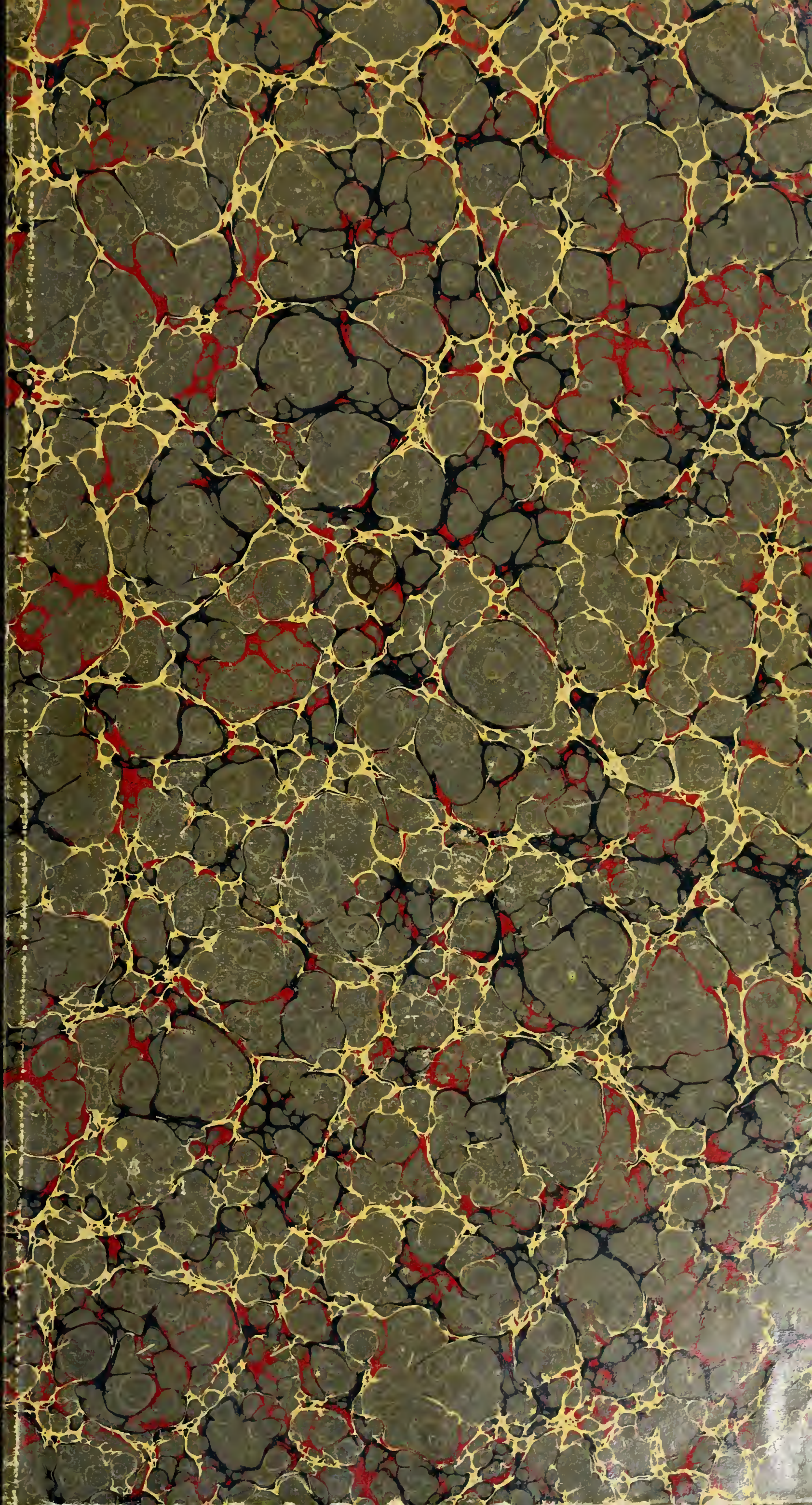

THE PLANT WORLD

A Monthly Magazine of General Botany

Established 1897

Edited by

FORREST SHREVE

Published by

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NOTES ON THE GEOLOGIC HISTORY OF PLATANUS

EDWARD W. BERRY

The Johns Hopkins University, Baltimore, Md.

The Plane-trees, Sycamores, and Buttonball or Buttonwood trees, comprise the family Platanaceae and well repay consideration. Not only are some of them among the most attractive, but they are the most massive among our deciduous trees, even if they are not the tallest.

They are a widely scattered but waning type in these modern days, for the family consists of the single genus *Platanus* with only six or seven species of Southwestern Asia, Eastern and Wesern North America, Mexico and Central America. The members of this small group are very uniform in general appearance, with large deciduous leaves, minute flowers in closely packed pendulous heads that remain attached during the winter, during which season the pappose fruits are widely distributed by the winds. The leafstalks are enlarged at the base to enclose the winter buds; and the bark is very thin, smooth, and pale green or whitish. The wood is likewise rather uniform, in all being light brownish or reddish in color with wide rays. It splits poorly and in general is of secondary commercial importance.

The known ancestral history of these trees extends back into the dim past a staggering number of thousands or even millions of years. A still flourishing forest giant with a height of upwards of 170 feet and a trunk diameter of ten or eleven feet, which are the dimensions of some individuals of our American sycamore (*Platanus occidentalis* L.), has survived more changes in human history than almost any royal or ducal line. Columbus might have seen a still surviving one as a young tree had he penetrated inland along the river bottoms of our southern states. The family history is surpassingly more majestic for it extends back to the days when even the ape-man was a distant promise and the reptilian tribe of animals were the lords of crea-

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tion. The gigantic uncouth dinosaurs of the late Cretaceous, so many of which have been unearthed and are now mounted in our larger museums, carry us a long way back and yet we know from the records, that when the breath of life left their massive bulks some of the leaves that fell around them were those of plane trees not very different from the leaves that strew the ground in our parks in October.

These trees have interests for the forester, the lumberman, the votary of culture and the botanist. For the latter they have an especial interest because of their affinity with the figs (another group of great antiquity) and their disputed position in the current schemes of classification.

A brief consideration of the Cretaceous records of *Platanus* sheds a significant light on the place of origin of the genus. Excluding the Laramie formation, since its records are confused in the literature with those of the basal Eocene, I have collected the following references to the existence of *Platanus* during the Cretaceous:—The oldest occurrences are two species in the Raritan formation of the New Jersey region and two different species from the lower beds of the Tuscaloosa formation of the Alabama region. Very slightly younger are the strata of the Dakota Group extending from Minnesota and Colorado to Texas from which Lesquereux has described ten species and varieties. About the same age as the latter is the Magothy formation of our Northern Atlantic coastal plain with one species and the Atane beds of West Greenland with another. The somewhat younger Patoot beds of West Greenland furnish one species, there is another in the Ripley formation of Eastern Alabama and a third in the Montana Group of Utah. These American records total sixteen forms. The only other Cretaceous records known to me are the not certain identification of two Dakota Group forms from the Upper Cretaceous of Argentina, one certainly not a *Platanus*, and three supposed species from the Cenomanian of Bohemia described by Velenovsky and Marik. The latter I regard as referable to the probably allied genus *Credneria* of Zenker.

Regarding the authenticity of the botanical determination of these various species it is probable that some of the records are worthless, but enough remain which are based upon an abundance of absolutely characteristic leaves, in some cases accompanied by typical fruits, to render it certain that in Middle Cretaceous times, ancestral plane trees were an abundant element in the flora of North America, and that later in the Cretaceous they had spread to South America and the Arctic region. They may have continued across the latter region into Europe although the records are not entirely convincing as regard the Cretaceous but are more ample in support of such a migration in the Tertiary.

These early ancestors had somewhat elongated rhomboidal leaves, with irregularly and remotely toothed margins, decurrent on the petiole, which was conspicuously enlarged at the base. There was a tendency, not especially pronounced, toward palmate trilobation. The floral axes were already shortened and aggregated and the fruiting heads were racemose as is indicated by the predominancy of this habit in the existing species and its frequent occurrence in forms like *Platanus occidentalis* that normally have but one fruiting head to a peduncle. These ancestral leaf characters are deduced from the form of the earliest species and from the substantial agreement between them and the leaves of modern seedlings and adventitive shoots from old stumps both of which are supposed to exhibit more or less reversionary characters. Several of these are figured in the present connection.

Reacting to the genial influences of the Cretaceous climate these early forms soon broadened their leaves, which also became lobate, so that *Platanus Kümmeli* Berry of the Magothy Formation is scarcely distinguishable from the leaves of the existing species, especially *Platanus orientalis.* Its leaves are exceedingly abundant and the clays in places are packed with the remains of its fruits—true midcretaceous "buttonballs." From that remote age to the present time *Platanus* leaves have all shown a very strong generic likeness so that they are relatively easy of determination.

A quarter of a century ago Professor Ward wrote a paper on the paleontologic history of the genus *Platanus*[1] in which he ad-

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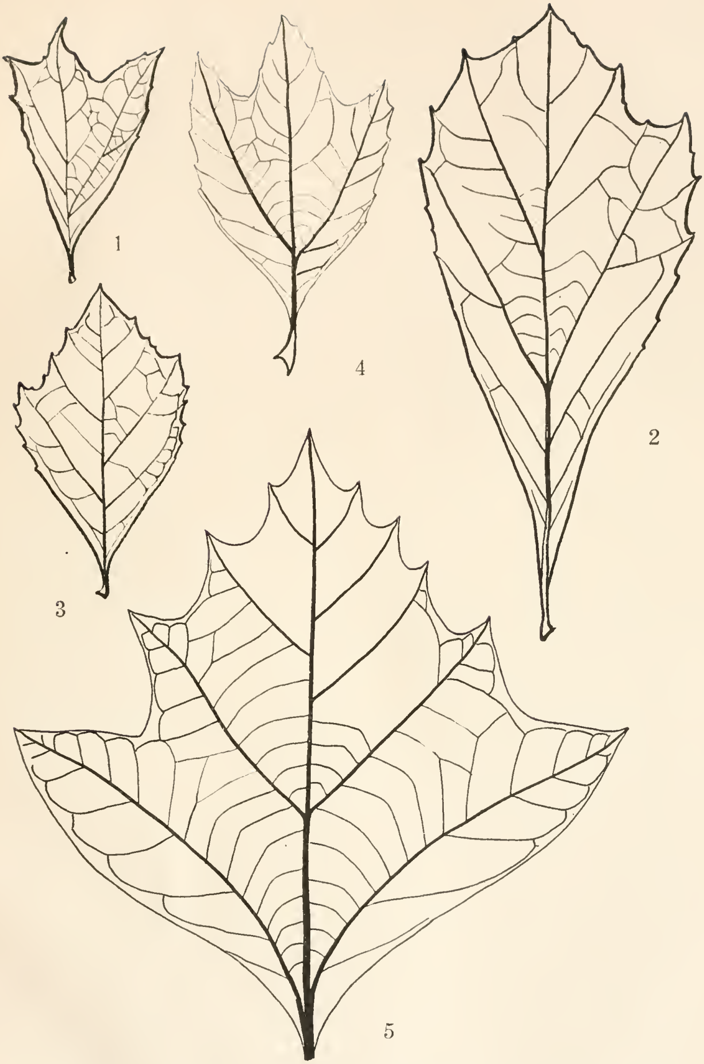
[1] Ward, Proc. U. S. Natl. Mus., **11:** 1888, pp. 39–42, pls. 17–22.

vocated the probable origin of the modern stipules from basilar leaf lobes. This suggestion was based on the basal lobes of several early Tertiary species and the occasional occurrence of comparable lobes in the modern *Platanus occidentalis*. This suggestion while interesting has not met with a ready acceptance. At the time that Ward wrote much less was known of the paleontologic history of the genus, especially its earlier manifestations, than is known today. At the present time the major outlines of this history can be sketched in with a good deal of certainty.

With the dawn of the Eocene, *Platanus* is abundant in North America, its original home. It would seem that the Eocene witnessed the greatest specific differentiation of the genus for no less than sixteen different species have been described. North America is still the home of the majority of these but the genus had undoubtedly spread into Asia and it is exceedingly common in the Arctic regions in the so-called Arctic Miocene which is really much older than Miocene. From these far northern and now boreal lands *Platanus* has been recorded in Siberia, Greenland, Iceland and Spitzbergen. At this period it appears to have been too warm in low latitudes, for *Platanus* is absent from the Eocene floras of Southeastern North America where the remains of tropical strand floras are found, and from the South European Eocene. The abundant American species occur for the most part in the low hilly country which marks the site of the present Rocky Mountains. From some of these basins, which at that time enjoyed a humid climate and supported a rich fauna and flora, plane-tree leaves nearly two feet in diameter have been collected. The most southern Eocene record in the European area thus far discovered is in deposits interbedded with the basaltic lava flows of this period on the Isle of Mull from which staminate catkins, fruit and leaves have been described as *Platanus hebridicus*.

The Oligocene period which succeeds the Eocene was a period of land emergence and dry hot climates. Consequently the localities where plane trees may be presumed to have flourished have been regions where their remains failed to become preserved. North America is especially poor in Oligocene plant remains of all kinds and no Olgiocene species of *Platanus* have been discovered



1, 2 *Platanus occidentalis* L. Leaves from adventitive twigs from old stumps. 3, *Platanus occidentalis* L. Leaf from seedling. 4, *Platanus shirleyensis* Berry, from the Tuscaloosa formation in Alabama. 5, *Platanus kümmelii* Berry, non-lobate form from the Cliffwood clays of New Jersey. All figures natural size.

although they must have been abundant since they again appear in the North American fossil record after the close of the Oligocene. Two or three species of *Platanus* of Oligocene age have, however, been discovered in European plant beds.

The Oligocene period was followed by the Miocene, a period during the early part of which the Oligocene elevation culminated and subsidence set in. This was accompanied by a striking climatic change, at least in the Eastern United States. In our southern states the Oligocene faunas and floras were such as flourish today under the equator. The succeeding Miocene deposits which overlie them in Northern Florida and elsewhere contain leaves of trees of the temperate zone and the remains of a marine fauna which had advanced from the New Jersey-Maryland region as the tropical fauna was driven southward. North America does not contain very many Miocene plant beds but nevertheless the remains of plane trees have been collected from Oregon and California on the Pacific coast, from the Yellowstone Park, and from Virginia on the Atlantic Coast. In Europe where Miocene plant beds are more frequent the leaves of *Platanus* are abundant and widely distributed although they belong to but few species—five have been described. One of these, *Platanus aceroides*, first described by Gœppert in 1852, is the dominant Miocene form of the whole northern hemisphere. Its European records include Baden, Switzerland, Silesia, Italy and many localities in Austria Hungary—a region remarkably rich in plant bearing deposits of Tertiary age.

Succeeding the Miocene are the deposits of the Pliocene lakes, rivers and seas. The Pliocene is the youngest period of the Tertiary age. North America was of much the same geographical extent as it is today and fossil plants are almost entirely unknown, consequently although the plane trees were unquestionably present they have left no records. Europe on the other hand was a region of great geographical change and mountain-making. The chief of these changes centered about the Mediterranean sea, the center of the classical world. At one time its waters withdrew westward to Italy leaving behind a chain of lakes. A wide grassy plain occupied the present Aegean region, another broad land bridge stretched across from Sicily to the site where Carthage was subsequently founded on the African coast, and a third united Spain with Morocco. At another time the Mediterranean waters extended over a vast area in Southeastern Europe. The climate was mild and humid and some of the finest forests that Europe has ever known clothed its shores. Pliocene remains of *Platanus* have been collected in Italy along the foothills of the rising Apennines, from France, Spain, Styria, and Slavonia.

The Tertiary was succeeded by the Quaternary, the fourth age of the older cosmogonists who divided the rocks into primary, secondary, tertiary and quaternary. The latter includes the Pleistocene, and the Recent period in which we are now living. The Pleistocene is marked by climatic changes which brought about the extensive glaciation of the ice age, that most profound factor in the distribution of modern animals and plants. The most interesting Pleistocene deposits in the eyes of the botanist are those of old forest beds and peat bogs. These show that the plane tree was still present in Central Europe, although today it is not a native in that region except as it is planted. American records show that our modern sycamore was already in existence with habits much like it has at the present time. Its leaves and fruits have been unearthed in the clays of river terraces around Morgantown, West Virgniia; in the sediments that filled the bone cave at Port Kennedy, Pennsylvania, once the lair of various Pleistocene wild animals; and in the buried river swamps of North Carolina and Alabama. During an Interglacial period it spread northward to Southern Canada and left its leaves in the clays of the Don Valley near Toronto.

I have written several similar brief sketches of the geologic history of different American forest trees and hope to add similar accounts of others from time to time. My object is not purely cultural. I hope that my readers will become awake to the records of the ages preserved in the structure and habits of our commoner forest trees. This fruiting habit acquired perhaps in the Eocene three millions of years ago, this anatomical feature of the wood acquired perhaps in the Upper Cretaceous—the changing environment of the successive ages that moulded each type until it is what we see it today. Let imagination play over the world history enacted in the shadows of these trees—the building of the Rockies, the evolution of the mammals and of primitive man. If the building of the tower of Babel, the hanging gardens of Babylon, or the pyramids, are awe-inspiring, what shall we say of the slow formation of the Himalayas, during which faunas came and went while the sycamore line flourished on and on. Beside the sycamore, oak or pine, the Rosetti stone or Elgin marbles are things of yesterday. Why should we not venerate our forest trees as we do man-built temples of classic days? When we are confronted by a sycamore that witnessed De Soto crossing the Tombigbee shall we not hesitate at the wanton destruction of what should mean so much to us?

RAINFALL AS A DETERMINANT OF SOIL MOISTURE

FORREST SHREVE

The Desert Laboratory, Tucson, Arizona

The influence of rainfall upon the distribution and seasonal activities of plants is obviously exerted chiefly through its power to replenish the moisture of the soil. In physiological plant geography much good use has been made of annual totals of rain, the seasonal distribution of rain, and the correlation of rainfall and evaporation, as criteria for explaining the distribution of various types of vegetation. In more intensive investigations it is desirable to replace the consideration of rainfall—which is mediate in its relation to plants—by a consideration of soil moisture, which is immediate in this relation. The general parallelism of rainfall and soil moisture conditions over large areas, and the ready accessibility of rainfall records, contrasted with the scarcity of soil moisture data, will long continue to be ample justification for giving rainfall a prominent place as a so-called factor in determining plant distribution.

It is the purpose of the present paper to present a digest of a short record of desert rainfall, interpreted in terms of its possible effect upon soil moisture; to give data showing the annual march of water content at three depths in a retentive clay soil; to indicate the relative potency which different falls of rain were found to have in renewing the store of soil water; and to estimate the relative efficiencies of various percentages of soil water for the maintenance of plant activity by correlating them with the concurrent rates of aerial evaporation.

The desert regions of North America are characterised by a low rainfall which is chiefly made up of a large number of light rains and a small number of torrential rains. The soil of such regions may very well be thought of as a gigantic reservoir which is replenished at infrequent intervals, and is drained continually by underground seepage, by surface evaporation and by the draught of plants upon it. It is obvious that the influence which the individual falls of rain exert during the course of the year in replenishing the soil moisture is not proportional to their actual amounts. The light rains often fall on a warm, parched soil and are totally converted into vapor within a few hours; the heavy rains are often of such short duration that the run-off is very great, resulting in a thorough wetting of upland soils and also an addition to the soil water of flood plains and valleys.

In tropical and temperate regions of copious and well distributed rainfall the moisture of the soil is maintained at such high and constant percentages that it fails to be a differential factor in plant distribution. The importance of the sustained soil moisture of such regions is no less great, however, and the heavy rainfall to which it is due exerts direct effects upon the vegetation which are unknown in semi-humid and arid regions.

RAINFALL

The record of precipitation at the Desert Laboratory, at Tucson, Arizona, now covers eight calendar years without break—1905 to 1912 inclusive—and the manuscript records of the daily falls since January 1, 1907, have been available in the present digest. The Laboratory is situated in the eastern foothills of a low range of mountains, and exhibits a slightly higher rainfall than the Arizona Experiment Station, situated 4 miles east of the Laboratory on the mesa of the Santa Cruz Valley. The precipitation has been measured by means of the ordinary type of metal gauge, in addition to which an electrical recording gauge has been installed since January 1, 1912.

The average annual rainfall from 1905 to 1912 inclusive was 14.60 in. (37.1 cm.), the lowest annual fall being 11.11 in. (28.2 cm.) in 1906 and the highest 23.32 in. (59.2 cm.) in 1905. The seasonal distribution of the precipitation is such that there are two well marked periods of rainfall, separated by intervals in which the fall is usually extremely scant. The winter months (December to March) embrace a period in which gentle rains of several hours duration are common; the arid fore-summer (April to June) is the driest portion of the year, with low precipitation, high evaporation, and increasing temperature; the humid midsummer (July to September) is characterised by frequent thunder showers, which may be light or heavy but are usually of short duration; the arid after-summer (October and November) is frequently as dry as the fore-summer, but is moderated by lower temperatures and cool nights. The rainfalls of each of the four seasons form the following percentages of the annual total: winter, 30.5 %; arid fore-summer, 5.5 %; humid mid-summer, 53.7 %; arid after-summer, 10.3 %. The total fall of the two rainy seasons forms 84.2 % of the annual total. For the 34 year record of Tucson the percentages of the seasonal rainfalls are as follows: 31.7 %, 5.9 %, 50.7 %, and 11.7 %, which is in close agreement with the percentages for the short record of the Desert Laboratory.

The average dates of the first and last occurrence of rains of 0.10 in. (0.3 cm.) or more in the summer rainy seasons of 1907 to 1912, are July 9 and September 10. In other words, slightly more than half of the annual rainfall takes place within 63 days, under normal conditions. The winter rainy season is not so regular in the time of its occurrence, nor is it so sharply confined to a short period (see fig. 1).

The average number of rainy days per annum is 61.5, but the number of days with slight rainfall is very high. The character of the individual falls of rain is of the first importance to vegetation, and figures have been deduced from the records to show the relative abundance of rainy days with falls of different intensities, and also to show the total rainfall yield of the rains of different intensities (table 1). There is an average of 17.5 days per annum with a trace of rainfall, 12.6 days from with 0.01 to 0.05 in., and the total number of days with less than 0.25 in. (including the above) is 45.2, or slightly less than 75% of the total number of rainy days.

The addition of the total rainfall yield of the several classes of rainy days shows that the days with 0.25 in. (0.65 cm.) or less furnish slightly less than 20% of the annual total. Although the heavier falls of rain are less frequent, the totals which they yield

TABLE 1

Rainy days grouped according to amount of rainfall, together with the total rainfall yield of each group

GROUP LIMITS IN INCHES	NUMBER OF RAINY DAYS IN GROUP		TOTAL RAINFALL YIELD OF GROUP FOR SIX YEARS
	In six years	Average per year	
Trace	105	17.5	14.96
0.01–0.05	76	12.6	
0.06–0.10	34	5.7	
0.11–0.15	22	3.7	
0.16–0.20	19	3.2	
0.21–0.25	15	2.5	
0.26–0.50	45	7.5	16.82
0.51–0.75	21	3.5	12.90
0.76–1.00	16	2.7	14.22
1.01–1.25	7	1.2	8.14
1.26–1.50	3	0.5	4.30
1.51–1.75	1	0.2	1.56
1.76–2.00	1	0.2	1.83
2.51–2.75	1	0.2	2.60
5.01–5.25	1	0.2	5.01

are approximately the same as the total for the lighter rains, up to 1 in. (2.5 cm.). The rains of more than 1 in. are still less frequent, but all of them together form a considerable proportion of the annual total. In fact, the 32 days of 1907 to 1912 on which there were rains of 0.75 in. (1.9 cm.) or more yielded 46 % of the total rainfall of the six years, although these 32 days were only 8.6 % of the total number of rainy days.

The existence of two seasons of precipitation, separated by weeks or months of pronounced aridity, gives to the vegetation a marked periodicity of activity. The desert perennials of the upland situations do no more than maintain their existence during the arid seasons, while the herbaceous flora confines its activities to the two humid seasons.[1]

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[1] For descriptions of the seasonal behavior of the vegetation at Tucson, see MacDougal, D. T., The Course of the Vegetative Seasons in Southern Arizona, The Plant World **11:** 189–201, 217–231, 237–249, 261–270, 1908; and Spalding, V. M., Distribution and Movements of Desert Plants, Publ. 113, Carnegie Institution, 1909.

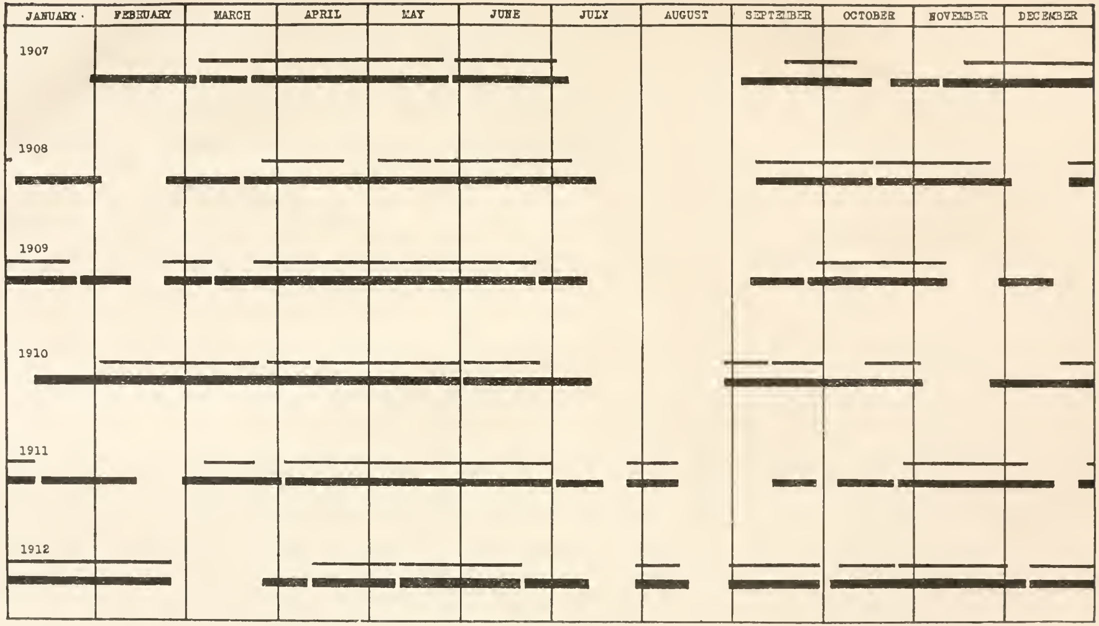

Fig. 1. Diagram to show duration of rainless periods (light lines) at the Desert Laboratory, and of periods without rainfall of sufficient amount to affect soil moisture (heavy lines).

In order to show graphically the duration of the rainless periods, figure 1 has been drawn, so as to indicate by lines the length of periods of two weeks or more which received no rain or only a trace or 0.01 in. (thin lines), and the periods which received no rains above 0.15 in. (heavy lines). It will be shown presently that few rains of less than 0.15 in. have an influence on soil moisture at 15 cm. or below, and that most rains above that amount have an appreciable wetting effect. The thin lines of figure 2 indicate the rainless periods from a climatological standpoint, the heavy lines indicate the rainless periods from the standpoint of the influence of rain upon soil moisture.

The lines of figure 2 show at a glance that the principal drought periods of the year fall in April, May and June, and that July and August are the months most regularly free of drought. The rainless intervals of October and November are less regular in their occurrence and not so great in their duration as those of the arid fore-summer, and the winter rainy period is also much more irregular and uncertain than the summer rainy period.

The longest abeyance of rain was in 1909, from March 23 to June 26—94 days in which there was one day with 0.01 in. of rain, and were three days with traces. The longest period without significant rain extended from January 11 to June 1, 1911—a stretch of 140 days during which occurred one rain of 0.13 in., one of 0.05 in. and six showers of less amount.

The extent to which the soil water that is derived from the heavy rains of restricted periods is conserved through the weeks of drought will be brought out in the discussion of soil moisture. It is not the absolute rainfall figures alone which furnish a criterion of the climate, in this case and in the case of other desert regions; the maximum duration of the drought periods constitutes a limiting climatic factor of the foremost importance to plants.

SOIL MOISTURE

A series of weekly determinations of soil moisture was made from August, 1910, to July, 1911, at a single locality on the slopes of Tumamoc Hill, near the Desert Laboratory.[2] The soil concerned is a very fine brown clay, derived from the weathering of basaltic rock. The surface of the soil is covered with a rock mulch of pebbles and larger stones, and throughout the soil rock fragments are extremely numerous. At a depth varying from 8 to 16 in. (20 to 40 cm.) the larger stones are cemented together with hardpan, or "caliche," beneath which is found either the rock *in situ*, or else lower pockets of soil. Throughout the deeper portions of the soil are still deeper extensions which fill cracks in the bed rock. It is mainly in these deep pockets of soil that the root systems of the adult desert perennials are located, and the successful establishment of their seedlings is largely a matter of the chance finding of such pockets by their extending root systems.

The weekly samples of soil for moisture determination were taken at depths of 3, 15 and 30 cm. (1.2, 5.9 and 11.8 in.), placed at once in bottles with tight stoppers, weighed, unstopped, and dried in a gas oven until successive weighings showed no further loss of weight. The temperature at which the soils were dried was not allowed to exceed 100°C., as higher temperatures are calculated to destroy the organic material of the soil and to occasion losses of weight not due to the escape of soil moisture. The percentage of moisture was calculated on the dry weight. A single series of samples was taken each week, each from immediately under the preceding sample. On the following week the series was taken from a spot about 2 m. distant. At no time were the three samples which formed a weekly reading taken from different holes, and at no time were successive weekly readings taken in widely separated spots. The taking of four series of samples on the same day, from the corners of a square of 2 m. diameter

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[2] The annual march of soil moisture in four soils in the vicinity of the Desert Laboratory, including the clay of Tumamoc Hill, has been described by: Livingston, B. E., Relation of Soil Moisture to Desert Vegetation. Bot. Gaz. **50**: 241–256. 1910.

showed that readings may be expected to vary from 2% to 4% at the same depth.

The entire series of readings has been brought together in figures 3 and 4 in such a way as to present a graphic picture of the annual march of soil moisture at the three depths. Each vertical series of three figures shows the moisture conditions on the date given at the top of the vertical line, the topmost figure giving the percentage of moisture at 3 cm., the middle one at 15 cm., and the lowest at 30 cm. Each horizontal series of figures shows the percentages of moisture that were found, week by week, at the same depth. In order to make clearer the march of the moisture conditions a series of curves has been drawn between the moisture figures in such a way as to separate the latter by gradations of 2 %. Over the soil curves are given two graphs which show the weekly rate of evaporation (solid line) and the weekly ratio of evaporation to the moisture of the soil at 30 cm. (dotted line), and also vertical lines which indicate the dates and amounts of rainfall. It is thus possible to examine together the march of the soil moisture conditions, and the relation which rainfall and evaporation sustain to this march.

RELATION OF RAINFALL TO SOIL MOISTURE

A few instances may be given of the manner in which the rainfall affects the soil moisture conditions: On November 3 there was a shower of 0.04 in. and on the following day a rain of 0.34 in. When the soil moisture was determined on November 7 it was found to have risen from 3 % (on the preceding week) to 17 % at 3 cm. and from 7 % to 9 % at 15 cm., but to have fallen from 12 % to 10% at 30 cm. The moisture at 3 cm. was, of course, much above 17 % on the days immediately following the rain; the moisture had had time to penetrate to 15 cm., but not sufficient time to reach the 30 cm. level. On November 13 there was a rain of 0.70 in. and on November 14 a rain of 0.03 in. As a result the moisture at 3 cm. was 24 % on the 14th, from which it fell to 14 % on the succeeding week. At 15 cm. the soil had risen from 9 % on November 7 to 11 %, but as a result of the rain of November 4 and not of the rain of the 13th, for it was two weeks after the latter rain before the moisture at 15 cm. had been raised to 13 %, and four weeks after before it had been raised to 16 %. As a result of another light rain of 0.15 in. on November 26 the moisture at 15 cm. was maintained at 15 %, until December 19. Other cases may be found by inspection of the diagram in which the influence of heavy rains is felt immediately at 3 cm. but is registered at 15 cm. only after one or two weeks.

A long period of progressive desiccation of the soil which occurred from November 26 to January 10 (see also fig. 1) was suddenly terminated on the latter date by a rain of 0.77 in. followed on the succeeding days by rains of 0.18 in. and 0.02 in., which resulted in a rise of the moisture at 3 cm. from 8 % on January 9 to 19 % on January 16; and at 15 cm. a rise from 14 % to 22 %; at the same time that the soil at 30 cm. was unchanged at 15 %, although it rose to 19 % on January 23.

The long rainless period from April 2 to July 1 was accompanied by a slow desiccation, in which the soil at 3 cm. remained at about 2 %, that at 15 cm. fell from 14 % to 7 %, and that at 30 cm. from 15 % and 16 % to 9% and 10 %. The rise of moisture at the lower depth on dates in June, when there was no rainfall, may be due merely to the variation of the moisture in the places at which samples were taken, or it may be due to the capillary rise of water from lower bodies of soil which had remained at a higher moisture. The rain of 0.98 in. which ushered in the summer rainy season on July 1 raised the moistures on July 4 to 18 % at 3 cm. and 11 % at 15 cm., but did not affect the moisture at 30 cm. so quickly.

An unbroken continuation of the soil records became impossible after July 4, but a series of three weekly sets of readings was taken in August, 1911, after the summer rains had had an opportunity to replenish the soil moisture. There were several light rains in July, terminating on July 25 in a rain of 0.33 in. There then followed a period of 18 days without rain (see fig. 1). On the thirteenth day of this dry period—August 7—the moisture of the soil at the three depths was respectively 3 %, 13 % and 16 %. On August 13 the dry period was terminated by a rain of 0.30

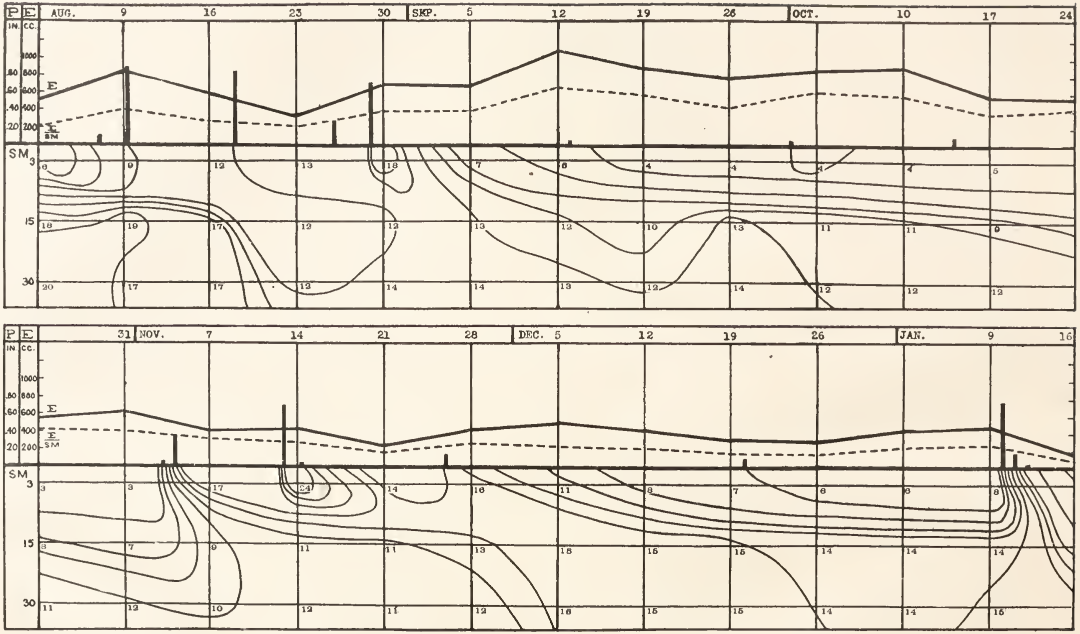

Fig. 2. Diagram to show the incidence of rainfall (vertical lines, scale P) at the Desert Laboratory, and the march of soil moisture (SM), evaporation (E), and the evaporation-soil-moisture ratio $\left(\frac{E}{SM}\right)$ from August, 1910, to January, 1911.

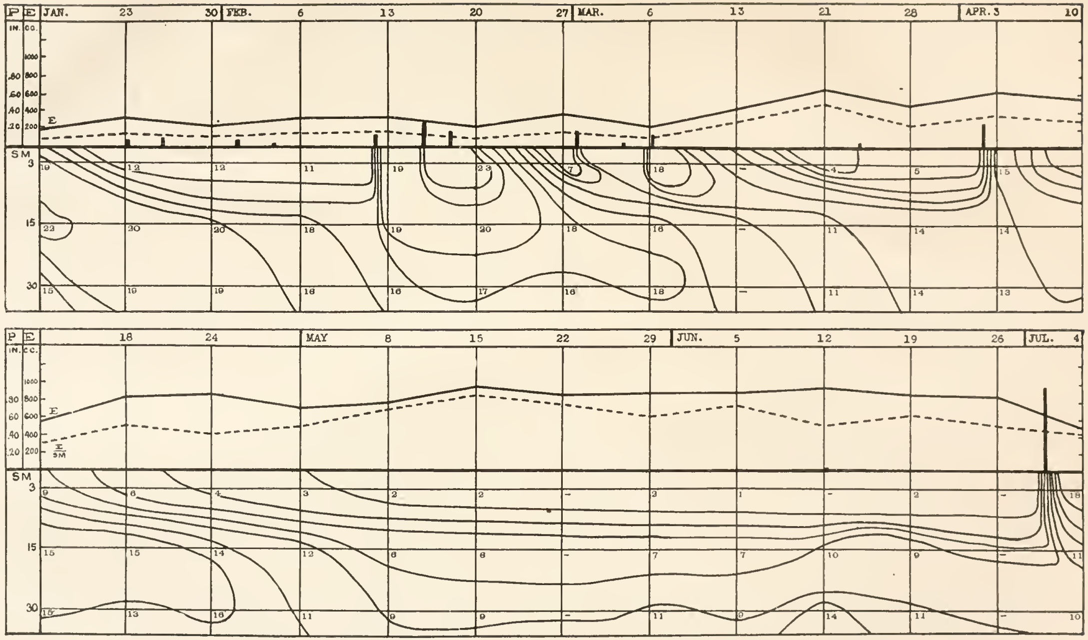

Fig. 3. A continuation of figure 2 from January, 1911, to July, 1911

in., which raised the moisture at 3 cm. on the 14th to 17 %, but did not affect the lower soil, which was still dry, under the influence of the rainless period, having a moisture of 11 % at 15 cm. and 12 % at 30 cm. During the eight days from August 14 to August 22 there were five rainy days with falls of the following amounts: 0.52 in., 0.46 in., 0.53 in., 0.76 in., and 0.88 in. The total effect of such an unusually wet week was to raise the moisture to 27 %, 28 % and 32 % at the three depths, reading from the surface. These figures undoubtedly come close to representing the maximum conditions of soil moisture for the Tumamoc clay.[3]

It will be observed that the light rains between December 23 and February 6—0.06 in., 0.09 in., 0.07 in., and 0.02 in. respectively—were without effect upon soil moisture, except in so far as they contributed to a lowering of the evaporation rate and a consequent conservation of the soil water. Rains of 0.10 in. on October 14 and December 20 were without effect on the soil moisture at 15 cm. and 30 cm. A rain of 0.15 in. on November 26 had the apparent effect of raising the moisture at 15 cm. from 13 % to 16 %, but this rise was in large measure due to the rain of 0.70 in. on November 13, which had already caused a rise of the 15 cm. soil from 11 % to 13 %. A rainfall of 0.18 in. on February 28 did not prevent a continuation of the drop in the moisture at 15 cm. from 18 % to 16 %, although the rain of 0.13 in. on March 6 was responsible for a rise in moisture at 15 cm. three weeks later, but possibly only in conjunction with the rain of 0.18 in. The rain of 0.28 in. on April 2 caused a marked rise in the well desiccated surface soil, but effected only slight rises at 15 cm. and 0.30 cm. depth.

