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A study of the ecological anatomy of the leaves of certain orchard and native plants was made with a view to learn something of the ecological relations under climatic conditions found in the Willamette valley near Corvallis, Oregon, with special reference to water and light.

A brief historical summary of ecological relations of leaves to surrounding conditions as they pertain to the present study has been prepared, mainly taken from Maximov's, "The Plant in Relation to Water", and F.E. Clements', "Plant Physiology and Ecology", and a few others.

Three sites were selected as sample plots because of their accessibility and surrounding vegetation. Average trees were chosen in each site as follows: Site I, two pear trees (Pyrus communis L.), one hawthorn (Crataegus douglassii Lindley), one serviceberry (Amelanchier alnifolia Nutt.) and one cascara (Rhamnus purshiana De Candolle); Site II, one prune (Prunus domestica L.), one oak (Quercus garryana Hooker),

one cascara (Rhamnus purshiana De Candolle) and one hawthorn (Crataegus douglassii Lindley); Site III, one pear (Pyrus communis L.), one cascara (Rhamnus purshiana De Candolle) and one hawthorn (Crataegus douglassii Lindley).

Leaves were collected from the north and south sides of the trees situated in and adjacent to the Corvallis Orchards about three miles west of Corvallis, Oregon. Material was taken from the current year's growth and at an uniform height; two leaves were chosen from a shoot on the north side of the tree, one from the apex and the other from the base of the same shoot and two leaves similarly chosen from the south side. Half of each leaf was fixed by the chromo-acetic fixing method and the other half treated with formalin-alcohol solution. Imbedding and sectioning were done according to standard technique, followed by two stain combinations, viz.--Delafield's haematoxylon; and safranin and fast-green. Sections were mounted and detailed microscopic studies and measurements were made. The measurements upon which the results and conclusions of this paper are based were tabulated and herewith included.

Measurements of all the leaf structures including upper and lower epidermis and cuticle, palisade, spongy parenchyma and the intercellular spaces were made. From these measurements the results and discussion were prepared under three headings, namely; (1) Water relations, (2) Light relations and (3) Site relations.

Water relations were noted among leaves on the same side of trees and at different heights on the stem. Some of these observations are as follows: (1) thicker leaves were found at the apex of stems than at the base of the same stem, (2) the epidermis was thicker on the upper surface of leaves than on the lower surface and also thicker on apex leaves as compared to base leaves of the same stem, (3) the palisade tissue showed better development in the apex leaves, especially on the south side of the tree.

Light relations were noted among leaves on opposite sides of tree, such as: (1) leaves thicker on south side of tree, (2) slight differences in epidermis of leaves, (3) spongy parenchyma measurements not conclusive, (4) palisade tissue was better developed on south side of tree and at apex of stem.

Site relations were inconclusive; however, Site III which is the most fertile and protected location showed thicker leaves and leaf elements.

Cuticle and intercellular measurements were the same for both water and light relations and showed no striking responses.

A very considerable amount of data and material has been collected from which results and conclusions presented in this study have been taken.

ECOLOGICAL ANATOMY OF WOODY PLANTS WITH SPECIAL REFERENCE TO LEAF VARIATIONS

By

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FOREWORD

Under the able guidance of Professor H. P. Barss and members of the Botany Department, many investigations concerning the relation of plants to their environment have been carried on here at Oregon State College. The investigation to be discussed here was started in the fall of 1932, and while one year is far from sufficient time in which to conduct an experiment of this nature, the writer hopes that some data and conclusions will be presented which will be of use and assistance to any one who may carry on further work in this field.

The writer is grateful to Professor W. E. Lawrence for his interest and help in arranging and interpreting the data secured. He also wishes to thank Professor C. E. Owens for his advice and assistance in the technique used in the investigations.

ECOLOGICAL ANATOMY OF WOODY PLANTS WITH SPECIAL REFERENCE TO LEAF VARIATIONS

INTRODUCTION

The ecological factors of a locality are usually responsible to a certain extent not only for the type of vegetation existant on an area but also for variations in structure of the plants and plant parts. Ecological anatomy has become an intimate part of the broad field of ecology and is assuming an importance in plant relationships both cultivated and native that can no longer be denied, especially in those sections where edaphic and climatic conditions are severe. Such conditions are prevalent throughout the Willamette Valley where continual cloudiness and rain occur during the fall, winter and spring and a dearth of moisture is common throughout the summer months, thus giving a fertile field in which to carry on an investigation concerning anatomical-ecological phenomena.

Because the leaf is the place of very important physiological functions and also readily subject to modifications by external factors it has been a source of much investigation. Few workers have, however, endeavored to delve into the complex relationships of the leaf in relation to its surrounding physical factors, but have rather confined their studies to the histology, morphology or physiology of this essential plant part. Among some of the pioneers in this new branch of Botany and Ecological-Anatomy are E. S. Clements, F. E. Clements, W. B. MacDougal and N. A. Maximov. Perhaps the most noteworthy work concerning ecological leaf anatomy has been done by W. Zalenski, a Russian worker, but very little literature of his is available to the world in general because it has not been translated from the original Russian; however, Maximov summarizes and quotes his work extensively. Many other investigators have followed numerous paths similar to the problem herein discussed but few have arrived at any definite conclusions or proved any hypothesis, yet each has added his or her bit of knowledge and experience to the common accumulation from which will eventually arise a more complete and exact understanding of plant relationships.

A subject of this nature embraces all the phases of Botany, and also turns to the fields of physics, chemistry, soils and many other sciences in order to answer the confusing and conflicting questions that arise. Needless to say, the worker must realize the enormity of the problem and limit his efforts to the very small scope wherein he is fitted to gather any information that may contribute to the whole. A knowledge of morphology is very essential and many workers have limited their efforts to descriptions of the anatomy of plant parts, a truly important role in the gathering of botanical data. Also the contribution of the ecologist is needed in order to obtain the data concerning the plant environment. The information brought forward by these two factors, augmented by that of other branches of science, should be so tabulated and correlated as to bring out some facts concerning the relationships desired.

More specifically, some of the problems that are as yet unsettled in this particular field of investigation are: (1) the effect of light upon leaf structures as, epidermal thickness, cuticle thickness, amount of palisade tissue, amount of spongy parenchyma, air spaces, venation and number and size of stomata; (2) the effect of available water on the leaf structures; (3) the effect of temperature on the leaf structures; and (4) the effect of humidity and other lesser factors as kind of soil, exposure, aspect and wind upon the leaf structures. Preferably controlled conditions should be used wherein all factors would be held constant except for one which could be varied over a period of time sufficiently long so that leaves would go through the complete cycle from the bud until they fall. Exact measurements of leaf structure and physical factors for many species would add a great deal to the data now at hand concerning ecological leaf anatomy.

The writer could not hope to cover the entire field or even a major branch of the field in the short time available, but if some material can be collected or some new bit of information discovered, that will be of assistance to another who follows along this road, the efforts put forth will not have been put forth in vain. With this in mind leaves of several species of trees under different conditions and with particular positions on the tree and twig were gathered with the view of making careful anatomical observations and measurements. This necessitated fixing, imbedding, sectioning, staining and mounting the material which was then to be the object of study. Also physical factors surrounding the sites where the material was gathered were to be studied and observations recorded. From these two sets of data it is hoped that some correlations or some new facts might be ascertained.

