Proceedings of the
AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE
1938 436:255-258

Starch in the Avocado Tree

S. H. CAMERON AND GEORGE BORST,
University of California, Los Angeles, Calif.

As one phase of our study of irregular bearing of certain avocado varieties in southern California (3, 4) we are investigating the effect of fruiting upon the carbohydrate and nitrogen cycles in the tree. These studies are in the main quantitative. However, since starch is easily, and from certain standpoints, more satisfactorily determined by microchemical methods a preliminary determination of the starch cycle in bearing and non-bearing trees has been made using the michrochemical technique.

Apparently the only previous studies of seasonal changes in starch content of avocado trees were made by students in our laboratory. Gee (2) studied fluctuations in starch content of material collected at Riverside at bi-weekly intervals between January 2 and April 14, 1928. As a result of this short study he suggested that in the avocado tree there was "but one long cycle in starch storage, a reduction during the entire growing season and an accumulation during the dormant period". Sclivanos (6) also working with material collected at Riverside at bi-weekly intervals between September 2, 1930, and April 15, 1931, reported a minimum starch content between October 15 and December 21 and a maximum in February and March.

MATERIALS AND METHODS

The conclusions presented in this paper are the result of a study of two lots of material. One series of collections involved whole trees, the other, branches from individual trees. We hoped that by checking the results of one series against those of the other to be able to take into account individual tree variability in the one case and the effect of removal of leaf surface in the other.

Between January 18 and December 3, 1936, 16 carefully selected 6-year-old Mexican seedling avocado trees, all progeny of the same parent tree, were excavated and prepared for chemical analysis. As each tree was fractioned, from 20 to 32 samples representing all parts of the tree were collected and preserved in alcohol. This material was subsequently sectioned, stained in IKI solution, mounted in glycerine and the starch content estimated by observation under the low power of a microscope. A second, less detailed but in some respects more satisfactory, method of estimation was also used. About a dozen stained sections representing various sized roots or branches were placed in water or glycerine in a Syracuse watch glass. Two such preparations were made for each tree, one containing sections from trunk and branches, the other sections from various sized roots. By observation against a white back-ground the relative amount of starch can readily be estimated. By arranging the dishes in relation to two axes, one representing date of collection and the other density of color on an arbitrary

scale, the positions they occupy will determine a curve representing the seasonal trend in starch content. The curves presented in the accompanying figures were constructed in this manner. Several colleagues confirmed our opinion regarding the location of the dishes thus minimizing the personal factor, always present in methods involving estimation of values.

The trees used in this study were large for their age and were growing vigorously. Although rather variable in foliage and fruit characters, they were, we believe, sufficiently uniform in growth, blossoming and fruit setting to satisfactorily portray the seasonal starch cycle. They set very little fruit in 1936 and may therefore be considered non-bearing trees.

Beginning in July 1935 and continuing into November 1936, branches about 2 centimeters in diameter at the basal end were collected at intervals of from 2 to 6 weeks, from two 14-year-old Fuerte trees in an orchard near La Habra. This material was studied as described above. The trees were located in adjacent rows about 40 feet apart and were therefore subjected to similar environmental conditions. Both were producing alternately small and large crops but in opposite phase at the time collections were begun. The yield behavior of the two trees for 9 years is indicated in Table I.

TABLE I—Yield of Fuerte Avocado Trees in Number of Fruits per Tree

Tree	1928–29	1929–30	1930–31	1931–32	1932–33	1933–34	1934–35	1935–36	1936–37
1–12.....	629	5	697	81	600	202	1,402	15	Large
2–9.....	139	264	224	570	0	635	90	909	Small

A freeze in January 1937 destroyed the 1936-37 crop. Prior to the freeze the crop on tree 1-12 was estimated as larger than the 1934-35 crop and that on tree 2-9 also larger than that of 1934-35 but still small, indicating that the alternation continued throughout the period of collections. Tree 2-9 was somewhat smaller than tree 1-12 which probably accounts for the smaller crops produced.

MICROCHEMICAL OBSERVATION AND DISCUSSION

Fig. 1 illustrates the starch cycle in the excavated trees. Smooth curves have been drawn through points obtained by estimation as described above. These curves represent the starch cycle in branches and roots more than one centimeter in diameter. Branches, and to a lesser degree roots, less than 1 centimeter in diameter were more variable in starch content than the larger units. This variation is probably clue to inclusion in the sample of tissues of various ages; the localized effect of growth, and, in the case of small branches, to position in relation to an appreciable leaf surface. Variations in starch content of small branches were greater than we have observed in shoots of temperate zone deciduous trees, possibly because length growth is more localized than in the deciduous tree.