It is possible to say in summation, that rains of less than 0.10 in. are without effect on the moisture of the soil at 15 cm., at least if such fall occurs after a dry period of two or three weeks, on a soil with a moisture of 4 % to 7 % at 3 cm. A rain of 0.15 in. may have an effect if it falls on soil which is already moist,

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[3] The highest moisture recorded by Livingston (as cited) was 35 % at 30 cm., after two weeks with a rainfall of 18.52 in. The maximum water-retaining power of Tumamoc clay was determined by Livingston as 48 % of its dry weight.

as in the case of the rain of November 26, with surface soil moisture of 14 %. A rain of 0.18 in., with surface soil moisture of 5 %, was of some effect. The actual potency of a given amount of rainfall in replenishing the store of soil moisture depends on the moistness of the surface soil at the time of the fall, but to some extent on the moistness of the lower soil as well. The atmospheric conditions immediately following a rain also help to determine whether it sinks into the soil or is rapidly evaporated. It would require a long series of observations to establish the force of these and other conditions in determining what is the minimum amount of significant rain. So far as the above data indicate, a conservative approximation of the lower limit of significant rainfalls may be placed at 0.15 in. The plotting of the periods during 1907 to 1912 which were without significant rain (fig. 1) has been done on the basis of a lower limit of 0.15 in. For soils of greater wettability than the Tumamoc clay the limit of significant rainfall would be much lower, and the entire march of soil moisture conditions, and the relation of rainfall and of atmospheric and soil evaporation to the moisture of the soil, would be altogether different.

From a knowledge of the dry weight of Tumamoc clay, and of the percentage of water in it at a given time, it is possible to calculate the amount of water contained in a unit of the soil at the given percentage. The weight of the dry soil, free of all rocks and stones, is 1.38 grams per cubic centimeter. In a unit of soil with a surface area of 1 sq. m. and a depth of 30 cm. there are 414 k. The average moisture down to a depth of 30 cm. may be approximated by using the actual readings for 3, 15 and 30 cm., interpolating percentages for 10, 20 and 25 cm., and taking the average of the six values. The actual amount of water in an ideal, rock-free unit of soil can be determined by multiplying the average percentage of soil moisture by 414.

During the driest weeks of June the average soil moisture was 6.5 %, and in the wettest week of August, 1911, it was 29 %. These percentages would give a water content of 26.9 k. for June, and of 120 k. for August, per soil unit. The actual amounts of water contained in average units, as they vary from spot to spot, would be less than the figures given, according to the rockiness, but would be proportional to them. This indicates that in the soil of Tumamoc Hill at its minimum annual water content there is between one-fourth and one-fifth as much water as there is at its maximum annual content.

The average annual rainfall of the Desert Laboratory is 14.60 in., or 37.1 cm., an amount which places on the surface of each soil unit 371 k. of water per annum. At its minimum water content the soil contains, therefore, somewhat less than one-fourteenth of its available annual supply. This fraction is lessened in the case of rocky units of soil, and is increased in the case of a year in which the run-off is great.

RATIO OF EVAPORATION TO SOIL MOISTURE

The curve of weekly rates of evaporation given in figures 2 and 3 is based on figures secured from porous cup atmometers which are run continuously on the roof of the Desert Laboratory. The results of these readings are collated and reduced to standard by Dr. B. E. Livingston, to whom I am indebted for the figures used here. The readings of evaporation were taken on the same day of the week that the soil samples were secured, and the reading plotted to each date is the total evaporation for the preceding seven days.

The weekly loss registered on August 23, 1910, was 318 cc. For three weeks thereafter the rate rose until it reached 1084 cc. on October 12, the maximum for the arid after-summer. The rate then fell throughout the winter to the annual minimum of 173 cc. on the week ending January 16. The rate remained low thereafter until March 6, with a reading of 242 cc., and then rapidly rose to a loss of 836 cc, on April 18. From the latter date until July 4 there was a sustained high rate of evaporation, attaining its maximum of 990 cc. on May 15.

The total evaporation from August 3, 1910, to July 31, 1911, was 31,447 cc. In order to convert this amount into terms of loss from a free water surface it is necessary to multiply it by 0.76, a factor which has been experimentally determined by comparison of losses from the atmometer and from a petri dish of

69.3 sq. cm. area.[4] The conversion of the total gives an annual rate of evaporation of 345 cc. per square centimetre. The average annual rainfall for the Desert Laboratory—14.60 in.—yields an annual fall of 37.1 cc. per square centimetre of soil surface. The ratio of the evaporation to the rainfall is as 9.3 : 1. The average annual rainfall for the 34-year record of Tucson is 11.57 in., an amount which yields a fall of 29.4 cc. per square centimetre. The ratio of the evaporation at the Desert Laboratory to the rainfall at Tucson is as 11.6 : 1.

The ratio of evaporation to rainfall has been used as a criterion of the moisture conditions of climates in relation to vegetation,[5] and as a criterion of extremely general application it is not without its usefulness. The fact, however, that it is not the actual amount of rainfall which is of importance to plants, but the amount of soil moisture, makes it worth while to determine the ratio of evaporation to soil moisture. Such a ratio does not contain the error due to the fact that the insignificant and the superfluous rainfall forms a part of the annual total, and is an actual expression of the relation of the moisture supply for plants to the atmospheric moisture drain which is continually made upon them. The fact that there is a certain residuum of soil moisture at low percentages which is not available to plants would make it desirable to use, in calculating this ratio, only the available moisture content of the soil. Although such a procedure would make more comparable the ratios determined for soils of different textures, it has not been done in this case owing to the fact that the lower limit of available soil moisture is different for different species of plants, and that the limit for a given species has been shown to vary with the atmospheric conditions themselves.[6]

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[4] The arbitrary character of all conversions of atmometer losses into terms of evaporation from a water surface, and the dependence of the conversion on the character of the water container, has been emphasized by: Livingston, B. E., Operation of the Porous Cup Atmometer. The Plant World **13**: 111–119. 1910.

[5] Notably by: Transeau, E. N., Forest Centers of Eastern North America. Am. Nat. **39**: 875–889. 1905.

[6] Brown, W. H., The Relation of Evaporation to the Water Content of the Soil at the Time of Wilting. The Plant World **15**: 121–134. 1912.

The annual march of the ratio of soil moisture to evaporation is drawn (as a dotted line) together with the curve of evaporation on figures 2 and 3. The arbitrary figures in which the ratio is expressed were secured by dividing the weekly evaporation rate in cubic centimeters by the figures for the percentage of soil moisture at 15 cm., as determined on the same day. The ratio curve will be seen to follow the evaporation curve in a general manner. The high points in the curve indicate a high rate of evaporation with a low soil moisture, and the low points indicate the converse. The ratio curve, as plotted, approaches most nearly to the evaporation curve when the evaporation is high and the soil moisture is low, as on May 8 and 15. The two curves depart slightly further when the evaporation is high and the soil moisture is relatively high also, as on August 9 and April 24. During December, January and February the ratio curve runs about half-way between the evaporation curve and the base line, whereas in September and in May and June it runs well above the middle of this interval. In other words the ratio is relatively high in the winter months, as contrasted with the evaporation rate.

The dotted curve shows that week by week the evaporation rate is dominant in controlling the ratio itself, while between the seasons of the year the soil moisture is potent in determining the values of the ratio. This result is due in part to the smallness and narrow range of the figures which represent the soil moistures and the largeness of the figures which indicate the evaporation rate; in part it is an expression of the conservative changes of the soil moisture in contrast to the wide fluctuations of evaporation rate.

The highest value for the ratio curve is 110 for May 15, the lowest is 11.5 for January 16. Since the ratio itself is an expression of the conditions that chiefly control the maintenance of the absorption-transpiration balance in plants, the maximal and minimal values of the ratio indicate that these conditions are ten times as severe in the most arid part of the year as they are in the least arid.

A determination of the soil moisture and evaporation ratio has been made by the writer for six altitudes in the Santa Catalina Mountains, near Tucson, from 3000 ft. to 8000 ft. for the arid fore-summer, the season in which there is the maximum differentiation of the conditions at the base and the summit of this desert mountain range.[7] The ratio of soil moisture to evaporation at 3000 ft. is to the ratio for 8000 ft. as 9.7 is to 1. In other words the ratios for the base and summit of the mountain range are to each other in the same proportion as the maximum and minimum ratios for the year at the Desert Laboratory. The annual range of moisture conditions at the Desert Laboratory is as great, then, as it is through 5000 ft. of altitude in the adjacent mountains in the most arid season of the year.

SUMMARY

The chief importance of rainfall to vegetation lies in its restoration of the supplies of soil moisture. In desert regions the rainfall consists largely of light, insignificant showers and heavy rains with high run-off. In a study of desert rainfall in relation to the march of soil moisture it is necessary to determine the lower limit of amount of significant rainfalls. It is also necessary, in relation to vegetation, to ascertain the lengths of periods without significant rainfall.

The average annual rainfall at the Desert Laboratory is 14.60 in. There are two rainy seasons, that of the summer averages 63 days in length, but yields 54% of the annual rainfall. The average number of rainy days is 61.5 per annum, on 46.2 of which the rainfall is less than 0.25 in. In six years there were 32 days with more than 0.75 in. of rain, and they yielded 46 % of the total rainfall of the six years. There have been periods of 140 days without rainfall of sufficient amount (0.15 in.) to affect the soil moisture.

The march of soil moisture during the year is closely related to the amounts of the significant falls of rain, and the changes of moisture content are conservative at the lower depths (15 cm. and 30 cm.) in the heavy clay soil investigated. The moisture

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[7] See Carnegie Institution Year Book No. 11, p. 59. 1912.

at 3 cm. falls as low as 1 % and that at 30 cm. rises to as much as 32 %. The average moisture of the soil from the surface to 30 cm. in the driest weeks of the year is 6.5 %, in the wettest is 29 %. At its minimum water content the clay soil contains about one-fourteenth of the annual supply of water furnished it by the normal rainfall.

The weekly rate of atmospheric evaporation ranges from a minimum of 173 cc. to a maximum of 1084 cc.—the annual total being 31,447 cc., in terms of loss from a porous cup atmometer. This is equivalent to a loss of 345 cc. per square centimetre from a free water surface. The ratio of evaporation to rainfall is as 9.3 is to 1.

The ratio of evaporation to soil moisture fluctuates from a minimum amount to a maximum which are in the proportion of 1 to 10. The ratio of evaporation to soil moisture at the foot of the Santa Catalina Mountains is 9.7 times the same ratio for their summit. The annual amplitude of moisture conditions at the Desert Laboratory is as great, therefore, as that which exists in the most arid portion of the year between localities which are 5000 vertical feet apart.

BOOKS AND CURRENT LITERATURE

Higher Plants and Nitrate Formation.—This memoir[1] contains the result of investigations conducted during the past six years upon the relations of certain crops to the nitrate content of the soil. The authors had previously advanced the hypothesis that certain non-leguminous plants exert a stimulating or a depressing influence on the process of nitrate formation, depending on the stage of growth. In the present paper the data substantiating this contention are assembled. It was found that during the most active growing period of maize, nitrates are frequently higher under this crop than in cultivated soils bearing no crop, a result contrary to the general teaching and belief. This phenomenon is accounted for on the assumption that nitrate formation is stimulated by some processes connected with the active growth and absorbing function of the plant, although there are indications that maize obtains a large part of its nitrogen in some other form than as nitrates. The combination of these conditions may account for the very high nitrate content of the soil under maize. Under a mixture of maize and millet, when both crops were most actively growing, the nitrates are higher than under millet alone.

It was also found with oats as well as with maize that the nitrate content was higher at the time when the crop was making its greatest draft on the soil nitrogen, than in the later stages of growth, in spite of the fact that the nitrates in the uncropped soil were increasing while those on the cropped soil were disappearing. When, late in the season, nitrogen absorption had practically ceased under both oats and maize there was no increase in nitrates, although there was a very marked increase in nitrates in uncropped soil. These facts indicate that during the later period of their growth, oats and maize exert in some manner a depressing influence on nitrate formation.

A characteristic relation of the several plants to the nitrate content of the soil in the year following that in which the plants had been grown was also noted. Central plats were planted to maize, oats, and potatoes,

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[1] Lyon, T. Lyttleton and Bizzell, J. A., Some relations of certain higher plants to the formation of nitrates in soils. Cornell Agr. Exp. Sta. Memoir No. 1: 1–111, 1913.

in 1910 and kept bare of vegetation in 1911. Determinations of the nitrate content of these plats were made during the early part of the growing season of 1911. The plat which had grown maize was the only one which had a higher nitrate content than unplanted soil, potato soil was next highest and oats soil contained the least nitrates. Timothy and blue grass gave much less nitrogen in the crop and drainage water combined than was in the drainage water from unplanted soil.

The association during growth of two different kinds of plants, in soil and in quartz to which nitrates had been added, was found to result in a larger growth of one or both kinds than when either plant was grown in pure culture.—FREDERICK A. WOLF.

CHEMISTRY OF PLANT PRODUCTS.—Plant physiologists are very fortunate in possessing a number of excellent text-books on the principles of their subject. However, the developments in the chemical aspects of the subject have been so rapid and extensive that an incorporation of plant chemistry in these texts has been greatly neglected or considered as beyond the scope of these works. Likewise, the texts of organic, general physiological, and pharmaceutical chemistry have omitted the greater portion of this work. A compilation and discussion of the contributions to the chemistry of plant products is therefore exceedingly welcome. This work[1] devotes a section each to: (1) fats, oils, waxes, and phosphatides, (2) carbohydrates, (3) glucosides, (4) tannins, (5) pigments, (6) nitrogen bases, (7) colloids, (8) proteins, (9) enzymes; giving in each case the occurrence, the industrial significance, if any, methods of obtaining, characteristic properties and reactions, microchemical reactions, quantitative methods of estimation, and finally their physiological significance. We miss here any treatment of the resins, terpenes, essential oils, and organic acids. Some knowledge of organic chemistry is absolutely essential for the book to be of any value to a student, and in a few cases it is necessary to know the original work in order to gain clarity on the subject discussed, *e. g.* the discussion of the amphoteric nature of certain proteins (p 302). The application of the principles of physical chemistry is greatly neglected, especially is this the case in the chapters on colloids and enzymes. The tannins are very well treated, and the chapter on chlorophyll gives a very good résumé of the recent work, especially that of

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[1] Haas, Paul, and Hill, T. G., An Introduction to the Chemistry of Plant Products. 8vo. Pp. 401. London, Longmans, Green and Company, 1913.

Willstätter. The references to the literature are very well chosen to lead to a more extensive study. On a careful perusal of the book a great many problems for investigation suggest themselves which fill the reader with a great desire to extend his knowledge by further reading and research.—H. A. SPOEHR.

IDENTITY OF BROWN ROT IN AMERICA.—The opinion has been quite generally held that the American brown rot of stone fruits is caused by *Sclerotinia fructigena.* European writers, following the lead of Aderhold and Ruhland, maintain that the form occurring on stone fruits is to be regarded as *S. cinerea,* and the one on pome fruit as *S. fructigena.* An extensive study[1] of the behavior of *S. cinerea* when grown on apples, pears, quinces and plums, and in pure cultures, of the size of its conidia, asci and ascospores, leads to the conclusion that the American brown rot of stone fruits should properly be referred to *S. cinerea.*—FREDERICK A. WOLF.

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[1] Matheny, W. A., A comparison of the American brown rot fungus with Sclerotinia fructigena and S. cinerea of Europe. Bot. Gaz. **54**:418–432, figs. 6. 1913.

NOTES AND COMMENT

A series of eleven papers constituting a symposium on the subject of forest types has been published in the Proceedings of the Society of American Foresters (**8**: no. 1, April, 1913).

The classification of public lands with respect to their forest cover and their agricultural possibilities is by no means a simple matter. Nearly all of the shades of opinion regarding it are reflected in the symposium, in the course of which it is not always clear whether the discussion concerns the economic classification of land or the scientific classification of forests.

Those who are interested in the practical work of taking stock of the present timber resources of the country are accustomed to use the term forest type in the sense of a body of standing timber of definite composition. Those who are interested in silvicultural methods, however, use forest type in the sense of a body of timber requiring definite physical conditions and a uniform management. The "management type" of the silviculturist is a selected or cultural aggregation of species and is not always identical with the natural or "cover type" recognized in the reconnaisance of virgin forests. The areal delimination of cover types gives an ecological classification of forest areas, based on specific composition—an easy task which fulfills the practical needs of the present. The silviculturist demands a physiological classification of forest areas and an exact knowledge of physical conditions, a demand which pure botany is not yet prepared to meet. If such knowledge were at hand it would make it possible to develop the optimum forest crop for each region and each topographic site without the delay and expense of empirical methods. The fact that there is just as close a correlation between the physical conditions and the cover types of the virgin forest as there can be between the conditions and the management types, is sometimes lost sight of in the symposium, although in this correlation is the only immediate source of aid for the silviculturist.

THE SEASONAL LIFE-CYCLE OF SOME RED ALGAE AT WOODS HOLE

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The complete life-cycle of the red algae has been a subject of speculation rather than exact knowledge. For various reasons the Florideae have not been much studied during the winter, and the difficulty of cultivating them in the laboratory has prevented satisfactory experimental work. In the course of some field work done at Woods Hole in 1911–1913 it has been possible to follow the history of certain typical species throughout the year.

Some of these results have already been published.[1] In the present paper will be given the conclusions drawn from some cultures of *Dasya elegans*, *Griffithsia Bornetiana* Farlow (= *G. globifera* Ag.), and *Polysiphonia violacea*, which lasted from July, 1912, until August, 1913.

Both tetraspores and carpospores of the species mentioned were sown on oyster shells in the laboratory in July, 1912. In about twenty-four hours, when the resulting sporelings were firmly attached, the shells were clamped to boards by means of galvanized iron screws, and the boards were then nailed to the piles at the outer end of the Fay Wharf.

In August of the same year the shells were examined in a cursory way, and cumulative evidence was obtained corroborating the previous conclusions that tetraspores produce sexual plants without exception. The shells on which tetraspores had been sown were covered with a dense growth of young plants which random samplings showed to be sexual. The carpospores produced an equally vigorous growth, but no fertile individuals were found.

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[1] I. F. Lewis, Alternation of generations in certain Florideae. Bot. Gaz. **53**: 236–242. 1912.

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In this condition the shells were left. They were not examined again until June, 1913, when they were found to be bare of red algae, or at least as bare as the neighboring piles. It is evident that the individuals forming the abundant growth of the preceding September did not survive. It may be stated as a general rule that the plant which has attained any considerable size or which has produced reproductive bodies dies at the approach of cold weather. Only the very young sporelings are able to resist the changed conditions and remain dormant during the winter.

Some of the shells, and also slivers of wood cut from the adjoining piles, were carefully examined. Small red dots were found sparsely on shells and wood alike. This condition is to be contrasted with that of the previous August, when the shells were abundantly covered with crowded sporelings and the piles almost or entirely bare of the species under observation. On examination, the small dots proved to be the tiny holdfasts of species which could not be identified with the data at hand. In addition to these holdfasts, there were also present on the shells various brown algae and sponges.

In July young plants of the three species employed were found sparingly on all the shells and rather abundantly on the piles. It is a point of special importance that these species had not previously been seen on the piles of the Fay Wharf, this being one of the reasons why this particular spot had been selected for the experiments.

As they matured, these plants proved to be prevailingly tetrasporic, as is generally true of specimens collected at random at this season. In early August they began to be replaced by sexual plants, as is also true generally. In hundreds of collections made in July, about ten tetrasporic plants to one sexual individual were found, while in August the majority of plants collected were sexual. This has been shown to be true of many other species, as well as of those with which the experiments were carried out.

From the available data the entire life-cycle of the species used can be reconstructed. In July the tetrasporic plants produce tetraspores in great numbers, and scattering sexual plants produce some carpospores. The carpospores germinate readily, but reach maturity slowly, so that only a small proportion of these produce reproductive bodies (tetraspores). The tetraspores, however, give rise to sporelings which quickly reach maturity. Of the large number of sexual plants so produced, some form carpospores in abundance.

Thus it may be seen that the entire growth of a single summer may be divided into two well marked phases. The earlier, or July crop, is characterized by the predominance of tetrasporic individuals, whereas the later, or August crop, consists mostly of smaller sexual plants, among which many large tetrasporic individuals, relics of the July crop, may still be seen. These old specimens usually come to grief in August, at which time they are torn from their supports and washed up on the beaches in large quantities. The late crop, therefore, becomes increasingly sexual.

With the approach of autumn all individuals of both these generations die, not even the holdfasts remaining alive. The abundant carpospores of early autumn become sporelings, of which the holdfasts persist through the winter. In the early summer following these give rise to the tetrasporic plants so abundant at this season. The few tetrasporic plants that reach maturity in late August or early September also produce spores, from which sporelings arise with holdfasts sufficiently resistant to last over the winter and produce the scarce sexual plants of the next July.

It is an interesting fact that the second generation (the August crop of sexual individuals) is found in many species, as well as in the three under discussion, on other algae and on eel-grass, while the first generation (the July crop of tetrasporic individuals) is mostly confined to more permanent objects such as stones or piles. The generation on which falls the task of overwintering is that of the tetrasporic plants, which thus, in spite of their morphological identity with the gamete-producing individuals, begin to show a physiological or seasonal differentiation.

For the overwhelming majority of individuals of the species mentioned the following schedule holds true:

July: tetrasporic plants release tetraspores.

August: the second generation of smaller sexual plants matures and releases carpospores.

September: the carpospores germinate and produce resistant holdfasts.

June: adventitious shoots appear on the tiny holdfasts.

July: these develop into tetrasporic plants.

Observations in the field corroborate these conclusions drawn from the intensive study of a few species, and indicate that many of the red algae common at Woods Hole will show on investigation a similar life cycle. Of these may be mentioned *Champia, Grinnellia, Agardhiella, Chondria*, and the species of *Polysiphonia* other than *P. violacea.*

This may be regarded as the complete and typical life-cycle for the New England coast, in just the same way that the complete and typical life-history of a liverwort comprises an alternation of sexual and asexual generations. The exceptions, however, which are rather rare in the liverwort (*e.g.* the continuance of the gametophyte by means of the gemmae of *Lunularia*), or in the ferns (*e.g.* the continuance of the sporophyte by vegetative propagation by means of adventitious buds in *Camptosorus* and in certain species of *Asplenium*) are somewhat common in the Florideae. Good examples are known in *Spermothamnion Turneri* in New England, where sexual plants very rarely appear; in *Rhodymenia palmata* on the Atlantic coast, where sexual reproduction is unknown; in *Nemalion* and many of the Nemalionales, in which asexual reproduction has not been developed except as the conception is involved in the formation of the carpospores from the fertilized egg. A most striking example is *Dudresnaya* at Naples. Although in *Dudresnaya coccinea* both sexual and tetrasporic individuals are found in abundance, in the nearly related *Dudresnaya purpurifera* only sexual plants are known.

There are also exceptions to the separation in point of time of the two generations. This separation is never of a perfectly sharp and definite character, as the generations always overlap to a certain extent in midsummer. Furthermore, a respectable minority of sexual individuals is always present even when the asexual plants are most dominant, and vice versa. In some species the two generations occur side by side so that neither is dominant at any season. Such species are *Ceramium rubrum* and *Corallina officinalis,* both of which occur at all seasons.

Interesting data have recently been furnished by Davis[2] of the seasonal distribution of marine algae at Woods Hole. Excluding the Nemalionales, 65 species of Florideae are covered in Davis' list with particulars of their seasonal occurrence. Of these, 53 are found in summer, 8 of which also occur in spring. The conclusions set forth in the present paper apply more particularly to these summer forms. Twelve species are mentioned by Davis as occurring at all seasons, and of these only one (*Agardhiella tenera*) shows the two generations clearly separated in point of time. In this species the second generation (sexual individuals) occurs like the first on stones, and not, as is so often the case, on eel grass and on other algae.

It may be mentioned here, however, that though Davis speaks of this species as occurring in "summer, undoubtedly at other seasons," no specific records are given of its collection in winter. The present author's observations on *Agardhiella* were all made near the entrance to Eel Pond, and here it may be stated with certainty that the approach of winter witnesses the death of all the larger individuals. In spite of Davis' statement, therefore, *Agardhiella* should be classed, as far as the present discussion goes, with the summer forms. This leaves all the perennial species as exceptions to the general rule given above.

SUMMARY

The tetraspores of *Dasya*, *Griffithsia*, and *Polysiphonia violacea*, abundant in July, produce a second generation of sexual plants in August. Carpospores from these produce sporelings which survive the winter by means of resistant holdfasts. All older plants perish. The surviving sporelings are prevailingly tetrasporic, which accounts for the predominance of tetrasporic plants in early summer.

Probably the majority of summer species on the New England coast behave as the species mentioned. There are, however, a number of exceptions to the general rule, and the conclusions reached do not apply to the perennial species.

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[2] Davis, B. M., A catalogue of the marine flora of Woods Hole and vicinity. Bull. U. S. Bureau of Fisheries **31**: part 2, pp. 795–833. 1911.

PHYTOGEOGRAPHICAL NOTES ON THE COASTAL PLAIN OF ARKANSAS

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Less botanical work seems to have been done in Arkansas than in any other state bordering the Mississippi River, and what little has been done has been almost entirely floristic. The best known floristic papers are probably those of Professor F. L. Harvey, mostly published in the Botanical Gazette between 1881 and 1885, and the catalogue of plants by Branner and Coville in the fourth volume of the report of the Geological Survey of Arkansas for 1888. In the way of descriptions of vegetation there are a few meager details in Nuttall's narrative of his journey to the "Arkansa Territory," 1821, D. D. Owen's two reports on the geology of Arkansas, 1858 and 1860, Loughridge's report on cotton production in the fifth volume of the Tenth Census, Sargent's report on forests in the ninth volume of the same series, reports by Branner and his assistants published by the state geological survey about twenty years ago, and the soil surveys of certain counties published by the U. S. Department of Agriculture in recent years. More useful to the phytogeographer and plant sociologist are Bulletin 32 of the U. S. Bureau of Forestry, entitled "A Working Plan for Forest Lands Near Pine Bluff, Arkansas," by F. E. Olmsted, 1902, and part of S. M. Coulter's "Ecological Comparison of Some Typical Swamp Areas," in the fifteenth report of the Missouri Botanical Garden, 1904.

In June, 1911, I spent something over five days in the coastal plain of Arkansas, and although I collected no specimens and made no startling discoveries, I gathered considerable information about the vegetation which will probably be as new to most persons who read this as it was to me.

On the tenth of the month named I stepped off a Mississippi River steamboat at Luna Landing, in the southeasternmost county, and went in a general northwesterly direction by the Iron Mountain Route to Little Rock, the capital and railroad center as well as the approximate geographical center of the state, missing the last 45 miles of scenery on account of the train being over two hours late. During the night I went to Arkadelphia, near the fall-line in Clark County, 65 miles southwest of Little Rock, where I remained until the afternoon of the thirteenth. I then returned to Little Rock by daylight, and on the fourteenth and fifteenth went eastward to Memphis, Tennessee, by the Rock Island Route, 133 miles, stopping a few hours in Prairie County and about a day in St. Francis County.

The coastal plain of Arkansas, unlike that of most other states, is about half alluvial bottoms, very similar to the "Yazoo delta" just across the river in Mississippi.[1] From Luna Landing on the Mississippi to Pine Bluff on the Arkansas (where darkness overtook me) I was in bottom lands practically all the way. The land of course rises as one leaves the Mississippi River, and more than it does on the east side, but so gradually as to be almost imperceptible to the traveler. And although the bottoms near Pine Bluff are evidently higher and drier than those in Chicot County, it does not seem possible to draw a geographical boundary at any intermediate point.

Southeastern Arkansas seems to have a much larger proportion of woodland at the present time than the corresponding "delta" of Mississippi, but probably more on account of its more recent settlement than of any fundamental edaphic factors. The plants listed in Table A were observed more than once between Luna Landing and Pine Bluff, by way of Lake Village and McGehee, a distance of about 89 miles.

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[1] See Bull. Torr. Bot. Club **40**:390–394, *pl. 21*, August, 1913.

TABLE A (LUNA LANDING TO PINE BLUFF)

	TREES
27	*Quercus Phellos*
21	*Ulmus crassifolia*[2]
20	*Liquidambar Styraciflua*
20	*Gleditschia triacanthos*
18	*Taxodium distichum*[3]
16	*Diospyros Virginiana*
15	*Quercus Michauxii*
15	*Ulmus alata*[2]
14	*Quercus Texana?*
14	*Hicoria aquatica*[4]
11	*Fraxinus Americana?*
10	*Quercus nigra*
10	*Salix nigra*
10	*Quercus pagodaefolia*
9	*Celtis sp.*
8	*Hicoria ovata*
8	*Acer rubrum tridens?*
7	*Quercus lyrata*
7	*Morus rubra*
6	*Ulmus Americana?*
4	*Quercus alba*
4	*Populus deltoides*
4	*Planera aquatica*
3	*Hicoria sp.*
2	*Ilex opaca*
2	*Cornus florida*

	SHRUBS AND VINES
9	*Sabal glabra*
6	*Rhus radicans*
6	*Brunnichia cirrhosa*
2	*Ampelopsis cordata*
2	*Phoradendron flavescens*
2	*Sambucus Canadensis*
2	*Berchemia scandens*
2	*Tecoma radicans*

	HERBS (mostly weeds)
19	*Anthemis Cotula*
10	*Sorghum Halepense*
6	*Daucus pusillus*
6	*Juncus effusus*
3	*Sitilias Caroliniana*
3	*Tripsacum dactyloides*
3	*Zizania aquatica?*
2	*Helenium tenuifolium*
2	*Hydrocotyle Bonariensis?*
2	*Dracopis amplexicaulis*

As in the Yazoo delta, *Ilex opaca* is the only evergreen tree, and it constitutes less than 1 per cent of the forests; a fact which seems to be correlated with the richness of the soil. Vines are common and native herbs inconspicuous, as in alluvial soils elsewhere. *Gleditschia* and *Diospyros* seem more abundant here than they are anywhere east of the Mississippi, where they usually appear as if introduced.

At Pine Bluff the aspect of the landscape seemed to change a little, and by the light of the full moon I could see that much of the country between there and Little Rock was undulating, and short-leaf pines (probably both *Pinus Taeda* and *P. echinata,* the

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[2] I am not sure that I always distinguished these two small-leaved elms rightly, never having seen *U. crassifolia* until a day or two previously.

[3] See Science II. **36**: 760–761, November 28, 1912.

[4] Some of this may have been *H. Pecan,* which looks very similar.

only pines known in Arkansas) were rather common, just as in the Eocene region from South Carolina to Mississippi, of which this seems to be a counterpart. (I soon afterwards saw some typical Eocene country near Arkadelphia.)

Around Arkadelphia I made no quantitative studies of vegetation, but I was taken to one place of considerable interest a few miles west of there, namely, the eastern end of a belt of Cretaceous country which extends southwestward into Texas. In crossing it rapidly I noticed essentially the same kind of soil and topography and treeless horizons and some of the same weeds and crops that characterize the geologically similar black belt or prairie region of Alabama and Mississippi.[5]

Between Arkadelphia and Little Rock the railroad runs so close to the fall-line that much of the scenery can hardly be regarded as typical of the coastal plain. For the first 15 miles or so it keeps pretty close to the Ouachita River, and traverses bottomlands very similar to those already described. In many places in Hot Spring and Saline Counties are level comparatively open forests of *Pinus Taeda*, much like some in southeastern Virginia and adjacent North Carolina except for one striking topographic feature, namely, the frequent occurrence of lenticular mounds, averaging perhaps five feet high and forty feet in diameter. Somewhat similar mounds are known in most of the other states west of the Mississippi River—but in none farther east—and their origin is still one of the unsolved mysteries of geomorphology.[6] I was not able to identify many herbs in these pine forests, perhaps chiefly because few were in bloom at the time. (Conditions might have been better a little later in the season.) Between Arkadelphia and Little Rock, as elsewhere in the coastal plain, *Pinus echinata* seemed to be confined to higher ground.

Leaving the fall-line at Little Rock and going eastward, alluvial bottoms of the usual character begin immediately, and continue without much variation for nearly 20 miles. Then without any perceptible change in topography, and little if any change in ele-

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[5] See Bull. Torr. Bot. Club **40**: 381–384, August, 1913.

[6] The latest discussions of them are by A. C. Veatch in U. S. Geol. Surv. Prof. Paper **46**: 55–59. 1906; and M. R. Campbell in Journ. Geol. **14**: 708–717, 1906.

vation, the trees suddenly become scarcer and the traveler finds himself in a prairie, something rather exceptional for the coastal plain. From about Lonoke to DeVall's Bluff, a distance of some 25 miles, one can look for miles and miles north and south over a vast level grassy plain, interrupted by occasional clumps, strips and groves of hardwood trees. This particular prairie area, known as Grand Prairie, was traversed and mapped by Nuttall over ninety years ago, and mapped again by Sargent (or by Harvey for him) in the ninth volume of the Tenth Census, and has been described superficially in some of the works mentioned at the beginning of this paper, perhaps best in the U. S. soil surveys of Prairie County and the Stuttgart area. But to this day no one seems to have attempted to list the plants growing there, or published any photographs of the vegetation. (The fact that this very interesting vegetation, traversed by a comparatively old and important railroad, has remained undescribed so long seems to indicate a singular apathy on the part of modern phytogeographers.)

Fig. 1. *Quercus palustris* in a prairie slough about one and one-half miles south of Hazen, Prairie County. Herbaceous vegetation in the foreground.

In order to learn something about this unique and scientifically neglected prairie I stopped a few hours at Hazen, which is near the middle of it, and walked about four miles south from there, returning by a slightly different route, keeping pretty close to a new branch of the Cotton Belt Route (St. Louis Southwestern Ry.), which was then not quite completed.

The flatness of the surface of the Grand Prairie is varied by occasional very shallow broad elongated depressions or sloughs, which evidently serve as waterways in wet weather, and by numerous lenticular mounds, perhaps due to the same unknown cause as those between Arkadelphia and Little Rock,[7] but much smaller, averaging about a foot high and a few yards in diameter, and hardly perceptible in summer except where the grass has been mowed.

The soil is a sort of yellowish silt, and at the time of my visit every wagon passing along the roads through the prairie stirred up great clouds of dust. The ground is perforated with crawfish holes, averaging about one to a square yard, which seems to indicate that the area becomes pretty wet at times. Like other prairies, this is probably swept periodically by fire, but there was very little direct evidence to be had on this point in midsummer.

Early in the present century (about 1902, it is said) it was discovered that this prairie was well adapted to the cultivation of rice, and some newspaper accounts within a year or two preceding my visit had given me the impression that the whole area was about to be given over to that industry, with the consequent destruction of the native vegetation. But the damage to the vegetation had been overestimated, and there were (and probably are even at this writing, two years later) still thousands of acres of undisturbed prairie within easy reach of railroad stations. The portions where the lenticular mounds are most numerous will probably escape the longest, for it would be difficult to extend the artificial inundation required in rice-growing to the tops of the mounds.

A botanist exploring the Grand Prairie after midsummer would encounter a serious difficulty of another sort, however. At the

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[7] See also C. L. Webster in Am. Nat. **31**: 114–120, February, 1897.

time of my visit the native vegetation was being converted into baled hay and shipped away by rail at a rapid rate. This has probably been going on for years, and although it may not have much permanent effect on the composition of the vegetation, any more than similar operations on the natural meadows of New England, it certainly spoils the botanizing for the time being.

The elongated depressions or dry channels above mentioned are well wooded with oaks, which seem to be mostly *Quercus palustris*; and other oaks, mostly *Q. stellata,* make scattered clumps in the level prairie. Comparatively few of the shrubs and herbs could be identified from the train, and the list given in Table B is based on observations at close range, made while walking out from Hazen and back.