Work has been started upon a series of investigations here in the Willamette Valley to discover relationships between the plant and its environment, under the circumstances peculiar to this region. The investigation here discussed is a part of that series and if added data and information are secured, the work will have added its link to the chain.

SUMMARY OF PRESENT INFORMATION OF ECOLOGICAL LEAF ANATOMY

Many authors have written upon the various phases of ecological anatomy in their treatises and books; some have even given detailed accounts of investigations concerning leaf structure and its environmental factors, but in the writer's opinion N. A. Maximov, W. Zalenski and R. H. Yapp overshadow all other workers in the field of ecological leaf anatomy. Not alone for their own investigations are they held thus, but because they have gathered together perhaps the most comprehensive and best selected information concerning the plant in relation to its habitat, particularly as regards water relations. While Maximov was the original author of the book, "The Plant in Relation to Water", much credit needs be given to R. H. Yapp, an eminent English scholar and botanist, who although confined to a sick bed worked throughout a year with great heroism so the English speaking peoples might have Maximov's work in its present form. Yapp had just finished the final proofs when he died, but his additions, corrections and notes gave to the botanical world the great work of the Russian botanist, Maximov. The writer feels that a study of the book, "The Plant in Relation to Water", is a literature review in itself and while some other authors may be quoted and discussed and many others read and cited, the greater part of the historical review will be confined to those two inspiring and able men, Maximov and Yapp.

Maximov (22) is indebted to Zalenski for much of the data and conclusions incorporated in his book. Zalenski (32), a Russian worker, made some remarkable quantitative anatomical discoveries concerning different leaves of the same plant. This was in 1904 and according to Maximov might well have been the turning point in the history of the problem of ecological leaf anatomy had it not been that the results of the investigation were published in the Russian language only and in a not readily procurable edition. Some of the results and conclusions given by Maximov are essential in a discussion of this problem.

The starting point of Zalenski's work was his observation in 1901 that the network of veins in the leaves of plants growing in open, dry habitats is far better developed than in plants growing in shade or under conditions of low evaporation. This was directly opposed to the prevailing conviction that plants of dry soils were well protected against excessive evaporation and, therefore, had no need of a rapid water supply. From this start Zalenski began a series of detailed experiments to learn the rules that govern the modifications of leaves on different parts of the same tree or plant. He found a number of interesting and important facts as in the case of leaf venation, that there was a greater density of venation on ascending the stem and this condition was more pronounced in plants well exposed to direct sunlight while there was little difference in plants growing in the shade.

Further investigation showed that all the cells of the leaf, epidermal, palisade and spongy parenchyma were invariably smaller the higher the point of insertion of the leaf on the shoot, also the intercellular spaces were smaller. This phenomenon of structural differences between the upper and lower leaves was more pronounced the drier the habitat. Palisade tissue was often wanting in the lower leaves but was well developed in the upper leaves of the same plant. The palisade was observed to be more typically developed the higher the insertion of the leaf on the stem, but sponge tissue showed less typical development. The upper leaves of a shoot show a more xeromorphic structure. The result of Zalenski's measurements and observations is to establish the general rule that the anatomical structure of the individual leaves of one and the same shoot is, so to speak, a function of their distance from the root system; this may be justly known as Zalenski's Law. From these observations Zalenski concluded that differences in anatomical structures of different leaves on the same plant may be qualitative as well as quantitative.

Yapp (31) in his investigational work obtained the same results as Zalenski and advanced, as the probable reason for the upper leaves having a more xeromorphic structure, that the lower leaves intercepted much of the water that would otherwise go to the upper leaves. Also he concluded that the structure of leaves is very deeply influenced by conditions of transpiration as well as by the water supply. Another interesting and very important point put forth by Yapp is that the water factor probably influences leaf structure mainly during the actual expansion of the leaf, a comparatively late stage of development. The critical stage of development is then no doubt the stage of cell enlargement after leaving the bud because at this period the cells are still plastic and fluctuations of turgor are greatest. This is in contrast to another worker's theory as shall be pointed out later. Yapp continues with a short discussion on the influence of light in which he says that one of the most striking differences between sun and shade leaves is the prevalence of palisade mesophyll in the former and of spongy mesophyll in the latter. Sun leaves tend to be thicker with more closely fitting cells, and smaller intercellular spaces.

- Presenting a contrasting view in respect to Yapp's theory, Nordhausen (23) believes that in the case of trees and shrubs the anatomical differences are not the result of the direct influence of light and water on the unfolding leaves but are predetermined by the conditions of illumination and transpiration under which the buds were formed during the previous year. As proof of this theory he exposed buds formed under shade conditions to strong light in the following spring and obtained leaves with a shade structure; conversely, buds formed in strong light produced leaves of the sun type when subsequently transferred to shade. This phenomenon might be explained as hereditary factors predetermined in the plant instead of any stimulatory action of the leaf's environment.

Maximov (22) further complicates the problem when he states:

> "The exact quantitative correlation between light intensity and the anatomical structure of the leaf can be ascertained only by the use of artificial illumination, as natural daylight is too variable to be measured accurately."

In some of his other experiments, results indicated that damp air had much the same effect as shade on the form and structure of the plants, while the influence of dry air was very similar to that of strong light. Maximov lists other workers who have found results almost directly opposed to his on the same question, showing that the relationships between moisture and plant structure are far from a simple problem.

Heuser (17) carried on some investigations with wheat plants and discovered many of the phenomena that

Zalenski had observed a decade or so earlier. Heuser found that invariably with increased soil moisture the length and width of the leaf increased and individual cells were larger, but leaf thickness decreased.

Thus far all the literature reviewed has been that of foreign workers, which does not mean that American botanists have overlooked a problem so important to agriculture and research activities. No discussion upon an ecological problem would be complete without the mention of such workers as F. E. Clements, D. T. MacDougal, Cowles and Edith Clements.

Fredric Edward Clements (5) long associated with the University of Nebraska and well known for his work with prairie vegetation and its environment, discusses plant relationships to considerable extent in his book, "Plant Physiology and Ecology". From this, general results and conclusions will be taken and discussed without going into the detail of his many experiments and investigations.

Clements (5) states that the first response of a plant to a stimulus is always functional, the nature and intensity (duration) of the stimulus determine whether this is also followed by a structural response. Indirect factors, i.e., such as soil, wind, physiography, pressure and rainfall, which can affect a function only by acting upon another or direct factor, do not properly produce response. More specifically, modifications in leaf structure are principally an adjustment to water supply, for example, leaves of a xeromorphic nature often have a thick cuticle which is generally thicker on the upper surface of horizontal leaves.

