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For morphological investigations the selection of material is of primary importance. This is especially significant in the comparative study of leaves since these organs may have marked differences in size and structure on a given branch or on a single twig. During development they are responsive not only to environmental conditions but also to factors operating within the plant. Trees often develop diminutive foliage and insertion of the dwarf leaf on the axis may be very close to others of larger growth. This anisophylly is pronounced in many plagiotropic shoots and may also be associated with basal-apical relations. Such dwarf leaves are common in *Cercis Canadensis,* especially on secondary branches. This paper takes up the dwarf, palmate leaf of *Cercis* in comparison with its sun and shade leaves of larger growth. These results are also compared with the findings of Obaton who studied the dwarf, pinnate leaves of several species. (Obaton, F., 1922, Revue Gen. de Bot. Vol. 34). The contrasting expressions in these two types of dwarf leaves are of special interest.

Material: Three representative leaves were selected from the south side of a *Cercis* tree, about 12 feet in height, that stood in the southern border of a clump of shrubbery on a lawn in Iowa City. The tree received full sunlight most of the day and was in some degree sheltered from drying southwest winds by nearby trees and buildings.

The largest of the three leaves, and best illuminated, was third from the tip of an intermediate branch. This twig carried no dwarf foliage though the lower leaves were smaller than the upper. The two partly shaded leaves were from the terminal portion of a lower branch; the larger of these leaves was third from the tip and the smaller, the dwarf leaf, was seventh on this axis. While the dwarf leaf was shaded more than the other on this twig both were in favorable light through much of the day. These three leaves will here be referred to as "sun," "shade," and "dwarf," respectively.

At the time the leaves were collected sample areas, about 3 x 10 mm, were cut out of the lateral half of each blade at seven selected stations (Fig. 1). Four of these were distributed along the midrib from near the base towards the apex, but far enough from the center to escape the local thickening of blade near larger veins. Three stations were located nearer the margin, somewhat back from the edge, to avoid the peripheral thinning of blade. These excised portions were killed in Nawaschin's solution, imbedded in paraffin and sectioned 12 microns thick. A smaller part of each sample-area was cut transversely, and the remaining larger part was sectioned in paradermal direction, that is, parallel to the surface of the leaf. A useful stain was the Safranin-Haematoxylin combination.

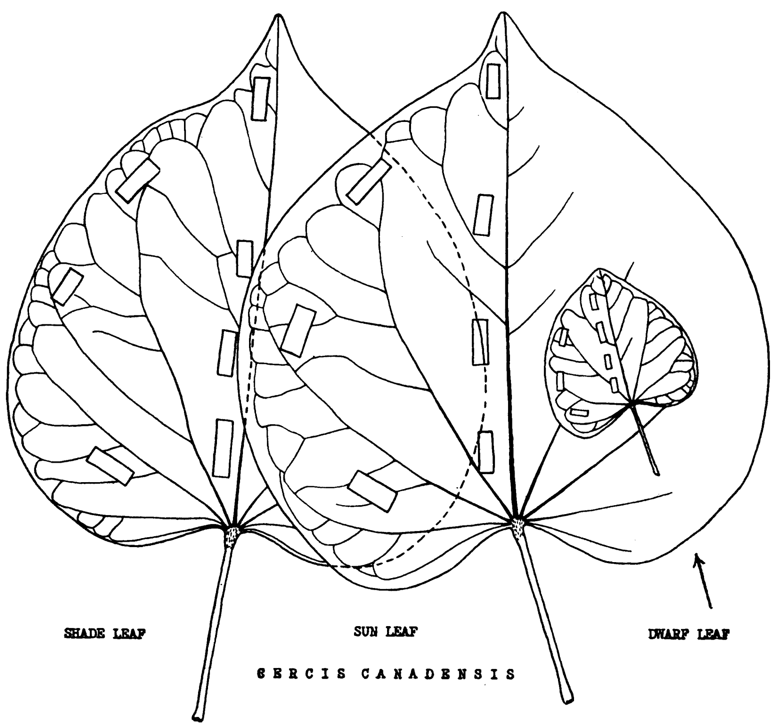

FIG. I.