TABLE B (PRAIRIE VEGETATION)

	SHRUBS
6	*Rhus copallina* (mostly on mounds)
5	*Cephalanthus occidentalis* (mostly in depressions)
5	*Sassafras variifolium*
4	*Hypericum apocynifolium?*
2	*Ceanothus Americanus*
2	*Trachelospermum difforme*
	HERBS
12	*Helenium nudiflorum*
11	*Vernonia sp.*
9	*Koellia flexuosa*
9	*Baptisia leucantha*
9	*Baptisia leucophaea*
7	*Aster Novae-Angliae?*
7	*Cracca spicata*
7	*Juncus brachycarpus*
7	*Boltonia sp.*
7	*Ruellia ciliosa*
8	*Manisuris cylindrica*
6	*Helianthus angustifolius*
5	*Euthamia sp.*
5	*Juncus aristulatus?*
5	*Leptocaulis inermis?*[8]
5	*Rudbeckia alismaefolia*
5	*Rhexia Mariana*
5	*Rudbeckia hirta?*
5	*Silphium integrifolium?*
5	*Linum medium*
5	*Fimbristylis puberula*
6	*Aletris farinosa*
4	*Sabbatia angularis*
4	*Morongia sp.*
4	*Hypericum maculatum*
4	*Aster dumosus*
3	*Brauneria sp.*
5	*Pentstemon Digitalis?*
3	*Chaetochloa sp.*
3	*Diodia Virginiana?*
3	*Ambrosia psilostachya?*
3	*Cracca Virginiana?*
3	*Coreopsis auriculata?*
3	*Polytaenia Nuttallii*
4	*Eryngium yuccifolium*
3	*Mesadenia tuberosa*
3	*Laciniaria pycnostachya?*
3	*Euphorbia Darlingtonii?*
3	*Silphium laciniatum*
3	*Plantago Virginica*
2	*Juncus acuminatus?*
2	*Petalostemon candidus?*

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[8] An unidentified Umbellifer with much the aspect of *Apium Ammi* or *Ptilimnium capillaceum.*

TABLE B—Continued

2	*Monarda fistulosa*	2	*Asclepiodora viridis*
2	*Helenium sp.*	2	*Buchnera Americana?*
2	*Tradescantia sp.*	2	*Carex vulpinoidea?*
3	*Acerates Floridana*	2	*Kneiffia sp.?*
2	*Senecio sp.?*	1	*Elymus sp.*
2	*Juncus tenuis?*	2	*Parthenium integrifolium*
2	*Eupatorium perfoliatum*	2	*Scleria triglomerata*
1	*Andropogon sp.?*	2	*Psoralea pedunculata?*

This is evidently a very imperfect list, as shown by the large number of interrogation points in it, but it was the best I could do in a few hours without botanical literature or any facilities for collecting specimens. Most of the species seen only once are omitted, as are those seen more than once which I was unable to identify even generically, for lack of flowers or some other reason. Notwithstanding the difficulty just mentioned, I recognized more species of plants in this prairie in one day than I have in the prairies of Long Island[9] in three summers. The flora is evidently very rich, and it is reasonably certain that a careful taxonomic study of it would reveal at least 150 species, a few of them probably as yet undescribed.

From what is already known it is evident that Compositae, Leguminosae and Juncaceae are pretty well represented in proportion to the total number of species in the prairie, or the size of these families, or both. Gramineae and Cyperaceae are less prominent, and Ericaceae appear to be entirely absent, as they are from some other prairies. The very interesting geographical affinities of this flora can be discussed much better after a more complete and accurate list of plants is made. It might be remarked in passing, however, that some of the species occur also in the prairies of Illinois, and some in the southeastern pine-barrens, while others are pretty widely distributed in the eastern states.

After crossing the White River near DeVall's Bluff the railroad passes through about 12 miles of alluvial bottoms, partly cultivated, and then about 16 miles of prairie (from about Brinkley to Palestine), more interrupted by oak groves and cultivated fields than the Grand Prairie of Prairie County. In some places in Monroe County east of Brinkley there was a good deal of *Pinus*

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[9] See Torreya **12**: 277-287, December, 1912.

Taeda,[10] bearing much the same relation to the neighboring prairie that *P. rigida* does to the Long Island prairies above referred to.

No satisfactory solution for the whole prairie problem has yet been found, and the occurrence of prairie vegetation in what has evidently been a flood-plain in the recent geological past would seem still harder to explain than the better known upland prairies of the upper Mississippi Valley. It appears from the colored geographical map in Bulletin 494 of the U. S. Geological Survey, on the New Madrid earthquake, by M. L. Fuller, published some time in 1912, that more or less similar prairies are rather widely distributed in the coastal plain of Missouri and Arkansas, and there are meagre records of the same sort of thing in the "delta" of Mississippi.[11] I do not know whether any of these other prairies have ever been visited by botanists, or even whether

Fig. 2. Prairie landscape just south of the slough shown in fig. 1, looking west.

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[10] This is the only place where I saw this pine between Little Rock and Memphis.

[11] See Hilgard, Tenth Census U. S. **5**: 242, 1884.

any natural vegetation still remains on them; but they ought to be investigated before it is too late.

Forrest City, the county-seat of St. Francis County, where I stopped twenty-three hours, is on the western slope of Crowley's Ridge, which is probably the most conspicuous topographic feature in the whole coastal plain of Arkansas. Volume 2 of the reports of the Geological Survey of Arkansas for 1889, by R. Ellsworth Call, published in 1891, is wholly devoted to this singular ridge, so that I will not undertake to describe it in detail here. It extends in a gentle curve from somewhere in southeastern Missouri to Helena, Arkansas (on the Mississippi River), averaging several miles in width, and standing over 100 feet above the river-bottoms on either side. Its eastern slope in the latitude of Forrest City, where the St. Francis River washes its base, is very precipitous for an earth slope, and from that side one could probably see some of the tall buildings in Memphis, forty miles away, if the air were clear enough.

The ridge is covered with loess, which looks like common yellow dust compacted and is usually many feet thick. Some late Tertiary gravels and older formations are exposed in ravines and on steep slopes. About half the area is cultivated, and the remainder is nearly all covered with hardwood forest. In Call's monograph just referred to there is an interesting annotated list of about fifty species of trees growing on or near Crowley's Ridge, with about a third of a page devoted to each; but a few of the species seem to have been erroneously identified, as if the author had relied too much on the common names.

On June 15 I walked diagonally across this ridge in St. Francis County from Colt, nine miles north of Forrest City, to Madison, four miles east, and noted the plants listed in Table C, in dry woods, ravines, bluffs, creek bottoms, etc. They are arranged as nearly as possible in order of abundance, as usual, but the frequency numbers are omitted, because they are too small to have much significance.

TABLE C (CROWLEY'S RIDGE)

TREES

Cornus florida
Quercus alba
Quercus velutina
Fagus grandifolia
Ostrya Virginiana
Acer Floridanum
Morus rubra
Diospyros Virginiana
Ulmus Americana?
Cercis Canadensis
Magnolia acuminata
Sassafras variifolium
Quercus falcata
Gleditschia triacanthos
Quercus stellata
Quercus Marylandica
Pinus echinata
Liriodendron Tulipifera
Quercus Muhlenbergii
Celtis sp.
Fraxinus Americana
Hicoria alba
Quercus Michauxii
Platanus occidentalis
Quercus coccinea

SHRUBS AND VINES

Aralia spinosa
Batodendron arboreum
Rhus radicans
Rhus copallina
Berchemia scandens
Asimina parviflora
Vitis rotundifolia
Hydrangea arborescens

HERBS

Anthemis Cotula
Helenium tenuifolium
Perilla frutescens
Solidago caesia
Cracca Virginiana
Polystichum acrostichoides
Podophyllum peltatum
Phegopteris hexagonoptera
Vagnera racemosa
Equisetum hyemale
Cunila Mariana
Arisaema Dracontium

The first three herbs are only roadside weeds. In traveling by rail through a hardwood region one always sees more species of trees than of native herbs, but here I was on foot and had ample opportunity to see all the herbs that were in recognizable condition. That the list of trees should still be about twice as long as that of herbs under these circumstances is rather interesting, but not easy to explain in a few words.

One representative of the Ericaceae, a semi-evergreen at that, appears in this list, namely, *Batodendron arboreum.* It was confined to the driest ridges. The only evergreen tree is *Pinus echinata,* and that was seen only on the precipitous eastern slope; which agrees with Call's observation that in this region it is absent from the loess and confined to the Tertiary sands and gravels. Call reports *Gymnocladus Canadensis* and *Xanthoxylum Clava-Herculis* as common on Crowley's Ridge, but he does not mention the common *Cercis Canadensis* and *Aralia spinosa*, which he may possibly have mistaken for *Gymnocladus* and *Xanthoxylum*—which I did not see at all—on account of a similarity of common names, in the latter case at least.

From Madison on the St. Francis River to the banks of the Mississippi opposite Memphis, a distance of 37 miles, the railroad is built on an embankment eight or ten feet high through river bottoms, too often inundated to support much permanent population.[12] Descriptions of this swamp region can be found in Humphreys and Abbot's Report on the Mississippi River (a large quarto published by the U. S. War Department in 1861 and reprinted with some additions in 1876, which is one of the classics of potamology), and in S. M. Coulter's paper on swamps above referred to. Bulletin 38 of the U. S. Biological Survey, on the

Fig. 3. Near view of prairie vegetation about three miles south of Hazen. The most abundant plant in the foreground is *Brauneria*.

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[12] In April, 1912, and again a year later, the whole area is said to have been submerged. During the flood of 1912, according to contemporary newspaper stories, persons traveling from Memphis to Little Rock had to go by steamboat as far as Madison, and even the telegraph wires along there were put out of commission by the high water.

birds of Arkansas, by A. H. Howell, 1911, contains a few photographs of vegetation taken in the same general region. Almost the only signs of civilization between Madison and Memphis were some small sawmill settlements and a few cultivated fields, most of the latter in recent small clearings. The native vegetation was therefore in excellent condition for study; and the species named in Table D were noticed more than once.

TABLE D (MADISON TO MEMPHIS)

TREES		SHRUBS AND VINES	
18	*Salix nigra*	19	*Brunnichia cirrhosa*
12	*Quercus Phellos*	11	*Vitis aestivalis?*
11	*Populus deltoides*	8	*Cephalanthus occidentalis*
9	*Taxodium distichum*	3	*Arundinaria macrosperma*
9	*Quercus lyrata*		
7	*Hicoria aquatica?*		
7	*Liquidambar Styraciflua*		
7	*Ulmus crassifolia?*		
6	*Quercus Texana?*		
5	*Planera aquatica*		
4	*Diospyros Virginiana*		
4	*Gleditschia triacanthos*		
3	*Nyssa uniflora*		
3	*Fraxinus sp.*		
3	*Quercua Michauxii*		
2	*Quercus nigra*		
2	*Acer rubrum tridens?*		
2	*Acer saccharinum*		

Five other trees, six other shrubs and vines, and two herbs were each seen once. More herbs might perhaps have been identified earlier in the day; but this trip was made after 6 P.M., and darkness began to interfere with my observations toward the end of it. The only evergreen in the list is the *Arundinaria*.

No important conclusion is to be derived from any of the foregoing notes, perhaps, but if they stimulate others to study the phytogeography of this comparatively neglected part of the coastal plain they will not have been published in vain.

NOTES ON THE TECHNIQUE OF THE DETERMINATION OF THE DEPRESSION OF THE FREEZING POINT OF VEGETABLE SAPS

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During the summer of 1912 and 1913 we found it necessary to carry out very extensive series of the observations needed in the determination of certain of the physico-chemical constants of vegetable juices. Since such work is receiving constantly increasing attention—as is attested by the Symposium on Permeability and Osmotic Pressure before the Botanical Society of America at the Cleveland meeting, the papers of which have been published in this journal—it may not be out of place to state some of the results of our experience in the routine of such determinations. This seems the more desirable because of the fact that many of those who may wish to undertake such work are unacquainted with some of the precautions necessary in even the rough physico-chemical work possible with vegetable and animal juices.

The first step is the collection of the samples of sap. Up until the last few months workers have almost invariably, if not always, done this by pressing the fresh material with or without antecedent grinding. Some have used agate mortars to avoid possible influence of the metal, but most have employed an ordinary metal press. But in February, 1913, Dixon and Atkins[1] pointed out that extractions representing much more accurately the solutes of the whole tissue (because containing a much larger proportion of the sap from the smaller vacuoles) could be made by freezing the tissues to increase their permeability.

This suggestion, which they have tested with thoroughness, is undoubtedly of great importance. We doubt whether the

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[1] Dixon, H. H. and W. R. G. Atkins, Sci. Proc. Roy. Dublin Soc. n. s. **13**: 422–433. 1913.

differences between saps extracted by pressing after grinding and by means of pressing after freezing need be as large as some they have recorded. But the ease, rapidity (with consequently a minimum concentration by evaporation, or contamination from the air) and completeness with which the sap may be expressed after freezing renders the method one of the greatest utility. Furthermore, samples may be frozen and kept in this condition for hours before analysis with little probability of change.

The method of freezing suggested by Dixon and Atkins is that of immersion in liquid air. For some purposes, for instance in the study of the properties of the sap of small quantities of tissue as soon as possible after their collection, the method is doubtless very useful. But for the great bulk of the work it seems to us as superfluous and undesirable as it is unavailable to the average botanist.

We have depended entirely upon the ordinary salt and ice mixture. The tissues are placed in as large quantities as possible in *thick-walled* test tubes. These are corked (preferably with rubber stoppers) and to preclude every possibility of contamination are capped with oiled paper held firmly by a strong rubber band wrapped several times around the tube. These tubes are plunged into a slushy mixture of finely chopped ice and salt, with which a temperature of –15° to –17° C. can be easily attained and maintained for hours. Of course, any receptacle will serve for the freezing mixture, but we have found a water tight wooden box, fitting neatly in our general laboratory ice box to conserve ice, advantageous. In any case, the cover should be an inch board with holes closely fitting the body of the tubes. This holds the tubes firmly, allows uniform space for freezing mixture, and by keeping the mouths of the tubes well above the surface of the mixture is a further precaution against contamination.

Thus the liquid air method is expensive and cumbersome, available to only the man working in the rarely equipped laboratories. The method which we have employed with complete success is so simple that it could be used in the field for the collection of samples under their peculiar environmental conditions. A freezing box could easily be devised for a run of many miles into the desert by automobile or for a several hours trip down the mountains by pack mule. One of the criticisms which has been urged against some of the field work on osmotic pressure in plants is that the sample could not be worked with until profound changes through evaporation or otherwise had taken place. The immediate freezing of the material would have obviated all this.

When thoroughly frozen the tubes are removed, washed under a tap to remove salt from the surface, gently warmed until thawed, carefully wiped outside and around the mouth to remove any remaining traces of salt and the contents folded in a small square of extra heavy muslin cloth (which has been boiled through three changes of distilled water and dried away from dust) for thorough squeezing in a heavily tinned "beef juice" press. The sap is then either filtered through Schleicher and Schüll "Barium" filter (No. 589) or better still centrifuged at high speed. The removal of suspended solids by means of a centrifuge makes for more rapid work and prevents the loss of the juice necessary to wet the filter paper.

The classical method of determining osmotic pressure by freezing point lowering is that of Beckmann. Recently, other methods have been suggested by Dixon[2] and followed by Ohlweiler.[3]

The slowness of the exceedingly simple Beckmann method seems to us to have been over emphasized. The rapidity of Beckmann determinations like that of any other piece of laboratory routine depends largely upon the skill and practice of the operator and the care with which every detail of the work is systematized.

Mr. Lawrence, who did the bulk of our freezings, after a little practice easily averaged over twenty in a half day. This was possible by using two freezing tubes[4] which were filled and

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[2] Dixon, H. H., Sci. Proc. Roy. Dublin Soc. n. s. **12**: 275–311 1910, **13**: 49–62. 1911.

[3] Ohlweiler, W. W., Ann. Report Mo. Bot. Garden **23**: 101–131. 1912.

[4] The standard Beckmann freezing tube is supplied with a small side tube for the introduction of additional quantities of solvent or of weighed amounts of the solute under investigation, so that more than one determination of molecular weight may be carried out without removing the thermometer. This extra open-

numbered by one of us and placed in ice water for preliminary cooling, by having the freezing mixture vessel of the thermometer insulated, by having an auxillary jar with ice and salt at about –4° for cooling the sample (transferred to the freezing tube) down to near its freezing point[5] before placing in the air jacket, and by using a steel air jacket[6] instead of the conventional glass tubes which are apt to be broken by rapid work. After cooling to near its freezing point in the auxillary bath the freezing tube (containing the thermometer bulb) was quickly dried by filter paper and transferred to the steel jacket, the air in which was kept at a low temperature by corking the tube when not in use.

The freezing point of double distilled water, or better of conductivity water, should be redetermined at the beginning and end of each day's work, for in addition to the secular change possibly correctly explained by Atkins[7] as due to the distillation of mercury from the more convex surface to the more plane surface beneath in the upper reservoir, there may be a material change over night when the instrument has been constantly used during the day. Probably this is due to variations in the wall of the bulb which slightly alter its volume.[8]

The methods here described are the outcome of the experience

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ing has no advantages when one is working with vegetable saps, is often in the way, and causes trouble in cleaning and drying the tubes. So we have had tubes an inch shorter than the standard ones, and lacking the useless accessory, made to order (at about half the price of the others) and have found them very convenient.

[5] To avoid too great variations in the wall of the thermometer bulb this cooling (which draws a relatively large volume of mercury from the upper chamber through a fine capillary tube) must not be carried out with too great rapidity—hence the importance of having this bath at only –2° to –4°. Because of the air jacket and because of the fact that the mercury is already low in the capillary, the insulated Beckmann jar may be kept at –15° or lower.

[6] We have found the steel jackets for the 100 cc. centrifuge tubes of the International Instrument Company to be admirable for this purpose.

[7] Atkins, W. R. G. Sci. Proc. Roy. Dublin Soc. n. s. **12**: 124. 1909.

[8] Our maximum difference in the zero point of the instrument as observed at the beginning and end of the day's determinations does not exceed 0.001° or 0.002° C. while the change from one evening to the next noon (the instrument standing at laboratory temperature) has in *some* cases been 0.01° or slightly more. Errors of determinations of the zero point on the instrument of 0.001° to 0.002° might easily be made, but discrepancies as large as 0.01° cannot be thus explained.

gained in a very heavy series of determinations. That they are thoroughly practical is perhaps evident from the fact that by their use we have been able (beginning with the tubes in the freezing mixture) to carry out the determination of specific gravity (by weighing in a pycnometer), total solids, freezing point depression and electrical conductance of more than 800 samples[9] of sap in about two months time. Three of us took part in this work, but two could only give half of their time to this phase.

The rapidity with which large series of determinations can be carried out is our justification for the detail in which these minor points of technique are described. In the more exact sciences of physics and chemistry where external conditions can be closely controlled the number of individual experiments which are necessary is generally not large. But in biology, where there are so many unknowable factors which have their influence upon one's samples the value of any piece of work is much more nearly proportional to the number of observations upon which it is based.

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[9] Two readings were made when there was the slightest suspicion of error, but not otherwise. The Wheatstone bridge and the conductivity cell were frequently checked against 0.10 N KCl. and the thermometer tested by the freezing of conductivity water.

BOOKS AND CURRENT LITERATURE

Nova Scotia Forests.—The Commission of Conservation of Canada has issued a careful report[1] upon the forest conditions of Nova Scotia, prepared by Dr. B. E. Fernow, assisted by Dr. C. D. Howe and Mr. J. H. White. The publication is of value to technical foresters, especially to those interested in the region of which it treats, rather than to ecologists and plant geographers, since the economic aspects are everywhere emphasized. The work is divided into two parts. The first, by Dr. Fernow, is entitled Forest Conditions of Nova Scotia, and is general in its nature. The second, by Dr. Howe, entitled Distribution and Reproduction of the Forest in Relation to the Underlying Rocks and Soils, is detailed, describing the forest conditions of the province county by county.

The matters of principal interest to plant geographers and ecologists are as follows:

Three regions are distinguished: (1) The Atlantic slope of the peninsula; (2) the northern slope, tributary to the Bay of Fundy, Minas Basin, and Northumberland Strait; (3) Cape Breton Island. The rocks of the Atlantic slope are mainly granite, quartzite, and slate. In the granite country the higher ridge tops, with thin soils, support a coniferous forest, mainly of *Abies balsamea*. Upon the slopes, and upon lower ridges, is a mixed forest of *Fagus grandifolia, Acer saccharum, Betula lutea, Picea rubra* (the principal lumber tree of the province), and *Tsuga canadensis*. Bogs and barrens occur, the latter due in part to severe fires. The quartzite areas are poorly forested, the soils being sour and ill-drained. The slate areas are fertile and occupied largely by farms. The northern slope is much more diversified geologically than the southern, and the rocks in general are of kinds that disintegrate much more readily. The soils are thus deeper and of better quality. All the forest types of the south slope are repeated here, and an additional one, characterized by *Pinus Banksiana*, is present upon conglomerate ridges. The forest in general is more luxuriant than

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[1] Fernow, B. E., assisted by Howe, C. D. and White, J. H. Forest conditions of Nova Scotia. Commission of Conservation, Canada. Ottawa, 1912.

upon the Atlantic slope. On Cape Breton Island *Abies balsamea* is the dominant tree, with a little spruce and still less of *Betula alba papyrifera.*

Burned areas are extensive throughout the province, some of them reproducing well, others poorly. Mechanical analyses show that the soils with poor forest reproduction contain a large proportion of coarse gravel (average 32%), while those with good reproduction average only 15% of coarse material.

The observations of Fernow and Howe confirm the correctness of placing Nova Scotia in the transitional zone between the Eastern Deciduous Forest Region and the Northeastern Conifer Forest Region. The climax forest seems to be the mixed type, consisting of *Fagus grandifolia, Acer saccharum, Tsuga canadensis* (climax trees of the Eastern Deciduous Forest), *Abies balsamea, Picea canadensis, Betula alba papyrifera* (climax trees of the Northeastern Conifer Forest), and *Picea rubra* and *Betula lutea* (mainly transitional in range). Ganong[2] gives a similar forest type, the "mixed maple-birch-spruce-fir association" as the climax forest of New Brunswick. There is no indication as to whether the beech and sugar maple are following their usual custom: *i.e.*, tending to replace the other species. Possibly the northern half of Cape Breton Island should be removed from the transitional zone and placed within the Northeastern Conifer Region, since the forest there is largely *Abies balsamea*, with admixture of *Picea* sp. (*rubra* or *canadensis*?) and *Betula alba papyrifera.* This is the climax type upon Isle Royale in Lake Superior[3] and probably over most of the Northeastern Conifer Forest.

Occasionally, though not often, in the work under consideration, there is uncertainty as to the species referred to by reason of the use of ambiguous common names, as for instance a case on p. 20, referred to in the last paragraph, where "spruce" is mentioned as a constituent of the Cape Breton forest. The fault is a common one in forestry publications. The photographic illustrations are unsatisfactory, but the maps are detailed and excellent.—William S. Cooper.

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[2] Ganong, W. F. Preliminary outline of a plan for the study of the factors determining the features of New Brunswick vegetation. Bull. Nat. Hist. Soc. New Brunswick **17**: 127–130. 1899.

Ganong, W. F. A preliminary synopsis of the grouping of the vegetation (phytogeography) of the province of New Brunswick. Ibid. **21**: 47–60. 1902.

[3] Cooper, W. S. The climax forest of Isle Royale, Lake Superior, and its development. Bot. Gaz. **55**: 1–44, 115–140, 189–235. 1913.

NOTES AND COMMENT

Our attention has been called to the fact that the list of doctorates in botany which was recently published in THE PLANT WORLD (December, 1913) did not contain the seven degrees conferred at the University of Chicago (which were not published in Science), and that one of the degrees conferred at Harvard University was accidentally omitted. The total number of doctorates that were conferred in botany in 1913 is thus raised to forty-six. The omitted names and dissertations are as follows, the last-named being the Harvard conferee:

WINIFRED MCKINZIE ATWOOD: A Physiological Study of the Germination of *Avena fatua.*

GEORGE DAMON FULLER: Evaporation and Soil Moisture in Relation to the Succession of Plant Associations.

JOHN BENJAMIN HILL: The Anatomy of Six Epiphytic Species of *Lycopodium.*

LEE IRVING KNIGHT: A Chemical Study of Dormancy in the Buds of *Liriodendron tulipifera.*

JOHN NATHAN MARTIN: Comparative Morphology of some Leguminosae.

LOREN CLIFFORD PETRY: The Anatomy of *Ophioglossum pendulum* L.

NORMA ETTA PFEIFFER: The Morphology of *Thismia* (*Bagnisia*) *Americana* n. sp.

ORLAND EMILE WHITE: Studies of Teratological Phenomena in their Relation to Evolution and the Problems of Heredity.

In accordance with plans laid a year ago, the Botanical Society of America has begun the publication of an official organ, The American Journal of Botany. The Journal will be edited by a committee of the Society, of which Prof. F. C. Newcombe is the chairman, and will be published in coöperation with the Brooklyn Botanic Garden. No one can have ground to doubt the ability of American botany to support and to fill such a technical journal of the highest class. The expressed preference of the editors for short papers still leaves no haven of publication open to those who persist in writing long ones.

THE EFFECT OF DUST FROM CEMENT MILLS ON THE SETTING OF FRUIT

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Fruit growers in the vicinity of Hudson, New York, in the spring of 1910 complained that their crops were seriously damaged by dust from large cement mills which had recently been located there. They noticed particularly a decrease in the amount of fruit that was set on trees within the dust zone. They also feared permanent injury to the foliage and young shoots. The investigations recorded below were undertaken in order to determine the nature and extent of the alleged injury and, if possible, to find a remedy.

Appearance of the foliage. The foliage in the dust zone is covered with a fine, gray, gritty dust mixed with minute black granules (evidently cinders). The coating is heavier near the mills but is plainly noticeable at a distance of two miles. A greenhouse located a mile away was so heavily coated within a month after the plant started operations that the passage of light through the glass was seriously interfered with. Hard rains wash the coarser part of the dust from the leaves and while they are wet they appear green, but, on drying, become white again from a thin film which cannot be washed off. On a rigid surface, however, such as a greenhouse roof, the dust collects and sets very rapidly, forming an opaque covering which can be removed only by the use of acid. Under certain weather conditions the same hard crust is formed on the leaves and remains on them throughout the season.

Source of the dust. That the dust comes from the mills—not from the roads or soil—is evident from the following considerations: (1) It is found nowhere else except in an area about the mills; (2) it falls just as heavily when the ground is soaked and

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the roads muddy from hard rains; (3) it does not look or feel like road dust; (4) it gives an alkaline reaction with phenolphthalein, which is not true of any other dust sample collected in that county; (5) its chemical composition (given below) shows it to be a partially burned dust.

A study of the mills in operation showed that there were two main sources from which a large amount of dust came: (1) The crushing, pulverizing and drying mills, where the raw mixture of limestone and shale is reduced to an extremely fine, dry powder (technically called composition); (2) the stacks of the kilns in which the composition is burned and fused to clinker (unground cement). The second is undoubtedly the principal source of the dust on the foliage because: (1) The strong draft in the kilns, produced by the burning, powdered coal and air forced in below under a pressure of 100 pounds to the square inch, must necessarily carry some of the dry, fine composition dust out of the top of the stacks; (2) the distance to which the dust is carried points rather to the high kiln stacks and forced ejection rather

TABLE I

Chemical analyses of dust samples

	CEMENT DUST FROM PULVEROMETER	CEMENT DUST FROM RASPBERRY BUSHES	ROAD DUST	ROAD DUST (MACADAMIZED)	SOIL NEAR PULVEROMETER	ATLAS PORTLAND CEMENT
*Number of sample	1442	1452	1453	1495	1451	
Silica (SiO_2)	20.32	21.14	61.06	40.60	75.42	23.50
Iron and alumina ($Fe_2O_3 + Al_2O_3$)	10.52	11.26	10.86	8.66	13.90	10.04
Lime (CaO)	42.25	44.12	10.83	24.05	0.93	62.08
Magnesia (MgO)	1.02	1.04	2.26	1.30	2.30	1.23
Sulfur trioxide (SO_3)	1.24	0.27	0.15	1.85	0.13	1.63
Loss by ignition	22.49	20.33	13.20	23.40	5.86	1.30
Total	97.84	98.16	98.36	99.86	98.54	99.78
Carbon dioxide (CO_2)	not determined	12.10	not determined	18.90	not determined	not determined
Insoluble (in hot HCl)	21.00	19.41	70.96	50.59	90.07	not determined

* Sample book of the chemical laboratory of the Atlas Portland Cement Company, Hudson, New York.

than the low pulverizing and drying mills; (3) chemical analysis shows that the dust on the foliage has been partially burned.

Amount of the dust. A simple "pulverometer," for collecting and measuring the amount of dust, was made by supporting upright a large tin funnel (2 feet in diameter at the top) with a detachable, tight-fitting, glass cylinder at the bottom, into which the dust collected or was brushed down from the sides of the funnel. From the amount of dust caught in the cylinder (knowing the area of the mouth of the funnel) it is easy to calculate the amount of dust that falls on an acre. An average record (August 22, 1910) when the wind was blowing toward the pulverometer, gave 167.6 pounds of dust deposited on an acre in twenty-four hours, or 2½ tons of dust per acre in a month. But actually, no acre in the vicinity of the mills receives this amount because the wind does not blow constantly from one direction.

TABLE II

Analysis of cement dust collected in the pulverometer August 22, 1911. Analyzed by Prof. Enrique Touceda

		SOLUBLE IN WATER	INSOLUBLE IN WATER
Silica	21.94	0.23	21.27
Iron and alumina	9.10	0.44	8.73
Lime	46.65	7.81	38.99
Magnesia	1.17	0.078	1.10
Carbonic anhydride	17.50		
Comb. water and organic	3.64 by dif.		
	100.00%		

Chemical analyses. Numerous chemical analyses were made of the dust collected as above and also of dust shaken from the raspberry bushes a quarter of a mile distant from the mill. Average samples of these analyses are given in table I (samples 1442 and 1452). For comparison, there are also included in this table analyses of (1) soil near the pulverometer, (2) average sample of Portland cement, (3) two samples of road dust, No. 1453 a road dust sample taken at random near the mills, and No.

1495 from a recently macadamized road where the percentage of limestone was high.

Table II gives an analysis of cement dust collected from the same locality and analyzed by Prof. Enrique Touceda of the Troy Polytechnic Institute.

Three points should be noticed in these analyses: (1) The soil and road dust sample show such striking differences from cement dust in the proportion of constituents that neither of them could possibly be the source of the dust on the leaves; (2) a large part of the limestone in the cement dust has had the carbon dioxide removed and the lime is left in the caustic condition. Sample 1452, for instance, contains 12.10% of carbon dioxide. If the lime and magnesia here were in the form of a natural limestone—*i.e.*, calcium and magnesium carbonates, as they are in the road dust sample 1495—the dust should contain 37.78% of carbon dioxide. In other words, over two-thirds of the limestone has had the carbon dioxide removed from it—a condition which could be brought about only in the kilns. (3) Nearly 8% of the dust is lime that is soluble in water. The soluble lime is the cause of the extreme alkalinity of the dust and, as will be indicated below, is probably the source of injury to the fruit blossoms.

Less fruit on the dusted side of the trees. Our first observations were in the summer of 1910. During the entire blooming season of that year, a continuous south wind blew the dust from the mills onto a cherry orchard where our laboratory was established. The blossoms on the south side of the tree were literally plastered with dust while those on the north side were more or less protected. When the fruit was about half grown, the number of cherries on each side of eighteen trees were counted and there was found to be 29% more fruit on the north side than on the south side of the trees. The same number of trees outside the dust zone were counted as a check and it was found that there was a difference of only 2.2% in the number of cherries on the south and north sides and that in favor of the south side. This led us to suspect that the dust did in some way influence setting of the fruit.

Dusting experiments. During the blooming season of the next year (1911) the mills were temporarily closed. Therefore it was necessary to depend on artificial dusting for our experiments. This however was really an advantage since it offered the opportunity of having dusted and untreated check blossoms all on the same tree, making the conditions entirely equal Sweet cherry, sour cherry, pear and apple trees were used. Two branches were selected from each tree which were as near alike in size, position, etc. as could be found. Cement dust, which had been collected from foliage the previous summer and had been kept in air-tight bottles, was blown over the blossoms of one of the branches as soon as they opened, while the blossoms on the other branch were left untreated. When the fruit was about half grown, the number which had set on each branch was counted. The cherries and pears were dusted twice each day; the apples on the other hand, only at irregular intervals. The results from the latter are included in the table below to show that even an occasional dusting is injurious. In each case, ten to twenty branches were treated, but in the table, the total number of blossoms is given for all the branches that received the same treatment.

TABLE III

Shows the number of treated and untreated fruit blossoms which set fruit

	DUSTED		PER CENT	UNTREATED		PER CENT
	Blossoms	Fruit set		Blossoms	Fruit set	
Sweet cherries	1618	24	1.48	1767	582	32.93
Sour cherries	1536	122	7.94	1975	1287	65.16
Pears	2908	11	0.37	3181	587	18.43
Apples	1126	67	5.95	1507	752	49.90

From Table III it will be seen that only a very small percentage of the blossoms that had dust blown over them set fruit. It will be asked why *any* of the fruit at all set when the blossoms were *all* dusted. In the first place, all of the blossoms may not have been reached by the dust. In the second place it is known that the growth of the pollen tube is very rapid in warm weather and it is quite likely that some of the blossoms were already fertilized when the dust was applied. It is not certain but that in the latter case the fruit would set normally.

It should be mentioned in this connection that for some time after the falling of the petals, no difference could be observed between fruits on treated and untreated branches. Both kinds grew at the same rate. Often it was ten days to two weeks after blooming before any difference became noticeable. Then the unfertilized fruit stopped growing and soon dropped.

Nature of the injury. Having demonstrated that dust did prevent setting of fruit, the next question to arise was: what is the injurious constituent in the dust and how does it act on the flower? A "cement dust solution" was made by shaking up a quantity of dust in distilled water and then letting it set for several hours in order to allow any soluble parts to go into solution. This was then filtered and the filtrate applied to the flowers as a spray. It prevented setting of fruit almost as effectually as the cement dust itself. As indicated by the analyses there is only one thing in the dust that goes into solution to any appreciable extent and that is lime. It was reasonable then to infer that the latter was the injurious part of the dust. A solution of pure lime was made and applied in the same way. The results were the same as those secured by spraying the flowers with cement dust solution.

In another series of experiments, the blossoms of some large lillies in the greenhouse were used. Cement dust was applied to the stigmas only and then they were pollinated by hand. Checks were pollinated but not dusted. One hundred per cent of the checks set but none of those flowers which were dusted produced seed. From these experiments it was concluded that the lime of the dust affected the stigma or the stigmatic secretions in such way as to interfere with fertilization and thus prevent setting of the fruit.

It is a well known fact that the stigmatic secretions of most plants are acid in character. One may easily demonstrate this point by moistening a piece of blue litmus paper and merely touching it with the stigma of a cherry blossom. A pink spot will appear on the paper at every point touched. If a minute quantity of the cement dust is placed on the stigma, however, it no longer gives this reaction but becomes alkaline due to the lime which is dissolved in the secretions. This is what takes place when the dust from the mills settles over the orchards. What is the effect of this change on germination of pollen? Will pollen germinate at all in an alkaline calcium solution? To determine this point, artificial pollen germination tests were made.

Pollen germination tests. The method used for germination was this: A definite weight of cement dust, collected from the leaves, was placed in a flask and a measured volume of distilled water added, well shaken and permitted to stand over night, then filtered. After determining the strength of sugar solution required—differing for almost every species tried—the required weight of saccharose was dissolved in the filtrate. Check solutions of saccharose of equal strength were made in the same way by using distilled water instead of the dust solution. Pollen from freshly opened anthers was put in drops of these solutions on slides in moist chambers. Checks were always run on the same slide as the tests in order to make conditions the same.

TABLE IV

Shows results of comparative germination tests of sweet and sour cherry pollen in cement dust solution and check sugar solutions. Strength of dust solution 1–170

Cherry pollen

STRENGTH OF SUGAR SOLUTION	CHECK		CEMENT DUST	
	Sweet cherry	Sour cherry	Sweet cherry	Sour cherry
2%	7%	8%	0	0
3%	9%	13%	0	0
4%	13%	17%	0	0
5%	19%	27%	0	0
7%	17%	23%	0	0
10%	17%	29%	0	0
12%	18%	7%	0	0

Cherry pollen. The first artificial germination tests were made during the winter of 1910–11. Twigs of both sweet and sour cherry were brought into the greenhouse and placed in a jar of water, where they bloomed. In testing the pollen thus secured, various strengths of sugar solutions were used in a solution of the cement dust 1–170 (*i.e.*, 1 g. of dust to 170 cc. of water). The results are given in Table IV.

During the blooming season of 1911 the experiments were repeated with pollen which matured naturally on the trees. The results practically duplicated those given above. The writer has not been able to explain satisfactorily the low percentage of germination in the checks. A possible explanation is that they required an acid solution, while we were using a neutral one. No germination whatever was secured in the cement dust solution.

TABLE V

Shows apple pollen germination. Counted after eighteen hours

STRENGTH OF SUGAR SOLUTION	CEMENT DUST SOLUTION 1-100		DISTILLED WATER CHECK	
	Per cent germination	Length of tubes	Per cent germination	Length of tubes
2%	0	0	64	6
5%	0	0	67	7
7%	0	0	76	7
10%	3	3	98	25
12%	1	2	95	20
15%	0	0	87	15
17%	0	0	83	15
20%	0	0	63	10
25%	0	0	53	4

Pear pollen. Better success was obtained in artificially germinating the pollen of pears. Solutions of 20, 22 and 25% saccharose were used and between 65 and 75% germination was constantly secured in the checks but none at all in the 1–100 cement dust solution.

Apple pollen. This was the most satisfactory set of experiments. The blooming season of the apple is longer and gave more opportunity for an extended set of experiments. Table V shows the results of tests where various concentrations of saccharose were used. The optimum concentration, as indicated here, was 10%. This concentration was therefore used in the further tests. Germination in the dust solution of 1–100 was practically nil.

Table VI gives the results of tests in which the concentration of the dust solution was decreased to 1–300. Even here there was very little germination.

Calcium a toxic agent. It has been mentioned previously that in the writer's opinion it is the alkaline calcium salt which prevents germination. That such is the case is very strongly indicated by the following experiment: When a drop of the cement dust solution is permitted to remain exposed to the air for an hour or two, the greater part of the calcium crystallizes out in the form of calcium carbonate. If tested when exposed, the drop gives an immediate alkaline reaction with phenolphthalein; several hours later there is no reaction, showing that the carbon dioxide of the air has completely neutralized the alkaline salt.