Touching more closely upon the work of the investigation herein undertaken, Clements (5) says further that mesophytic species grow in habitats that are neither extremely dry nor wet and consequently, they show no striking response to water supply or loss. They possess a form or structure that is more or less characteristic by reason of the absence of distinct modifications. Mesophytic species are in two groups, sun and shade plants; however, the factor becomes not one of water but of light. Light stimuli call forth functional responses which produce changes in form or structure or in both, the leaf undergoes by far the greatest modification from such stimuli. The palisade cell is the normal result of the response of the chloroplasts to sunlight, while the sponge cell is due to the action of diffuse light or shade upon the chloroplasts. The interior leaves of trees and shrubs naturally contain much more sponge than leaves of the same plant that are exposed to the direct rays of the sun. However, Clements (5) believes that the increased size of epidermal cells in many shade forms is for the purpose of increasing translocation and water loss and bears no direct relation to light. Shade leaves show an outline more nearly entire and in general larger than the sun leaves, which are thicker in cross section. The relative size and vigor of sun and shade plants must of necessity be taken into account in all comparisons of the leaves of the two plant types.

Dr. Edith Clements (8) published one of the early articles on leaf structure in relation to physical factors in 1905 in which she presented drawings, tables and cuts that were of help and interest in preparing the data of this investigation.

As stated before, many other books and papers were consulted in an attempt to discover the results and conclusions that might have a bearing upon the writer's problem or in some way help him to make his work one of profit.

THE INVESTIGATION

Methods and Materials

History of Area

The area selected as typical of the Willamette Valley region is located about three miles west of Corvallis, Oregon, and is known as the Corvallis Orchards. The early history of the Corvallis Orchards is similar to that of most of the fruit growing sections throughout the valley in that the land was originally inhabited by scrub oak (*Quercus garryana*), poison oak (*Rhus diversiloba*), some species of wild currants (*Ribes*), serviceberry (*Amelanchier*), *Rosa* and other shrub-like plants, along with numerous minor plants and grasses. These species were cleared from the soil and grain (wheat, oats and barley) was raised for some years before the fruit trees were planted. Although exact data is not available the probable length of time the soil has been under cultivation is between twenty and thirty years, the greater part of which was as fruit orchards. Most of the orchards are still under cultivation and bearing fruit; however, some parts have been neglected and are now over-grown with weeds, showing a total lack of care in the past few years. The sides of the roads and strips along fences have been allowed to revert to a natural state, wherein native species have again established themselves. That, briefly, presents the early history and conditions prevalent on the area used as a sample plot in this investigation.

Site -- Soil Conditions

Three sites were chosen with a view of obtaining accessibility, variation in soil conditions, exposure, altitude, drainage, slope and the plants available to be studied. For location of these sites or sample plots, see map in appendix, page XVI.

Site I was selected along the road where drainage is fairly good, the land slightly sloping toward the north and at an elevation of approximately 250 feet. The soil as listed by Carpenter and Torgerson (3) is a clay loam, known as Amity Silty Clay Loam. Water often stands on the ground during the rainy season although surface drainage is comparatively good. The soil is deep and plastic when wet but has a tendency to bake upon drying; underdrainage is restricted. Carpenter and Torgerson indicate that the soil is not so well adapted to fruit trees; however, some commercial fruit orchards are located in this soil type. The sample plot is so located that it includes trees in a well cared for orchard and also trees in a neglected orchard, with native species growing along the fence and road.

Site II is located about a half mile from site I and is on top of a small hill, thus giving good drainage, surface and underdrainage. A prune orchard extends over the hill and the slopes, scrub oak and other indigenous arborscent species are more in evidence along the road and fence than were found down on the flats. The elevation is about 350 feet; the hill overlooks the lower valley and is in turn overlooked by the higher foothills of the Coast Range. The soil is not so deep as in site I, ranging from two to six feet where it grades into partly weathered parent sandstone or shale from which it came. It is known as the Melbourne Silty Clay Loam and is listed as being more favorable to fruit trees.

Site III shows a well developed drainage and the soil type is usually found in positions slightly higher than the surrounding soils. The soil type is called Willamette Silt Loam and appears to be well adapted to nearly all crops; fruit, however, is a minor crop because of frosts. The sample plot is in the valley below site II and at about the same elevation as site I.

Climate was not discussed with each site because all were in close proximity to each other and for practical purposes reacted to the same climatic forces. Climatic and edaphic measurements were not taken in the field for the reason that this investigation was not begun until the fall of the year, at which time the plants had ceased to react to the influences of climate and soil as far as anatomical structure for the current year was concerned. Other features of the sites that may later indicate an influence upon this investigation will be brought up in the discussion of the results.

Preparing the Material

At each of the three sites average trees or shrubs of different species or plants of the same species under different conditions were selected. From these plants leaves were taken from the north side and the south side of the tree, one from the apex and one from the base of the current year's growth, thus making four leaves from each tree. Small vials containing fixing solution were carried into the field, half of them containing chromo-acetic fixing solution and the rest containing formalin-alcohol fixing solution made up according to the formulae given by Chamberlin (4). Half of each leaf was cut into small rectangles and placed in the one kind of fixing solution and the other half cut and placed in the second kind of fixing solution. Small, heavy paper labels written in India ink were put in the vials designating the species, side of tree, leaf position on the twig and the site of each leaf gathered. The leaves were then allowed to remain in the fixing solution the standard length of time. (See table I in appendix). Those treated with the chromo-acetic method were washed in running water before starting through the alcohol or dehydrating series. The formalin-alcohol group did not require the washing but were taken from the fixing solution and placed in the alcohol series. For the schedule as used consult table I of the appendix.

Upon completion of the dehydrating series the leaf sections were imbedded in paraffin as described by Chamberlin. The India ink labels were carried throughout the alcohol series and imbedded in the paraffin blocks. The blocks were then cut into small cubes to fit the rotary microtome and allowed to soak in water until sectioned. A standard hand rotary, Bausch and Lomb, microtome was used for sectioning with the usual technique employed in cutting, mounting and sticking the paraffin ribbons. Because of the large number of slides needed and the abundance of material, four slides from each vial were cut, 10 microns thick, and four slides 15 microns thick, thus insuring one or two good slides from each leaf to be studied. With practice the technique improved and fewer slides were made. Each leaf was given a number and all slides made from one leaf bear the number of that leaf. From this a key was prepared in order that complete identification of the slide and its treatment could be easily found. See table II of appendix.

Because of a shortage of 100% alcohol, acetone was used extensively in the clearing and dehydrating series.

The slides were stained by two methods; one, the safranin and fast green method and the other, Delafield's haematoxylon method. Experience showed that in most instances the safranin and fast green was superior to the haematoxylon stain. Evidence up to this point also indicated that those sections fixed in formalin-alcohol were clearer and lighter, showing up the cell structure to better advantage than those fixed in chromo-acetic acid. Chamberlin's (4) schedule for staining was followed quite closely in this work; slight variations in timing were used, but no particular reactions were noted.

The writer began the mounting work with Canadian balsam, but after experimenting with diaphane found the latter to be preferable to the balsam because it dries faster, more evenly, gives a thinner seal and thus clearer slides; also diaphane does not have the yellowish color characteristic of the balsam.