These three *Cercis* leaves were surveyed both with respect to differences among the seven stations of each blade and also by comparison with one another. Micro-measurements of each sample-area were made covering (1) total thickness of blade, and of each component layer,—upper epidermis, palisade, spongy mesophyll, and lower epidermis; (2) cell size (measured in upper epidermis); (3) radial diameter of border-parenchyma; and (4) total vein-length per unit area of blade. Any figures used represent an average of ten to twenty measurements, depending upon the degree of variation. The actual areas of the blades were determined by planimeter, and extent of venation by direct linear chartometer measurement of drawings made by projection from the prepared slides.

Observations: The leaves of *Cercis* back from the tip diminish rapidly in size especially on branches of slower growth and on secondary twigs. For an axis carrying seven leaves their relative areas, from apex downward, were as 10.2, 11, 11.3, 8.4, 5, 2, and 1; for an adjacent and shorter lateral twig, with 5 leaves, the series was 11, 8.7, 5, 1.6, and 1; and for a semi-interior twig on the same branch, having four leaves, their relative areas were as 13.5, 7, 2.1, and 1.

These three selected leaves were alike in form but differed greatly in size. (fig. 1) The "sun" leaf was largest with an area of 141.3 sq. cm.; the "shade" leaf, next in size, 121.9 sq. cm.; while the "dwarf" had an area of only 12.7 sq. cm. They were similar in shape and had the same number of major veins radiating from the petiole at about the same angles. When drawings of all three leaves were made to equal size and superimposed only minor differences in outline and major venation were noted.

This is in striking contrast to Obaton's observations on the venation in dwarf leaves of *Castanea vulgaris, Ulmus campestris, Fagus sylvatica* and other lanceolate forms with pinnate venation. In the nine species that he studied there were differences in form of blade and the major lateral veins were fewer in the dwarf leaves, some having less than half the number found in normal leaves. Similar differences in pinnate leaves of other species were confirmed by field and herbarium observations in connection with this study, though these leaves have not yet been submitted to tissue analysis in this laboratory.

While outwardly alike except for size, microscopic study of sections from these *Cercis* leaves revealed considerable differences in their organization. Taking the mean of the seven stations for each leaf as a basis of comparison, thickness of blade was greatest in the sun leaf (166 μ.). It was much thicker than the shade leaf (101 μ.), which was nearly the same size and had corresponding position on its twig. Thinnest was the dwarf leaf (99.6 μ) which was seventh in series downward on its axis. These records for thickness are not in agreement with the figures given by Obaton for the dwarf pinnate leaves which he surveyed. He found they had approximately the same thickness in each case as the large leaf of the species. In five of his plants the large leaves were thicker; in the three the dwarfs were thicker and in one they had the same thickness. The sum of leaf thickness for all nine of his dwarfs was only 0.38% less than that for the sum of all the large leaves. The sun leaf of *Cercis* was about 66% thicker than the dwarf.

Comparing the values for the seven stations of each of the *Cercis* leaves there were some differences in the distribution of blade thickness. Of these reference will here be made only to total thickness. All were thickest in the medium basal region. The shade leaf was thinnest in the median sub-terminal area while the others were thinnest in the marginal region near the part with greatest width.

Epidermal thickness was greatest in the sun leaf, with shade and dwarf in the order named. While the total range in the upper epidermis was over seven microns neither the thickest nor thinnest area for any two of the leaves was found in the corresponding stations. Radial thickness of the border-parenchyma was greatest in the shade leaf and least in the dwarf, but as noted elsewhere, this layer is more nearly constant than any other of the blade.