TABLE VI

Tests with various concentrations of the cement dust solutions. All solutions of 10% saccharose. Checks same as the 10% solution in the preceding table

STRENGTH OF SOLUTION	PER CENT GERMINATION	LENGTH OF TUBE
1–100	2.5	1.5μ
1–150	2.0	4.0
1–200	3.0	5.0
1–250	3.5	4.0
1–300	4.0	3.0

Now if the pollen grains are put to germinate at once there is practically no germination, as given in the table above. If, however, the drop is allowed to stand until neutralization occurs and the pollen then put in, it germinates almost as well as the checks. Numerous tests of the substance which crystallized out failed to show anything present except calcium carbonate. If then this is the only substance which it is necessary to remove in order to get germination, the conclusion is inevitable that this is the toxic substance. It must not be understood, however, that all the calcium crystallized out. Even after remaining exposed to the air for a long time, some calcium in the solution can be brought down with ammonium oxalate. This calcium is probably in the form of bi-carbonate and therefore gives no reaction with phenolphthalein, nor does it seem to be toxic to the apple pollen. In fact apple pollen germinates in tap water which contains a relatively large amount of calcium almost as well as it does in distilled water.

Raspberry. This was not the case with the raspberry pollen which was next used. When the solutions for this experiment were made with tap water, 18% germination of the grains was secured, while with distilled water 83% germinated. The germ tubes in the former were not as long nor as vigorous. Tests of this same pollen were made in the water after the calcium had been crystallized out as previously, but here the germination was reduced to 11%; this shows quite a different result from that obtained with the apple pollen. In this case the calcium is evidently toxic whether in the caustic condition or not.

The raspberry pollen experiments were to determine two points: (1) How weak a solution of the cement dust will prevent germination? (2) How weak a solution of calcium oxide will prevent germination? Raspberry pollen germinated very readily in 30% saccharose. No check gave less than 90% germination. Solutions of the cement dust were made up 1–500, 1–700, 1–800, 1–1000, 1–1200, 1–1500, 1–1600, 1–1800, and 1–2000. After filtration these were used to make 30% saccharose solutions. Up to 1–1500 there was no germination except for an occasional short tube. Above this, slight germination occurred, reaching 6% in the 1–2000 solution. But even here the tubes were rarely more than four times as long as the diameter of the grain, while in the checks in the same period of time, they were thirty times the diameter of the grain. The results of the second series is given in the following table.

TABLE VII

Shows the comparative germination of red raspberry pollen in different concentrations of the cement dust solution

	STRENGTH $Ca(OH)_2$							
	0.1	0.2	0.05	0.02	0.01	0.005	0.002	0.001
Per cent of germination......	0	0	0	0	0.5	1.5	3.0	7.0

An extremely small amount of lime is evidently sufficient then to prevent germination. The writer had hoped to test out all the other constituents of the dust but has not found opportunity to do so. It is possible that other substances in the dust may go into solution in the acid stigmatic secretions to an extent sufficient to prevent pollen germination. Whether this be so or not, it is certain that the injury from the lime alone is sufficient to account for the damage.

Work of Professor Beach. There should be mentioned at this point the work of Professor Beach[1] who investigated the effect of spraying fruit trees in bloom. Artificial germination tests in the laboratory were used here also. Two paragraphs are quoted from Professor Beach's bulletin in which are given the results of his investigation.

From page 433 of that bulletin:

> From these investigations it appears that if before pollination occurs, the stigmatic surface of the pistil should be covered either with bordeaux mixture alone or with arsenical poison alone, of the strength commonly used in spraying orchards, there would be no germination of any pollen which might afterwards reach the stigmatic surface and so fertilization would be prevented and no fruit would be formed. *Even the presence of lime alone,* of the strength commonly used in spray mixtures, *prevented the germination of pollen.* Bordeaux mixture was diluted in aqueous sugar solution to 500 parts, 200 parts, 100 parts, 50 parts, 2 parts, and 1 part in 10,000 of culture media into which various kinds of pollen were introduced. Even when diluted to 50 parts in 10,000 it prevented germination to large extent and where germination did occur the growth which followed was decidedly slow and the pollen tubes were dwarfed. When diluted to 100 parts, 200 parts, or 500 parts either no germination or practically none was found.

Also on page 442:

> In the tests where the trees were sprayed repeatedly during the blooming season so as to hit as many as possible of the new blossoms which opened from day to day, but very few blossoms survived the treatment and consequently but little fruit set. This shows that the ordinary spray mixtures surely prevent the setting of fruit when applied to the blossoms soon after they open.

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[1] Beach. S. A.and Bailey, L. H. Spraying in bloom. New York (Geneva). Agr. Exp. Sta. Bull. 196. 1900.

The principle apparently is the same in these cases as in that of the blossoms covered with cement dust, *i.e.*, lime is the toxic ingredient. About the only difference between spraying the flowers with these mixtures and dusting them with cement dust is that in one the lime is in water while in the other it is dry.

SUMMARY

We may briefly summarize the results of the investigation:

1. Dust from the cement kiln stacks settles on the vegetation within a radius of two miles from the mills.
2. This dust contains a large amount of alkaline, soluble calcium salts.
3. When the dust falls on the fruit blossoms some of it goes into solution in the stigmatic secretions and pollen falling on the stigma will not germinate. Thus the flowers will not be fertilized.
4. Artificial germination tests show that pollen will not germinate even in very weak solution of the dust.
5. When the blossoms are dusted as fast as they open, only a very small percentage sets fruit.

AGRICULTURE IN THE NILE VALLEY

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The amazing and apparently everlasting fertility of the Nile Valley which has always been a favorite theme of travelers in Egypt, possesses a special interest for those who are working toward an understanding of the problems incidental to the reclamation and development of arid areas.

Under present social conditions matters are at rest along the Nile, and this has rendered possible those vast engineering works, designed for the conservation and utilization of the river water, which represent the last word in irrigation practice, and for the moment serve as models for the rest of the world.

Any adequate conception of Egypt, however, must always take into consideration, in addition to these modern developments, the real economic backbone of the country: the teeming population of the hundreds of mud-walled villages, whose methods of irrigation and intensive cultivation, primitive though they may be, are still responsible for the larger part of her present prosperity.

In common with all other rivers which combine heavily silt-laden flood water with a regularly fluctuating seasonal flow, the Nile is continually building for itself an elevated trough above the general level of its valley floor, and this fact has in great measure determined the character of irrigation evolved for the adjacent land. The upbuilding of its bed must perforce go on but slowly, because the gradient of the river through lower Egypt is but slight. It has nevertheless, amounted, according to reliable records from the various nilometers, to from 12 to 15 cm. per century during historic times, and has sufficed to keep pace with the aggregate gain of the valley floor; and so the banks of the river are in general higher than the ground immediately behind them. This configuration lends itself to a system of irrigation by submersion and so it has happened that at a very early period the land was watered and fertilized by a simple cutting of the bank and subsequent control of the outpouring water, during the season of highest river and maximum silt content.

In order to render this annual flooding more certain and safe, the irrigable areas were soon traversed by a reticulation of earthen dikes or barriers, and many of these, slightly modified from time to time to suit the growth or decline of various communities, are doubtless still in use today.

The method of irrigation is substantially as follows: The river gates are opened to admit the rising Nile about the middle of August, and the water is allowed to fill the basins between the various dikes to an average depth of about 5 feet, and remain upon the land for a period of forty days. The silt has settled during this time and the clear water is then allowed to return to the river, or, if it is a season of comparatively low Nile, it is used to flood other basins further down the valley.

This system of submersive irrigation possesses the merit of feeding as well as watering the thirsty soil, for at the time of the admission of the water, the annual silt-laden flood from the Atbara, the lowest of the Nile's tributary streams, is supplementing the clearer water of the Nile itself.

The disadvantage of the system lies in the fact that even in this land of perpetual sunshine and perennial plant growth, it only provides for one cropping per year, and so a dependence upon submersive irrigation alone would soon have failed to provide for the dense population which thronged the valley of Egypt even under the Pharaohs. The construction of canals in conjunction with temporary and partial barrages in the river, designed for the purpose of getting water upon the land at other times of the year, was undoubtedly begun at a very early period, and thus the purely submersive system was supplemented by the perennial method of irrigation. The available resources of the ancient Egyptians perhaps hardly enabled them to cope successfully with a complete damming and control of their great river, although this is the line along which modern engineering effort has been chiefly directed; but in default of such power, various devices were adopted to lengthen the growing season by an adequate supply of water.

Two such inventions, the *shaduf* and the *sakiyah*, both dating probably from almost the dawn of civilization in Egypt, are still in use by the *fellahin*, or native farmers.

The *sakiyah* utilizes the energy of beasts; oxen, buffaloes, donkeys or even camels, and the *shaduf* pits the dorsal and shoulder muscles of mankind against the threatened desiccation.

The *sakiyah*, being the more elaborate and expensive of the two machines, is built for permanency upon a firm and solid site close to the edge of the river or other source of water supply. It may be individually owned or be a community affair, and is capable of watering from a few square rods up to an acre or two of ground, according to the character and needs of the crop. There are many points along the Nile above the first cataract, where a small isolated bench of tillable land, perched between the river bank and the rocky rampart of the desert represents the whole cultivated breadth of Egypt and is watered by means of a single *sakiyah*.

Fig. 1. A *sakiyah* in operation near Khartoum

Fig. 2. A pair of *shadufs* arranged for double lift

This venerable and interesting contrivance varies more or less in material and method of construction, but consists essentially of an upright revolving shaft, turned by the pole or sweep, to the end of which the patient motive power is attached, and actuating through the medium of wooden spur and crown wheels, a horizontal tumbling rod. This in turn carries between suitable bearings, a ribbed drum over which an endless double line of straw rope bearing a series of earthenware jars, is laid.

The blindfolded motive power is goaded around a circular path by a small boy; the mechanism creaks and groans, and presently the ascending jars begin to empty their small contributions into the trough or shoot from whence it is carried to the ditch.

The straw ropes can be lengthened and more jars added as the level of the water supply lowers, and the only limit to the capacity of the machine is the ability of the straining animals to lift the line of full jars. The loss by friction in the roughly constructed shafts and gears is of course enormous, but the jars, of perhaps two gallons each, are emptied into the trough at about the rate of one per second, although the rate is largely dependent upon the height of the lift.

The *shaduf*, being a more simple and portable arrangement, is erected in situations where the water supply is temporary, the needs of the crop evanescent or the means of the farmers not sufficient to support the more elaborate contrivance.

The machine is simply the ordinary well-sweep, the method of construction being governed largely by the material available in different localities, though practically unchanged since very early times, as is evidenced by many ancient representations.

The only permanent part about it is the lifting rod, for the sweep pole is generally built up of odd fragments of drift or other wood, lashed together; the counterpoise is a large lump of mud sun-dried on to the lower end of the sweep; the bucket is merely a piece of goat or other hide, caught up at the corners by thongs, and the supports for the fulcrums are usually made of small bundles of *dhurra* (maize) stalks, incorporated with and surrounded by a mass of dried mud. Equipped with this machine, the irrigator pulls down the long end of the sweep by means of his wooden or bamboo rod, dips his bucket, lets the rod slide upward again between his hands (the full bucket being slightly overbalanced by the counterpoise), tips out the water and repeats the cycle indefinitely.

The lift may be anywhere from 5 to 12 feet, or sometimes even more, and the time of the complete cycle is perhaps 10 to 15 seconds. The bucket or skin may contain from one to five gallons and so quite a generous quantity of water is raised by this simple contrivance, limited only by the endurance of the operator.

Sometimes the *shaduf* is large and worked by two men, but more frequently by one, who stands stripped to a loin-cloth, his brown skin glistening under the combined influence of the exertion and the sun, and the loads of water are delivered into the thirsty throat of the tiny ditch with machine-like regularity.

As the level of the supply is lowered and the lift becomes in consequence too great for a single machine, others are frequently added at lower levels until batteries of three or four are installed, sucking the last drops from the fast drying chain of stagnant pools in the canal bottom and carrying the little life-giving stream by consecutive steps to the crop above. Watering his land thus, the Egyptian farmer has learned, through the experience of generations, all that can be learned about the saving of water. His seed beds are small, often not more than 3 or 4 feet square, with tiny borders formed and patted into shape with hoe and hand, and in spite of the high rate of evaporation, one *shaduf* is made to suffice for a surprisingly large area of ground.

Fig. 3. *Shadufs* and irrigated fields near a village

Fig. 4. A small cultivated bench between river and desert

Under such a system of irrigation as that used in Egypt, the main feature of which is the annual flooding of the land, a large amount of community work must perforce be done. The clearing out of the main supply and drainage channels, the repair of dikes and barriers, and the watching and guarding of the banks of the river during the periods of high water, have all to be attended to in addition to actually bringing the water on to the land. Under a despotism this means forced labor, and so it has always befallen along the Nile. The peasantry were drafted by the ruler for the time being, to build, to dig or to watch, and so the greater works were rendered possible.

Modern sentiment however, is against such a practice and under the present regime the "*corvee*" has been abolished and the upkeep of all necessary structures by means of hired labor, made a charge upon the national exchequer.

The modern engineering works inaugurated and carried to completion under British rule have been planned as parts of one comprehensive scheme for the conservation, control and perennial use of the Nile water, and this scheme embodies four major projects in different parts of the valley. These comprise firstly the great Asuan dam, which is primarily for the purpose of forming a storage reservoir. The barrages of Esna and Asiut, which were designed mainly to raise the water level during years of low Nile sufficiently high to fill the canals and insure adequate floodings of the basins, and lastly the great double barrage across the heads of the Damietta and Rosetta mouths, which controls the flow of water over the delta. Several great canals such as the Ibrahimiyah, the Suhakiyah, the Bahr Yusuf, and the Girga, are also incorporated in the system and supply water to different portions of the valley, and provide for the domestic needs of the scattered farming communities. A land of irrigation and intensive cultivation must always tend to become a land of villages, and so it has been in Egypt. The mass of the population has always dwelt in the fields in spite of such adventitious local attractions as the great centers of river commerce or royal and ecclesiastical magnificence which have existed from time to time along the banks of the Nile.

The typical village of the fellahin is built upon a small mound, the remains of numberless former villages upon the same site. It is thus raised well above the level of the waters during the season of flood. The component parts of such a village are dried mud, fragments of *sunt* or palm wood, palm leaves or *dhurra* stalks. The sanitary conditions within the walls are in general indescribable, and one wonders how the small human animal survives amid such surroundings. Sunshine is one of the best and most potent of prophylactic agencies however, and the daily work in the fields is of the healthiest when once it is begun, and so a fair proportion reach maturity.

Roads, there are none, strictly speaking, outside of a few main arteries. Paths follow the tops of canal banks and dikes and these suffice, since wheeled vehicular traffic is almost non-existent. One meets along these paths an almost endless succession of camels, buffaloes, cattle, donkeys, sheep or goats, driven, led, ridden or coaxed along by humanity of all sizes and sexes. The mud walls of the villages serve as an enclosure for the nightly safe-keeping of flocks and herds, and all paths leading toward villages become thronged as evening approaches. Tired oxen that have been at work in the fields all day, camels from transport duty or from some of the *sakiyahs,* and the rest of the rabble seemingly from any and every direction and occupation.

There is an air of excitement about it all as though it were a totally new feature of village life instead of a regular custom since the time of the Pharaohs, but bye and bye it is all finished safely and satisfactorily, the last arrivals *just* manage to get within the walls; the village gates are closed, the noise and hubbub dies down and nothing is heard thereafter but the barking of the village dogs upon the house tops.

BOOKS AND CURRENT LITERATURE

The Water Requirement of Plants.—An interesting and important study by Briggs and Shantz has lately appeared on the water requirement of plants.[1] The research is chiefly of an economic nature, having for its ultimate object the scientific determination of the agricultural plants best suited for use on the Great Plains. The scene of the research is laid at Akron, Colorado, and Amarillo, in the Panhandle of Texas. The rainfall at these stations is relatively small and the evaporation relatively great, so that the results of such studies as the one in question should be applicable also in a large measure to other semi-arid regions.

It will not be necessary for the purpose of this note to describe the methods employed or give in detail the work of the investigators. Suffice it to state that the methods are probably the most satisfactory yet used where plants are handled on so large a scale. The forms employed were mainly crop species, such as oats, wheat, corn, millet, sorghum, alfalfa, and others, and, in addition, there were three introduced or native plants. The latter were *Amaranthus graecizans*, *A. retroflexus*, *Artemesia frigida*, and *Salsola pestifer*. Of the wild species, *Artemesia* is perennial and native to Colorado, occurring in the dry hills. The species of *Amaranthus* are introduced and, as weeds, have become serious pests. It may be safe to assume that the introduced annuals and the native perennial may be representative of the most successful analogous native species, so far as the water requirement is concerned, which may enable one to extend somewhat the results of the research.

The line of experimentation followed was the exact determination, under the conditions given, of the "water requirement" of the species studied, which is defined by the authors as "the ratio of the weight of water absorbed by a plant during its growth to the weight of dry matter produced." The water requirement is an inconstant quality, even for the same species. Thus, from the extensive literature list given,

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[1] Briggs, L. J. and Shantz, H. L. The Water Requirement of Plants. I. Investigations in the Great Plains in 1910 and 1911. Bull. 284, Bur. Pl. Ind.; II. A Review of the Literature. Bull. 285, Bur. Pl. Ind., 1913.

we learn that, among other factors, the water requirement is influenced by the use of fertilizers, by the limitation of available soil, by soil type which is associated with the food supply, by atmospheric conditions, and by parasites. It is greater in dry than in moist air.

Although not definitely stated it appears that the type of development sought was that normal for the species. The crops of the experiment were "harvested at the stage when similar crops were harvested in the field." Thus, whatever care may be taken with the physical side of the research there perforce remains much that is inexact, because one is dealing with living plants which vary among themselves not only as species, but also as individuals. Not to be captious, it may be suggested that it is hardly just to compare the grain stage of the wheat with the flowering stage of alfalfa, for example, as regards the water requirement. It is well known that the physiological activities as a whole of a plant at the time of flowering are relatively great, so that it is possible that, if determined at this period, the water requirement might be quite different than if the determination were made at a later period. In this connection, however, it is recalled that the end sought by the experiments was an economic one primarily, and that, consequently, it is the flowering condition of the alfalfa, and the ripened wheat, that are the centers of interest.

Taking the results as tabulated by the authors we find that the water requirement of the races and species studied, when compared to wheat as unity, is very unlike. For example, alfalfa is 2.11, and millet is 0.54, which are the extremes of the series. The actual figures show that millet, as a crop, uses 275 times as much water as the dry material produced, and that alfalfa uses 1068 times as much water as the dry material produced. The immediate purpose of this note is to institute a similar comparison, using the data of Briggs and Shantz, with two of the wild species as unity, with whose water requirement that of the cultivated species will be compared. The details of the comparisons are given in the following tables.

Water requirement of Artemesia frigida

Artemesia frigida	1.0
Millet	0.35
Sorghum	0.4
Wheat	0.66
Barley	0.7
Oats	0.8
Peas	1.04
Alfalfa	1.39

Water requirement of Amaranthus graecizans

Amaranthus graecizans	1.0
Sorghum, blackheaded kaffir	1.01
Sorghum, dwarf milo	1.21
Corn	1.34
Wheat	1.84
Barley	1.96
Oats	2.23
Alfalfa	3.88

It is of interest to observe that the water requirement of the annual *Amaranthus*, which is a highly successful weed, is less than that of any cultivated form growing under the same conditions. The water requirement of *Artemesia*, the native perennial, on the other hand, is greater than any used in the experiments excepting only the peas and alfalfa. Thus we have the novel conclusion that the most perfectly drought resistant species, of those experimented with, requires more water to produce a given amount of dry matter than the ephemeral species which are but slightly drought resistant! This is explained by the authors as a result of the slow growth of this species.—W. A. C.

Nitrate Determination.—The problems, purely scientific and applied, relating to nitrification in soils have been subjected to some careful researches. Since their solution is of such vital importance the writers of the present paper[1] call attention to certain inaccuracies which arise out of the employment of the colorimetric method for determining nitrates. They find that the alkali salts which occur frequently in arable soils in California interfere with the phenoldisulphonic acid method of nitrate determination. Sodium chloride, because of its chlorine, induces much greater losses than sodium sulphate while sodium carbonate has no effect. Explanation of this lies in the fact that sodium sulphate induces the loss of nitric acid from the solution, while the latter is being evaporated, and that sodium carbonate, containing only a weak acid radicle, possesses no such power. Lime is more reliable in coagulating clay and organic matter from solutions in which nitrates are to be determined, as it induces smaller losses of nitrates, than bone black, which is most commonly employed, or potash alum and aluminium cream.—Frederick A. Wolf.

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[1] Lipman, C. B. and Sharp, L. T. Studies on the phenoldisulphonic acid method, for determining nitrates in soils. Univ. of Calif. Publ. in Agr. Sci. **1**: No. 2, 21–37. 1912.

Flora of California.—The fourth part of Jepson's Flora of California,[1] which appeared at the beginning of the new year, follows consecutively after Part 2, and includes the families from Platanaceae to Aizoaceae inclusive. Compared with Watson's Botany of California there is an increase in these families of but three genera: *Chorizanthe* has the same number of species, 27 in each; *Eriogonum* is increased from 55 to 65, and *Atriplex* from 21 to 28. The illustrations in the present part are of structural details, and are unusually clear and well executed. The steady and rapid progress of this important work is a source of gratification to all students of the plant life of California.—S. B. Parish.

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[1] Jepson, W. L. A Flora of California. Part 4, pp. 369–464, figs. 66–91. San Francisco, January, 1914 ($1.00).

NOTES AND COMMENTS

Dr. M. E. Hardy has contributed to The Oxford Geographies (Clarendon Press), a booklet of 192 pages, entitled An Introduction to Plant Geography. The principal vegetations of the world are described, such as selvas, monsoon forests, caatinga, deserts, temperate scrubs, taiga, tundra, etc., with no attempt to treat of their floristic composition. The vegetation is also still more briefly described under a geographical arrangement. Vegetational maps of the continents are given, on a small scale, and excellent illustrations are mingled with very unsatisfactory sketches, many of which are re-drawn from long familiar illustrations of a superior character. Although such a book is a gratifying testimonial of the increasing interest which geographers are manifesting in vegetation, we suspect that few people will wish to go as far into the subject of plant geography as this introduction will take them without wishing to go much further at the outset.

An elaborately illustrated volume on The Indigenous Trees of the Hawaiian Islands has been privately published by Mr. Joseph F. Rock, of the College of Hawaii, Honolulu. Much of the virgin forest of Hawaii has been destroyed by cattle or replaced by stands of introduced trees. All the more interest attaches, therefore, to the native silva of 300 species, over 80 % of which are endemic. An introductory chapter on the floral regions contains much of interest, particularly regarding the island of Hawaii proper, where climatic contrasts are strongly drawn within extremely limited space, and where the story of the extinction of species by flows of lava is plainly written.

THE RELATION OF ATMOSPHERIC EVAPORATING POWER TO SOIL MOISTURE CONTENT AT PERMANENT WILTING IN PLANTS.[1]

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INTRODUCTION

It is now generally recognized that the moisture residue remaining in the soil at the time when plants growing therein become permanently wilted varies greatly according to the nature of the soil, this moisture content being higher in the case of soils having a greater water holding capacity and lower in the case of soils with less power of retaining water. It is only in comparatively recent years, however, that detailed attention has been given to the relations of atmospheric conditions to this soil moisture residue and to the phenomenon of wilting itself. In the earlier literature dealing with the relation of plants to soil moisture, atmospheric conditions, if considered at all, were described only in the most general way, and adequate quantitative measurements of these conditions were not attempted. More recent work has considered the aerial environmental factors, especially the evaporating power of the air, as of fundamental importance in dealing with the water relations of plants.

Briggs and Shantz[2] have recently maintained that the atmospheric environmental conditions that obtain during the process

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[1] Botanical contribution from the Johns Hopkins University, no. 37.

[2] Briggs, L. J., and Shantz, H. L., (1) Application of wilting coefficient determinations in agronomic investigations. Proc. Am. Soc. Agron. **3**: 250–60. 1912.

——, (2) The wilting coefficient and its indirect determination. Bot. Gaz. **53**: 20–37. 1912.

——, (3) The relative wilting coefficients for different plants. Bot. Gaz. **53**: 229–35. 1912.

——, (4) The wilting coefficient for different plants and its indirect determination. U. S. Dept. Agric. Bur. Plant Ind. Bull. 230. 1912.

——, (5) Die relativen Welkungskoeffizienten verschiedener pflanzen. Flora **105**: 224–40. 1912.

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of wilting have little or no effect upon the residual water content here considered, and they also conclude that this soil moisture residue (which they term the "wilting coefficient"[3]) for any given soil, remains constant, for all species of plants grown in it, and for various stages of their development. Furthermore, Briggs and Shantz have found certain definite relations to exist between this so-called wilting coefficient, on the one hand, and (1) the hygroscopic coefficient, (2) the moisture equivalent, (3) the moisture holding capacity, and (4) the numerical data expressing the mechanical analysis of the soil, on the other. They have given mathematical expression to these relations, making it apparently possible to calculate the soil moisture residue at permanent wilting from any one of these physical constants of the soil. Considering the numerous wilting tests carried out by these authors, and the data collected by them from a large number of experiments extending over considerable time, there can be no doubt that their conclusions are correct for the conditions under which their experiments were carried out. But Briggs and Shantz made no attempt at quantitative description of environmental factors other than those of the moisture residue in question and the physical properties of the soil employed; they describe the atmospheric conditions under which their experiments were carried out only in the most general way, so that their results are not available for quantitative comparison with those obtained by other authors under possibly different aerial conditions.

Brown's[4] work on the conditions determining the beginning of actual wilting (temporary wilting of Briggs and Shantz) showed clearly enough that this phenomenon depends upon the evaporating power of the air as well as upon the physical characters of the soil; with high evaporation rates the residual soil moisture at the time of temporary wilting is much higher, for any given soil, than is the case with low evaporation rates.

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[3] As Caldwell has well remarked (in his paper about to be cited), this term is unfortunate in that it logically should apply to the plant, which wilts, and not to the soil, which does not wilt. The term will be avoided here on this account.

[4] Brown, W. H., The relation of evaporation to the water content of the soil at the time of wilting. Plant World **15**: 121–34. 1912.

Caldwell,[5] working at the Desert Laboratory of the Carnegie Institution of Washington, carried out numerous experiments bearing on the question whether the residual water content of a given soil remains constant when the wilting of the plants rooted therein occurs under widely varying atmospheric conditions, and whether, therefore, the amount of this moisture can be satisfactorily calculated from the water holding power of the soil, according to the formula apparently established by the experimentation of Briggs and Shantz. The results of Caldwell's work led him to the following conclusions, among others not bearing closely upon the present discussion. (1) The amount of water left in any given soil at the time of permanent wilting of plants rooted therein is not generally to be regarded as independent of the atmospheric conditions under which wilting has occurred. (2) The magnitude of this water residue for any given soil is determined largely by the evaporating power of the air during the period of wilting. (3) If the period of wilting be one of low evaporation rates, so that the rate of water loss by transpiration from the plant never greatly exceeds that of its gain by root absorption, wilting occurs only when the water supply fails at the surface of the absorbing organs. (4) If the period of wilting is characterized by high rate of evaporation, the plant loses water by transpiration at a rate which greatly exceeds that of absorption by the roots, and under these conditions wilting should occur long before the water ceases to enter the latter organs at a considerable rate. In such a case the failure of the water supply which brings about wilting occurs somewhere between the absorbing and transpiring surfaces, and soil moisture residues observed under these conditions are higher than those observed with wilting under conditions of low evaporation intensities. (5) In order that the soil moisture residue may be determined solely by soil conditions, it is only necessary that the evaporating power of the air do not exceed a certain limit.

Caldwell clearly points out that the limit just mentioned is deserving of attention and that when this limit becomes known

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[5] Caldwell, J. S., The relation of environmental conditions to the phenomenon of permanent wilting in plants. Physiol. Res. **1**: 1–56. 1913.

it will be necessary only that the evaporating power of the air do not surpass it, in order that the soil moisture content at the time of permanent wilting of the plants may be determined by soil conditions alone. This conclusion is based on the results recorded by Briggs and Shantz, to the effect that the residuum of moisture remaining in the soil at permanent wilting was uninfluenced by such variations of the aerial conditions as were employed by these authors; they obtained the same residual soil moisture content from wiltings in a glass damp chamber as resulted from wiltings in their unshaded greenhouse, and it is thus apparent that the limit of the evaporating power of the air here postulated must lie somewhat above the evaporating power that prevailed in the unshaded greenhouse of these authors. Caldwell's moist chamber produced first wiltings with soil moisture residues not very unlike the calculated residues derived from the Briggs and Shantz formula. A study of Caldwell's published data shows that the observed moisture residues from these wiltings were usually somewhat above the calculated values; they were seldom identical with the latter and in only one case recorded (*loc. cit.*, page 33, table VIII) was an observed residue less than the calculated, the ratio being 0.98 in this single instance. It thus appears that Caldwell's moist chamber usually gave an evaporating power of the air slightly too high to bring the observed and calculated residues into perfect agreement. This evaporating power produced a rate of water loss from the standard porous cup atmometer of from 0.2 to 0.3 cc. per hour, during the hours when wilting occurred (Caldwell, *loc. cit.*, page 33, table VIII). It appears highly improbable that the corresponding hourly evaporation rates in the unshaded greenhouse of Briggs and Shantz may have been lower than, or even as low as, 0.3 cc. What these latter rates may really have been cannot now be determined, but if they be assumed as greater than 0.3cc. per hour, there then appears a serious problem in the relation between the results of Briggs and Shantz on the one hand and those of Caldwell on the other; for the earlier series of experiments surely gave excellent agreement between the observed and calculated moisture residues, while the later series indicated that an evaporation rate during wilting, of 0.3 cc. per hour from the standard atmometer was still somewhat too high for such agreement. Of course this discrepancy means either that some environmental condition besides the nature of the soil (as shown by its water holding power) and the evaporating power of the air must have been effective in determining the soil moisture residuum of one or both of the two series of experiments so far recorded, or else that the plants used by Caldwell at Tucson were in some way different in their physical nature from those used by the Washington experimenters.

With these considerations in view, it becomes even more highly desirable than is indicated by Caldwell's statement (*loc. cit.*, page 50), that it be determined whether, with decreasing evaporating power of the air, the limit assumed by the last-named writer may be actually attainable. Beyond such a limit, if it be found, any further decrease in the evaporating power of the air should have no marked effect upon the magnitude of the soil moisture content at permanent wilting; the latter having thus become practically a constant, as is indicated for the conditions employed by Briggs and Shantz. The study to be reported here was planned to determine whether Caldwell's physiological limit might indeed be determined by simple methods and, if so, to approximate its magnitude.

The experiments of the present work were performed during the months of July, August and September, 1913, at the Desert Laboratory of the Carnegie Institution, at Tucson, Arizona, where atmospheric conditions are very favorable for experiments involving the wilting of plants. It is a pleasure to acknowledge here the writers' obligation to the Department of Botanical Research of the Carnegie Institution of Washington, for the facilities of the Desert Laboratory during the summer just mentioned and for financial support in carrying out the study.

METHODS

The natural soils used in these experiments were two, a coarse sand and a clay loam, the former from a streamway north of the

Desert Laboratory and the latter from the experiment grounds of that institution. The air dry soils were sifted through a wire screen with openings 2 mm. in diameter, and a sufficient quantity of each was stored for use during the work. Plants were grown in the clay loam and in two mixtures of this and sand, one mixture containing equal parts by volume, and the other one part by volume of loam and three parts of sand. The required volumes of the two original soils were measured in the air dry condition, without any packing, as by jarring or tapping. The mixtures, after having been made as uniform as possible, were passed twice through a sieve before being used. Their moisture holding capacities were determined by means of the method of Hilgard,[6] which employs sheet metal pans with lateral walls 1 cm. high, the bottoms being perforated. The results are stated in terms of percentage of dry weight. This method is the same as that used by Briggs and Shantz and by Caldwell, and the water holding powers dealt with in the present study should therefore be comparable with the similar data given by those authors. Table I presents these moisture holding capacities of the three soils here used (these data being averages from six determinations, which were in close agreement), together with their respective compositions in terms of the original sand and clay loam.

The formula empirically derived by Briggs and Shantz (*loc. cit.* (4), page 68), for expressing the relation between the moisture holding power of any soil and its water residue at permanent wilting of plants rooted therein, involves a decrease of the value of the moisture holding power (expressed as per cent. of dry weight) by the subtraction therefrom of a constant (21), and a dividing of the remainder by another constant (2.90). The result is expressed as per cent. of dry weight of the soil and its value should be practically identical, according to the experiments and deductions of these writers, with that of the actual soil moisture residue as derived from experimental permanent wiltings, similarly expressed. The calculated moisture residues

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[6] Hilgard, E. W., Soils, their formation, properties and composition. Page 209. New York, 1911.

thus derived, for the three soils here employed, respectively, are appended also to table I.

The containers used for the plants were tinned sheet-iron cylinders, each with a capacity of either 500 cc. or 2000 cc., according to the plants employed. These were perforated at the bottom to allow for drainage.

Zea mays Lin., a quick-growing variety, *Phaseolus vulgaris* Lin., and *Capsicum annuum* Lin., a variety of Spanish pepper much cultivated in southern Arizona, were used. The seeds were planted directly into the cylinders and the cultures thus prepared were kept in a lath shelter with walls and top so constructed as to allow about one-half of the total sunlight to pass. Here the plants were cared for and allowed to grow to such an age and stage of development as to assure apparently reliable results.

From twelve to twenty-four hours before the plants were to be used, they were watered and dripping was allowed to cease. The upper surface of the soil and also the perforations at the bottoms of the cylinders were then sealed with plastiline (the same as was used by Caldwell), to prevent evaporation from the surface of the soil. Since a very long time was apt to elapse (during which the plants might alter considerably (see Brown, *loc. cit.*, page 132) before the advent of permanent wilting in the case of those cultures which were placed in the glass box, it was found expedient to water these but sparingly or not at all before sealing. Thus it sometimes happened that permanent wilting occurred in the glass box earlier than in some of the other exposures, although the latter were always characterized by more intense evaporating powers of the air.

Soil samples were taken from top to bottom of the cylinders, with a cork borer 18 mm. in diameter, in the manner already employed by Brown and by Caldwell. The upper portion of the soil column thus obtained, 2 cm. in length, was discarded, since few or no roots occurred in this region of the soil mass. This method was adopted in preference to that of weighing the total soil content of the cylinders, since by repeated tests it yielded results quite in accord with those of the latter method and had the advantage of only slightly injuring the root system; thus it was possible to use the same plants again, for later experiments, after the lapse of from ten days to two weeks, the opening left in the soil mass by the removal of the sample being of course refilled. The soil samples were collected directly into weighed screw-cap bottles, and their moisture contents were determined in the usual way, by drying to constant weight at a temperature of from 102° to 104°C.

As in the experiments of the earlier workers upon this subject, it was necessary in these studies to provide a series of exposures for the wilting plants, characterized by markedly different evaporating powers of the air. Since facilities for the adequate control of these environmental conditions, in the presence of daylight, have still to be devised, the methods here employed were very crude. These methods consisted merely in arrangements by which the evaporating power of the air in inclosed chambers was reduced to a greater or less degree below that prevailing in the open. Of course this condition in the open was subject to fluctuations, from day to day as well as from hour to hour of the same day, and this consideration entails corresponding but less marked fluctuations within the enclosures. The highest evaporating powers of the air were naturally obtained in the open, where the plants and instruments were exposed on a table constructed of parallel-placed slats 8 cm. wide, with intervening openings of the same width, thus allowing considerable opportunity for vertical air movement. This table was 1 meter high and stood in a freely exposed position, at least 15 meters from the nearest building. Another exposure, partly shaded and partly shielded from wind movement, was obtained upon a table in the lath shelter previously mentioned. This is the lath shelter employed by Brown and by Caldwell, it is about 5 meters square and 3 meters high, the walls and top being mainly composed of parallel-placed laths (about 3 cm. wide), with openings equal to the width of a lath. For still lower evaporating powers two cheesecloth chambers were constructed, by stretching the cloth over wooden frames to make cubical enclosures a meter in diameter. The walls and top were of cloth and the bottom of thin sheet iron. The bottom was 75 cm. above the ground. In these cloth chambers the evaporating power of the air was reduced to about one-half of that prevailing just outside the chamber. One of these chambers stood in the lath shelter just noted, with free circulation of air on all sides. The outside of this chamber received only that portion of full insolation and wind movement which was allowed to pass the walls and roof of the lath shelter. The second cloth chamber was placed in the open, near the table described above, and its outside received the full natural sunlight and wind.

The lowest evaporating powers of the air experienced in these wiltings were obtained in the glass-walled, glass-roofed, rectangular box (dimensions about 1.5 x 1.0 x 0.75 meters) earlier employed by Brown and by Caldwell, so placed under a small canvas shade in the lath shelter that no direct sunlight could reach it, but with free air circulation about it. Within this box the daily range of temperature was almost the same as that without, and the relative humidity inside was maintained high and nearly constant by means of water-saturated cloths suspended in the chamber and covering its floor.

For determining whether the plants were permanently wilted, as in the work of Briggs and Shantz and of Caldwell, a chamber containing air as nearly saturated with water vapor as possible was needed. This condition was attained in a cylindrical sheet-iron tank about 1 meter high and 75 cm. in diameter, tightly closed above with a sheet-iron cover. A circular opening in the cover, 25 cm. in diameter and closed by a glass plate, admitted light and made observation possible without opening the chamber. This tank stood in the thick-walled, small-windowed adobe building at the experiment grounds of the Desert Laboratory, and its daily temperature fluctuations were never nearly as great as those in the open. At the bottom of the cylinder was exposed a free water surface and the saturation deficit of the contained air was always exceedingly small. The evaporation rate in this chamber never exceeded 0.2 cc. per hour from the standard porous cup atmometer.[7]

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[7] Livingston, B. E., A rotating table for standardizing porous cup atmometers. Plant World **15**: 157–62. 1912. Earlier references are there given.