From the 250 stained and mounted slides forty-eight of the best slides were selected for anatomical measurements and study. A standard Bausch and Lomb compound microscope was used and an eye-piece micrometer calibrated in the usual way as described by Ganong (12). The low power calibration unit of the eye-piece was .015 mm. and the high power unit was .0036 mm. A table was prepared to give direct readings in millimeters for the units on the eye-piece micrometer thus saving much time; also a form was made for recording the measurements of the leaf elements. Measurements were then carefully made of the leaf elements, starting with the cuticle, and proceeding on through the leaf section, recording the thickness of each anatomical division as the epidermis, palisade tissue, spongy parenchyma, lower epidermis and lower cuticle. Upon these measurements the results, discussion and conclusions of this investigation depend.

Leaves were taken from twelve different trees as follows: Site I included two pear trees (Pyrus communis L.), one of which was designated as pear X to show that it came from a neglected orchard; also serviceberry (Amelanchier alnifolia Nutt.), cascara (Rhamnus purshiana De C.) and hawthorn (Crataegus douglassii Lindley). Site II contained a prune tree (Prunus domestica L.), hawthorn (Crataegus douglassii Lindley), oak (Quercus garryana Hooker) and cascara (Rhamnus purshiana De C.). Site III included one pear tree (Pyrus communis L.), one cascara (Rhamnus purshiana De C.) and one hawthorn (Crataegus douglassii Lindley).

Measurements of all the leaves of the different species were used to show general trends in strucutre instead of designating characteristics of the individual species. For instance, a survey of each species as given in table III shows that in all but a few cases (e.g. Site I--pear X--slides 13 and 14) the upper cuticle is thicker than the lower cuticle of the same leaf, therefore, in the discussion (page 25) a general statement is made that the upper cuticle is thicker than the lower. The results and discussion are based upon all the species and not individual characteristics.

RESULTS AND DISCUSSION

As suggested in the introduction an investigation of this nature is so broad and yet so intensive that the worker must use considerable judgment as to what to present as a contribution to the work already done in this field. A great quantity of material has been accumulated and it will be difficult to select individual items that will show correlations of a definite nature.

It is evident from the literature review that the problem herein discussed is a very complicated one, and also that certain factors are of only secondary importance, exerting an influence upon primary factors, but producing no response in themselves. Such factors are wind, physiography, soil, temperature, humidity and soil treatment. The two primary factors that will be considered here are water and light. However, if Mr. Clement's (5) theory is accepted, the factor of water will have to be discounted as he states that mesophytic plants show no distinctive response to water. The worker feels, however, that as shown by Zalenski (32) and Maximov (22) there is a probable response or influence of water supply in the two leaves on the same side of the tree; however, a comparison between the north and south side of the tree would hardly be expected to show positive results. Each element of the leaf will be discussed in turn with any correlations noted.

Water Relations

A survey of the data in tables III and IV of appendix shows that the total leaf thickness of all the species was decidedly greater at the apex of the stem than at the base. In a very few instances on individual stems negative results can be noted, but no explanation is evidenced in the data for this reversal of form. The probable explanation as given by Zalenski and Yapp is that the water is intercepted by the lower leaves thus giving the apex leaves a more xermorphic structure. The fact that the apex leaves are generally thicker than the base leaves is no doubt a water relation only and therefore no comparison between the north and south side of the tree would be logical.

In every case, as shown by inspecting the individual species in table IV, the upper surface of the leaf showed a thicker epidermis than the lower surface of the same leaf. This might be attributed to light influence rather than water, although the more probable explanation is protection from excessive water loss. Concerning the apex leaves and the base, the upper surface of the apex leaves was, in the majority of cases, thicker than the upper surface of the lower leaves. Granting a more xeromorphic structure above, this phenomenon is in keeping with what would be expected. The lower surface of the apex and base leaves showed wide variations; in some species the lower leaf had the thicker epidermis, as in the Cascara, Site I, table IV, and in others the apex leaf, (Hawthorne, Site I and II, table IV); other species showed equal thickness (Cascara, Site II, table IV). Although some uniformity might be expected, the writer feels that a comparison of the lower epidermis, unless made of a great number of specimen of the same species under different conditions, is valueless.

Cuticular measurements were very difficult and the data secured not sufficiently accurate to base conclusions upon; however, the cuticle was very generally thicker on the upper surface of the same leaf and usually thicker on the apex leaves as compared with the base leaves.

As regards the spongy parenchyma (also the palisade) can it be said that water is the factor that produces the response structurally? The writer is in doubt upon this point, but will record his observations. On the north side of the tree there appeared to be more sponge tissue in the apex leaves than in the base leaves. The leaves taken from the south side of the tree showed neither the apex nor base leaves with a greater amount of sponge, except in instances where the base would contain more and other instances where the apex would contain more. With respect to the relation of sponge and palisade few conclusions can be made as about fifty per cent showed more sponge and the rest showed more palisade. As indicated by Clements (5), perhaps it is useless to try to find structurally characteristics in mesophytic species of this nature.

A slight difference was found in the palisade tissue of the various leaves; generally there was found to be a better development of palisade in the apex leaves, especially was this true on the south side of the tree. In a slight majority of instances the palisade tissue composed the greater part of the mesophyll of the leaf.

Small difference in the intercellular spaces was noticed; however, the tendency was for larger intercellular spaces in the base leaves and smaller, fewer spaces in the apex.

The data discussed shows that there is beyond doubt a very considerable influence exerted by water relations upon the structure of the leaves of plants. A careful, detailed study of the data as presented in the appendix would show a great many interesting phenomena. However, the writer believes that the generalizations given in the above discussion are indicative of the trend of the relationships found in these plants and are of value within their limitations. Added proof that the water, light or other environmental factors do produce structural response can only be supplied through further investigation along this line, and is not feasible in this limited investigation.

Light Relations

Just as the water relations were concerned with comparisons between the apex and base leaves on the same side of the tree, so are the light relations concerned with comparisons between leaves in the same relative positions, that is apex or base, but on opposite sides of the tree or the north and south. While the light relations were not so clearly and definitely shown by the data given in the tables of measurements, as for the water relations certain trends and influences were noted and will be discussed.

A comparison of the total leaf thickness, as given in table III, showed that in a small majority of cases the leaves on the south side of the trees were thicker than those on the north side, particularly was this true of the apex leaves. The base leaves showed more discrepancies which might be a water influence or the fact that base leaves receive more shade than the apex ones, no matter which side of the tree.

The upper epidermis was observed to be thicker in leaves on the south side of the tree in about half of the measurements and thicker on the north side in the remaining half. The lower surfaces of the leaves showed the same results as for the upper surface. On the north side of the tree the upper epidermis was thicker on the apex leaves, while the lower epidermis showed very little variation between apex and base. The south side of the tree had apex leaves with thicker upper cuticle than the base, but the lower epidermis was generally thicker on the base leaf. While it is possible that light is at least in part responsible for these variations, water content and relations play a very important part in this phenomenon.

As would be expected the upper cuticle was in general slightly thicker than the lower, also there was a tendency for the cuticle to be thicker on the south side of the tree and on the apex leaf.

The spongy parenchyma gave measurements that were somewhat conflicting and difficult to interpret. There was slightly more sponge tissue on the north side of the tree and at the apex of the stem on the north side. The south side of the tree showed the reverse, with more sponge in the base leaf.