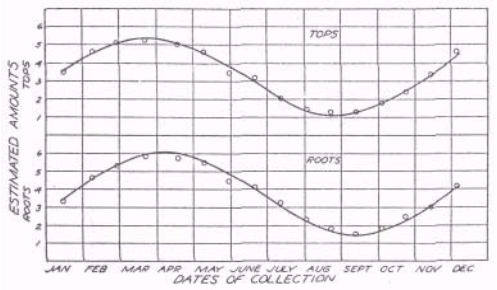

FIG. 1. Seasonal fluctuations in starch content of tops and roots of Mexican seedling avocado trees.

Considering the tree as a whole, an examination of Fig. 1 indicates that the maximum starch content occurs in midwinter and the minimum in late summer and autumn. Between the winter maximum and the autumn minimum there is a gradual decline in starch content. This period coincides with that of growth activity of the top. It apparently indicates a rate of utilization of carbohydrates greater than the rate of synthesis. When growth diminishes or ceases in the autumn the rate of production apparently exceeds the rate of utilization, and starch is deposited, accumulating gradually until the winter maximum is again attained. This sequence is almost identical with that previously reported for the orange tree (1) and suggests that it may be a general condition for evergreen trees in subtropical regions.

We were unable to detect an appreciable delay in starch storage in roots as compared with branches, which is not in accord with the generally recorded observation that roots lag behind the tops in both accumulation and depletion of starch. This may be due to the fact that the trees were permitted to branch close to the ground and the roots were therefore not far removed from a large leaf surface. Ishibe (5, Fig. 7) illustrates a similar condition in *Pinus densiflora* in Japan. The rate of decline was however somewhat slower in the roots than in the branches possibly due to delay in growth activity of roots as compared with shoots. On this point we have no evidence.

The results of the study of individual branches of the Fuerte trees at La Habra are presented in Fig. 2. Tree 1-12, which was in the off-crop phase, bearing 15 fruits at the time collections were started in 1935, shows the typical curve for non-bearing trees illustrated in Fig. 1. It produced much new growth during that summer, blossomed profusely during the winter and spring of 1936 and set a heavy crop during the latter part of May and the first week of June. It produced very little new growth during the summer of 1936.

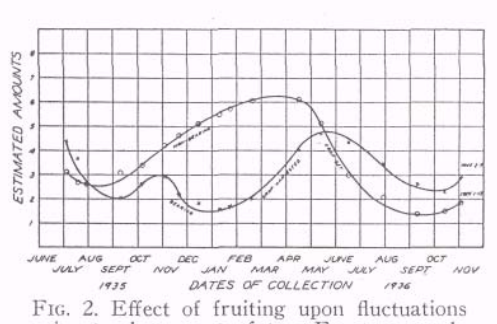

FIG. 2. Effect of fruiting upon fluctuations in starch content of two Fuerte avocado trees.

Tree 2-9 which matured 909 fruits (approximately 450 pounds) during the first year of collection shows a much lower starch content throughout the summer and autumn than the non-bearing tree. Apparently storage of starch during the autumn and early winter was reduced by the demands of the developing fruit. After the crop was harvested, during March and April, the starch content increased to a late maximum in May and June. This tree produced practically no new growth during the summer of 1936 while it was carrying a heavy crop. The following spring it produced a late light bloom which was followed by much new growth.

Observations made upon material collected in other seasons and from other districts indicate that the periods of maximum and minimum starch content are not constant but fluctuate from season to season, depending upon environmental conditions, size of crop and time of harvest. During the current season the starch of Fuerte trees at Los Angeles declined until mid-November, which is approximately 2 months later than that indicated in Figs. 1 and 2 and corresponds with that recorded by Sclivanos (6) for material collected at Riverside.

Seasonal changes in starch content were gradual in all parts of the tree as previously noted for the orange (1). However the avocado seems to contain more starch at all times than the orange. Readily detectable quantities of starch were present, particularly in the primary xylem throughout the minimum period, whereas in the orange, during the corresponding period, frequently only a few scattered starch grains could be found. The roots contain relatively more starch at all times than branches of similar diameter.

LITERATURE CITED

1. CAMERON, S. H. Starch in the young orange tree. *Proc. Amer. Soc. Hort. Sci.* 29:110-114. 1932.
2. GEE, A. R. Unpublished report. 1928.
3. HODGSON, R. W., and CAMERON, S. H. On the bearing behavior of the Fuerte avocado variety in southern California. *Proc. Amer. Soc. Hort. Sci.* 32:200-203. 1934.
4. _____, and _____. Studies on the bearing behavior of the Fuerte avocado variety —a progress report. *Yearbook, Calif. Avocado Assn.* 156-165. 1935.
5. ISHIBE, O. The seasonal changes in starch and fat reserves in some woody plants. *Mem. College of Science. Kyoto Imp. Univ. set.* Bull: 1-53. 1935.
6. SCLIVANOS, G. Unpublished report. 1931.