The data characterizing the atmospheric conditions for each of the different exposures employed were recorded at intervals of two hours. .Temperatures were obtained from shaded thermometers. The evaporating power of the air was automatically summed for each two-hour period by means of the porous cup atmometer, operating from a burette as reservoir; for convenient reading the burettes were placed outside the various chambers. The readings were corrected in the usual way, to give average rates for the periods in question, in cubic centimeters per hour. Relative humidity readings were obtained from hair hygrographs, though these were omitted in a number of cases where but one or two plants became permanently wilted during a period. The readings of these instruments showed that there were, for any given period of a few hours, but small differences in temperature between the several exposures described above. They also showed, on the other hand, that the two cloth chambers and the lath shelters offered three different evaporating powers of the air intermediate in magnitude between the extremes offered by the open and by the glass box. Data to be given in the next section will present the quantitative aspect of this serial arrangement.

Each experimental series involved sixty cultures, in five groups of twelve cultures each, one of these groups being subjected to the conditions of each of the five different exposures. By the exercise of care in selecting the cultures for each group, bringing together only plants which had attained approximately the same degree of development, it was possible to secure groups in which wilting occurred in the majority of the plants during the same hour of the same day. When several plants were included in the same culture they all attained the permanently wilted condition at about the same time, at least within the same two-hour period.

As soon as a culture appeared to be permanently wilted its soil sample was taken, and the culture was then placed in the moist chamber, to test the possibility of recovery without watering. If recovery did not then occur within a period of twenty-four hours, the culture was considered to have been truly in the permanently wilted condition. If however, recovery did occur within twenty-four hours, this was considered proof that permanent wilting had not yet been attained. At the end of the test period the seals were removed, the openings made in removing soil samples were refilled, the plants were revived by application of water to the soil, and the cultures were returned to the general stock for further recovery and use in subsequent experiments.

EXPERIMENTATION

Several preliminary experiments dealt with the question whether the percentage of residual moisture left in a given soil by maize plants at various stages of development was sensibly constant when wilting occurred under similar atmospheric conditions. Plants twenty days old left residues only slightly greater than the residues remaining at permanent wilting of much older individuals. With other plants twenty-eight days old, whose root systems seemed to be well developed and equally distributed in the soil masses of the cylinders, the soil moisture residues at permanent wilting were not appreciably different from those obtained with plants six or eight weeks of age. It thus appears that, within these limits at least, the stage of development of maize plants is not an important factor in determining the moisture content in question. The other forms here employed were not tested in this regard. The question here raised is, however, not a vital one in the present study, for all the plants used in any experiment were of the same age and had grown side by side under the same environmental conditions. All were apparently healthy.

In the consideration of the experimental data it is to be borne in mind that some error must result from the more or less pronounced inability of the observer to fix upon the exact attainment of the condition of permanent wilting. Error from this source results, however, only when wilting is allowed to proceed too far, since plants which have not attained the permanently wilted condition revive without watering when placed in the moist chamber for twenty-four hours. No such test can be applied in case of excessive wilting. To avoid such error as far as possible it was necessary to try always to consider plants as permanently wilted before excessive wilting had occurred, and this attempt rendered it necessary to reject a number of determinations because the plants in question revived later, without watering, in the moist chamber test. Nevertheless, it seems probable that the soil moisture contents here considered as the residues at permanent wilting are more generally apt to be too low than too high. It seems that this error can not be very large, however.

From the standpoint of the considerations just discussed it is highly desirable that there be found some more easily determined critical point than that of permanent wilting, for the carrying out of such studies as these. It seems probable that the ingenious balancing method devised and described by Briggs and Shantz (*loc. cit.* (4), page 47) may become highly valuable in this connection. If the plants were all grown under the same environmental conditions, it appears probable that the stage of incipient drying which is indicated by the balancing response might be as definite a critical point in the march of the soil-plant relation as permanent wilting has proved to be. If so, the employment of this response might result in a much improved accuracy of experimentation, for there appears to be but little chance of error in the use of the Briggs and Shantz device. It must be remembered however, as was pointed out by Livingston and Brown,[8] that the balancing response can not be expected to occur at the same time as does permanent wilting, as appears to have been assumed by the authors just mentioned; it should occur at an earlier time. As has been pointed out by Caldwell (*loc. cit.*, page 9), permanent wilting (or the corresponding stage of drying-out met with in plants which do not actually show wilting on the exterior) is an advanced stage of the incipient drying of Livingston and Brown (*loc. cit.*). This in turn is an advanced stage of Renner's[9] saturation deficit, which it is safe to suppose

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[8] Livingston, B. E., and Brown, W. H., Relation of the daily march of transpiration to variations in the water content of foliage leaves. Bot. Gaz. **53**: 309-30. 1912.

[9] Renner, O., Experimentelle Beiträge zur Kenntnis der Wasserbewegung. Flora **103**: 171-247. 1911.

is usually present in non-submerged plants. As the saturation deficit increases, the condition of incipient drying ensues, where the transpiration rate is decreased as a concomitant of lowered water content of the transpiring organs. As incipient drying increases, temporary wilting eventually results (if the plant be of a kind which wilts), and with still further increase of incipient drying (in a manner made relatively clear by Caldwell's discussion) permanent wilting is at length brought about. It appears probable that the balancing method of Briggs and Shantz should detect incipient drying directly, at some fairly well defined stage, and this before any sort of wilting might have become evident. The soil moisture residue at this supposed stage of incipient drying may be expected to possess a higher magnitude than that concomitant with permanent wilting. This matter is worthy of an experimental study.

Another source of possible error in the present experimentation may lie in the use of the white porous cup atmometer for indicating evaporation conditions. In some of the exposures here employed direct sunlight was surely an important factor in the determination of the velocity of transpirational water loss from the plants. As has been shown by Livinsgton,[10] where radiant energy is involved it is expedient to employ the dark cup of the radio-atmometer, which integrates not only the evaporating power of the air but also the influence of direct radiation upon evaporation. The tests of the last named author show that the black porous clay cup is considerably more sensitive to the accelerating influence of sunlight upon evaporation than are ordinary plant leaves, so that the employment of this cup may have introduced an error in the opposite direction. The evaporation rate which should have been employed in the present work,—if these considerations are sound,—should have had a magnitude somewhat above that given by the ordinary atmometer and somewhat below that given by the radio-atmometer. In further work of this kind this matter should receive attention.

The result of five series of wiltings will now be presented and

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[10] Livingston, B. E., Light intensity and transpiration. Bot. Gaz. **52**: 418–38. 1911.

discussed, each series comprising, as has been stated, twelve cultures in each of the five different exposures. During the progress of an experiment it sometimes happened that plants became injured in other ways than by mere wilting, and in such cases the cultures containing these plants were discarded from the group. It also sometimes occurred that cultures supposed to have been permanently wilted proved later (when tested in the moist chamber, as above described) not yet to have attained this condition; these were also omitted. Thus the results given below do not account for all of the original quota of sixty cultures. Relatively few are thus omitted, however.

TABLE 1

Characteristics of the soils used in wilting experiments

COMPOSITION	MOISTURE HOLDING CAPACITY ON DRY WEIGHT BASIS	CALCULATED MOISTURE RESIDUE AT PERMANENT WILTING. ("WILTING COEFFICIENT" OF BRIGGS AND SHANTZ), ON DRY WEIGHT BASIS
	per cent.	*per cent.*
Loam without admixture of sand....	57.32	12.52
Half sand and half loam, by dry volume..........................	38.36	5.92
Three-fourths sand and one-fourth loam, by dry volume..............	32.02	3.80.

Series I. Maize plants were used in this series, the plants being four weeks old at the beginning of the experiment, which was begun August 8, 8 a.m. The soil mixture contained three volumes of sand and one volume of clay loam, with a moisture holding power of 32.02 per cent., of its dry weight. From the Briggs and Shantz formula the calculated moisture residue at permanent wilting is, for the soil, 3.80 per cent. of the dry weight. There were three plants in each culture. The first permanent wilting occurred in the chamber in the open, August 8, during the sixteenth hour; *i.e.,* between 3.00 and 4.00 p.m. Twelve cultures became permanently wilted during this hour and the average soil moisture residue from these was 6.04 per cent. The average evaporation rate for the two-hour period during which wilting occurred was 3 cc. Permanent wilting occurred in the glass box on August 9, in the open on August 10, in the shelter on August 12, and in the chamber in the shelter on August 13.

The numerical data pertaining to this series are given in table II, the column headings of which are self-explanatory. It will be noted that the data are serially arranged according to the hourly evaporation rates, beginning with the lowest. Each item refers to a single culture. Where two or more cultures wilted under the same conditions and at the same time, the results have been averaged and these averages are also shown in the table.

It is clear from table II that Caldwell's main general conclusion is definitely substantiated, and that with increasing evaporation rates for the period of wilting, the moisture remaining in the soil at permanent wilting also increases. That the data from individual cultures does not always agree with this generalization is not surprising (for there must be considerable experimental error involved with methods as crude as those here employed, error brought about by unknown conditions either within or without the plant), but if the data referring to single cultures and to averages of only two are neglected, there are then no discrepancies between the actual facts and the requirements of the generalization.

To determine what may be the limits of the atmospheric evaporating power, within which this factor may be considered as without important effect upon the magnitude of the soil moisture residue, the data of residues and evaporation rates have been plotted to form a graph (fig. 1), in which abscissas represent evaporation rates and ordinates represent soil moisture residues. In order to indicate, in a general manner, the relative weights to be attached to the various points of the graph, those referring to the averages of the larger numbers of cultures wilting at about the same time and under about the same conditions are denoted by heavy circles. The range of variation of the group from which each of these averages has been derived is shown by a vertical line; the ordinate of the upper extremity of this line represents the maximum and that for the lower end the minimum moisture residue as actually encountered in the group. Other averages are shown by light circles, and data from single cultures (where no

TABLE 2

(*Series I*)

Numerical data bearing on the permanent wilting of plants of Zea four weeks old at beginning of experiment, each culture comprising three plants; in soil mixture of three volumes sand and one volume clay loam (water holding power, 32.02 per cent.; calculated soil moisture residue at permanent wilting, 3.80 per cent., of dry weight).*

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
0.3	3.96	1.04	Box	Aug. 9, 8	24	
	4.54	1.19	Box	Aug. 9, 10	26	
	4.96	1.30	Box	Aug. 9, 12	33	
	4.06	1.06	Box	Aug. 9, 18	33–25	98
	4.46	1.17	Box	Aug. 9, 18	33–25	98
	4.47	1.18	Box	Aug. 9, 18	33–25	98
	4.18	1.10	Box	Aug. 9, 18	33–25	98
	4.02	1.06	Box	Aug. 9, 18	33–25	98
	4.50	1.18	Box	Aug. 9, 18	33–25	98
	4.46	1.17	Box	Aug. 9, 18	33–25	98
	Av. 4.30 (1)	Av. 1.13				
	5.68	1.49	Box	Aug. 9, 20	25	
	5.11	1.34	Box	Aug. 9, 20	25	
	Av. 5.39	Av. 1.41				
1.5	5.80	1.53	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.45	1.43	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.09	1.34	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.08	1.34	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.13	1.35	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.62	1.48	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.65	1.49	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.53	1.45	Ch., Sh.	Aug. 13, 12	24–34	35–32
	5.52	1.45	Ch., Sh.	Aug. 13, 12	24–34	35–32
	6.01	1.58	Ch., Sh.	Aug. 13, 12	24–34	35–32
	Av. 5.48 (2)	Av. 1.44				
2.2	6.41	1.69	Ch., Sh.	Aug. 13, 15	30	
	6.71	1.77	Ch., Sh.	Aug. 13, 15	30	
	Av. 6.56	Av. 1.73				

TABLE 2—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
2.4	5.61	1.47	Shelter	Aug. 12, 12	29–31	30–25
	5.94	1.56	Shelter	Aug. 12, 12	29–31	30–25
	5.81	1.53	Shelter	Aug. 12, 12	29–31	30–25
	5.96	1.57	Shelter	Aug. 12, 12	29–31	30–25
	5.22	1.37	Shelter	Aug. 12, 12	29–31	30–25
	6.13	1.61	Shelter	Aug. 12, 12	29–31	30–25
	5.72	1.51	Shelter	Aug. 12, 12	29–31	30–25
	5.90	1.55	Shelter	Aug. 12, 12	29–31	30–25
	5.61	1.47	Shelter	Aug. 12, 12	29–31	30–25
	6.41	1.40	Shelter	Aug. 12, 12	29–31	30–25
	5.31	1.40	Shelter	Aug. 12, 12	29–31	30–25
	Av. 5.78 (3)	Av. 1.52				
2.5	6.19	1.63	Shelter	Aug. 12, 14	37	
3.0	6.53	1.72	Ch., open	Aug. 8, 16	32	19–21
	5.24	1.38	Ch., open	Aug. 8, 16	32	19–21
	5.84	1.54	Ch., open	Aug. 8, 16	32	19–21
	6.30	1.66	Ch., open	Aug. 8, 16	32	19–21
	5.36	1.48	Ch., open	Aug. 8, 16	32	19–21
	5.44	1.43	Ch., open	Aug. 8, 16	32	19–21
	5.20	1.37	Ch., open	Aug. 8, 16	32	19–21
	5.81	1.53	Ch., open	Aug. 8, 16	32	19–21
	6.06	1.60	Ch., open	Aug. 8, 16	32	19–21
	5.91	1.56	Ch., open	Aug. 8, 16	32	19–21
	5.70	1.50	Ch., open	Aug 8, 16	32	19–21
	5.16	1.36	Ch., open	Aug. 8, 16	32	19–21
	Av. 6.04 (4)	Av. 1.58				
3.7	5.98	1.57	Open	Aug. 10, 12	26–31	20–18
	6.69	1.76	Open	Aug. 10, 12	28–31	20–18
	5.81	1.53	Open	Aug. 10, 12	26–31	20–18
	6.61	1.74	Open	Aug. 10, 12	26–31	20–18
	6.40	1.68	Open	Aug. 10, 12	26–31	20–18
	6.59	1.73	Open	Aug. 10, 12	26–31	20–18
	5.99	1.58	Open	Aug. 10, 12	26–31	20–18
	6.17	1.62	Open	Aug. 10, 12	26–31	20–18

TABLE 2—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
3.7	6.10	1.61	Open	Aug. 10, 12	26–31	20–18
	5.86	1.54	Open	Aug. 10, 12	26–31	20–18
	5.70	1.50	Open	Aug. 10, 12	26–31	20–18
	Av. 6.16 (5)	Av. 1.63				

* Calculations made by means of the Briggs and Shantz formula, from the water holding power of the soil used.

† The word *box* here denotes the glass box; *ch., sh.*, denotes chamber in shelter; *ch., open* denotes chamber in open.

‡ The hours of the day are simply numbered in a single series, from 1 to 24; thus, the thirteenth hour is the first hour after midday, etc.

averages are possible) are shown by dots. The ordinate for each point shown is indicated by a light broken line projecting the point to the horizontal line below. The parenthetical numbers near the bases of these ordinates for the main averages refer to corresponding numbers following the main averages in table II. The axis of ordinates is shown in the graph, the numbers at its left indicating percentages on the dry weight of the soil. The axis of abscissas is not shown; the horizontal line below the graph bears, however, the values of the different abscissas. These values are in terms of cubic centimeters per hour, loss from the standard porous cup atmometer.

The general arrangement of the heavy circles on the graph of figure 1 strongly suggests that these points lie on a regular curve, a curve which approaches a vertical line with low values of x and a horizontal line with high values. This observation leads to the conclusion that, in this case at least, the range of evaporating powers supposed by Caldwell to exist with low values of the intensity of this condition (within which range evaporation intensity is supposed to be without effect upon soil moisture residue at permanent wilting) must be very small and must include only values that closely approach an intensity of zero. The region of the curve where differences of evaporation rate produce the smallest differences in the soil moisture residue at permanent wilting lies in its upper portion, with high values of x. But even here, for the highest intensities of the atmospheric evaporating power experienced in this experiment, the relation between the two conditions is still obvious enough.

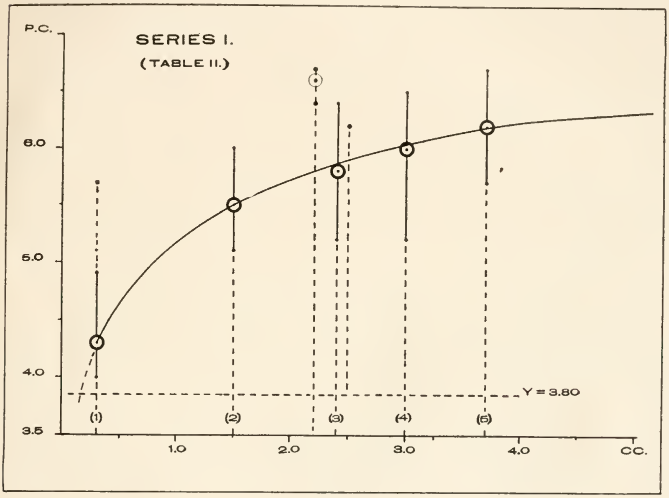

Fig. 1

A further observational study of the curve denoted by the five main averages brings out the apparently important fact that this curve very closely approximates that of a logarithmic function in which, for each geometrical increase in the evaporation rate (x), there is an arithmetical increase in the value of the moisture residue (y). The general equation of such a curve referred to the axes, $x = 0$, $y = 0$, is: $x = k^{\frac{y}{a}}$, where k is the constant ratio by which x increases and a is the constant difference by which y increases. If k be taken as 2 in the present case, to enquire how much is added to the soil moisture residue for each doubling of the evaporation rate, the equation becomes, $x = 2^{\frac{y}{a}}$. In the present instance it is desired to find the value of a which satisfies this equation and brings the curve in question to pass through the first two main averages of the graph ($x = 0.3$, $y = 4.30$, and $x = 1.5$, $y = 5.48$). It is clear that the value 4.30 must be considered zero, thus passing the axis of abscissas through this point. Referring to the axes of the general curve above given, the two points to be considered become (0.3, 0) and (1.5, 1.18). Now if the curve, $x = 2^{\frac{y}{a}}$, passes through these two points, it follows that the two equations, $0.3 = 2^{\frac{0}{a}}$, and $1.5 = 2^{\frac{1.18}{a}}$, must be simultaneous. Dividing each member of the second by the corresponding member of the first, $5 = 2^{\frac{1.18}{a} - \frac{0}{a}}$ or $5 = 2^{\frac{1.18}{a}}$. The last equation is the same as, $\log 5 = \frac{1.18}{a} \log 2$, or $a = \frac{1.18 \log 2}{\log 5}$, from which it appears that $a = 0.504$.

The curve actually shown in figure 1 has the constant difference (a) taken as 0.50, the constant ratio as 2, and it passes through the first two points designated by heavy circles. It is clear at once that this theoretical curve, derived from the first two main averages, very nearly passes through the points representing the three remaining averages. From the equation $\log x = \frac{y}{0.5} \log 2$, may be found the value y for any given value of x. The agreement between the ordinates of the last three averages and the corresponding ordinates thus calculated is very close, so close that there is left no doubt that the given logarithmic curve represents the relation sought. It may therefore be stated that, for the present series, each doubling of the evaporating power of the air as here measured is accompanied by an arithmetical increase equal to about 0.5 per cent. of the dry weight of the soil, in the soil moisture residue remaining at permanent wilting.

On the graph of figure 1 the calculated value (from the Briggs and Shantz formula) of the moisture residue is indicated by the horizontal broken line, $y = 3.80$. It is obvious that all of the observed residues are much greater than the values thus calculated, although (as Caldwell has already clearly shown), with low evaporation rates the two values differ less markedly than they do with high rates. With an evaporation rate of 0.15 cc. per hour from the standard instrument, the theory of the curve above considered demands that the soil moisture residue become 3.8 per cent., thus agreeing with the calculation based on the formula of Briggs and Shantz. It seems improbable that the evaporation intensities prevailing in the glass chamber of the last-named authors should have been as low as 0.15 cc. per hour, and it is almost certain that their other exposures must have all given higher intensities of evaporation than did their glass chamber. No attempt is as yet possible, to explain this apparently pronounced disagreement between the results of the Washington workers and those here brought forward. It may be merely suggested that the explanation sought may have to do with different physical conditions within the plant, depending upon the environment in which it grew; thus the plants with which Caldwell and the present writers worked may have been markedly and definitely different from those with which the experiments of Briggs and Shantz were carried out.

Series II. Phaseolus was employed in this experiment, the plants being six weeks old at the beginning. Three plants comprised each culture. The soil used was the same mixture of sand and clay loam as that employed in series I. The experiment was begun September 8, 8 a.m. The first permanent wilting occurred in the chamber in the open, on September 8. On September 11, permanent wilting was attained in the chamber in the shelter and in the open; on September 13, permanent wilting occurred in the glass box.

The numerical data obtained from this series make up table III, in which the arrangement and notations are quite similar to those used in table II.

It is again generally clear, in table III, that the higher evaporation rates accompany high soil moisture residues and that low

TABLE III

(*Series II*)

Numerical data bearing on the permanent wilting of plants of Phaseolus six weeks old at beginning of experiment, each culture comprising three plants; in soil mixture of three volumes sand and one volume clay loam (water holding power, 32.02 per cent.; calculated soil moisture residue at permanent wilting, 3.80 per cent., of dry weight).*

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE AT PERMANENT WILTING, (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
0.1	4.21	1.11	Box	Sept. 13, 13	30	
0.2	5.07	1.33	Box	Sept. 13, 9	25	
	4.93	1.30	Box	Sept. 13, 12	30	
	4.62	1.22	Box	Sept. 13, 15	29	
	4.88	1.28	Box	Sept. 13, 16	32–31	98
	4.27	1.12	Box	Sept. 13, 16	32–31	98
	5.22	1.37	Box	Sept. 13, 16	32–31	98
	4.69	1.23	Box	Sept. 13, 16	32–31	98
	4.46	1.17	Box	Sept. 13, 16	32–31	98
	Av. 4.70 (1)	Av. 1.25				
0.9	6.43	1.69	Ch., sh.	Sept. 11, 9	30	
2.3	5.04	1.33	Ch., sh.	Sept. 11, 13	35–36	33–31
	5.32	1.40	Ch., sh.	Sept. 11, 13	35–36	33–31
	5.35	1.41	Ch., sh.	Sept. 11, 13	35–36	33–31
	5.74	1.51	Ch., sh.	Sept. 11, 13	35–36	33–31
	5.31	1.40	Ch., sh.	Sept. 11, 13	35–36	33–31
	5.41	1.42	Ch., sh.	Sept. 11, 13	35–36	33–31
	Av. 5.36 (2)	Av. 1.41				
2.4	5.92	1.56	Ch., sh.	Sept. 11, 17	28	
	5.34	1.40	Ch., sh.	Sept. 11, 17	28	
	Av. 5.58	Av. 1.48				
2.8	5.60	1.47	Ch., sh.	Sept. 11, 15	35	
	5.68	1.44	Ch., sh.	Sept. 11, 15	35	
	Av. 5.64	Av. 1.46				
2.9	6.40	1.68	Ch., open	Sept. 8, 17	34	
	6.42	1.69	Ch., open	Sept. 8, 17	34	
	Av. 6.41	Av. 1.69				
3.0	6.63	1.74	Ch., open	Sept. 8, 15	31–34	31
	5.19	1.37	Ch., open	Sept. 8, 15	31–34	31
	5.94	1.56	Ch., open	Sept. 8, 15	31–34	31
	6.39	1.69	Ch., open	Sept. 8, 15	31–34	31
	6.98	1.83	Ch., open	Sept. 8, 15	31–34	31
	Av. 6.22 (3)	Av. 1.63				

TABLE III—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE AT PERMANENT WILTING, (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
3.5	5.10	1.34	Shelter	Sept. 11, 17	32	
	5.23	1.36	Shelter	Sept. 11, 17	32	
	Av. 5.17	Av. 1.36				
3.6	7.32	1.93	Ch., open	Sept. 8, 13	31	
	7.42	1.95	Ch., open	Sept. 8, 13	31	
	Av. 7.37	Av. 1.94				
	5.33	1.40	Shelter	Sept. 11, 11	30–35	30–28
	5.83	1.53	Shelter	Sept. 11, 11	30–35	30–28
	6.01	1.58	Shelter	Sept. 11, 11	30–35	30–28
	5.63	1.48	Shelter	Sept. 11, 11	30–35	30–28
	5.81	1.53	Shelter	Sept. 11, 11	30–35	30–28
	Av. 5.73 (4)	Av. 1.51				
3.8	6.43	1.69	Shelter	Sept. 11, 15	35	
4.3	5.40	1.42	Shelter	Sept. 11, 13	36	
4.4	5.14	1.35	Open	Sept. 11, 18	30	
	6.42	1.69	Open	Sept. 11, 18	30	
	7.10	1.87	Open	Sept. 11, 18	30	
	Av. 6.22	Av. 1.64				
4.8	5.75	1.51	Open	Sept. 11, 16	34–36	25–26
	5.40	1.42	Open	Sept. 11, 16	34–36	25–26
	5.63	1.48	Open	Sept. 11, 16	34–36	25–26
	7.36	1.93	Open	Sept. 11, 16	34–36	25–26
	7.03	1.85	Open	Sept. 11, 16	34–36	25–26
	7.14	1.88	Open	Sept. 11, 16	34–36	25–26
	6.14	1.62	Open	Sept. 11, 16	34–36	25–26
	Av. 6.35 (5)	Av. 1.67				

* Calculations made by means of the Briggs and Shantz formula, from the water holding power of the soil used.

† The word *box* here denotes the glass box; *ch., sh.* denotes chamber in shelter; *ch., open* denotes chamber in open.

‡ The hours of the day are simply numbered in a single series, from 1 to 24; thus, the thirteenth hour is the first hour after midday, etc.

rates are concomitant with low residues, but the arrangement of the five main averages is not here nearly so consistent as in the case of series I; it appears that the main averages (2) and (4) are relatively low as compared to the averages (3) and (5).

The graph of figure 2, in which notations and arrangements are the same as in figure 1, brings out the point just mentioned, as well as other relations.

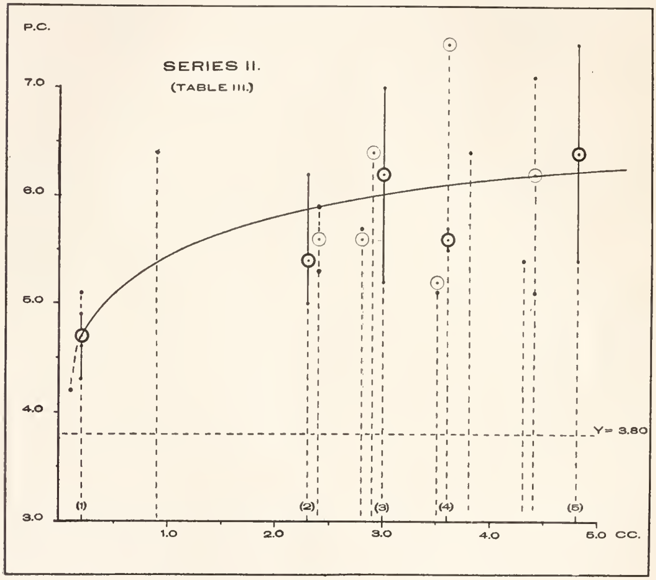

Fig. 2

The superficial generalizations drawn from the results of series I (table II and fig. 1) are supported by the data here set forth. The soil moisture residues at permanent wilting become smaller with lower intensities of atmospheric evaporating power, but no actual soil moisture residue was obtained in this series which was not considerably greater than that indicated by the value calculated from the Briggs and Shantz formula. It appears here also that there can be no range of low evaporation intensities within which this factor is without marked effect upon the magnitude of the soil moisture residue, unless indeed this range be limited to evaporation intensities very closely approaching zero; the curve of these data, like that of the data of series I, is persistently convex upward and approaches a vertical line for small values of the evaporation rate. Furthermore, these results agree with those of the preceding series in showing that the relative effect of alteration in the evaporation rate, upon the magnitude of the moisture residue, becomes small with the highest rates here dealt with.

It is obviously not legitimate here to attempt to pass a curve for all five main averages through the points representing the first two, as it was found to be possible in the case of series I. Apparently such a generalized curve should pass below the points for averages (3) and (5) and above those for averages (2) and (3). The curve shown in figure 2 is a logarithmic one, similar to that of figure 1, passing through the point for average (1) and fulfilling the conditions just stated for the remaining four. The constant geometrical ratio is here taken again as 2, but the constant arithmetical difference is 0.32, instead of 0.5 per cent. as in the former case. All data being considered, it appears that this generalized or theoretical curve represents fairly well the relations concerned, albeit the graph of figure 2 is not as satisfactory as that of figure 1. The only known fundamental difference between the determining conditions of the present series and those of series I lies in the fact that series I employed Zea and series II employed Phaseolus plants. The other experiments of this study throw no light upon the question thus raised.

Series III. The soil mixture employed in this series was identical with that used in the two series just discussed, but the containers had each a capacity of two liters, four times the capacity of the cylinders used in the preceding and subsequent series. Capsicum plants were here used, one plant in each culture. They were nearing maturity, some being in bloom at the time of wilting while others were in the process of fruit formation. The

TABLE IV

(*Series III*)

Numerical data bearing on the permanent wilting of plants of Capsicum nearing maturity at beginning of experiment, each culture comprising one plant; in soil mixture of three volumes sand and one volume clay loam (water holding power, 32.02 per cent.; calculated soil moisture residue at permanent wilting, 3.80 per cent., of dry weight).*

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING, (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*degs., C.*	*per cent.*
0.5	4.78	1.26	Box	Aug. 17, 16	30	
	5.29	1.39	Box	Aug. 17, 16	30	
	Av. 5.54	Av. 1.33				
	4.84	1.27	Box	Aug. 17, 18	30	94
	5.03	1.32	Box	Aug. 17, 18	30	94
	5.32	1.40	Box	Aug. 17, 18	30	94
	5.26	1.38	Box	Aug. 17, 18	30	94
	5.22	1.37	Box	Aug. 17, 18	30	94
	Av. 5.13 (1)	Av. 1.35				
1.7	6.17	1.62	Ch., sh.	Aug. 18, 13	36	
1.9	7.19	1.89	Ch., sh.	Aug. 18, 15	34	
	6.94	1.83	Ch., sh.	Aug. 18, 15	34	
	Av. 7.07	Av. 1.86				
2.2	5.42	1.42	Ch., sh.	Aug. 18, 17	35–34	28–30
	5.40	1.42	Ch., sh.	Aug. 18, 17	35–34	28–30
	5.33	1.40	Ch., sh.	Aug. 18, 17	35–34	28–30
	5.88	1.55	Ch., sh.	Aug. 18, 17	35–34	28–30
	5.15	1.35	Ch., sh.	Aug. 18, 17	35–34	28–30
	5.30	1.40	Ch., sh.	Aug. 18, 17	35–34	28–30
	Av. 5.41 (2)	Av. 1.42				
2.6	5.49	1.44	Shelter	Aug. 17, 12	34	
2.9	5.92	1.56	Ch., open	Aug. 14, 11	32	
3.2	5.01	1.32	Shelter	Aug. 17, 18	31–26	21–24
	6.10	1.60	Shelter	Aug. 17, 18	31–26	21–24
	6.05	1.59	Shelter	Aug. 17, 18	31–26	21–24
	5.43	1.43	Shelter	Aug. 17, 18	31–26	21–24
	6.18	1.63	Shelter	Aug. 17, 18	31–26	21–24
	6.17	1.62	Shelter	Aug. 17, 18	31–26	21–24
	5.54	1.46	Shelter	Aug. 17, 18	31–26	21–24
	6.02	1.58	Shelter	Aug. 17, 18	31–26	21–24
	6.15	1.62	Shelter	Aug. 17, 18	31–26	21–24
	Av. 5.85 (3)	Av. 1.54				

TABLE IV—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING, (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
3.3	5.46	1.44	Shelter	Aug. 17, 14	35	
3.4	5.98	1.57	Shelter	Aug. 17, 16	30	
3.5	6.21	1.63	Ch., open	Aug. 14, 13	35	
3.9	6.59	1.73	Ch., open	Aug. 14, 15	35	20–22
	6.38	1.80	Ch., open	Aug. 14, 15	35	20–22
	5.80	1.53	Ch., open	Aug. 14, 15	35	20–22
	6.78	1.77	Ch., open	Aug. 14, 15	35	20–22
	6.74	1.77	Ch., open	Aug. 14, 15	35	20–22
	6.82	1.79	Ch., open	Aug. 14, 15	35	20–22
	Av. 6.59 (4)	Av. 1.73				
4.3	6.60	1.74	Ch., open	Aug. 14, 17	34	
	6.59	1.73	Ch., open	Aug. 14, 17	34	
	Av. 6.60	Av. 1.74				
5.9	7.16	1.88	Open	Aug. 14, 13	35	
	7.84	2.06	Open	Aug. 14, 13	35	
	Av. 7.50	Av. 1.97				
6.1	6.98	1.83	Open	Aug. 14, 15	35	17–16
	7.14	1.88	Open	Aug. 14, 15	35	17–16
	7.92	2.08	Open	Aug. 14, 15	35	17–16
	7.06	1.86	Open	Aug. 14, 15	35	17–16
	7.56	1.99	Open	Aug. 14, 15	35	17–16
	6.23	1.64	Open	Aug. 14, 15	35	17–16
	7.37	1.94	Open	Aug. 14, 15	35	17–16
	7.17	1.89	Open	Aug. 14, 15	35	17–16
	Av. 7.17 (5)	Av. 1.88				
6.5	7.52	1.86	Open	Aug. 14, 17	34	

* Calculations made by means of the Briggs and Shantz formula, from the water holding power of the soil used.

† The word *box* here denotes the glass box; *ch., sh.* denotes chamber in shelter; *ch., open* denotes chamber in open.

‡ The hours of the day are simply numbered in a single series, from 1 to 24; thus, the thirteenth hour is the first hour after midday, etc.

experiment was begun August 14, 8 a.m. The first permanent wilting occurred in the chamber in the open, on August 14. On August 17, permanent wilting was attained in the shelter and in the glass box, and on August 18, the same stage was reached in the chamber in the shelter.

The numerical results of series III are set forth in table IV, which conforms with the preceding tables.

In consequence of the large volume of soil in the containers, the time required for the plants to attain the permanently wilted condition was comparatively long in this case, and yet the general results of this series do not differ essentially from those of the two preceding series. There is no such discrepancy here, in the relative order of magnitudes of the five main averages, as was found in the case of series II. It appears, however, that although it is strictly true that the main averages do increase with higher intensities of evaporation, yet averages (2) and (3) are somewhat too low to allow all five to lie on a consistent curve.

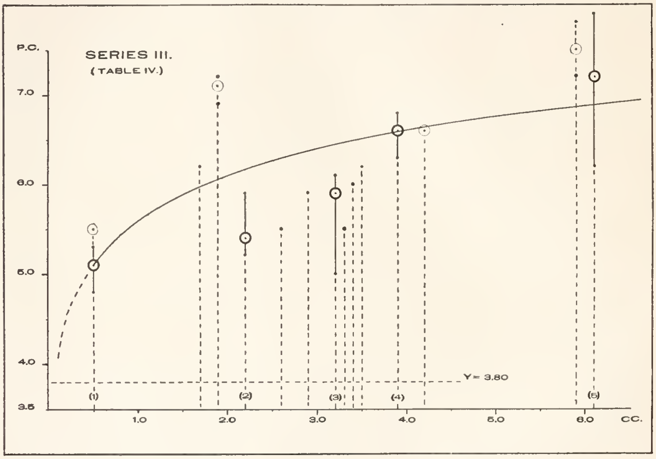

Fig. 3

The graph of figure 3 brings out this and other points, this graph being plotted similarly to those for series I and II.

Figure 3 shows a generalized curve, of logarithmic form, passing through the points representing averages (1) and (4); it is seen that this curve falls but a little below the point representing average (5). Averages (2) and (3) lie farther from and below the generalized curve. In plotting the latter, the constant geometrical ratio was again taken as 2 and the value of the constant difference as 0.5 per cent.

Series III agrees, therefore, with series I, in furnishing main averages that may be satisfactorily considered (within the limits of probable experimental error) as forming a logarithmetic curve for which each doubling of the evaporation intensity is concomitant with an addition of 0.5 to the value of the percentage representing the residual soil moisture at permanent wilting. Although the observed residues approach the calculated value (from the Briggs and Shantz formula) for low evaporation intensities, they are all, as in both the preceding series, much greater than the percentage demanded by the calculation.

Series IV. Phaseolus plants were used in this series, seven weeks old at the beginning of the experiment. Each culture comprised three plants, the containers being of the same size as those employed in series I and II. The soil mixture here used was different from that of the series heretofore considered; it consisted of a mixture of equal volumes of sand and clay loam. Its water holding power was found to be 38.16 per cent. of its dry weight, thus giving a calculated moisture residue (according to the formula of Briggs and Shantz) of 5.92 per cent. of the dry weight. The series was started September 11, 8 a.m., and the first permanent wilting was observed, in the chamber in the open and also in the open, on the first day. Permanent wilting occurred in the chamber in the shelter on September 12, it was attained in the glass box on September 17, and in the shelter on September 18. The numerical results of the series are presented in table V, in in which the arrangement and notations are uniform with those of the preceding three tables.