In only about half of the leaf sections there was more palisade on the south side of the tree than on the north. There was, however, uniformity in that on both the north and south sides of the tree the palisade was better developed in the apex leaves.

The same results were secured for the intercellular spaces as in the discussion of water relations, namely, that the spaces were smaller and fewer on the south side of the tree and at the apex of the stem.

Site Relations

In the case of the two native species, Cascara and Hawthorne, that were found on all three sites, there was evidence of slightly thicker leaves and leaf elements in site III with its more fertile soil (see page 15), than in the other two locations. The cascara showed thinnest leaf structure in site I while hawthorne had the thinnest leaves in site II. The two species were subject to the same climatic conditions and it is possible that edaphic influences brought about the different responses. The specimen pear X was growing under almost native conditions, that is, the ground and tree had received no care or treatment for a number of years, while the other two pear specimen were from well cultivated orchards. All three were the same species and the one labelled pear X had not received care as the other two; however, there was no appreciable difference in the structure of the three, with the exception that the pear specimen on site III was slightly smaller. As listed earlier in this paper, the sites represent three different soil types, some of which are more favorable than others for growing certain crops or trees. This may be a major cause for the structural differences noted.

The results obtained and recorded do not bear out former workers' findings and conclusions in every particular, but no conflict is present with the underlying principles as discovered by such men as Yapp, Zalenski and Clements. The measurements and observations indicate that there is some correlation between the water supply and structure of the leaves on the same side of the tree, and especially with reference to their point of insertion on the stem; also tendencies were noted that pointed strongly to the influence of light upon certain structural responses. While no specific and outstanding facts or conclusions have been brought forth, the writer believes that the data collected here is a beginning toward the direction of a better understanding of plant relationships in the Willamette Valley.

SUMMARY

This investigation has not been a simple one in which the principal features stand out in bold relief, but has rather been confused and conflicting. An endeavor will be made, however, to select those parts of the investigation that seem most outstanding, so as to give in perspective the work done on this problem.

1. Three sites were chosen, each having a different soil type and plants desired for study.

2. No climatic field records made as material was collected in fall when the current year's growth had ceased to respond to the physical factors.

3. Four leaves were obtained from each sample tree; two leaves from the south side of the tree and two from the north; one leaf from the apex and one from the base on each side of the tree.

4. Leaves were fixed, imbedded, sectioned, stained and mounted in the usual way; formalin-alcohol fixing solution and safranin and fast green stain were found to be superior to chromo-acetic fixing solution and Delafield's haematoxylin stain for study of leaf structure.

5. The following points were observed as water relations of the leaves:

   a. Leaves thicker at apex of stem than at base.

b. Upper surface of leaf had thicker epidermis than lower surface of same leaf. The upper surface of the apex leaf was generally thicker than the upper surface of the base leaf.

c. Cuticle tended to be thicker on upper surface of leaf and on apex leaves.

d. Data not conclusive as regards the amounts of spongy parenchyma in the various leaves.

e. Palisade slightly better developed in apex leaves, especially on south side of the tree.

f. Small differences in the intercellular spaces, tended to be smaller and fewer at apex and on the south side of the tree.

6. Conclusions as to light phenomena were as follows:

a. Light produces more comparative response between leaves on opposite sides of the tree than between apex and base on the same side of the tree.

b. Leaves were slightly thicker on south side of tree.

c. Very little or no difference between epidermis on north and south side of tree.

d. Cuticle tended to be thicker on south side of tree.

e. Spongy parenchyma measurements not conclusive, tend to be more on north side of tree.

f. Palisade better developed at apex and slightly more on the south side of the tree.

g. Intercellular spaces showed same as for water relations, smaller and fewer at apex and on south side of the tree.

7. Relations among the sites were not of much importance, but did show:

a. Thicker leaves and leaf elements for both cascara and hawthorne were found in site III which was the most fertile and better protected location.

b. No appreciable differences were observed for the three specimen of pear growing under different conditions and sites.

8. The two main factors, water and light, were attributed with powers of producing structural response in leaves, but more specific and accurate data deemed necessary to prove their relationships.

A very considerable amount of material in the form of mounted slides, imbedded leaf cuttings and microscopic measurements were collected in this investigation and are available to another who may wish to continue this work. It is possible that more recent methods in technique would open more opportunities than those herein employed, however, the fixing solution and stain combination found most successful and the advantages of diaphane, given on page 18, over Canadian balsam may be of some benefit to anyone undertaking a problem of this nature.

It is very evident that over so short a period little can be accomplished upon such an enormous project as ecological anatomy of leaf structure. The work was begun and material collected in the fall of the year at which time the current year's growth has ceased to respond to environmental conditions, particularly the leaves. It would be far better to begin the investigation in the spring or winter so as to record the physical factors that are present when the leaves are developing, then secure the leaves before they fall in the autumn. In this way one would be better fitted to discuss the observations and data secured and perhaps point out some definite correlations and relations between the structure of the leaves and their environment.

This investigation has brought to light a considerable amount of data, and it is hoped that the material collected and observations made will act as a stepping stone for one who will carry on this work to a more profitable end.

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APPENDIX

Species of Leaf	Date When Collected	Time Fixed (Hrs)	Time Washed (Hrs)	Time (in Hrs) in Alcohols. Acetone used in place of 100%.Alc. (3-1),(2-2),(1-3), proportion Acet.-xylol														
				5	10	15	20	30	40	50	70	85	95	100	3-1	2-2	1-3	0-4
Site No. II																		
Prune	10-24-32	120	120	24	18	3	3	18	48	32	*	14	10	14	5	4	10	10
Oak	10-24-32	120	120	24	18	3	3	18	48	32	*	14	10	14	5	4	10	10
Hawthorne	10-24-32	120	120	24	18	3	3	18	48	32	*	14	10	14	5	4	10	10
Cascara	10-24-32	120	120	24	18	3	3	18	48	32	*	14	10	14	5	4	10	10
Site No. I																		
Pear	10-25-32	96	48	48	24	24	18	3	3	18	*	14	10	14	5	4	10	10
Serviceberry	10-25-32	96	48	48	24	24	18	3	3	18	*	14	10	14	5	4	10	10
Hawthorne	10-25-32	96	48	48	24	24	18	3	3	18	*	14	10	14	5	4	10	10
Cascara	10-29-32	24	48	24	24	18	3	3	18	48	**	14	10	14	5	4	10	10
Pear X	10-29-32	24	48	24	24	18	3	3	18	48	**	14	10	14	5	4	10	10
Site No. III																		
Pear	11-13-32	36	32	24	15	24	36	9	24	*	14	10	14	10	10	5	4	10
Cascara	11-13-32	36	32	24	15	24	36	9	24	*	14	10	14	10	10	5	4	10
Hawthorne	11-13-32	36	32	24	15	24	36	9	24	*	14	10	14	10	10	5	4	10

Site No. II: * Material kept in 70% for 38 days

Site No. I: ** Material kept in 70% for 36 days   * Material kept in 70% for 38 days

Site No. III: * Material kept in 70% for 24 days

Table II

Key for the Identification of Slides

Side of tree designated by N and S for north and south; fixing solution by Ch for chromo-acetic and FA for formalin-alcohol; position of leaf on stem as A or B for apex and base; stain used as SG or D for Safranin-fast green and Delafields haematoxylon; thickness of section measured in microns.

