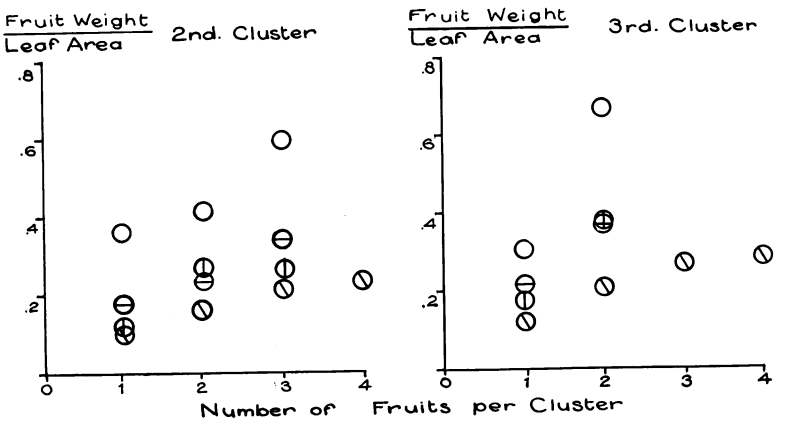

FIG. 1. Ordinate: Efficiency of the plant is represented by weight of fruits produced divided by leaf area. Abscissa: Number of fruits per cluster. Plain circles denote plants having only one leaf; circles with horizontal lines, plants with two leaves; circles with perpendicular lines, plants with three leaves; circles with slanting lines, plants with four leaves. Plants grown in summer of 1933.

three fruits in the third cluster, this value was 1.01, but as there was only one plant, it is not included in the graph. It will be noted that with one leaf the efficiency is the greatest, increasing as the number of fruits in the cluster becomes larger, but with an increase in the number of leaves the efficiency decreases. This is as one might expect, for, with a larger number of leaves some of the manufactured food probably is stored in the leaves and stems. No determination of dry material was made. The plants with several leaves were no larger than the plants with one leaf, and the plants with one leaf had the largest area per leaf. WEINBERGER (**12**) found that peaches produced by plants having fewer leaves had a lower sugar content and a lower percentage of dry material than fruits produced by plants having a larger number of leaves per fruit. There is no evidence for or against this in the tomatoes here discussed. However, from previous work

on the dry weight of tomatoes (1) it would seem that the percentage of dry weight was constant in this fruit. Judging from the color and taste, the fruits produced with one leaf per plant were normal. If the fruits and stems of plants with the larger number of leaves contain no more dry material than those of plants with only one leaf, it may be concluded that the plants with only one leaf are either more efficient, or that the rate of photosynthesis is greater. Can it be possible that photosynthesis is slowed down owing to the slow removal of the photosynthate, and that when the leaf area per fruit is small the removal of the photosynthate is more rapid? Since only one plant having one leaf produced four fruits, it seems probable that three fruits per leaf is the maximum production.

Because of the small number of plants of certain combinations that were carried through in 1933, the experiment was repeated in the summer of 1935. All of the fruits in 1935 were produced in the third cluster. The efficiency curves of these plants are shown in figure 2. These plants show

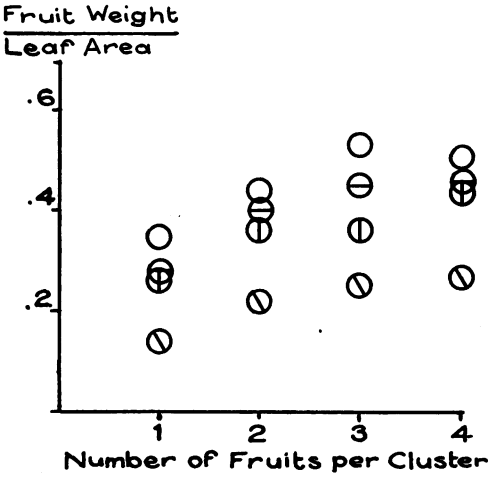

FIG. 2. Same as figure 1, except that plants were grown in summer of 1935.

even better the decrease in efficiency with increase in number of leaves than the plants experimented upon in 1933. Too detailed comparisons cannot, however, be made. For example, two leaves with two fruits are more efficient than one leaf with one fruit, while four leaves with four fruits are less efficient, and three leaves and three fruits are about the same as one leaf and one fruit.