TABLE V

(*Series IV*)

Numerical data bearing on the permanent wilting of plants of Phaseolus seven weeks old at beginning of experiment, each culture comprising three plants; in soil mixture of half sand and half clay loam (water holding power, 38.16 per cent.; calculated soil moisture residue at permanent wilting 5.92 per cent., of dry weight).*

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
0.2	5.92	1.00	Box	Sept. 17, 10	24	
	6.03	1.02	Box	Sept. 17, 10	24	
	Av. 5.97	Av. 1.01				
	5.75	0.97	Box	Sept. 17, 12	28	
	6.21	1.05	Box	Sept. 17, 14	32	
	Av. 5.98	Av. 1.01				
	6.10	1.03	Box	Sept. 17, 16	32–31	98
	5.84	0.98	Box	Sept. 17, 16	32–31	98
	6.20	1.05	Box	Sept. 17, 16	32–31	98
	5.80	0.98	Box	Sept. 17, 16	32–31	98
	6.00	1.01	Box	Sept. 17, 16	32–31	98
	5.50	0.93	Box	Sept. 17, 16	32–31	98
	Av. 5.90 (1)	Av. 1.00				
	6.21	1.05	Box	Sept. 17, 18	32	
1.5	6.57	1.11	Ch., Sh.	Sept. 12, 17	25	
	6.84	1.16	Ch., Sh.	Sept. 12, 17	25	
	Av. 6.71	Av. 1.14				
2.0	8.07	1.36	Ch., Sh.	Sept. 12, 15	36–35	30
	7.71	1.30	Ch., Sh.	Sept. 12, 15	36–35	30
	7.84	1.32	Ch., Sh.	Sept. 12, 15	36–35	30
	7.46	1.23	Ch., Sh.	Sept. 12, 15	36–35	30
	8.33	1.41	Ch., Sh.	Sept. 12, 15	36–35	30
	Av. 7.85 (2)	Av. 1.23				
2.4	8.71	1.48	Ch., Sh.	Sept. 12, 13	34	
	7.94	1.35	Ch., Sh.	Sept. 12, 13	34	
	Av. 8.06	Av. 1.42				

TABLE V—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
3.1	9.58	1.62	Shelter	Sept. 18, 13	35	
	9.05	1.53	Shelter	Sept. 18, 13	35	
	9.37	1.59	Shelter	Sept. 18, 13	35	
	Av. 9.33	Av. 1.58				
3.3	7.91	1.34	Shelter	Sept. 18, 15	36–35	29–26
	8.05	1.36	Shelter	Sept. 18, 15	36–35	29–26
	8.12	1.37	Shelter	Sept. 18, 15	36–35	29–26
	8.40	1.42	Shelter	Sept. 18, 15	36–35	29–26
	8.22	1.39	Shelter	Sept. 18, 15	36–35	29–26
	8.26	1.39	Shelter	Sept. 18, 15	36–35	29–26
	Av. 8.16 (3)	Av. 1.37				
3.5	7.75	1.33	Shelter	Sept. 18, 17	30	
	7.57	1.28	Shelter	Sept. 18, 17	30	
	8.82	1.49	Shelter	Sept. 18, 17	30	
	Av. 8.05	Av. 1.37				
3.8	7.00	1.19	Ch., open	Sept. 11, 17	28	
4.2	7.67	1.30	Ch., open	Sept. 11, 15	34	
	7.67	1.30	Ch., open	Sept. 11, 15	34	
	Av. 7.67	Av. 1.30				
4.5	8.00	1.35	Ch., open	Sept. 11, 13	33–35	24–23
	8.20	1.39	Ch., open	Sept. 11, 13	33–35	24–23
	8.62	1.45	Ch., open	Sept. 11, 13	33–35	24–23
	8.50	1.43	Ch., open	Sept. 11, 13	33–35	24–23
	8.27	1.40	Ch., open	Sept. 11, 13	33–35	24–23
	8.17	1.38	Ch., open	Sept. 11, 13	33–35	24–23
	8.17	1.38	Ch., open	Sept. 11, 13	33–35	24–23
	Av. 8.27 (4)	Av. 1.39				
5.8	8.37	1.47	Open	Sept. 11, 11	29–33	20–19
	8.94	1.51	Open	Sept. 11, 11	29–33	20–19
	8.17	1.38	Open	Sept. 11, 11	29–33	20–19
	8.36	1.41	Open	Sept. 11, 11	29–33	20–19

TABLE V—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
5.8	8.13	1.37	Open	Sept. 11, 11	29–33	20–19
	8.26	1.40	Open	Sept. 11, 11	29–33	20–19
	Av. 8.37 (5)	Av. 1.41				
6.9	8.22	1.39	Open	Sept. 11, 15	34	
	9.10	1.53	Open	Sept. 11, 15	34	
	Av. 8.66	Av. 1.46				

* Calculations made by means of the Briggs and Shantz formula, from the water holding power of the soil used.

† The word *box* here denotes the glass box; *ch., sh.* denotes chamber in shelter; *ch., open* denotes chamber in open.

‡ The hours of the day are simply numbered in a single series, from 1 to 24; thus, the thirteenth hour is the first hour after midday, etc.

In this series there is no irrationality in the relative arrangement of the main averages with reference to the corresponding evaporation intensities; here there is always an increase in the moisture residue accompanying each increase in the atmospheric evaporating power. The curve formed by these five averages is clearly convex upward and approaches a vertical line with low evaporation rates, quite as in the cases previously discussed. Here average (1) falls almost low enough to coincide with the calculated value of the moisture residue (5.92) derived from the Briggs and Shantz formula, a feature not encountered in any of the earlier series. This is probably related to the fact that the soil mixture here used possessed a higher water holding power than did the mixture employed in earlier series. A graph of the results of series IV is given in figure 4, constructed as were the preceding graphs.

The generalized curve of figure 4 shows almost as satisfactory agreement between its points and the corresponding ones representing the five main averages as does that of figure 1. The present generalized curve was plotted to pass through the point representing average (1), using the constant ratio 2, as heretofore, and the constant difference 0.55, with the logarithmic equation already stated.

It is obviously not far from the truth to assert that in this series each increase of about 0.55 in the magnitude of the percentage of soil moisture residue is accompanied by a doubling of the evaporation intensity as here measured.

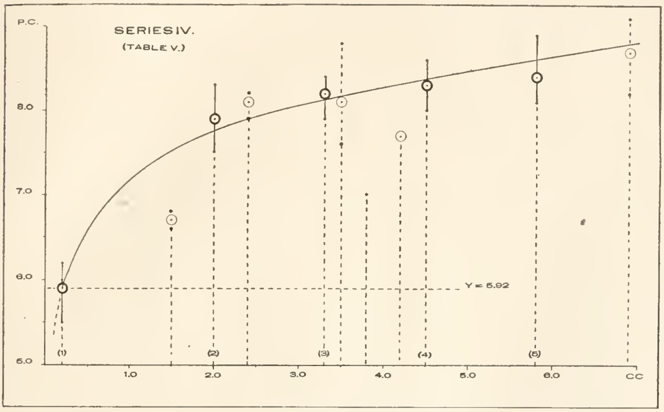

Fig. 4

Series V. In this series plants of Zea were employed, three plants in a culture, eight weeks old at the beginning of the work. The soil used was the natural clay loam above referred to, without admixture of sand. The water holding power of this soil was found to be 57.32 per cent., from which the calculated soil moisture residue at permanent wilting (from the formula of Briggs and Shantz) becomes 12.52 per cent. of the dry weight of the soil. The experiment was begun on August 21, 8 a.m. The first permanent wilting occurred in the open, in the chamber in the open and in the shelter, on the first day. On August 22, permanent wilting was attained in the chamber in the shelter, and on August 27, the same condition was reached in the glass box. The numerical results of this series are given in table VI, which is essentially uniform with the tables for the preceding series.

Series V furnishes another case where it is strictly true that the five main averages of soil moisture residue show an increase with increasing atmospheric evaporating power. It can be readily noted, however, that average (3) is relatively too low to be joined with the others on a consistent curve.

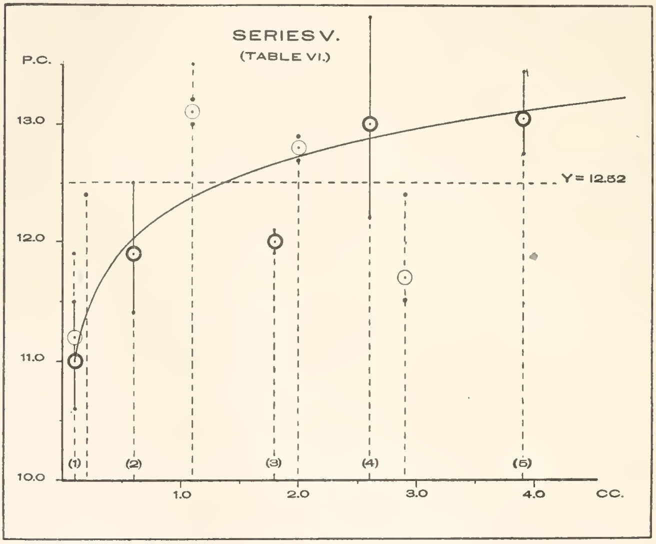

Fig. 5

The detailed relations between the different quantities involved in the results of this series are shown in the graph of figure 5, which is plotted uniformly with the preceding graphs.

The generalized curve of figure 5 was derived from the logarithmic equation heretofore employed, with the constant ratio

TABLE VI

(*Series V*)

Numerical data bearing on the permanent wilting of plants of Zea eight weeks old at beginning of experiment, each culture comprising three plants; in clay loam without admixture of sand (water holding power, 57.32 per cent.; calculated soil moisture residue at permanent wilting 12.52 per cent. of dry weight).*

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
0.1	11.87	0.95	Box	Aug. 27, 15	35	
	10.90	0.88	Box	Aug. 27, 17	33	99
	10.55	0.84	Box	Aug. 27, 17	33	99
	10.95	0.87	Box	Aug. 27, 17	33	99
	11.46	0.92	Box	Aug. 27, 17	33	99
	10.96	0.88	Box	Aug. 27, 17	33	99
	11.42	0.91	Box	Aug. 27, 17	33	99
	10.82	0.87	Box	Aug. 27, 17	33	99
	Av.10.99 (1)	Av. 0.88				
	11.14	0.98	Box	Aug. 27, 19	26	
	11.17	0.89	Box	Aug. 27, 19	26	
	Av.11.16	Av. 0.89				
0.2	12.39	0.99	Box	Aug. 27, 13	34	
0.6	11.56	0.92	Ch., sh.	Aug. 22, 17	30	39–42
	11.36	0.99	Ch., sh.	Aug. 22, 17	30	39–42
	11.74	0.94	Ch., sh.	Aug. 22, 17	30	39–42
	11.51	0.92	Ch., sh.	Aug. 22, 17	30	39–42
	12.46	1.00	Ch., sh.	Aug. 22, 17	30	39–42
	11.71	0.94	Ch., sh.	Aug. 22, 17	30	39–42
	Av.11.89 (2)	Av. 0.95				
1.1	13.18	1.05	Ch., sh.	Aug. 22, 15	31	
	13.21	1.06	Ch., sh.	Aug. 22, 15	31	
	13.02	1.04	Ch., sh.	Aug. 22, 15	31	
	Av.13.14	Av. 1.05				
	13.51	.	Ch., sh.	Aug. 22, 16	31	

TABLE VI—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
1.8	12.05	0.96	Shelter	Aug. 21, 15	32–36	36–40
	12.15	0.97	Shelter	Aug. 21, 15	32–36	36–40
	12.04	0.96	Shelter	Aug. 21, 15	32–36	36–40
	11.89	0.95	Shelter	Aug. 21, 15	32–36	36–40
	11.91	0.95	Shelter	Aug. 21, 15	32–36	36–40
	12.18	0.97	Shelter	Aug. 21, 15	32–36	36–40
	Av.12.03 (3)	Av. 0.96				
2.0	12.82	1.02	Shelter	Aug. 21, 17	35	
	12.87	1.03	Shelter	Aug. 21, 17	35	
	12.87	1.03	Shelter	Aug. 21, 17	35	
	12.72	1.02	Shelter	Aug. 21, 17	35	
	Av.12.82	Av. 1.03				
2.6	13.55	1.08	Ch., open	Aug. 21, 13	30–32	30–31
	12.73	1.02	Ch., open	Aug. 21, 13	30–32	30–31
	13.93	1.11	Ch., open	Aug. 21, 13	30–32	30–31
	13.50	1.08	Ch., open	Aug. 21, 13	30–32	30–31
	12.74	1.02	Ch., open	Aug. 21, 13	30–32	30–31
	12.55	1.00	Ch., open	Aug. 21, 13	30–32	30–31
	12.38	0.99	Ch., open	Aug. 21, 13	30–32	30–31
	12.22	0.98	Ch., open	Aug. 21, 13	30–32	30–31
	12.93	1.03	Ch., open	Aug. 21, 13	30–32	30–31
	Av.12.95 (4)	Av. 1.04				
2.8	14.55	1.16	Ch., open	Aug. 21, 15	34	
	13.92	1.11	Ch., open	Aug. 21, 15	34	
	14.50	1.16	Ch., open	Aug. 21, 15	34	
	Av.14.66	Av. 1.14				
2.9	12.43	0.99	Open	Aug. 21, 15	32	
	11.91	0.95	Open	Aug. 21, 15	32	
	11.95	0.96	Open	Aug. 21, 15	32	
	11.52	0.92	Open	Aug. 21, 15	32	
	Av.11.70	Av. 0.96				

TABLE VI—Continued

HOURLY RATE OF LOSS FROM STANDARD ATMOMETER DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	ACTUAL SOIL MOISTURE RESIDUE AT PERMANENT WILTING (AV., AVERAGE)	RATIO OF ACTUAL TO CALCULATED* MOISTURE RESIDUE	EXPOSURE OF CULTURES†	DAY AND HOUR OF PERMANENT WILTING‡	TEMPERATURE DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED	RELATIVE HUMIDITY DURING TWO-HOUR PERIOD IN WHICH PERMANENT WILTING OCCURRED
cc.	*per cent. of dry wt.*				*deg., C.*	*per cent.*
3.9	13.12	1.05	Open	Aug. 21, 13	29–31	28–30
	12.88	1.03	Open	Aug. 21, 13	29–31	28–30
	13.33	1.06	Open	Aug. 21, 13	29–31	28–30
	13.46	1.08	Open	Aug. 21, 13	29–31	28–30
	13.13	1.05	Open	Aug. 21, 13	29–31	28–30
	12.83	1.02	Open	Aug. 21, 13	29–31	28–30
	Av. 13.13 (5)	Av. 1.05				

* Calculations made by means of the Briggs and Shantz formula, from the water holding power of the soil used.

† The word *box* here denotes the glass box: *ch.*, *sh.*, denotes chamber in shelter; *ch.*, *open* denotes chamber in open.

‡ The hours of the day are simply numbered in a single series, from 1 to 24; thus the thirteenth hour is the first hour after midday, etc.

taken again as 2 and the constant difference as 0.40 per cent. This curve passes through averages (1) and (5) and passes very nearly through averages (2) and (4). As has been noted average (3) is unaccountably too low to find a place on any consistent curve that includes the other averages. This generalized curve is therefore to be considered as in very good agreement with the experimental evidence. It is convex upward and approaches a vertical line with low values of evaporation intensity, thus showing clearly (as do all the other curves previously discussed) that the only considerable region of its length where evaporation intensity may be without marked influence upon soil moisture residue, is in its upper portion, with high evaporation rates.

The value given to the calculated moisture residue by the formula of Briggs and Shantz is in this case seen to take an entirely different position on the graph from that taken in the series previously discussed; in this series alone, of the five here presented, do observed values of this residue fall *below* the calculated value, which they do in the case of the first three main averages. But, if the third average were on the generalized curve, it would depart but slightly from the value given by the formula of the Washington writers. This suggests that an evaporation intensity of 1.8 cc. per hour might be expected, with this soil, to give observed values about equal to the calculated one. In connection with the discussion of figure 4 it was pointed out that the observed soil moisture residue (average (1), series IV), occurring with the lowest evaporation intensity is but little greater than the calculated value; this being apparently related to the nature of the soil used. In the present series, which employed a soil with still greater water holding power than that possessed by the soil of series IV, this relation is still more pronounced; the observed values for the lower evaporation intensities here fall below the calculated value and those for the higher intensities of evaporation approach the calculated value. There can be no doubt that this feature is related to the nature of the soil employed.

GENERAL CONCLUSIONS

The experiments above presented lead first to the substantiation of the general principle, already established by Caldwell, that the amount of water left in any given soil at permanent wilting of plants rooted therein is a function of the intensity of atmospheric evaporating power for the period during which permanent wilting is attained. It thus appears, as Caldwell has also emphasized, that the assumption by Briggs and Shantz of universality in the application of their conclusions is not in accord with empirical fact. To the statement of the last named authors, that atmospheric conditions are practically without influence upon the soil moisture residue at permanent wilting, must be added a statement to the effect that the first proposition can, from its very physical nature, be supposed to express the truth only within some as yet unestablished range of atmospheric and plant conditions, and that it does not at all apply in cases where permanent wilting occurs under evaporation intensities ranging from 0.1 or 0.2 cc. to 3 or 4 cc. per hour, loss from the standard porous cup atmometer, with other conditions such as were provided in the present study, and with plants such as were here used.

The studies of Caldwell and of the present writers have thus established a range of atmospheric evaporation intensities within which this universal conclusion of Briggs and Shantz does not, at least generally, obtain; it remains to be determined under just what sort of conditions the moisture residue at permanent wilting, for any given soil, may be practically unaffected by variation of evaporation intensity within a considerable range. The descriptions of the exposures employed in their studies, as given by Briggs and Shantz, lead to the conviction that their evaporation intensities were almost certainly not below, 0.1 or 0.2 cc. per hour, loss from the standard atmometer, and it is highly improbable that their intensities were above 3 or 4 cc. per hour. The range of atmospheric evaporating power covered in the present studies thus appears probably to have included the corresponding range used by Briggs and Shantz.

From these considerations it is suggested that the special conditions above mentioned, in regard to which the Washington experiments must have differed from those reported by Caldwell and in the present paper, may have been within the plant body. Brown (*loc. cit.,* page 132) emphasizes the observation from his experiments, that the atmospheric condition under which a plant has grown may frequently determine its nature as a water absorbing, conducting and transpiring system, and this idea is generally held by students of field ecology. It is true that Caldwell found the conditions under which his plants were grown to have no appreciable effect upon their behavior in regard to permanent wilting, but this may mean merely that he did not happen to have the requisite differences in these conditions. It remains at least possible that the explanation of the diametric opposition involved between the conclusions derived from the Briggs and Shantz experiments and those indicated by the work of Caldwell and of ourselves, may lie in some internal difference between plants grown in summer at Tucson, and those grown in the Washington greenhouse. There appears no reason at all to doubt the experimental accuracy and reliability of the extensive study of Briggs and Shantz.

If the supposition of Caldwell be true, that there exists a range of evaporation intensities within which this factor does not effect the soil moisture residue here dealt with, this range must lie in the region of high intensities, not in that of low ones as supposed by Caldwell. But to lie within this range the intensities must be extraordinarily high for natural conditions; they must be as high as, or higher than, the intensities experienced in the open during the Tucson summer, perhaps above 3 or 4 cc. per hour from the standard atmometer.

Turning now to the details of the quantitative relation which is found to hold between soil moisture residue and atmospheric evaporating power, this relation appears, from the present experimentation, to be a consistent one within the limits employed in these studies. It is very satisfactorily expressed as a logarithmic function of the form $x = k^{\frac{y}{a}}$, where x denotes the evaporation intensity as measured by the porous cup atmometer and y denotes the soil moisture content at permanent wilting, measured in terms of the dry weight of the soil. If the constant ratio k of this series be taken as 2, then the constant difference (a) is shown by our experiments to lie within the range of values from 0.32 to 0.55. The five values of this difference, for the five different series above described are 0.50, 0.32, 0.50, 0.55 and 0.40, and the average of these is 0.45. The first three of these values were obtained from experiments with a soil mixture having a water holding power of 32.0 per cent., and with three different plants Zea, Phaseolus and Capsicum. The fourth value (0.55) resulted from tests with plants of Phaseolus in a soil having a water holding power of 38.2; the last value (0.40) was derived from plants of Zea in a soil with a water holding power of 57.3 per cent. From these statements it appears that the variations just given, in the value of the constant difference for the logarithmic functions here in question, are not to be related to the water holding power of the soil used. Neither do these variations appear to be related to the kind of plants nor to the size of the containers employed in the experiments. The constant difference values are so nearly in accord that it is possibly safe to conclude that, within the limits of all the conditions of our studies, the relation of soil moisture residue to evaporation intensity is approximately expressed, for the three plants here used and for a wide range of physically different soils, by the equation,

$$x = 2^{\frac{y}{0.45}}.$$

The quantitative relations holding between the magnitude given to the calculated soil moisture residue at permanent wilting, by the Briggs and Shantz formula, and the observed magnitudes as shown in these experiments, remains to be considered. Caldwell has shown that, for lighter soils (with low water holding powers), the observed values are always much larger than the calculated, this discrepancy being greater, of course, with high evaporation intensities than with lower ones. On the other hand, the same author has established the fact that, with heavier soils (of high water holding powers), the observed values approach much more closely the calculated ones, being about equal to them under conditions of low evaporation intensities. These observations of Caldwell are clearly substantiated by the work here reported, excepting that the present experiments furnish a number of cases where the observed values fall markedly *below* the calculated ones (series V). As might be expected from Caldwell's results in this connection, these cases occur with low evaporation intensities and with the soil of highest water holding power. It is unnecessary here to enquire further into this relation, since it is quite obvious that the formula of Briggs and Shantz cannot be considered as of general application, but only as expressing a relation obtaining under some as yet undetermined range of external and internal conditions, within the limits of which must have lain the experimental conditions employed by these workers.

SKETCHES OF THE COLORADO DESERT

S. B. PARISH

San Bernardino, Cal.

RED CANYON

Red Canyon is situated on the southwestern slope of the Chuckawalla Range, which divides the Colorado from the Mojave desert. It is about 5 miles from Mecca, and when a torrential thunderstorm bursts over the naked peaks, Red Canyon discharges a flood of water over the intervening slope of Salton Sink, which may even reach the Salton Sea. Its mouth is some quarter of a mile wide, and is filled with coarse sand, as is the whole bed of the canyon The entrance is indicated by a dull red band along the flank of the mountain, whose side appears absolutely destitute of all vegetation. But a closer inspection detects, scattered at wide intervals, small tufts, an inch or two high, of *Aristida bromoides,* a few specimens of *Chorizanthe rigida, Eriogonum inflatum, Lupinus arizonicus,* and even a stunted *Opuntia ramosissima.*

The canyon speedily narrows, its inclosing walls rising perpendicularly fully 100 feet to their pinnacled summits. They are colored in varied shades of chocolate, red, yellow, gray and brown. Side canyons, mere crevices, whose lofty walls may be touched at once on either side by the outstretched hands, wind far back into the heart of the mountains. The whole system appears rather the result of seismic disturbances than of erosion.

Unbroken silence reigned; no song of bird was heard, nor hum of insect; no lizzard basked in the sun, or darted over the rocks. A solitary flycatcher peered from its nest in a cranny of the wall, and mice had made a faint trail in the sand at its base; so meager were the indications of animal life.

Vegetable life, also, was scanty. The faces of the cliffs were bare of even a lichen, but in the crevices at their bases grew a few of the plants usually to be found in the canyons of these deserts, as *Nicotiana trigonophylla*, *Gilia latifolia*, *Oenothera cardiophylla*, *Mohavea viscida* and *Cladothrix oblongifolia*. Here, too, was *Aster Orcuttii*, a rare and beautiful species, bearing large lilac-colored flowers. It is endemic in the mountains of the Colorado desert, replacing the allied *Aster tortifolius* of the Mojave desert. On the talus, fallen from a cliff, was an abundance of slender *Hoffmanseggia microphylla*, and over a bush clambered the rare cucurbit, *Brandegea parviflora*. A commoner member of the same family, *Cucurbita palmata*, trailed its vines, well set with golden, globular fruits, over the sandy floor of the canyon.

In these sands grew a few large shrubs, *Hyptis Emoryi*, *Acacia Greggii*, *Chilopsis linearis* and *Parosela spinosa*, the last two some times almost small trees. The leafless branches of the *Parosela* were hidden (June 27) beneath the abundance of its beautiful blue-purple flowers, while the *Acacia* was laden with ripe and ripening pods.

In the shelter of these cliffs *Acacia Greggii* is a several-stemmed shrub, with virgate branches 6 to 8 feet long. Further west, between Whitewater and Banning, where it grows in the open, wind-swept desert, it forms patches hardly exceeding 1 foot in height, dense with short, rigid intertangled branches. In the same region *Lycium Andersonii* var. *Wrightii* takes a like condensed and depressed form, while in a neighboring canyon it has long, virgate stems. They exemplify the opposite effects of exposure and shelter in modifying the forms of plants. *Encelia farinosa* affords a further example of the same thing. In the desert this grows in very compact rounded clumps, each of a single individual, but in sheltered canyons near San Bernardino it is a gregarious shrub, straggling in habit, and 3 or 4 feet high.

My driver had promised to take me to the summit of the divide, where we were to find a spring of pure water, beneath a grove of noble palms. But when we had ascended the canyon some 4 miles we entered, through a passage scant 12 feet wide, a little amphitheater, whose upper end was barred by a ledge of granite, worn to the smoothness of glass by a trickle of water, which sank at once in the sand at its foot. Far up on the summit of the cliff a solitary *Fouquiera splendens* projected against the sky its tall and slender stem, bare of leaf or blossom.

Clambering with difficulty over the smooth, wet barrier, we came above it to a tiny pool, and in the wet sand of its margin saw the footprints of mountain sheep, which come here to drink. We followed up the canyon for some distance, but it seemed to go on indefinitely, unchanged in character, and offering no prospect of novelty. So, as it was now a matter of walking in place of riding, the purpose of reaching the summit was abandoned, and the slippery granite ledge was descended with more difficulty, but with greater rapidity, than had attended its ascent.

SUPERSTITION MOUNTAINS

All the maps of Salton Basin give a prominent place to the Superstition Mountains. They are about half way between the present shore of Salton Sea and Signal Mountain, just over the boundary in Mexico The vanished waters of ancient Lake Coahuilla, which filled the Salton Sink, once washed their southern base. The contour map gives 764 feet as the altitude of the highest point.

The very name, Superstition Mountains, is alluring to the immagination; so it was gratifying to me to have an opportunity of visiting them, especially as I flattered myself that I would be the first botanist to explore their mysteries, as I certainly am the first to make a record of his visit.

As one approaches, leaving roads behind, and driving through the monotonous succession of low gray atriplexes which are widely spaced over the desert plain, the mountains present a puzzling aspect. A long, broken ridge, its sharp summits appearing as if covered closely with some low, dark vegetation, it bore a certain resemblance to the dunes of the desert, which are often capped by the verdant, ultimate branchlets of the buried mesquite trees which they entomb. But these acclivities were too steep for sand, and their summits too dark for the green of the mesquite.

The mountains, when reached, were found to be of hardened clay, deeply cut by ravines into steep ridges and pinnacles.

Through the clay run strata, 1 to 6 inches in thickness, indurated to stone, and burned to blackness by the heat. It is the broken plates and shards of this claystone which, thickly coating the upper parts of the mountains, give them their peculiar capped appearance. Fragments, which the wind and sand have carved into grotesque shapes, lie in lines along the outcrop of these strata. Many of the slopes glitter in the sunlight with bits of plate gypsum thickly imbedded in the brown clay. No marvel that the Indian, beholding all these uncanny things, should regard these mountains as the abode of evil spirits.

The place was full of interest for the geologist or the mineralogist, but to a botanist it was a disappointment. Not a single plant, living or dead, was to be seen on any of the acclivities, but in the wide ravines between grew a few stunted shrubs of *Atriplex canescens,* and *Parosela Emoryi,* both common throughout the desert. More abundant, and of greater interest, was *Ephedra trifurca,* now for the first time found on this side of the Colorado River.

THE BOTTOM-LANDS OF THE COLORADO RIVER AT FORT YUMA

The east-bound traveler approaches the Colorado River at Fort Yuma over a planada of so slight an inclination as to appear level. Thinly scattered over its else bare surface are stunted larreas, and the tall rod-like stems of *Fouquiera splendens.* Along the infrequent drainage channels, shallow and waterless, grow a few dwarfed leguminous trees—*Olneya Tesota* and *Cercidium torreyanum.* In the distance are long, rolling dunes, and ridges of barren, sun-scorched mountains.

It is but a slight drop from this scene of desolation to the crowded jungle which borders the Colorado River for a width of 1 to 3 miles. These bottoms are the uppermost extremity of the great delta which the river has built, and is still building, by the deposit of the silt with which its waters are heavily laden. However familiar a botanist may be with other parts of California, he here finds himself in novel surroundings, for this delta constitutes a distinct phytogeographical area, in which occur plants not found elsewhere in the state.

A great part of the bottoms is overgrown with thickets of slender willows and cottonwoods, so densely that it is difficult to force one's way through them. Growing in this crowded way, the willows shoot up to a height of 15 to 25 feet, with a base diameter of no more than 2 to 10 inches. They are of two species, but, as they were seen only in leaf, their identity is somewhat uncertain. They should be studied at a more favorable season. The smaller is probably *Salix exigua* Nutt., a species occurring widely in the Colorado desert. The other, readily distinguished at sight when at the sapling state by its rough bark, and eventually becoming a large tree, may be *S. Gooddingii* Ball. If so, it is hardly distinct from *S. vallicola* Britton, which, in turn, might well be left as a variety of *S. nigra*, as it was considered by Dudley, who first proposed it. Old trees, growing in isolation, have entire resemblance to the *S. vallicola* of the river banks of southern California. Such a specimen may be seen growing on the banks of the Colorado between the railway bridge and the Fort.

The delta cottonwood, *Populus Macdougalii*, is abundant along the lower Colorado River and its diffluent streams. The trees in the bottoms near the Fort were apparently of no great age, and no examples were seen exceeding 14 inches in diameter, and an estimated height of 35 feet, but in the lower delta there are trees fully 2 feet in diameter. As it usually grows, in close array on rich alluvial soil, it is a slender tree. It is conspicuous by reason of its very light gray bark, which on the branches, the larger ones as well as the branchlets, has a shining whiteness. The leaves are small, twice as wide as high, truncate at the base, and short-pointed at the apex. The Alamo River derives its name from the abundance of this tree along its intake and upper courses, and by it, and by New River, the delta cottonwood enters Imperial Valley.

Other than these the arboreal flora of the bottoms is very limited. Near the Indian church there is a single fairly large *Cercidium torreyanum*, and a few juvenile specimens were seen elsewhere. There is an occasional mesquite, never of full size, and more screw-beans, which hardly exceed the rank of shrubs.

Large areas of the bottoms are given over to thickets of *Atri-*

plex. The prevalent species are *Atriplex lentiformis* and *A. polycarpa*, but there is considerable *A. canescens.* They grow as high as 8 or 10 feet, and their innumerable branches are interlocked and dense as a hedge, so that it is impossible to force one's way through them. They are much overrun by a variety of *Philabertia linearis,* an Asclepiadaceous vine, which grows here unusually stout and vigorous. In early November this was spreading over the shrubbery fleeces of glistening whiteness, shed by the bursting pods. The only other shrubs were *Pluchea sericea,* gregarious and abundant, and an occasional *Lycium Torreyi.*

On the Arizona side of the river a range of low hills, on which the town of Yuma is built, comes down to its very brink. Opposite, on the California side, rises an isolated bluff of quartzose rock, some two hundred feet high. The tawny river washes its base, and a few stunted larreas cling to its crumbling sides. Hither came, in 1780, Padre Garces, and on its summit founded his ill-fated mission of La Purissima Conception, the first lodgment of white men on the banks of the Colorado. Long afterward it became the site of Fort Yuma, and now is occupied as a government school for Indians.

It seems strange that the river should flow through the narrow chasm between these two bluffs, there being in rear of the Fort a mile or two of low alluvium, where it might easily cut a more commodious passage. In fact, it does overflow some part of these flats in time of high water, and through them there is a channel, which then carries a part of the floods.

In November some of the depressions of this old channel still retained large pools of water, which the settling of the silt had left clear. From the shallower hollows the water had evaporated, leaving beds of earth which were still moist. Around the ponds, and in the damp basins, grew many interesting plants, not found in California except in the delta. Among these may be enumerated *Leptochloa imbricata, Scirpus paludosus, Cyperus erythrorhizos, Rumex Berlandieri, Sesbania macrocarpa, Ammania Koehnei, Physalis lanceifolia, P. Wrightii, Lippia nodiflora, Eclipta alba,* and *Aster spinosus.* Plants of wider Californian distribution were *Phragmites communis, Sesuvium sessile, Euphorbia* *albomarginata, Sida hederacea* and *Datura meteloides.* There was, also, another and handsomer *Datura,* namely *D. discolor.* This has a white corolla, with a narrow tube, 4 inches long, marked within by five purple bands, and a funnelform limb 2 inches in diameter. In the Synoptical Flora Gray questions whether this plant is indigenous in the Fort Yuma region, and the conditions of its occurrence do not enable one to determine the question with confidence. But if it is not a native, its introduction must certainly date back to Indian days. A third species, *D. quercifolia,* is credited by the Flora to these bottoms, but I did not see it. A very showy purple-flowered Aster, *A. canescens* var. *tephrodes,* was common on dryer banks.

The following February the pools and moist basins were dry, and all these plants had disappeared, or were only recognizable in withered remains. In their places *Spheralcea Fendleri* was beginning to bloom, and a perennial *Potentilla* was nearly in bud.

Above the Fort the river was bordered by a wide bar of silt, evidently deposited by the floods of the previous spring. It was from 2 to 5 feet above the present low stage of the river, which was now undermining and caving away its margins. Back of this was a higher bar, probably as much as five years old, thickly set with willow and cottonwood saplings, beneath which grew a carpet of *Scirpus speciosus.* This sedge is abundant in the bottoms, and varies in its habit in accordance with its exposure to direct sunlight. In the shade of the thickets it throws up solitary, slender, and elongated culms, bearing few-rayed unbels; along the banks of the old channels, where the light is strong, it grows in clumps, with tall, stout culms, and large, many-rayed umbels; while the form growing in the intense sunlight of the bare sand bar, is similar to the last, except that the culms are short, and the umbels more condensed.

There were but few willow or cottonwood seedlings on the recent bar, probably because it had been formed subsequent to the season when these trees fill the air with their wind-borne seeds. But of herbs there was an abundance, and a remarkable variety. A considerable number of them had never been reported from California, and a consideration of the known distribution of these render it probable that the seeds of them must have been brought hither by the waters of the Gila or the Colorado Rivers. Of these *Leptochloa imbricata, Scirpus paludosus, Cyperus erythrorhizos, Scirpus speciosus, Rumex Berlandieri* and *Ammania Koehnei* probably came down these rivers originally, but at a period so remote as to have long ago established themselves throughout the delta. But the conditions indicate, I think, the direct and immediate conveyance, by the floods of one or the other of these rivers to this bar, of the seeds of certain other plants which were growing there. Of these I reckon *Leptochloa filiformis, Panicum hirticaule, Eriochloa aristata, Eragrostis hypnoides, E. mexicana, Fimbristylis Vahlii, Nasturtium curvisiliqua, Physalis pubescens* and, probably, *Orobanche californica.* Other plants, of wide Californian distribution, were *Typha latifolia, Petunia parviflora* and *Pluchea sericea,* an insignificant part of the total bar flora.

In February all these herbs had vanished, except *Rumex Berlandieri,* which was making a strong new growth, and the few shrubs were flourishing. The loose silt in which these were growing made it easy to examine their root systems. The young willows had no tap roots, but five to eight nearly equal descending rootlets, 8 to 10 inches long. *Pluchea* sent down a slender tap, 6 to 8 inches in length, from the lower part of which a few short fibers were given off, while just below the collar started a cord-like root, running 1 or 2 inches below the surface, and often more or less exposed by the blowing away of the sand, which attained a length of even 6 or 8 feet, and was almost wholly destitute of fibers.

These bottoms are the ancestral homes of the Yuma tribe of Indians, and a large part of it is now set apart as their reservation. Their houses, made of small tree trunks set perpendicularly in the ground, the interstices plastered with mud, are hidden here and there in the jungle.

When first seen by the Spaniards the Yumans were an agricultural people cultivating cotton, corn, beans, muskmelons, watermelons and squashes. Cotton is no longer seen in the little fields about their houses, but all the other crops are still grown by them. Their clearings afforded an interesting study in weeds. For the most part these were native plants, *Amaranthus Palmeri*, robust, and sometimes more than 6 feet high, *Aster spinosus*, a most obnoxious weed, and *Leptochloa imbricata*, the three in about this order of frequency. The weeds of cultivation which are most common in other parts of California were here conspicuous by their rarity, or oftener by their entire absence. There was much Bermuda grass, and some purslane, but the abundant cockleburs of southern California, *Xanthium canadense* and *X. spinosum*, were here replaced by two other species, *X. strumarium* and *X. commune*, both plentiful, and not known in the state except in the delta region. Perhaps other Californian weeds might be discovered by a more prolonged search, but they can hardly be abundant. The isolation of the region, separated by two hundred miles of desert, has so far protected it from the noxious immigrants that have so successfully established themselves in the state. It will be of interest to observe how long this immunity will continue under the changed conditions that must result from the irrigation, and consequent cultivation and settlement, of the great areas of hitherto desert lands which are now in process of reclamation.

BOOKS AND CURRENT LITERATURE

Buoyancy of Seeds.—R. Lloyd Praeger has published[1] an interesting paper in which are summarized his own and others' observations on the buoyancy of seeds of British plants. He has tested 786 species and adds the results for 114 others taken from the writings of other students, principally that of H. B. Guppy, so that data for 900 species of British plants is available.

The term seed is used in its original sense, *i.e.*, for the natural unit of dispersal. The results show that 85 % sink at once or within a week, 5 % float for from one to four weeks, 3.3 % float from one to six months, 1.9 % float from six to twelve months and 4.4 % float for over twelve months. The more buoyant forms are as a rule inhabitants of stream-banks and seashores: 25 are aquatics, 42 marsh plants, 5 bog plants, 17 maritime plants, while 7 owe their buoyancy to their fleshy fruits having been dried before testing. The remaining 33 species are mostly plants of a mesophile habitat. Considering them by families the author finds that in certain families, *e.g.*, Papaveraceae, Cruciferae, Caryophyllaceae, Geraniaceae, Leguminosae, Crassulaceae, Saxifragaceae, Primulaceae, Gentianaceae, Scrophulariaceae and Juncaceae true seeds are generally the units of dispersal and these practically all lack buoyancy. On the other hand the Ranunculaceae, Compositae, Orobanchaceae, Orchidaceae, Cyperaceae and Gramineae are mostly buoyant and in most cases their unit of dispersal is either a one-seeded indehiscent fruit containing or retaining air, or a seed with a loose test enclosing air. Other families such as the Rosaceae, Umbelliferae, Rubiaceae, Ericaceae Boraginaceae, Labiatae and Polygonaceae show a wide variability in respect to buoyancy.