Site No. I

Slide No.	Species of plant leaf taken from	Side of tree	Part of twig	Stain used	Fix. sol.	Section Thick.
1	Serviceberry	S	B	SG	Ch	20
2	Serviceberry	S	A	D	Ch	15
3	Serviceberry	N	B	D	Ch	15
4	Serviceberry	N	A	D	Ch	10
5	Cascara	S	B	D	Ch	15
6	Cascara	S	A	SG	Ch	15
7	Cascara	N	B	SG	Ch	15
8	Cascara	N	A	SG	Ch	15
9	Hawthorne	S	B	D	Ch	15
10	Hawthorne	S	A	SG	Ch	15
11	Hawthorne	N	B	SG	Ch	10
12	Hawthorne	N	A	SG	Ch	10
13	Pear X	S	B	D	Ch	10
14	Pear X	S	A	SG	Ch	10
15	Pear X	N	B	D	Ch	15
16	Pear X	N	A	SG	Ch	10
17	Pear	S	B	SG	Ch	10
18	Pear	S	A	SG	Ch	10
19	Pear	N	B	SG	Ch	10
20	Pear	N	A	SG	Ch	10

Table II (Cont.)

Site No. II

Slide No.	Species of plant leaf taken from	Side of tree	Part of twig	Stain used	Fix. sol.	Section Thick.
41	Hawthorne	S	A	SG	FA	10
42	Hawthorne	N	B	SG	FA	15
43	Hawthorne	N	A	SG	FA	10
44	Hawthorne	S	B	SG	FA	15
45	Cascara	N	A	SG	FA	10
46	Cascara	S	A	SG	FA	10
47	Cascara	S	B	SG	Ch	15
48	Cascara	N	B	SG	Ch	15
49	Oak	S	A	SG	FA	15
50	Oak	N	B	SG	FA	10
51	Oak	N	A	SG	FA	10
52	Oak	S	B	SG	FA	10
53	Prune	S	A	SG	FA	10
54	Prune	N	B	SG	FA	15
55	Prune	N	A	SG	FA	10
56	Prune	S	B	SG	FA	10

Table II (Cont.)

Site No. III

Slide No.	Species of plant leaf taken from	Side of tree	Part of twig	Stain used	Fix. Sol.	Section Thick.
57	Cascara	S	A	SG	Ch	15
58	Cascara	N	B	SG	Ch	15
59	Cascara	N	A	SG	Ch	15
60	Cascara	S	B	SG	FA	10
61	Pear	N	A	SG	Ch	15
62	Pear	S	A	SG	Ch	10
63	Pear	N	B	SG	Ch	10
64	Pear	S	B	SG	Ch	15
65	Hawthorne	S	B	SG	Ch	15
66	Hawthorne	N	B	SG	Ch	15
67	Hawthorne	S	A	SG	Ch	10
68	Hawthorne	N	A	SG	FA	10

Table III

Measurement of Leaf Anatomical Elements in mm

Site No. 1

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Serviceberry	1	SB	.180	.018	.0144	.0018	.0018	irregular .054 thick medium size	.0882 2 rows, 1 long row medium dense	medium open
(Amelanchier anifolia)	2	SA	.210	.0252	.0126	.0036	.0036	.0756 size medium, irregular	.0810 2 rows irregular medium dense	small close
	3	NB	.1368	.0174	.0144	.0036	.0018	.0576 size medium, few in number	.0450 2 rows one short medium dense	large open
	4	NA	.1725	.0252	.0198	.0036	.0018	.0666 size medium, irregular	.0612 1 row slender, long not dense	medium open
Cascara	5	SB	.1332	.0216	.0162	.0018		.0396 size medium, many irregular	.0576 1 row medium dense medium wide	size med. medium open
(Rhamnus purshianum)	6	SA	.1368	.0234	.0162	.0036	.0036	.0342 med. small, many med. regular	.0548 2 rows med. short med. dense	small close
	7	NB	.1386	.0252	.0216	.0036	.0018	.0396 size medium, med. regular	.0432 1 row med. wide, short dense	small close
	8	NA	.1368	.0234	.0162	.0054	.0018	.0414 med. small, reg. roundish	.0468 1 row medium wide dense	medium medium close

Table III (Con't)

Site No. I

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Hawthorne (Crataegus Douglasii)	9	SB	.1836	.0288	.0180	.0036	.0036	.0612 med. small, few irregular	.0702 1 row medium wide compact	large very open
	10	SA	.1950	.0378	.0216	.0054	.0036	.0576 size medium, .0108 irreg. oblong	.0666 1 row med. wide compact	large open
	11	NB	.1800	.0234	.0144	.0036	.0018	.0692 med. large irreg. med. number	.0684 1 row wide, .009 compact	large very open
	12	NA	.1892	.0246	.0154	.0036	.0018	.0720 Large irregular med. number	.0684 1 row wide, not compact	large very open
Pear X (Pyrus Communis L.)	13	SB	.2625	.0252	.0198	.0036	.0036	.1402 size irregular, indistinct	.0738 1 row irregular not compact	irregular medium open
	14	SA	.2925	.0216	.0162	.0054	.0054	.1242 large irregular many cells	.1242 2 rows trace of three compact	medium open
	15	NB	.2475	.0198	.0126	.0018		.1312 large irregular many	.0792 2 rows 2nd irregular, wide compact	medium medium
	16	NA	.270	.0234	.0108	.0054	.0054	.1268 large irregular wide, compact	.1016 2 rows 2nd short, open 1st med. comp.	medium medium close

Table III (Con't)

Site No. 1

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Pear	17	SB	.2175	.0180	.0144	.0036	.0036	.0818 size irregular, many compact	.0980 2 rows trace of three med. wide, reg.	medium close
(Pyrus Communis L.)	18	SA	.300	.0198	.0126	.0036	.0036	.1260 size irregular, many not compact	.1440 2 rows trace of three wide, reg. com.	medium open
	19	NB	.270	.0234	.0108	.0036	.0018	.1278 irregular, open many	.1062 2 rows trace of three wide, reg. com.	medium open
	20	NA	.2850	.0216	.0108	.0018	.0018	..1216 irregular, open many	.1234 2 rows trace of three wide, irr. com.	medium open

Table III (Con't)