Since the writers were interested not only in the efficiency of the leaves but also in the size which the fruits might attain, the data were examined for the purpose of studying the effect that the increase in leaf area may have had upon the size of the individual fruit. In figure 3, the weight of

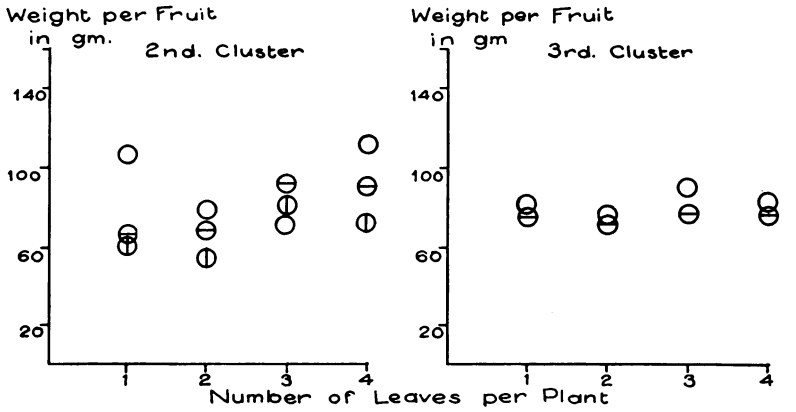

FIG. 3. Relation between individual fruit weight and number of leaves per fruit is shown. Plain circles denote one fruit per cluster; circles with horizontal lines, two fruits per cluster; circles with perpendicular lines, three fruits per cluster; circles with slanting lines, four fruits per cluster. Plants grown in summer of 1933.

the individual fruits is plotted against the number of leaves per plant. The figure shows no relation between fruit size and leaf area. This agrees with SINNOTT'S postulation that the fruit size is entirely determined by the number and not by the size of the cells. By the time the plants were pruned to the right number of leaves and number of fruits per cluster, the number of cells per fruit had already been established. Any increase in nutritional level could not, according to this theory, increase the size of the fruits.

During the 1935 season, the material was much more uniform in size, and the fruits were all produced in the third cluster. One hundred sixty-one plants were grown to the maturity of the fruits. Figure 4 shows a definite relation between individual fruit weight and number of leaves. With one fruit per plant the relation is almost linear up to three leaves per plant; but beyond this there is no further increase in fruit size with increase in leaf area. With one fruit per plant, when the number of leaves per plant was raised from one to three there was an increase of 40 per cent. in the weight of the fruit. With two fruits per plant the increase in fruit size continued even when four leaves per plant were left. The same is true for the plants with three and four fruits per plant. If it is true, as HOUGHTALING (5) states, that at the time of blossoming the ovary has the same number of cells which the fruit will have, it is obvious that the cells have reached their maximum size in plants having three leaves, and any further increase in the photosynthesizing area will have no effect upon fruit size.

The experiment demonstrates that by increasing the food producing area the fruit size can be increased considerably, although not in proportion

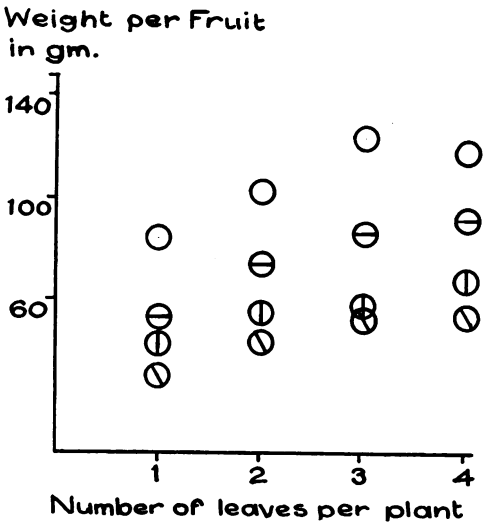

FIG. 4. Same as figure 3, except that plants were grown in summer of 1935.

to the increase in food material. This indicates that the fruit size is affected after setting as well as before. From the fact that the fruits did not increase in size in proportion to the increase in photosynthesizing area, it is obvious that factors other than nutrition at the time of enlargement influence the ultimate size of the fruit. How much could the fruits be increased in size by raising the nutritional level in the plant before the fruits have begun to develop? This question remains unanswered.

Summary

1. The efficiency of the plant, as far as fruit production is concerned, is greatest when the leaf area per fruit is small.

2. By increasing the leaf area, the size of the fruit can be increased after the time of setting.

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