The author's results confirm those of Guppy in showing that there is a marked relation between buoyancy and a seaside or riverside habitat. There is also shown to be considerable variability in the seeds of a single species. Seeds from fleshy fruits are found to be in general lacking in buoyancy and fruit-bearing branches whether fresh or dry add greatly to the power of dispersal by water as Darwin long ago pointed out.

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[1] Praeger, Scient. Proc. Royal Dublin Soc., vol. 14 (N. S.) No. 3, 1913.

This kind of an investigation is one that could be very profitably undertaken in this country, and the results of such a study for the strand flora of a region like southern Florida would prove of especial value.—Edward W. Berry.

The Red Pigment of Tomatoes.—Because of a confusion of terms applied to the coloring matter of tomatoes in previous studies by other workers the author employs the new name lycopersicin in this paper.[1] This study consists of some careful experiments on the effect of temperature upon the production of lycopersicin together with the relation of oxygen and other gases to the formation of this pigment. It was found that a yellow, orange or orange red color results instead of a red pigment when green fruits are ripened at a temperature of 30°C. or above. This inhibition of reddening between 30° and 37°C. is directly proportional to the temperature increase and inversely proportional to the age of the fruit used. When fruits were subjected to a high temperature for a time and were then returned to favorable conditions, pigmentation proceeded rapidly.

It is suggested that the suppression of lycopersicin development at high temperature may be related to decreased acidity or possibly to enzymic activity. Lycopersicin formation follows the destruction of the chlorophyll indicating that the processes of ripening in tomatoes are aerobic.

In the fruits exposed to atmospheres of oxygen, hydrogen, nitrogen, and carbon dioxide at laboratory temperatures no reddening occurred except in those fruits exposed to oxygen.—Frederick A. Wolf.

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[1] Duggar, B. M. Lycopersicin, the red pigment of the tomato and the effects of conditions upon its development. Washington Univ. Studies 1: No. 1. 22–45. 1913.

NOTES AND COMMENT

Dr. Frank E. Lutz, writing in The American Naturalist for February, has trenchantly criticised zoological experimenters for neglecting humidity as an environic factor of importance to animals, or for doing even worse in ascribing phenomena to temperature causes when humidity was neither controlled nor measured. A recent treatise on experimental entomology is cited in which much more space is devoted to a discussion of the literature of temperature effects than to that of all other factors together. Attention is called to the fact that animals suffer a water loss, which must be influenced by atmospheric humidity as surely as is the water loss of plants, and experiments are cited from the work of Tower to show that the influence of different humidities on the degree of melanism or albinism in beetles is as great as that of temperature and is similar to it when gradients of change are plotted.

It is very gratifying to have a man become vehement in his denunciation of methods or tendencies of which he disapproves, for he thereby testifies to the sincerity of his convictions and takes the surest mode of commanding attention. Dr. Lutz is very emphatic in his views regarding the use of empirical rather than experimental methods in seeking the causes of the distributional limitation of species. He says, "The study of distribution was long, and still is, largely an effort to get the ranges of animals and plants to fit isotherms. When yearly averages do not work, winter minima or summer maxima or accumulated temperatures are tried."

Dr. Lutz then cites the work of Transeau as being a successful attempt to avoid the adhesion to isotherms, saying ''Transeau has shown that if we plot the ratio of temperature to humidity we get a very close correspondence between distribution and climatic factors." Although the matter is not vital to the contentions of Dr. Lutz, it is necessary to state that the ratios plotted by Transeau were not those of temperature to humidity but those of rainfall to evaporation rate.

A recent bulletin of the Agricultural Department on American-grown paprika describes an investigation into the possibility of replacing the importation of this condiment by its production at home. The bulletin is a model of the thoroughness and practicality with which such matters are taken up by the Department, in their botanical, agricultural, commercial and legal aspects. The reader of the bulletin feels a growing pride in the efficiency of our governmental investigators and in the fitness of American soils and climate to produce one more article of import. On reaching the last paragraph of the publication, however, he learns that the entire annual importation of paprika might be grown on 500 acres. Are our farmers to be congratulated on the opening of this wide new avenue of plant production, or are they to be commiserated because the cost of the paprika experiments was not expended in a direction that would add 5 % to the present corn crop of the United States?

THERMOTROPISM IN ROOTS

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The effects produced by the application of heat to one side of a plant organ, which are termed thermotropic, have received but little attention in recent years, and the thermotropism of roots in particular has not been investigated in the last two decades. Steyer's paper on *Phycomyces nitens*[1] demonstrated the error of some current opinions concerning thermotropism, and indicated the necessity of further critical work in this field. It is moreover essential to check the results obtained by the physiologists of the 19th century, by the improved modern methods of work. The subject of this paper was suggested by Professor Jost and the experiments were carried out under his and Professor Kniep's direction at the Botanical Laboratory of the University of Strassburg in the winter semester 1912–1913. I take pleasure in thanking Professors Jost and Kniep here for their guidance and generous assistance in helping me with the experimental part of the work.

HISTORICAL

The physiological effects of temperature upon plants were recognized early by Sachs.[2] He found that heat had a marked and definite influence on the rate of growth, so that on this basis a minimum, optimum and maximum temperature could be determined empirically for each individual species. By measuring temperatures on the abscissae and the rate of growth on the ordinates, this influence may be graphically represented. The resulting curve outlines a bell, and resembles the probability curve.

Sachs[3] endeavored to explain hydrotropic bending of roots by the difference of temperature, that necessarily must exist between the opposite sides of a root,

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[1] Steyer, K., Reizkrümmungen bei *Phycomyces nitens*. Pp. 10–14, 20–21, Leipzig, 1901.

[2] Sachs, J., Jahrb. wiss. Bot. **2**: 338, 1860.

[3] Sachs, J., Ablenkung der Wurzeln von ihrer normalen Wachstumsrichtung durch feuchte Körper. Arb. d. bot. Inst. Würzburg, 1872.

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subjected to a one-sided stimulus of moisture, because of the greater evaporation from the drier side. In order to test this hypothesis, he placed rootlets of *Pisum, Sativum* and *Vicia Faba* so that they received radiated heat from one side. His failure to obtain any reaction sufficed to disprove his theory, as the difference of temperature obtained was very small, corresponding to any difference that could be produced by evaporation in the cases in question. It did not however suffice to disprove the existence of thermotropism in roots.

In the Traité de Botanique,[4] a French translation of Sachs' textbook of Botany with numerous annotations, Van Tieghem introduced several passages relating to this subject. He in fact originated the term "thermotropism," which in the sense made use of by him, signifies the ability of any organ to bend in reaction to a one-sided heat-stimulus. He makes the following deductions, which sound hypothetical, although he says in the second edition of his work[5] that they were substantiated by experimental results. "If the source of radiation is placed laterally, so that the plant receives more heat from one side than from the other, its growth will be unsymmetrical and consequently it will bend toward the source of heat or away from it, according to the temperature. If the plant receives the radiation on one side at its optimum intensity and on the opposite side at a point significantly higher or lower, it will become convex on the optimum side where it grows more, concave on the other side where it grows less, and it bends away from the optimum. If the two different temperatures are both above or both below the optimum, the organ curves itself in the first case toward the higher; in the second case toward the lower; always toward the one furthest removed from the optimum. It makes no difference if one temperature is above the optimum and the other below, unless they are just so, that the respective rates of growth have the same value, in which case the organ does not bend at all." He says further that secondary roots and roots of a higher order are especially sensitive to a one-sided heat-stimulus, because they are free from the hampering effects of geotropism.

In 1883 experiments were made by J. Wortmann[6] which did not allow of Van Tieghem's interpretation, but which led him to the conclusion that in thermotropism he was dealing with vital phenomena. As such they must be ranked along with those of geotropism and heliotropism as "a peculiarity of the plant organism based on the structure of irritable protoplasm to react to a one-sided disturbance through known factors or agents by means of bendings produced by growth, which bring the irritated plant part to a position of equilibrium, having a definite relation to the direction of the acting agent." Since these experiments of Wortmann are important as having established this conception of thermotropism in the literature of physiology, and as constituting the main bulk of work on this subject, it will be advisable to discuss them here at some detail.

The first experiments were made with the sporangiophores of *Phycomyces nitens* and with seedlings of *Lepidium sativum* and *Zea Mays*. They were carried out in a

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[4] Van Tieghem, P., Traité de Botanique par Julius Sachs, conformé à l'ètat présent de la science. Traduit de l'Allemand de la 3ième édition et annoté. P. 116, pp. 301–302. Paris, 1874.

[5] VanTieghem, P., Second edition of the same, p. 245. Paris, 1884.

[6] Wortmann, J., Über den Einfluss der strahlender Wärme auf wachsende Pflanzenteile. Bot. Zeit. **41**: 457–470, 473–480, 1883.

spacious room with three large windows on one side. The room temperature remained fairly constant at 12° C. A plate of sheet iron, 65 cm. square was used as the source from which the heat radiated. It was fixed in an upright position on a long table, which ran parallel with the windows. The plate was heated from behind by four movable gas burners; in front it was besmeared with soot. The objects experimented on were rotated on a clinostat in front of the iron plate, with the axis of the clinostat perpendicular to it. In this position the light from the three windows fell upon one side of the material under experimentation. In order to eliminate resulting heliotropic reactions, a mirror was placed on the other side of the apparatus reflecting the light from the windows opposite. This made the light received from the two sides approximately equivalent.

The spores of *Phycomyces nitens* were sown on four sides of a cubical piece of bread which was fitted with a cardboard box, provided with holes. This arrangement restricted the number of sporangiophores, as only a suitable number could grow through the holes, and also prevented too rapid evaporation, while being heated. Nevertheless the cardboard frame was sprayed with water every half hour. The cube of bread was inserted on the axis of the clinostat and rotated before the iron plate. The sporangiophores were shown by the experiments to be negatively thermotropic; that is, they bent away from the source of heat. They were subjected to various temperatures in the neighborhood of 25°C. If they were moved so far from the plate that the temperatures sank below 20°C., they failed to react.

Experiments with seedlings of *Lepidium sativum* showed them likewise negatively thermotropic as the first leaf of the epicotyl invariably bent away from the plate. The time elapsing before the commencement of the reaction was found inversely proportional to the intensity of the heat radiations falling on the plant. These experiments also contradicted Van Tieghem's hypothesis, for above the optimum temperature, which is 27°C. (De Vries) for *Lepidium sativum,* the bending was invariably and decisively negative.

The seedlings of *Zea Mays* prove positively thermotropic and although they did not react with the same sharpness and precision as did the *Lepidium* seedlings, yet their behavior was nevertheless consistent and instructive. The optimum temperature for *Zea Mays* shoots lies at 33.7°C., consequently if the seedlings were heated to a lower temperature, they should according to Van Tieghem bend away from the source of heat. In every such case however, they reacted positively. Wortmann concluded that these reactions can have no more relation to the *difference* of temperature on the two sides of the plant organ, than heliotropic reactions have with a corresponding difference of light intensity.

In 1884, Barthelemy[7] published a short article "De l'action de la chaleur sur les phenomènes de vegetation." He recognized three determining influences which regulate the direction assumed by adventive roots; the difference of temperature, the humidity and the nutritive value of the soil. In order to eliminate the last two of these, he selected bulbs, with roots growing in water. He placed a number of vases with the bulbs in a circle around an oven. The roots all grew toward the oven, while the leaves faced the window. Again he divided a glas jars into two compartments; in the one hyacinth bulbs floated in water of room temper-

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[7] Barthelemy, A., De l'action de la chaleur sur les phenomènes de vegetation. Compt. Rend. **98**: 1006–1007, 1884.

ature, in the other hot water was poured and frequently renewed. The roots grew toward the partition separating the two compartments. When the water was stained with turnsole-blue or soot, this reaction was not so pronounced, due as Barthelemy thought to the increased conductivity of the water. He emphasized that these are to be considered phenomena of growth and have nothing to do with a motive faculty. The experiments are interesting as being the first recorded examples of thermotropism in roots.

In 1885 Wortmann[8] extended his researches in thermotropism to roots. The apparatus used will be described more in detail later. It suffices to state here that the rootlets were placed in moist sawdust in a zinc box heated on one side by six gas flames, and cooled on the other side by running water. The temperatures were measured by three thermometers placed in the sawdust. The two end ones although only 5.5 cm. apart could measure as great a difference as between 50° and 8° C. Seedlings of *Ervum Lens, Pisum sativum, Zea Mays* and *Phaseolus multiflorus* were used for experimentation. The seeds were soaked for twenty-four hours in water, and then planted in moist sawdust with the radicles pointing down. When they had grown so that the roots were from 0.5 to 3 cm. long, seedlings of equal length were selected and carefully placed in the sawdust of the zinc box, care being taken to have them exactly vertical. The cotyledons were all pointed in the same direction with their planes of symmetry parallel. The seeds were aligned with the thermometers, so that the temperature at which reactions occurred could be determined as exactly as possible. After each experiment the sawdust was removed from the apparatus and was replaced by some freshly moistened. In order to determine if the roots had reacted, they were removed from the sawdust by forceps. As roots that had already bent could not be returned to the sawdust without injury, they were discarded, and only such as remained straight were replaced. Some of the roots nutated even in the sawdust. Consequently a careful distinction had to be made between the roots which bent diagonally or to one side and those that bent directly to or from the source of heat. Experiments with *Ervum Lens* led Wortmann to the following conclusions:

1. Roots of lentile seedlings react to one-sided warming by thermotropic bending.
2. The bending is positive at lower and negative at higher temperatures, in contradiction to Van Tieghem.
3. Thermotropism has consequently nothing to do with the growth curve formulated by Sachs.
4. Thermotropic reactions result more quickly at higher temperatures (above 40°C.) requiring an hour to an hour and a quarter, than at lower temperatures (in the neighborhood of 12°C.) when they take from $3\frac{1}{4}$ to $5\frac{1}{2}$ hours.

After repeated experiments at various temperatures he found a "critical" temperature where positive thermotropism ceases and negative begins. For *Ervum Lens* this lies at 27.5°C.; for *Pisum sativum* at 32° to 33°C., and for *Zea Mays* at 37° to 38°C. This critical temperature has no connection with the optimum temperature.

Experiments with *Pisum sativum, Zea Mays*, and *Phaseolus multiflorus* led to much

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[8] Wortman, J., Über den Thermotropismus der Wurzeln. Bot. Zeit. **48**: 193–200, 209–216, 225–235, 1885.

the same results as did those in the *Ervum Lens*. Wortmann therefore extended to roots generally the principle applied to sprouts, that the time required for the reaction to appear is inversely proportional to the intensity of the stimulus. *Zea Mays* gave positive reactions with great facility and definition; the negative reactions, however, were less distinct. *Phaseolus* showed no positive thermotropism whatever.

Wortmann experimented also with decapitated roots, to determine if the root-tip alone were capable of receiving and transmitting thermotropic stimuli. The four species already mentioned were again used, and in every case they gave negative thermotropic reactions. The results were seriously interfered with by nutation, especially at lower temperatures, when thermotropic bending was practically absent.

Thermotropic experiments were made with secondary roots of *Phaseolus multiflorus* in an apparatus similar in all essential respects to the one used before, except that it was smaller. After three or four hours negative bending was observed in roots at a temperature of 38° to 40°C. After five hours more, positive bending was seen in the roots at a temperature of 10°C. Only such roots came under consideration that grew parallel to the sides of the apparatus and thus received the heat stimulus on but one side. The reactions were not as vigorous as those observed in roots of the first order. Wortmann criticises Barthelemy's experiments as unscientific in method and valueless because of the want of particulars.

In 1888, Voechting[9] published an article concerning the thermotropism of magnolia flower-buds, interesting because it substantiates Van Tieghem's theory. He observed that buds of *Magnolia Yulan* and *Magnolia conspicua Soulangeana* often bent to the north away from the rays of the slanting spring sun. That bending also occurred when the buds were covered with a black paper cap or with a glass bulb painted with a solution of iodine in carbon bisulphide, showed that it was caused by heat and not by light. A considerable difference of temperature existed between the sunny and shady sides of the buds. Thermometers pressed against the outside registered a difference of from 2° to 45°C. Inserted between calyx and carolla, they showed a difference of 2.8° to 3.9°C., and between the inner and outer whorls of petals, 1° to 2.2°C. If the nights were cold, the buds bent better, because growth took place only during the day, when the thermotropic difference had effect. Voechting endeavored to reconcile the conflicting evidence of Van Tieghem and Wortmann by distinguishing between radiated and conducted heat. He suggested that their effects might be different and might counterbalance each other. No decisive conclusions, therefore, should be drawn from Wortmann's results as in his experiments on roots both kinds were present.

Two years later appeared another article by Voechting[10] dealing with the effects of heat on the movements of *Anemone stellata* peduncles. Three distinct phenomena were observed: the straightening of the flower stalk in the morning and the resumption of the sleeping attitude in the evening; the opening and closing of the flower; and the following of the sun's course. Of these movements, all of which were found

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[9] Voechting, H., Über den Einfluss der strahlender Wärme auf die Blütenentfaltung der *Magnolia*. Ber. d. Deut. Bot. Ges. **6**: 167–178, 1888.

[10] Voechting, H., Über den Einfluss der Wärme auf die Blütenbewegung der *Anemone stellata*. Jahrb. wiss. Bot. **21**: 284–292, 1890.

to be produced by growth, only the last concerns us. By protecting the blossoms from the light but allowing the heat rays to have effect, the following of the sun's course, which continued in darkness, was shown to be of thermotropic nature.

The work of John af Klercker[11] which appeared the following year, was more important. He considered that Van Tieghem's conclusions, which he characterizes as a "theory deduced from purely theoretical considerations," were decisively refuted by Wortmann's results. Special stress was laid on the discovery that the critical temperature was invariably found to be above the optimum. He distinguished between the experiments with *Phycomyces nitens*, *Lepidium sativum* and *Zea Mays*, and those with roots. The first were compared with results obtained by ultra-red rays, and as such was considered as an extreme case of heliotropism. He pointed out that but two factors could be responsible for the bending: first, an immediate stimulus from the heat waves; and second, a temperature difference at the opposite sides of the plant organ. He agreed with Wortmann in attributing the bending to the first of these, but laid little value on his results. The measurement of the temperature with ordinary thermometers suspended in the air was criticized, as the rapidity of evaporation, which must vary with the temperature, was left out of consideration. Klercker pointed out that the experiments with roots were carried out in a heterogeneous mixture of sawdust, air and water, present as vapour in the air and as films of liquid about the grains of sawdust. This rendered possible the joint action of several factors. The following were tabulated as having possible influence: (1) conducted heat; (2) radiated heat from the sawdust particles; (3) direct stimulus from air currents; (4) hydrotropism; and (5) geotropism. He suggested that the term "caloritropism' be used when the heat was conducted, and that thermotropism be reserved for radiated heat.

Klercker made use of two forms of apparatus. The one was modified from Wortmann's, the heat being derived from circulating hot water in place of the flames. He also constructed an apparatus of his own. This consisted of three zinc tanks, one within the other. Between the first and the second cold water circulated; between the second and the third was placed the sawdust for the roots, and in the innermost hot water was kept at a constant temperature through connection with the heating apparatus. that kept the hot water circulating. The sawdust was covered with cardboard, provided with rows of holes for the thermometers. By these, the temperature was shown not to vary more than three degrees in seven hours. The roots to be examined were removed with pincers and the angle of inclination was measured against a glass plate.

Pisum sativum, *Vicia Faba*, *Helianthus annuus* and *Sinapis alba* were the species experimented with. The results were graphically represented, by measuring the temperature on the ordinates and the angle of inclination from the vertical on the abscissae. Roots of the first three species showed only a negative thermotropism, the angle increasing as a rule with the temperature. *Sinapis alba* reacted positively. The reaction was especially vigorous between 19° and 24°C., and became weaker above and below this temperature. The critical temperature for *Pisum* was not determined, but from the results obtained it would be placed at a much lower temperature than Wortmann found for it. From the four widely different curves obtained,

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[11] Klercker, J. af, Über calotropische Erscheinungen bei einigen Keimwurzeln. Öfvers. Vetensk. Akad. Förhandl. **48**: 778, 1891.

he concluded that caloritropic phenomena are of complicated nature and are produced by at least two factors working antagonistically to one another. With the help of mathematics, including a careful employment of integral and differential calculus, he demonstrated that according to Van Tieghem's theory roots would react more vigorously between the optimum and minimum temperatures than between maximum and optimum. The exact opposite is indicated by the graphs.

Geotropism was shown to be an active factor opposing the action of caloritropism. Their interaction accounts for the zig-zag shape, which he observed in numerous roots, and which is due to the alternate action of these influences. His experiments did not enable him to decide if hydrotropism or the action of air-currents affected the caloritropic reactions, but he hoped to make special experiments to throw light on this question.

In 1901 Steyer[12] published a thesis dealing with the physiological aspects of *Phycomyces nitens*. A critical study of its thermotropic relations was made and Wortmann's experiments were repeated. He did not consider that Wortmann's apparatus insured a constant temperature evenly distributed over the surface of the plate used as a source of heat. Consequently he constructed the following apparatus. A zinc tank was made 20 cm. high, 20 cm. long and 7 cm. wide. Through this hot water was allowed to circulate, which was heated in a closed vessel connected with the tank by means of two tubes. This kept the water in motion and insured a constant temperature. The two ends and one side of the tank were packed in felt. Against the other side, which was smeared with soot, a glass cylinder 20 cm. long and 12 cm. in diameter was shoved, and the connection made tight with a felt ring. The other end was left open to secure a difference of temperature. As the possibility of hydrotropic influence must be eliminated, the atmosphere was kept as nearly saturated with moisture as possible. This was done by lining the cylinder with wet filter paper and placing a glass plate 2 cm. from the open end. This plate was also covered with filter paper and water flowed over it continually. The spores were sown on cubes of bread. When the sporangiophores had developed, the cubes were placed on mica plates and these put in the cylinder just before the sooted zinc surface. Experiments lasted eight hours and were carried out in a dark room. Steyer worked with temperatures varying from 13° to 33°C., but in no case was he able to obtain thermotropic reactions. Although he tried sporangiophores of several ages the results were the same.

He therefore concluded that Wortmann's results were due to hydrotropism against which he took no precautions, aided by positive heliotropism. Cultures placed before the heated zinc wall without the cylinder bend slightly away, showing that they were negatively hydrotropic. This reaction was not strong enough, however, to correspond to the results obtained by Wortmann. A consideration of the apparatus used by him showed that the iron plate which acted as the source of radiation, in all probability shut off considerable light, an error simply doubled by the mirror. As the sporangiophores are positively heliotropic, as was shown by other experiments, they naturally bend away from the plate, and more strongly the nearer they were to it. This experiment explained why Wortmann thought the intensity of the reaction increased with the temperature.

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[12] Steyer, K., *loc. cit.*

Although not included in his subject, Steyer repeated Wortmann's experiments with *Lepidium sativum* and *Zea Mays*, making use of his improved apparatus. The first leaf of the epicotyl was found to be really thermotropic in conformity with the results obtained by Wortmann.

More recently there has appeared an article by Pohl[13] discussing the thermotropism of flax. This shows strong resemblances to *Anemone stellata*, since it is positively thermotropic when acted on at ordinary temperatures, as by the sun's rays for instance. At excessively high temperatures it reacts by negative thermotropism.

In a series of articles called "Vergleichende Untersuchungen über die Tropismen," Porodko[14] discusses among others negative thermotropism. He worked in the temperatures ranging chiefly between 40° and 70°C. but ranging as high as 250°C. There could be no question of the confusion here of traumatropism or wound stimulus for thermotropism, as Porodko himself admits in the fifth paper of the series, which appeared only last June (1913). These results therefore need hardly concern us in this discussion.

EXPERIMENTATION

Method. For the experiments with thermotropism, the apparatus described by Wortmann was used. This was a zinc tank 20 cm. long and 14 cm. square on the end. A soldered zinc partition divided this lengthwise into two unequal compartments, the one 8 and the other 6 cm. wide. In the outer wall of the former, a short brass tube was soldered in the middle near the bottom, which was to serve as an inlet. On either end of this wall near the top, two more tubes were inserted to serve as outlets. These were connected by rubber tubes to the water supply, so that tapwater circulated continually through this compartment. The temperature was practically constant at 12°C., thus effectually cooling off the partition dividing the tank. The other compartment was filled with moist loose sawdust, like that in which the seeds were germinated. Its outer wall was besmeared on the outside with soot, and heated by a specially arranged fixture. This consisted of a T-shaped brass tube, the cross of which was 22 cm. long and closed at both ends. This was punctured by six holes,

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[13] Pohl, J., Der Thermotropismus der Leinpflanze. Beih. Bot. Cen. **24**^{1}: 111–131, 1909.

[14] Porodko, Th. M., Thermotropismus der Pflanzenwurzeln. Ber. d. Deut. Bot. Ges. **30**: 305–313, 1912; Das Wesen der traumatropen Erregung bei den Pflanzenwurzeln. Ber. d. Deut. Bot. Ges. **30**: 630-641, 1912. Das mikroscopische Ansehen der tropistisch gereizten Pflanzenwurzeln. Ber. d. Deut. Ges. **31**: 248–256, 1913.

spaced at intervals of 3 cm. The stem of the T was connected by a lead tube to the gas fixture, which permitted necessary manipulation and free movement. The six jets of flame of equal size issuing from the six equidistant punctures in the head of the T were arranged parallel to the sooted wall near the bottom. By varying the distance from the wall, the temperature could be regulated. In this way the outer wall of the sawdust compartment was heated uniformly, or very nearly so, throughout its length. The completed apparatus thus produced a constant and permanent difference of temperature in the sawdust. To measure the temperature, Wortmann used three thermometers, one near the cold partition, one in the middle and the third near the heated side. These were shoved into the sawdust an equal distance from the two ends of the tank. The thermometer by the outer wall was for convenience designated as T', that one in the middle as T'' and the third one near the cold partition as T'''. In the present experiments the same arrangement was followed except that the middle thermometer T'' was omitted. A zinc cover was cut to cover the sawdust and provided with two holes for the other thermometers.

The details of the method were in all essential respects identical with those mentioned by Wortmann. It may be specially emphasized, however, that the roots were always so placed that the thermotropic difference acted on their flanks. As all the roots in a given experiment were placed in the same relative position, this saved the trouble of marking the roots to know which side had been exposed to the heat, as was occasionally necessary. Special care was also taken to avoid geotropic reactions, which might injure the results in case of carelessness in transferring the seeds from one place to another. The roots were found to react best in rather moist sawdust.

Ervum, *Pisum*, *Phaseolus*, and *Zea* were selected for the experiments with agar-agar, because Wortmann had used these, and had based all his conclusions regarding themotropism on their behavior. *Lupinus* was also used.

Experiments. The experiments which Wortmann made with roots (*loc. cit.*) were repeated with *Ervum Lens* and *Lupinus albus.*

At higher temperatures, in these cases from 38° to 46°C., the roots reacted with negative thermotropism, at lower temperatures, from 12° to 15°C., with positive thermotropism. The negative bending occurred regularly and with precision; the positive was much more variable, and did not result in every case. No attempt was made to determine the critical temperature. The following experiments illustrate.

Experiments With *Ervum Lens*. First Series

First Experiment. Seeds of *Ervum Lens* were sprouted in moist sawdust. After forty-eight hours, those were selected with radicles 2 cm. long. Eight seedlings were aligned with T' and eight more with T'''. Forty-five minutes after the lighting of the gas, T' registered 43°C. and T''' 13°C. In three-quarters of an hour more, six of the roots by T' had bent negatively. After three hours and a half more, the other two by T' had bent, and three of those at T''' were bent positively. All the bent roots pointed away from the wall toward the middle.

Second Experiment. In the second experiment also with *Ervum Lens*, the radicles were but 1 cm. long. Six seedlings were aligned with T' and T''' respectively. Three-quarters of an hour after lighting T' registered 41° and T''' 12°C. After three-quarters of an hour more, five roots by T' were negatively bent. At the end of four hours more, two roots by T''' were positively bent; of those at T' all of which were now bent, four were especially strongly curved. At the end of the experiment T' was at 44°C. and T''' at 14°C.

In these experiments the sawdust was observed to become very dry along the heated side because of the rapid evaporation. For this reason, in all subsequent experiments a cover was used, a device suggested by Klercker's apparatus. This simple change noticeably increased the time required for the reaction, as will be observed in the following experiments.

Second Series.

First Experiment. *Ervum Lens* seedlings were used with radicles approximately 2 cm. long. Eight were placed on either side. Forty minutes after lighting T' was at 45° and T''' at 12°C. After two hours and twenty minutes, three roots at T' were negatively bent. After six hours more, two roots by T''' were bent positively No change occurred in those left at T'. At the end of the experiment T' was at 46° C. and T''' at 15°C.

Second Experiment. In the next experiment the radicles were but 1.5 cm. long, otherwise as in the last one. Three-quarters of an hour after lighting T' was at 38° and T''' at 11°C. After three hours five roots by T' were negatively bent.

After three more, one at T''' had reacted positively and one more at T' negatively. At this time T' was at 36°C. and T''' at 15°.

Third Experiment. Conditions identical with the last experiment. After forty minutes T' is at 42°C. and T''' at 11°C. After four hours more, six roots at T' had bent negatively. After four more, one root at T''' had reacted. T' was now at 46° and T''' at 13°C.

Fourth Experiment. In this experiment the radicles were as before 1.5 cm long and eight seedlings were placed on a side. T' was at 45°C. and T''' at 12°C. in forty minutes. After two hours, five roots at T' were negatively bent. In six more no change occurred and T' was at 46° and T''' at 13°C.

Fifth Experiment. This time four roots of *Ervum Lens* were placed on either side. The radicles were 2 cm. long. In forty minutes T' reached 40°C. and T''' 12°. After an hour three of those at T' were negatively bent. No more change in five hours. T''' registered 14°C. and T' 42°C.

Sixth Experiment: Again eight roots were placed along either side wall and as before the radicles were 2 cm. long. T' reached 38° and T''' was 13° in forty-five minutes. After two hours five roots at T' had reacted negatively. In another hour two more at T' were bent. After four more hours, one root at T''' was positively bent. T' was now at 37° and T''' at 14°C.

Seventh Experiment. In the last of these experiments the radicles were 1.5 cm. long. At the end of an hour T' was at 48° and T''' at 14°. One root at T' was already bent. As the light was extinguished no further reaction took place.

The use of the cover increased the length of time required for the reactions at higher temperatures from an hour or an hour and a half, to three hours. Those roots placed along the cool partition in some cases failed to react at all, and in the other cases only very slowly.

An attempt was made to see if the roots would react to a thermotropic stimulus if suspended in saturated air. For this purpose the sawdust was removed from its compactment, and warm water poured in the bottom. The roots were fastened to the cover, and hung down vertically above the surface of the water. No reaction was obtained. If the compartment were filled with water, and the roots immersed in it, in the same way, they grew in every conceivable direction without any bearing to the temperature differences. This, moreover, was found to be temporary, because of currents which soon rendered the temperature of the water equivalent throughout. To avoid these currents, the water was mixed with sawdust, almost to the point of its becoming solid. T' registered 40°C. and T''', 15°C. No bending was obtained. This experiment was repeated as follows: The just fluid mixture of sawdust and water was boiled until all the air was driven out, and the roots were immersed in this, and again no reaction was obtained. Later experiments showed that roots grow very poorly and sometimes not at all in such a mixture because of the absence of oxygen.

The right half of the shallow glass jar was filled with moist sawdust, such as was customarily used to sprout the seeds. The other half was filled in the same way with very dry sawdust. Seedlings of *Lupinus albus* were planted in the plane between these two vertical layers. After six hours, three of the ten seedlings so planted had wilted, two were straight and in good condition, while the other five had bent into the moist sawdust. The experiment was repeated with even better results, as this time eight of the ten grew sideways into the moist sawdust.

For the remaining experiments small zinc cases were used, 17 cm. long, 2 wide and 6 high. One side was cut out, and a piece of glass substituted. To render the tank waterproof, plastolinum was pressed into the cracks between the glass and the zinc. A 1.25 % solution of agar-agar in water was tried and found very satisfactory as a medium for roots to grow in because it is soft enough to allow the roots to bend in it and yet firm enough to preserve a solid consistency. The rate of growth in this medium averaged 2 mm. for every three hours. The mixture was poured into the zinc tanks while still hot. When it had become solid on cooling, holes were made with a glass needle, and the rootlets to be experimented on were carefully inserted in them. This was usually done under water, to avoid the entrance of air with the roots. The sawdust in the large tank was then cleared away from the outer side that was to be heated, and the can with agar-agar put in its place, with the glass wall facing inward. It was covered in and packed down on all sides with the moist sawdust. In this way the roots were placed in the same position that they had in Wortmann's thermotropic experiments, aligned a few millimeters from the wall, with T', which was now inserted in the agar-agar. The sole difference rested in that the roots were now surrounded with agar-agar instead of the moist sawdust. Observations of the progress of the experiments were easily made by removing the can, as the roots were visible through the agar and the glass wall. The solution proved to transmit the heat as readily as the sawdust mixture. Two thermometers placed side by side about one centimeter apart showed a difference of three to five degrees. The roots were marked with ink, and the distance from the mark to the tip measured before and after the experiment.

Experiments With Agar—*Ervum Lens* Used

Experiment I.

NUMBER	LENGTH OF ROOT	SAME AFTER 8 HOURS	AMOUNT OF GROWTH
	mm.	*mm.*	*mm.*
I	19	27	8
II	20	23	3
III	19	24	5
IV	20	25	5
V	17	22	5
VI	16	21	5
VII	19	26	7
VIII	24	29	5
IX	22	27	5
X	19	24	5

T′ measured 38°C. throughout the experiment and *T′* ″ 13°C. All the roots remained straight except number IV which was slightly bent to one side. Average growth per hour 0.66 mm.

Experiment II.

Using 12 roots of *Ervum Lens*

NUMBER	ORIGINAL LENGTH	LENGTH AFTER 7 HOURS	AMOUNT OF GROWTH
	mm.	*mm.*	*mm.*
I	25	29	4
II	20	24	4
III	22	26	4
IV	19	22	3
V	20	23	3
VI	20	24	4
VII	17	21	4
VIII	22	25	3
IX	26	29	3
X	17	21	4
XI	18	21	3
XII	26	28	2

T″ registered 30° and*T‴* 13°C. Numbers II and VII were bent diagonally in opposite directions. All the others grew perfectly straight. Average growth per hour 0.5 mm.

Experiment III.

Ten roots of *Ervum Lens,* as before

NUMBER	ORIGINAL LENGTH	AFTER $8\frac{1}{2}$ HOURS	NEXT MORNING—16 HOURS MORE
	mm.	*mm.*	*mm.*
I	20	24	26
II	25	28	29
III	21	23	25
IV	25	29	31
V	24	28	30
VI	27	30	31
VII	29	32	33
VIII	27		
IX	17	21	24
X	21	24	26

T' registered 34°C. and T''' 14°C. for the first nine hours. Later both registered 15°C. Number VIII was tightly rolled up, and could not be measured. All the other roots remained straight.

Experiment IV.

Five roots of *Lupinus albus*

NUMBER	ORIGINAL LENGTH	AFTER 12 HOURS	AMOUNT OF GROWTH
	mm.	*mm.*	*mm.*
I	25	32	7
II	19	26	7
III	21	26	5
IV	19	crooked	
V	23	28	5

T' registered 40°C.; T''' 13°C. All but number IV grew straight. Average growth per hour 0.5 mm.

Experiment V.

Seven roots of *Lupinus albus*

NUMBER	ORIGINAL LENGTH	AFTER 6½ HOURS	AFTER 17 HOURS MORE
	mm.	*mm.*	*mm.*
I	17	22	25
II	20	23	24
III	27	31	33
IV	17	22	24
V	26	28	31
VI	20	23	23
VII	18	20	22

T' registered 37°C. and T''' 14°C. for the first seven hours. Later both allowed to equal room temperature, 15°C. Number VI was very slightly bent to one side after six and one half hours. Several roots were bent the next morning after a total of twenty-three and one-half hours, but this could not have been due to thermotropism, first because there was no regularity and secondly because the temperature difference was not maintained.

Experiment VI.

Eight roots of *Pisum sativum*

NUMBER	ORIGINAL LENGTH	LENGTH AFTER 7½ HOURS	
	mm.	*mm.*	
I	30	32	
II	23	24	
III	24	30	
IV	22	28	
V	24	30	
VI	26	28	
VII	20	20	Did not grow.
VIII	25	28	

Number VI represents the only case in all these experiments of what might be called a negative thermotropic reaction. All the other roots remained straight, T' registered 38°C. and T''' 13°C. Number VII did not grow at all.

Experiment VII.

Experiment repeated with ten roots of *Pisum sativum*

NUMBER	ORIGINAL LENGTH	LENGTH AFTER 8 HOURS
	mm.	*mm.*
I	22	25
II	24	29
III	19	25
IV	23	28
V	24	31
VI	20	26
VII	23	27
VIII	23	26
IX	22	26
X	24	30

T′ was at 37°C.; *T‴* at 12°C. In this case all the roots grew beautifully straight.

Experiment VIII.

With five roots of *Zea Mays*

NUMBER	ORIGINAL LENGTH	SAME AFTER 7 HOURS
	mm.	*mm.*
I	17	23
II	27	37
III	21	27
IV	21	28
V	20	31

T′ registered 40°C. and *T‴* 12°C. All roots grew straight except number III which was a little bent to one side.

Experiment IX.

With six roots of *Phaseolus multiflorus*

NUMBER	ORIGINAL LENGTH	SAME AFTER 7½ HOURS
	mm.	*mm.*
I	30	33
II	29	35
III	29	34
IV	30	36
V	31	36
VI	30	35

T′ registered 39°C.; *T‴* 13°C. All the roots grew straight.

CONCLUSIONS

Klercker[15] mentioned five causes as possible factors in the thermotropism of roots as described by Wortmann but termed by himself caloritropism. To these we will add one, which gives the following list: (1) geotropism, (2) radiated heat, (3) air currents, (4) conducted heat, (5) hydrotropism, (6) traumatropism.

Geotropism cannot be considered an initial cause since it merely modifies the subsequent developments as Klercker has described. It therefore need not be considered here.

It seems improbable that radiated heat has an effect on roots. The experiments made with roots suspended in moist air subject to a difference of temperature demonstrate this. Similar experiments were made by Wortmann[16] with the same results. The same objections may be raised against air currents as determining factors.