Site No. II

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Hawthorne	41	SA	.1425	.0216	.0144	.0018	.0009	.0596 irreg. scattered loose	.0560 1 row, med. wide, not compact, short	large very open
(Crataegus	42	NB	.150	.0234	.0126	.0009		.0640 irreg. scattered, very loose	.0496 1 row med. wide, short very loose	large very open
Douglassi)	43	NA	.1275	.0180	.0144	.0009		.0554 irreg. very scattered very loose	.0398 1 row med. width, short not compact	large very open
	44	SB	.1364	.0216	.0162	.0009	.0009	.0590 irreg. very scatt. very loose	.0402 1 row med. width, short not compact	large very open
Cascara	45	NA	.180	.0396	.0144	.0054	.0036	.0468 more reg. close not loose	.0728 2 rows trace of three wide med. comp.	small medium close
(Phamnus purshianum)	46	SA	.1250	.0270	.0144	.0036	.0018	.0388 more reg., med. close	.0424 1 row wide, medium compact	small medium close
	47	SB	.1404	.0288	.0180	.0036	.0018	.0390 irreg. med. close numerous	.0510 1 row wide not compact	med. small medium open
	48	NB	.1650	.0252	.0144	.0036	.0036	.0378 med. reg. med. close, num.	.0784 3 rows med. wide, med. compact	medium small med. close

Table III (Con't)

Site No. II

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Oak (Quercus garryana)	49	SA	.1725	.0180	.0144	.0036	.0036	.0554 irreg. med. large not close, many	.0768 1 row upper 1 lower, long, narrow, med. compact	med. small & close
	50	NB	.1650	.0162	.0126	.0036	.0018	.0588 irreg. med. large med. compact	.0694 1 short 1 long, trace of row lower med. com.	med. small & close
	51	NA	.1925	.0162	.0162	.0054	.0018	.0692 med. reg. med. large not compact	.0854 2 rows long and narrow compact	small close
	52	SB	.1650	.0144	.0108	.0036	.0018	.0576 irreg. size med. not compact	.0756 1 row trace of two med. compact	med. small medium close
Prune (Prunus domestica)	53	SA	.2025	.0288	.0144	.0018	.0009	.0852 irreg. size med. not compact	.0716 2 rows 2nd irregular wide, med. comp.	small medium close
	54	NB	.1875	.0324	.0216	.0036	.0018	.0558 irreg. long, large not compact	.0738 2 rows 2nd irregular wide, med. comp.	med. small med. open
	55	NA	.1725	.0342	.0180	.0036	.0009	.0752 irreg. long, large not compact	.0420 1 row trace of two wide, med. comp.	medium open
	56	SB	.1950	.0252	.0144	.0018		.0782 irreg. size medium not compact	.0760 1 row trace of two wide, med. comp.	med. small med. close

Table III (Con't)

Site III

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Cascara (Phamnus purshianum)	57	SA	.2025	.0270	.0108	.0054	.0036	.0540 more reg., med. compact	.1008 3 rows med. wide compact	small medium close
	58	NB	.1725	.0288	.0144	.0036	.0036	.0396 reg. med. size, compact	.0832 2 rows trace of 3rd med. compact	small close
	59	NA	.2250	.0342	.0108	.0036	.0018	.0432 med. regular in size, comp.	.1314 3 rows med. wide compact	small close
	60	SB	.1650	.0270	.0126	.0018	.0009	.0396 med. irreg. small med. compact	.0822 2 rows trace of 3rd compact	small close
Pear (Pyrus communis L.)	61	NA	.2412	.0216	.0108	.0036	.0036	.1188 irreg. size, irreg. compact	.0810 1 row trace of 2nd med. wide med. comp.	small close
	62	SA	.2250	.0288	.0126	.0018	.0009	.1060 med.reg. med. size compact	.0792 2 rows med. wide med. compact	small compact
	63	NB	.2008	.0198	.0144	.0036	.0036	.0864 med. irreg. med. size & open	.0756 2 rows 2nd irreg. med.comp & wide	medium medium open
	64	SB	.2250	.0234	.0144	.0054	.0036	.0916 irreg. med. size med. comp.	.0828 2 rows med. wide compact	medium medium close

Table III (Con't)

Site III

Species of Leaf	Slide No.	Leaf position	Leaf thickness	Epidermis thickness Upper	Epidermis thickness Lower	Cuticle thickness Upper	Cuticle thickness Lower	Spongy parenchyma Nature	Palisade cells Nature	Intercellular spaces Nature
Hawthorne	65	SB	.2175	.0252	.0162	.0018		.0846 size reg. not compact	.0936 2 rows med. wide, 1st compact	medium open
(Crataegus	66	NB	.2302	.0308	.0180	.0036	.0018	.0828 irreg. size med., not compact	.0964 2 rows med. wide 1st row comp.	medium large open
Douglasii)	67	SA	.2148	.0252	.0162	.0036	.0009	.0792 med. irreg. & size not compact	.0918 2 rows med. wide compact	medium medium open
	68	NA	.2175	.0270	.0108	.0054	.0018	.0774 irreg. size med. not compact	.0926 2 rows med. wide compact	medium large open

Table IV

Comparison of Leaf Anatomical Elements by Species to Show Variations Among the Different Sites

Leaves from north side of tree

Species	Site	Leaf position	Measurement of Leaf Anatomical Elements in mm						
			Total leaf	Epidermis		Cuticle		Spongy parenchyma	Palisade cells
				Upper	Lower	Upper	Lower		
Cascara	I	apex	.1368	.0234	.0162	.0054	.0018	.0414	.0468
		base	.1386	.0252	.0216	.0036	.0018	.0396	.0432
	II	apex	.180	.0396	.0144	.0054	.0036	.0468	.0728
		base	.1650	.0252	.0144	.0036	.0036	.0378	.0784
	III	apex	.2250	.0342	.0108	.0036	.0018	.0432	.1314
		base	.1725	.0288	.0144	.0036	.0036	.0396	.0832
Hawthorne	I	apex	.1892	.0246	.0154	.0036	.0018	.0720	.0684
		base	.1800	.0234	.0144	.0036	.0018	.0692	.0684
	II	apex	.1275	.0180	.0144	.0009		.0554	.0398
		base	.150	.0234	.0126	.0009		.0640	.0496
	III	apex	.2175	.0270	.0108	.0054	.0018	.0774	.0926
		base	.2302	.0308	.0180	.0036	.0018	.0828	.0964

Table IV (Con't)