The vertical depth of spongy mesophyll differed but little among the three *Cercis* leaves. This zone was thinnest in the shade leaf (19.18μ), while dwarf and sun had nearly the same thickness (23.15 and 23.5μ respectively), but the range for all was less than 5 microns. The palisade on the other hand was the only layer showing striking difference in amount. It was thickest in the sun leaf (113.23μ), least in the dwarf (50.μ), and only slightly thicker in the large shade leaf (56.μ). Note that the sun leaf had considerably more palisade thickness than that of the two others combined. These figures for palisade parenchyma are very different from those given by Obaton for the dwarf pinnate leaves. For his nine species he found very little difference in amount of palisade, comparing large and dwarf leaves. In one species they were equal, in another the dwarf had thicker palisade, and, for the others there were slight differences in favor of the large, sun leaf. The total palisade thickness of the large leaves for his nine species was only 1% greater than the sum of measurements for this zone in the associated dwarfs. In *Cercis* the palisade layer of the sun leaf was 126% thicker than that of the dwarf.

Total vein length per unit area was greatest in the sun leaf of *Cercis* (88.5 cm. per sq. cm.), least in the shade leaf (75.0 cm. per sq. cm.) and intermediate in the dwarf (80.2 cm. per sq. cm.). This sequence is not what would be anticipated, but it should be added that measurement of vein-length for *Cercis,* however carefully made, may be of little relative value since this species has local areas of the blade, somewhat irregularly distributed, that have the minor veins much closer together, with corresponding increase in total vein length per unit area. A given sample, therefore, may be far from representative of the blade as a whole, and readings for certain stations of a given blade may appear to be inconsistent with others of the same leaf.

Cell size for these three leaves was measured in the upper epidermis of two stations, one central and the other marginal, and the mean was used for the given leaf. Average cell sizes were, sun leaf 665 sq. μ, shade 526sq. μ and dwarf, 499 sq. μ. The sun leaf had larger cells nearer the center of the blade while the others had larger cells in the sub-marginal stations. Obaton reported no study of vein length or cell size in his paper.

Cercis leaves differ from any other studied by the writer in having greater cell-width in the spongy mesophyll than in the upper epidermis. This disparity was least in the sun leaf and greatest in the shade leaf where the sponge cells measured in the paradermal plane, may be one fifth greater than those in the upper epidermis of the same sample. Due to the irregular outline of sponge cells, their actual area may be less but the total paradermal spread of cells is greater in this layer than in the epidermis. This was found to be true also in other *Cercis* leaves not involved in this series.

Conclusion and Summary. The diminutive leaf of *Cercis canadensis* seems to be a fairly normal shade leaf. In outline of blade, major venation pattern, cell size, total thickness, epidermal development and amount of mesophyll it fits into the sun-shade series of this species. In but two respects was it out of expected position. The total vein length per unit area for the dwarf ranked above that of the large shade leaf of higher insertion, and in relative amount of spongy mesophyll it also stood next to the sun leaf. But as noted above, measurements of vein length in this species are complicated by marked irregularities in the distribution of the minor venation. The relative amounts of sponge in these three leaves showed a range of less than 5 μ and minor fluctuations in this layer are not significant compared with the very great differences found in their palisade. The findings here recorded for the dwarf, palmate leaf of *Cercis* reveal rather striking contrasts to the results noted by Obaton for dwarf, pinnate leaves. The latter differed from the larger leaves of their respective species in form and major venation, but agreed closely with them in blade thickness and total mesophyll, as well as in sponge and palisade distribution. Such contrasts between dwarf palmate and pinnate leaves suggest that growth patterns are related to the major venation system and that the palmate type, with several digitate primary veins, offers greater freedom of expression in dwarf leaves than is found in the pinnate blade. It is to be recalled of course that while the survey of seven stations per blade protects the values for a given leaf, adequate sampling calls for the study of more leaves per category. This is, accordingly, a preliminary report and the findings are presented in the hope that they may be helpful in the selection of material for leaf study.

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