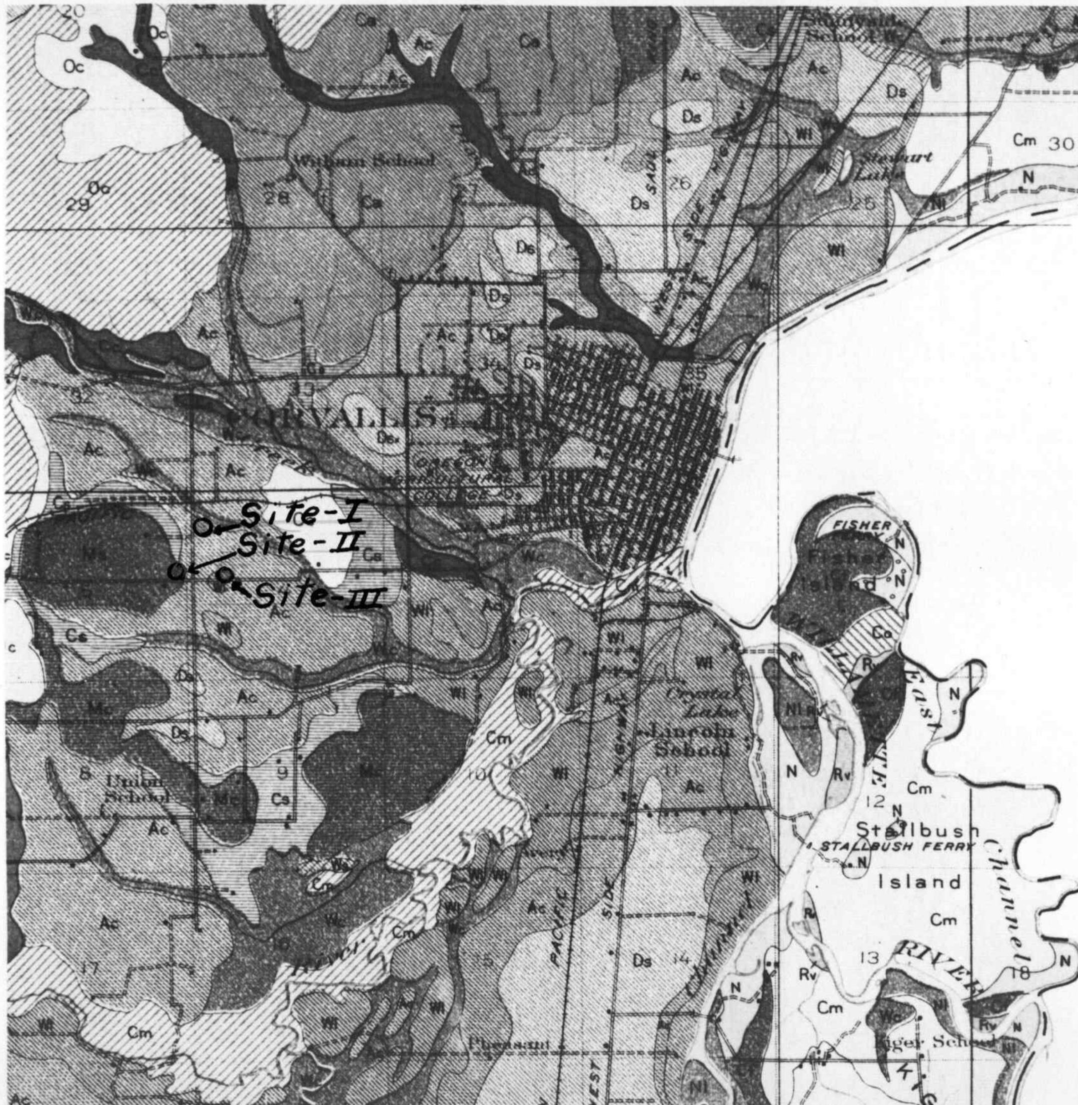
Species	Site	Leaf position	Total leaf	Epidermis Upper	Epidermis Lower	Cuticle Upper	Cuticle Lower	Spongy parenchyma	Palisade cells
			Leaves from south side of tree						
			Measurement of Leaf Anatomical Elements in mm						
Cascara		apex	.1368	.0234	.0162	.0036	.0036	.0342	.0648
	I	base	.1332	.0216	.0162	.0018		.0396	.0576
		apex	.1250	.0270	.0144	.0036	.0018	.0388	.0424
	II	base	.1404	.0288	.0180	.0036	.0018	.0390	.0510
		apex	.2025	.0270	.0108	.0054	.0036	.0540	.1008
	III	base	.1650	.0270	.0126	.0018	.0009	.0396	.0822
Hawthorne		apex	.1950	.0378	.0216	.0054	.0036	.0576	.0666
	I	base	.1836	.0288	.0180	.0036	.0036	.0612	.0702
		apex	.1425	.0216	.0144	.0018	.0019	.0596	.0560
	II	base	.1364	.0216	.0162	.0009	.0009	.0590	.0402
		apex	.2148	.0252	.0162	.0036	.0009	.0792	.0918
	III	base	.2175	.0252	.0162	.0018		.0846	.0936
Pear		apex	.3000	.0198	.0126	.0036	.0036	.1260	.1440
	I	base	.2175	.0180	.0144	.0036	.0036	.0818	.0980

Table IV (Con't)

Leaves from south side of tree									
		Leaf	Measurement of Leaf Anatomical Elements in mm						
Species	Site	position	Total leaf	Epidermis Upper	Epidermis Lower	Cuticle Upper	Cuticle Lower	Spongy parenchyma	Palisade cells
Pear	III	apex	.2250	.0288	.0126	.0018	.0009	.1060	.0792
		base	.2250	.0234	.0144	.0054	.0036	.0916	.0828
Pear X Pear	I	apex	.2925	.0216	.0162	.0054	.0054	.1242	.1242
		base	.2625	.0252	.0198	.0036	.0036	.1402	.0738
Prune	II	apex	.2025	.0270	.0108	.0054	.0036	.0540	.1008
		base	.1950	.0252	.0144	.0018		.0782	.0760
Ser-vice-berry	I	apex	.2100	.0252	.0126	.0036	.0036	.0756	.0810
		base	.1800	.0180	.0144	.0018	.0018	.0540	.0882
Oak	II	apex	.1725	.0180	.0144	.0036	.0036	.0554	.0768
		base	.1650	.0144	.0108	.0036	.0018	.0576	.0756

Table IV (Con't)

			Leaves from north side of tree						
			Measurement of Leaf Anatomical Elements in mm						
Species	Site	Leaf position	Total leaf	Epidermis Upper	Epidermis Lower	Cuticle Upper	Cuticle Lower	Spongy parenchyma	Palisade cells
Pear	I	apex	.2850	.0216	.0108	.0018	.0018	.1216	.1234
		base	.270	.0234	.0108	.0036	.0018	.1278	.1062
	III	apex	.2412	.0216	.0108	.0036	.0036	.1188	.0810
		base	.2008	.0198	.0144	.0036	.0036	.0864	.0756
Pear X	I	apex	.2700	.0234	.0108	.0054	.0054	.1268	.1016
		base	.2475	.0198	.0126	.0018		.1312	.0792
Prune	II	apex	.1725	.0342	.0180	.0036	.0009	.0752	.0420
		base	.1875	.0324	.0216	.0036	.0018	.0558	.0738
Service-berry	I	apex	.1725	.0252	.0198	.0036	.0018	.0666	.0612
		base	.1368	.0216	.0144	.0036	.0018	.0576	.0450
Oak	II	apex	.1925	.0162	.0162	.0054	.0018	.0692	.0854
		base	.1650	.0162	.0126	.0036	.0018	.0588	.0694



MAP SHOWING LOCATION OF SITES

Ac- Amity silty clay loam
Ca- Cascade clay loam
Cc- Cove clay
Cf- Chehalis fine sandy loam
Cm- Chehalis silty clay loam
Cs- Carlton silty clay loam
Ds- Dayton silty clay loam
G - Grande Ronde silty clay loam
Mc- Melbourne clay loam
Ms- Melbourne silty clay loam
N - Newberg fine sandy loam
Ni- Newberg loam
Ns- Newberg silty clay loam
Oc- Olympic clay
Oi- Olympic clay loam
Rv- Riverwash
Wc- Wapato silty clay loam
Wi- Willamette silt loam

From -

Carpenter and Torgerson