The phenomena under discussion have till now been attributed to conducted heat. The experiments with the agar-agar conclusively disproves this. It is essential for the validity of these results that the roots grow and be capable of reaction in the solution. Tests were made with geotropism, and the roots were observed to react without difficulty. According to Porodko, the normal rate of growth is one millimeter per hour. The tabulated data of the experiments show that the roots actually grew and that the rate of growth is from one half to two thirds the normal. On this account the reaction would be expected to require more time. In all experiments, the roots were therefore exposed to the thermotropic stimulus for a period of more than three times that ordinarily necessary, usually from seven to eight hours. After twelve hours in the agar, the rate of growth materially diminishes, in all probability because of more difficult respiration. This did not interfere with the experiments, however, which were finished before this time had elapsed.

The actual difference between the temperatures on the two sides of a root is exceedingly small in Wortmann's apparatus.

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[15] Klercker, J. af, *loc. cit.*

[16] Wortmann, J., *loc. cit.* 1885.

Although T' and T''' register a difference of thirty degrees, the fall in temperature is but one degree every 2 mm. At the tip of the root of *Ervum Lens* for instance, there would be barely a difference of half a degree. The same condition exists in the agar-agar, so that the roots here are under practically identical temperature relations. All the other factors which are variable in the sawdust, more especially the moisture difference, are included. The failure to obtain reaction from the roots in agar-agar *shows that conducted heat is not responsible for their bending in sawdust.*

That hydrotropism might be the cause of Wortmann's thermotropic reactions was suggested by Klercker. The negative bending is due to the drying out of the sawdust, which proceeds rapidly, when being heated. Since roots are positively hydrotropic, they bend toward the moist sawdust, consequently away from the source of heat. When the sawdust is covered, evaporation takes place less rapidly, the psychrometric difference is not so quickly established, and the reaction requires more time. Positive bending is produced likewise by a difference of moisture, but since it is much smaller, the reaction is less definite and constant. Warm air is capable of holding more water vapor than cold air. The positively hydrotropic roots bend toward the warmer sawdust, where the interstitial air-spaces offer a moister atmosphere. This accounts for the so-called positive thermotropism, the irregularity and uncertainty of its appearance, as well as the length of time necessary. The conditions of moisture depend on how damp the sawdust is at the beginning of the experiment and so vary materially. It is but natural that Wortmann and Klercker should disagree as to the critical temperature of *Pisum sativum.* The critical temperature is merely the point where the increased capacity of the air for holding vapor is offset by the evaporation. When the sawdust was made very wet, so that it flowed, the moisture-conduit was equalized throughout the mixture, and no reactions could be obtained.

In all probability, the negative bending was assisted and accelerated by a traumatropic stimulus. Wortmann often heated the roots above the maximum temperature. In experiments with *Ervum Lens, Pisum sativum* and *Phaseolus multiflorus,* the roots were heated as high as 50° C., and with *Zea Mays* as high as 49° C. In the present experiments, it was endeavored to keep the temperature of T' in the neighborhood of 40° C. to avoid hurting the roots.

Thermotropism therefore does not occur in roots. Our conception of this term must be confined to the reactions of sprouts, as described by Wortmann and confirmed by Steyer and of peduncles and flower-stalks which have been shown by the researches of Voechting and Pohl to be thermotropic. Thermotropism in the sense made use of by Porodko is in reality traumotropism. He says[17] in fact that "negative thermotropic and thermo-traumatropic reactions are distinguished only by the intensity and stability of the albumen coagulation conditioning them."

SUMMARY

1. The use of a $1\frac{1}{4}$ per cent solution of agar as a medium for the roots, effectually excludes all factors except the difference of temperature, but allows the roots to grow and bend.
2. No thermotropic reactions occur when agar is used.
3. The reactions in roots due to thermotropism according to Wortmann, or to caloritropism according to Klercker, must be explained by positive hydrotropism.
4. Traumatropism assists the reactions resulting at higher temperatures.

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[17] Porodko, Th. M. *loc. cit.* 1913. P. 248.

A LIST OF LICHENS COLLECTED IN NEWFOUNDLAND, WITH CRITICAL NOTES ON THE FAMILY *USNEACEAE*

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I left Boston for Newfoundland on July 4, 1911, arriving at Port-au-Basque on July 7, and proceeded at once to Stevenville Crossing, St. George's Bay. I collected in this region until July 16, when I returned to North Sydney. The specimens collected are deposited in my herbarium, and I extend my sincere thanks to Dr. Ludwig Scriba, Dr. Alex. Zahlbruckner, Dr. L. W. Riddle, and Dr. H. E. Hasse for their kindness in determining various species, especially in the *Cladoniaceae.*

Though I have examined in Paris and Philadelphia much of the material collected in Newfoundland and recorded in the following papers, I have made no attempt to correlate it here, except in the *Usneaceae,* to which I gave especial study of Newfoundland material while in Paris, and later through the kindness of Mr. Witmer Stone, the Waghorne material of this family sent me from Philadelphia. A complete study of the lichens of Newfoundland and adjacent islands can be made only after a thorough study of all the existing material.

Group: *Radiatae*

Family: *Usneaceae*

1. *Usnea barbata* (L) Web. (= *Us. dasypoga* (Ach.) Nyl.) Stevenville Crossing and Bottom brook on spruce, sterile. One specimen represents the phase known as *hirtella* Arn., another approaches the variety referred to by Tuckerman as *plicata* Fr.; the var. *plicata*. (Hoffm.) Hue of Dr. Zahlbruckner, who calls Heppian's No. 829 the typical *plicata* "grubig und rissig." This distribution,[1] though in one set seemingly *U. trichodea* Ach.,[2] is in another *U. cavernosa* Tuck.

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[1] Hepp. Flecht. Europ. **14**: No. 829. 1867.

[2] Howe, Class. *Usneaceae* 14. 1912.

The l'Abbe Hue records also *dasypoga* Ach., and *plicata* Fr. The Eckfeldt herbarium does not contain either of these plants from Newfoundland, though both were recorded in his list.

2. *Usnea florida* (L.) Web., Stevenville Crossing, sterile (form *hirta*) on spruce. Delamare records *barbata* L., which he considers a synonym of *florida*. Arnold recorded *florida* and form *glabrata* Ach., and Eckfeldt *florida* Fr., but the only plant of this stock from the island in his herbarium I refer to *U. cornuta* Flot., Dr. Zahlbruckner calling it *U. Steineri* Zahlbr., a closely allied species (series *Leptinae*). The status of *U. cornuta* Dr. Zahlbruckner believes doubtful, and though Koerber included Flotow's *cornuta* in his synonymy, Dr. Zahlbruckner considers them separable. *U. cornuta* Flot. has been attributed to British America by Stirton[3] and the plant represents an inflated condition of *florida* suggesting *U. articulata*.

3. *Usnea longissima* Ach., Bottom brook—sterile, on spruce. Represents phase *tenuis* Th. Fr., as do all our eastern North American specimens.

Arnold records *longissima* as does also Eckfeldt, but the latter's specimen represents a corticate and atypical condition, noted before from Barclay Sound, B. C.[4] which I have described as a variety, though Dr. Zahlbruckner considers it a variety of *U. californica* Herre. It represents the *Pachynae* group, however, to which *longissima* belongs and not the *Mesinae* group which should include *californica*, a phase of *U. plicata* (L.) Web. as already indicated in my former paper. The plant is *U. longissima* var. *corticata* Howe.[5]

The l'Abbe Hue also records *U. intestiniformis* Nyl. The specimen on which his record was based he advises me is impossible now to locate. The only other species recorded by Eckfeldt, represented by a specimen in his herbarium, is *U. trichodea*, the example so labelled, proving, however, to be *Alectoria sarmentosa* Ach. The others he records are var. *ceratina* Schaer., var. *hirta* Fr., form *strigosa* Ach., form *glabrescens* Nyl., and *cavernosa* Tuck. Arnold and Delamare record also *U. microcarpa* Arn., which I have found to be a synonym of *U. cavernosa* Tuck.

Eckfeldt records *Evernia prunastri* (L.) Ach., which for eastern plants = *Letharia thamnodes* (Flot.) Hue. No specimen of either plant is to be found in his herbarium.

4. *Ramalina farinacea* (L.) Ach., Stevenville Crossing, on spruce, sterile. Part of the material represents the phase *pendula* Ach. or *gracilenta* Ach. Delamare, Arnold and Eckfeldt all record this species, and material comparable with mine is preserved in the latter's herbarium.

5. *Ramalina dilacerata* (Hoffm.) Wain., Stevenville Crossing, on spruce, fertile. Delamare, Arnold and Eckfeldt all record this species under the synonym *minuscula* Nyl., but no specimens are in the Eckfeldt herbarium, though No. 207, Lich. Bor.-Amer. Cummings, etc. and No. 277, Decades N. A. Lich. Cummings, etc., were collected by A. C. Waghorne, April 3, 1897 at Middle Arm, Newfoundland.

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[3] Howe, Bull. Torr. Bot. Club **37**: 15. 1910.

[4] Howe, Bull. Torr. Bot. Club **37**: 9. 1910.

[5] Proc. Thor. Mus. Nat. Hist. **1**: 18. 1913. A letter from Dr. Zahlbruckner received since this paper was written states "Darin haben sie recht, dass *Usnea Californica* nicht zu des *Pachynae* gehört."

6. *Ramalina pollinariella* Nyl., Stevenville Crossing, sterile, on spruce. The type of this species[6] from "Terra Nova" Despreaux is preserved in the Museum d'Histoire Naturelle, Paris, *fide* author. Hue, Arnold and Eckfeldt all record it, and I find material in the latter's herbarium.

Arnold also records *fastigiata* Pers., *fraxinea* L., *scopulorum* Retz, *subfarinacea* Nyl., *cuspidata* Ach., *farinacea* form *minutula* Ach., *thrausta* Ach., and *intermedia* Nyl. The type of the last species[7] from "Terra Nova" is preserved in the Museum d'Historie Naturelle, Paris *fide* author, and material representing it is in the Eckfeldt herbarium, though besides those species above mentioned, none of the others that Eckfeldt records are present, *i.e.*, *calicaris* (L.) Fr., var. *canaliculata* Fr., *rigida* (Pers.) Tuck., *pusilla* Prev., var. *geniculata* Tuck., *polymorpha* Ach., and *pollinaria* Ach., Delamare records *cuspidata* Ach.

Dactylina arctica (Hook.) Nyl., recorded by Eckfeldt under the synonym *Cetraria arctica* Hook. is not represented in his herbarium.

Thamnolia vermicularis (Sw.) Ach. Both Arnold and Eckfeldt record this species, which is, however, not preserved in the latter's herbarium.

Coelocaulon aculeatum (Schreb.) Link. Hue, Delamare, Arnold, and Eckfeldt record this species under the synonyms *Cetraria* or *Cornicularia aculeata* (Schreb.), and the same authors its variety *muricata* Ach. The Eckfeldt and Paris herbaria contain material of the species.

Coelocaulon odentellum (Ach.) Howe. Eckfeldt records this species under the synomym *Cetraria odentella* Ach., but no specimen is found in his herbarium.

Coelocaulon divergens (Ach.) Howe. Hue, Arnold and Eckfeldt record this species under the synonym *Alectoria divergens* (Ach.) Nyl., a portion of the material no doubt is referable to *Alectoria nitidula* Th. Fr., as I found this species from Newfoundland preserved at Paris. Arnold's records states "mit apothecien," which is, I believe, the second record of the fertile state of this species. Eckfeldt's herbarium is now without material of this plant.

Cetraria islandica (L.) Ach. Hue, Arnold, Delamare, and Eckfeldt record this species and its variety *crispa* Ach. The variety is represented in the Eckfeldt herbarium.[8] *Cetraria hiascens* Th. Fr. = *C. islandica* var. *Delisaei* (Borr.) Schaer. is also recorded by the above authorities, and Arnold also records the form *fastigiata* Del. The distribution of *C. islandica* var. *Delisaei* (Borr.) Schaer. No. 118 Lich. Bor.-Amer. and No. 187; Decade N. A. Lich., was collected by Waghorne, Sept., 14, 1894 at Blanc Sablon. Arnold records *Cetraria cucullata* Bell. under the synonym *Platysma cucullatum* (Bell.) Nyl., and Arnold and Eckfeldt *Cetraria nivalis* (L.) Ach. the former under the synonym *Platysma nivalis* L. Material of *hiascens* and *nivalis* are now in the Eckfeldt herbarium. Eckfeldt alone records *C. Richardsonii* Hook., but the species is absent from his herbarium.

7. *Alectoria jubata* (L.) Ach., Stevenville Crossing, on spruce, sterile. The phase *cana* Ach. is suggested in part. The material is *atypical*, but represents the species more nearly than any yet examined from North America. Delamare, Arnold and Eckfeldt all record the species and it is represented in the latter's herbarium.

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[6] Recog. Mono. Ram. 165. 1870.

[7] Ibid. 166. 1870.

[8] Bryologist, **16**: *Pl.* 3. *f.* 2. 1913.

Fig. 1. Type of *Ramalina pollinariella* Nyl. preserved at Paris (upper figure). Type of *Ramalina intermedia* Nyl. preserved at Paris (lower figure).

8. *Alectoria jubata* var. *implexa* (Hoffm.) Ach. Bottom brook and Stevenville, on spruce, sterile. Eckfeldt records this variety and I find it also preserved in his collection.

9. *Alectoria sarmentosa* Ach. Stevenville Crossing and Bottom brook, on spruce, sterile. The varieties *crinalis* (Ach.) Oliv. and *luteola* (De Not) Howe are represented. The type of the latter preserved in the Institute e orto Botanico at Rome was from Terre-Neuve.[9] Arnold records both the species and the variety *crinalis*, Eckfeldt only the species, though both are represented in his harbarium. Hue, Arnold and Eckfeldt also record *Alectoria nigricans* (Ach.) Nyl., *A. ochroleuca* (Ehrh.) Nyl., *A. ochroleuca* var. *cincinnata* Fr.; Hue and Arnold *A. jubata* var. *chalybeiformis* Ach.; Arnold and Eckfeldt *A. bicolor* (Ehrh.) Nyl.; Eckfeldt *A. jubata* var. *prolixa* Ach., *A. capilliris* (Ach.) Nyl., = *cana* Ach., *A. ochroleuca* var. *rigida* Fr. and *A. ochroleuca* var. *osteina* Nyl., (= *A. lata* (Tayl.) Hue) of these *chalybeiformis*, *ochroleuca*, *nigricans*, and the var. *cincinnata* are represented in his herbarium, as also a fertile plant seemingly the var. *stricta* Ach.; Arnold and Delamare alone *Alectoria nidulifera* Norrl. Delamare also records *sarmentosa* Ach., *ochroleuca* (Ehrh.) Nyl., and *nigricans* (Ach.) Nyl., and De la Pylaie *trichodes* (= *A. j. implexa*).

Theloschistes chrysophthalmus (L.) Norm. though recorded by Eckfeldt is not to be found in his collections.

Group: *Stratosi-Radiatae*

Family: *Cladoniaceae*

10. *Stereocaulon paschale* (L.) Fr., Stevenville and Bottom brook, on rocks, fertile.

11. *Stereocaulon tomentosum* Fr., Stevenville, on moss, fertile.

12. *Baeomyces ericetorum* (L.) Wain. (= *Icmadophila ericetorum* (L.) Zahlbr.). Stevenville, on moss, fertile.

13. *Cladonia sylvatica* Hoffm., Stevenville, on ground, sterile.

14. *Cladonia deformis* Hoffm., Bottom brook, on stump, fertile.

15. *Cladonia cristatella* Tuck. Bottom brook and Stevenville, on stump, fertile.

16. *Cladonia furcata* var. *racemosa* Flk. Bottom brook, on moss, fertile.

17. *Cladonia cenotea* (Ach.) Schaer., Bottom brook, on stump, sterile.

18. *Cladonia gracilis* var. *hybrida* Flk., Bottom brook, on stump, fertile.

19. *Cladonia verticillata* Hoffm. Bottom brook, on stump, fertile.

20. *Cladonia pyxidata* var. *chlorophaea* Flk., Stevenville, on bark, fertile.

21. *Cladonia fimbriata* form *subulata* Wain., Stevenville, on moss, sterile.

22. *Cladonia ochrochlora* Flk., atypical. Stevenville, on rotton log, sterile.

Group: *Stratosae*

Family: *Pseudophysciaceae*

23. *Pseudophyscia aquila* var. *detonsa* (Tuck.) comb. nov. Stevenville Crossing, on spruce, sterile.

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[9] Howe, Class. *Usneaceae* **24**: *Pl.* 10 f. B. 1912.

Family: *Physciaceae*

24. *Physcia stellaris* (L.) Nyl., Stevenville Crossing, on spruce, fertile.

25. *Physcia tenella* (Scop.) Nyl. Stevenville, on spruce twigs, sterile.

26. *Xanthoria polycarpa* (Hoffm.) Flag., Stevenville, on spruce twigs and rails, fertile.

Family: *Caloplacaceae*

27. *Caloplaca gilva* (Hoffm.) Zahlbr. Stevenville, on spruce twigs, fertile.

Family: *Parmeliaceae*

28. *Nephromopsis ciliaris* (Ach.) Hue. Stevenville, fertile, on spruce, a lacinose, pale beneath form with white rhizoids.

29. *Platysma juniperinum* var. *Pinastri* (Ach.) Nyl., Stevenville, on bark and old wood.

30. *Platysma glaucum* (L.) Nyl. Stevenville and Bottom brook, on spruce and stumps, sterile.

31. *Platysma glaucum* var. nov. **platyphylla** Stevenville, on spruce, sterile. This material, with some collected in Newfoundland by Waghorne and now preserved in the Eckfeldt herbarium, represents a distinct morphological variety, not previously recognized, to which I am giving the name *platyphylla* on account of its large lobate thallus and peculiar lacunations. The type No. 2483 is in the author's herbarium, a portion of which was also sent to Dr. W. G. Farlow to be deposited in the herbarium of the Botanic Museum, Cambridge. This variety may be described as follows: Thallus platyphyllus, cum lobis rotundis, non laceratis et cum *rugis acutis* in superiore latere, non reticulato-cellulosus ut in *Platysma lacunosa* typica, etiam non laceratus aut lacunosus ut in *Platysma lacunosa* var. *atlantica* Tuck. It has the diagnostic *nitidens* under surface of *glaucum*, not dull beneath as in *lacunosa*.[10]

32. *Parmelia crinita* Ach., Stevenville, on spruce, fertile.

33. *Parmeliopsis ambigua* (Ach.) Nyl., Stevenville, on bark and old wood, sterile.

34. *Parmeliopsis aleurites* (Ach.) Nyl., Stevenville and Bottom brook, on spruce and on old wood, sterile.

35. *Parmelia physodes* (L.) Ach., Stevenville Crossing, sterile on spruce and stumps.

36. *Parmelia olivacea* (L.) Ach., Stevenville, on spruce, sterile. These plants represent the dark-colored isidioid form known as *verruculifera* Nyl.

37. *Parmelia tiliacea* (Hoffm.) Flk., Stevenville, on spruce, sterile.

Family: *Lecanoraceae*

38. *Ochrolechia pallescens* (L.) Mass. Stevenville, on twigs, fertile.

Family: *Peltigeraceae*

39. *Peltigera aphthosa* (L.) Hoffm. Stevenville, on moss, fertile.

40. *Peltigera polydactyla* (Neck.) Hoffm., Stevenville, decayed stump, fertile.

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[10] Bot Gazette, **56**: 499. 1913.

41. *Peltigera spuria* (Ach.) DC. Stevenville, on moss, fertile.
42. *Peltigera canina* (L.) Hoffm., Stevenville, on moss, fertile.
43. *Peltigera rufescens* (Neck.) Hoffm., Stevenville, on moss, fertile.
44. *Nephroma arcticum* (L.) Fr., Stevenville, on moss over ledge, fertile.
45. *Nephroma laevigatum* Ach., Stevenville, on spruce twigs, fertile.

Family: *Stictaceae*

46. *Stictina crocata* (L.) Nyl., Stevenville, on spruce, sterile.
47. *Stictina scrobiculata* (Scop.) Nyl., Stevenville, on trees, sterile.
48. *Lobaria amplissima* (Scop.) Arn., Bottom brook, on spruce, fertile.
49. *Lobaria pulmonaria* (L.) Hoffm., Stevenville, on spruce, sterile. The specimens show to some extent the darkened, tomentose under surface reticulations of the form *hypomela* Del.

50 *Lobaria pulmonaria* var. nov. minor. One set of specimens I am distinguishing as a new variety. Type No. 2459 in the author's herbarium, Stevenville, Newfoundland, July 9, 1911. It may be diagnosed as: Similis speciei sed *multo minor* cum lobis *plane pinnatis*.

Family: *Pannariaceae*

51. *Pannaria rubiginosa* (Thunb.) Del. Stevenville, on spruce, sterile.

Family: *Lecideaceae*

52. *Bacidia endoleuca* (Nyl.) Kickx., Stevenville, on bark, fertile.
53. *Lecidea flavido-livens* (Tuck.) Hasse *in litt.* Stevenville, on twigs, fertile.

Group: *Collemae*

Family: *Collemaceae*

54. *Leptogium tremelloides* (Linn. f.) Wain., Stevenville, on stump, sterile.
55. ? *Collema pycnocarpum* Nyl., Bottom brook, on rock, sterile.
56. *Collema flaccidum* Ach., Stevenville, on spruce, sterile.

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Delamare: Flora Miquelonensis, Denauld & Cardot, 67–77. 1888.
Eckfeldt: An Enumeration of the Lich. Newfoundland and Labrador. Bull. Torrey. Bot. Club **22**: 239-260. 1895. (This list did not distinguish between Labrador and Newfoundland in recording the species.)
Arnold: Lich. Fragm. Newfoundland, Oesterr. bot. Zeitschrift, 1896.

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[11] See also Fernald, Rhodora **13**: 109–162. 1911.

BOOKS AND CURRENT LITERATURE

Animal Ecology.—Adams' little book,[1] which aims to introduce students to the subject of animal ecology, should do much toward bringing into zoology that newer sort of field study which has so rapidly and so thoroughly replaced much of the mere collecting, naming and admiring once considered as botany. The author's statement that "ecology is a science with its facts out of all proportion to their organization or integration," is about as true in botany as in zoology, and his emphasis on point of view and upon the scientific method, together with his numerous literature references, will give the book a place in both biological fields. Its contribution is mainly a conscious attempt to organize the large numbers of more or less isolated facts with which ecologists are bound to deal. Relatively few writers on plants and animals in the field have approached their work with the apparent desire to solve a problem, and it has become evident in the past decade that the first fine frenzy of ecological interest usually or frequently results in the accumulation and publication of field observations (expressed in words and photographs) without much attention to valid generalizations. Adams' remark that "scientific work progresses more rapidly when consciously pursued than otherwise," partakes so much of the nature of a truism that it is almost startling to realize how ecology has come into being and grown to large estate with little more purpose than that of classification for purposes of presentation only. This quotation would form an inspiring motto for a student of any branch of science and might retard the wastefully elaborate study of phenomena which merely seem "interesting" in themselves.

The first chapter deals with the "aim, content and point of view." Here the author considers three kinds of ecology: that of the *individual*, which is virtually physiology, in its broader sense; that of *aggregates*, which has to do with communities of the same species, genus, etc.: and that of *associations*, which considers groups delimited by external conditions and including many forms of organisms. The relations between these three kinds of ecological endeavor are interestingly dis-

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[1] Adams, Charles C. Guide to the Study of Animal Ecology. 183 pp. New York, The Macmillan Company, 1913 ($1.25).

cussed. In the second chapter, on "the value and method of ecological surveys," the reader will find a goodly number of incisively stated truths which, while shamefully obvious, have been generally neglected or totally ignored. A criticism of a fashionable method of carrying out biological survey operations emphasizes the hopeless inadequacy, for any broad purpose, of mere collections. "The student eager for new and little known species is not the one to study" the dynamic status of the organisms and their surroundings. "So long as the success of a day's work is measured by the length of the list of novelties secured, rather than by the quality and quantity of ecological relations discovered, such students and surveys will not contribute largely to our knowledge of the economy of nature in the regions surveyed" (p. 31). "His institutional authorities often judge values by the cubic foot and pound, rather than by the quality of relations discovered" (p. 33).

Chapter three deals with "field study." Here again are many valuable things frequently said in a novel and convincing way. "For many students it is a good plan to make out a general outline of any proposed study. . . . . Perhaps the greatest value of such a plan is that it facilitates conscious effort to seek a definite goal by maintaining a standard of measurement" (pp. 36–37). "To learn how to study in the field, and not simply to collect, is one of the most important habits which a field naturalist . . . . has to acquire" (p. 37). Note-taking is emphasized. The reader is advised to take full notes in the field and to take plenty of them. Even the sort of note-book best suited to the purpose receives attention. "The collection, preservation and determination of specimens" forms the subject of the fourth chapter. "In the field study of behavior of a single species there may be almost no collecting of animals but much collecting of notes; but if one is devoted primarily to the . . . . study of the composition of associations and their interrelations, much collecting [of specimens] will have to be done" (p. 49). In the fifth chapter are dealt with: the "scientific method;" "collecting and preserving of specimens, photographing, surveying," etc., and "the preparation of papers for publication," etc. The author's remarks on the last topic, and many of his references should be familiar to every beginner in any line of intellectual activity. It is unusual, and hence all the more valuable here, to have this important phase of scientific investigation given its proper place in a book for beginners.

The remaining chapters deal with the "laws of environmental change," the "laws of internal change," and the "continuous process of adjustment." The book as a whole, especially the later chapters, is very largely made up of lists of apparently well-chosen literature references. This is a novel type of introductory scientific treatise, wherein the author himself says as little as possible and merely directs the student to writings already published. It seems probable that this type of introduction may prove more useful to the coming generation than the prevailing authoritative elementary text-book, which presents its science, not as it *is*, but as the author conceives it to be, or even as he thinks it *ought* to be, with few or no references to original sources. At any rate, it is hard to think of Adams' little book as ever being "taught" in the older way. Two very full indexes (to names as well as subjects) complete the volume.—B. E. L.

Agricultural Chemistry.—Although chemistry is the foundation on which modern agriculture has been erected, and the men most notable in the development of agriculture have been predominantly chemists, relatively few of the many books dealing with the chemistry of agriculture have borne the title Agricultural Chemistry. The title to Dr. Fraps' book[1] therefore immediately arrests our attention. What is agricultural chemistry? Naturally, the answer should be: the science of chemistry applied to the art of agriculture. Practically, we must look for the definition to the conception of the subject by the authors of the few books that bear the name. If agricultural chemistry were to surrender to agronomy, dairying, animal nutrition, plant physiology, and similar departments, those portions of its subject matter to which they also lay claim, there would remain but little. The author of this volume agrees in the scope of his work fairly well with that of Adolph Mayer, though the treatment is much abridged. The first and largest volume of Mayer's Agriculturchemie is essentially plant physiology; the other three deal with soils, fertilizers, and fermentation. Fraps gives much space to soil physics and chemistry, interspersed with plant physiology; two chapters to manures and fertilization; and the remainder of the book to the leading principles of animal nutrition, including milk production. In common with Mayer he has failed to include the chemistry of dairying,—an omission to be regretted.

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[1] Fraps, G. S. Principles of Agricultural Chemistry. Pp. 493, figs. 94. Easton, Pa., The Chemical Publishing Company, 1913 ($4.00).

Pedagogically, the author makes a commendable digression from his general treatment of the subject by introducing Mitscherlich's mathematical expression of the law of minimum. Possibly few students for whom the text was intended could decipher the expression; but the introduction of the student, occasionally, to something he cannot quite master is stimulating—A. E. VINSON.

THE FERNS OF OREGON.—A very attractive popular account of the ferns of Oregon has recently been issued[1] from the herbarium of that state. It is the joint work of Professor Sweetser, Miss Ruth M. Howell and Niss Hannah M. Kenworthy. Thirty species of ferns are listed, belonging to eighteen genera, but the fern-allies are not comprised in the treatment. The key seems to be a very usable one, and is illustrated with pen and ink drawings. A brief statement is given of the position of the fern group in the plant kingdom, and the mode of reproduction in ferns is described and illustrated. Although this description is designated non-sexual reproduction, it also includes an account of sexual reproduction. There is a list of synonyms for such of the ferns as are unfortunate enough to have more than one name. There is also a bibliography and a glossary. The ferns of the north-west are of such great interest that this work will be especially welcome as an aid in gaining a knowledge of them.—GEORGE B. RIGG.

[1] Sweetser, A. R. The Ferns of Oregon. Univ. Ore. Bull. N. S. 11, No. 2, 30 pp., 24 figs., September, 1913.

NOTES AND COMMENT

Mr. Humphrey G. Carter, of Cambridge University, has prepared a small volume entitled Genera of British Plants (Cambridge, University Press). Its pages contain brief characterizations of the major and minor groups of ferns and flowering plants, with keys to the genera of all families represented in Great Britain. While the book is of limited usefulness to the American botanist, its publication suggests the value that would attach to a similar compendium of the genera of higher plants for the entire United States. Mr. Carter acknowledges his debt to Engler's Syllabus der Pflanzenfamilien (Berlin, Gebrüder Borntraeger), a book of low cost and high utility which should be at the elbow of every botanist. The Syllabus is, in brief, Die Natürlichen Pflanzenfamilien boiled down to a compass of 250 pages. It characterizes the larger groups of the entire vegetable kingdom, down to the families, mentions many important genera and species, and sketches the geographical range of some of the groups. It opens with an essay on the principles of systematic classification, and closes with a conspectus of the phytogeographical regions of the world. A similar book—much fuller in its details, and well illustrated, but limited to the flowering plants—is Warming's Fröplanterne (Copenhagen, Gyldendalske Boghandel). This volume brings the old Warming-Potter Handbook down to date, but has thus far appeared only in the Danish language.

Prof. John M. Coulter read a paper on the Origin of Monocotyledony before the National Academy of Sciences at the meeting in April. He reviewed the investigations which indicate that the Monocotyledons have been derived from the Dicotyledons and described evidence of the manner of this derivation which has been secured through a study of *Agapanthus umbellatus,* a widely cultivated South African liliaceous plant. In material of *Agapanthus* which was occasionally dicotyledonous it was found that "In every case the cotyledonary apparatus begins as a ring, and continues its growth as one cotyledon or two. It is evident that there is neither suppression of one cotyledon nor fusion of two."

The Missouri Botanical Garden has issued the first number of its new quarterly series of Annals, a journal which is to contain papers by members of the staff of the Garden and by students in the Shaw School of Botany of Washington University. A Bulletin will be issued monthly, containing administrative reports and popular notes. The two publications will supersede the Annual Report of the Garden, which has been regularly issued for many years.

A joint meeting of The American Geographical Society and The Association of American Geographers was held in New York on April 3 and 4. Among the papers presented the following are of botanical interest: Botanical Phenomena and the Problem of Coastal Subsidence, by D. W. Johnson; The Period of Safe Plant Growth in Maryland and Delaware, by Oliver L. Fassig; and The Tree as a Factor in Man's Adjustment to Hilly and Rocky Land, by J. Russell Smith.

Announcement has been made of the summer courses at the Biological Station of the University of Michigan, located near the Straits of Mackinac. The courses in Field and Forest Botany, in Systematic Botany, in Ecology, and the research work in botany will be in charge of Prof. H. A. Gleason and Mr. Frank T. McFarland.

The following articles will appear in early issues of The Plant World: Notes on the Flora of some Alaskan Sphagnum Bogs, by George B. Rigg; An Improved Cog Psychrometer, by Harry B. Shaw; Notes on the Flora of Louisiana, by R. S. Cocks; On the Influence of the Order of Development of the Fruits of *Passiflora gracilis* upon the Frequency of Teratological Variations, by J. Arthur Harris; On the Density of the Cell Sap in some Desert Plants, by W. A. Cannon; and Notes on the Ecology of Sand Dune Plants, by Edward B. Couch.

NOTES ON THE FLORA OF SOME ALASKAN SPHAGNUM BOGS

GEORGE B. RIGG

University of Washington, Seattle, Wash.

In the course of the investigation of the kelps of western Alaska as a source of potash fertilizer[1] during the summer of 1913, the writer had opportunity to examine a number of sphagnum bogs situated near the sea shore and ranging in geographical location from Cape Spencer to the Shumagin Islands.

The easternmost bog examined is at Dixon Harbor, longitude 136° 57′, latitude 58° 22′. The westernmost one is on Unga Island (one of the Shumagin group), longitude 160° 10′, latitude 55° 20′. This is also the southernmost. The northernmost one is situated at Cordova in latitude 60° 33′.

Twenty-five species (not to mention varieties and forms) of the genus *Sphagnum* have been listed from Alaska so far as the writer has been able to consult the publications (Rothrock,[2] Turner,[3] Coville and Funston,[4] Setchell,[5] Trelease[6]). *Sphagnum* was not found in fruit, but sterile specimens were collected from various bogs. These have been submitted to Prof. Theodore C. Frye of the University of Washington for determination.

All of the spermatophytes found by the writer in Alaskan sphagnum bogs are included in the list of Alaskan plants by

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[1] The expedition of which the writer was in charge was a part of the general investigation of the fertilizer resources of the United States conducted by Dr. Frank K. Cameron of the U. S. Bureau of Soils.

[2] Rothrock, J. T., Sketch of the flora of Alaska. Smithsonian Report, 1868.

[3] Turner, L. M., Contributions to the natural history of Alaska, 1886.

[4] Coville, F. V. and Funston, F. The botany of Yakutat Bay, Contr. U. S. National Herbarium, **3**: No. 6. 1896.

[5] Setchell, W. A. Some unreported Alaskan *Sphagna*. University of California Publications, Botany, **2**: 309–315. 1907.

[6] Trelease, William, Alaskan species of *Sphagnum*. Harriman Alaska Series of the Smithsonian Institution, **5**: 331–337. 1910.

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Fig. 1. General view of bog at Sand Point in the Shumagin Islands.

Rothrock and interesting comments on the distribution and uses of several of them are made by Turner. Many of them are also included in the lists of Alaskan plants by Kellogg,[7] Muir,[8] Cooley,[9] Macoun,[10] and Evans.[11] Kellogg, Macoun and Heller[12] are, however, the only authors in whose works the writer finds any discussion of Alaskan bog floras as such.

[7] Kellogg, A., Report to George Davidson, Assistant U. S. Coast Survey, on the botany of Alaska. Rept. Supt. U. S. Coast Survey, **1867**: 318–324. 1869.

[8] Muir, John, Botanical notes on Alaska in cruise of the revenue steamer Corwin in Alaska and the N.W. Arctic Ocean in 1881, 47th Cong. 2nd Session, House Ex. Doc. **105**: 51–53. 1883.

[9] Cooley, Grace E., Plants collected in Alaska and Nanaimo, B. C., July and August, 1891, Bull. Torr. Bot. Club, **19**: 246. 1892.

[10] Macoun, J. M., A list of the plants of the Pribilof Islands, Bering Sea, with notes on their distribution. In Jordan fur seals of the North Pacific **3**: 573–575. 1896–1897.

[11] Evans, W. H., Report on agriculture in Alaska, U. S. Dept. Agr. Exp. Sta. Bull. **48**: 13. 1898.

[12] Heller, E., Partial list of plants, chiefly shrubs and trees. (Prince William Sound.) University of California Publications, Zoology. 1910.

Kellogg mentions the occurrence of *Vaccinium vitis-idaea* and *Oxycoccus* in "peaty bogs and sphagnous morasses." Macoun, writing of Saint George and Saint Paul Islands says: "The number of bog and marsh plants is very small, though many of the species that grow elsewhere are also found on the damp boggy spots that are so characteristic of both islands. There is but one true bog on Saint Paul Island, several on Saint George. On these *Rubus chamaemorus, Saxifraga hirculus, Pedicularis sudetica,* and *Petasites frigida* grow in profusion, but they are all found on other parts of the island. The greater part of the surface of both islands is tundra-like. . . . . There are many level areas of considerable extent on both islands, called by Dr. Merriam, moss-bogs; but no true bog plants are found on them. . . . . " Heller, speaking of the distribution of *Lysichiton camtschatkense* in the Prince William Sound region says: "About bogs and stream margins in the forest, this plant occurs abundantly." It seems evident, however, that he uses "bog" and "tundra" as synonyms. His list includes no plants that the writer has found characteristic of Alaskan sphagnum bogs.

DIXON HARBOR, VISITED MAY 15–16

The bogs at Dixon Harbor are small, none of them exceeding 60 feet in diameter. They are all located within a tundra-like area which comprises perhaps 25 acres. This area probable does not anywhere reach a greater elevation than 150 feet. It begins at the beach and borders a small mountain stream. The bogs are confined to places where sphagnum has grown abundantly in a place whose rocky substratum has a conformation that prevents drainage.

The neighboring mountain sides are covered with coniferous forest, often bordered near the beach by a growth of *Alnus sinuata.* Both within the tundra area and along the borders of the forest there are many rocks having no soil except in their crevices, but still supporting vegetation. The following species of plants are characteristic of the four habitats just mentioned.

Forest: *Picea sitchensis, Tsuga mertensiana, Pinus contorta, Chamaecyparis nootkatensis, Alnus sinuata.*

Tundra: *Picea sitchensis, Tsuga mertensiana, Pinus contorta, Chamaecyparis nootkatensis, Alnus sinuata, Betula* sp. *Lycopodium annotinum.*

Rocks: *Empetrum nigrum, Loiseleuria procumbeus, Betula* sp.

Bogs: *Sphagnum* sp., *Empetrum nigrum, Loiseleuria procumbeus, Ledum palustre, Kalmia glauca, Oxycoccus oxycoccus, Pinus contorta, Chamaecyparis nootkatensis, Picea sitchensis, Betula glandulosa.*

In the forest the trees were erect and were in every way normal. On the tundra-like area the trees were much distorted, many of them being practically prostrate. *Betula* was prostrate on the rocks but was more or less erect in the bogs, reaching there a height of one foot or more.

Sphagnum occurs commonly in various places in this tundra as well as elsewhere on the shores of this harbor, but it forms bogs only where the surface is so flat that there is practically no drainage. The peat in these bogs is brown and fibrous, evidently formed from sphagnum. The maximum depth of it measured was 2½ feet. Davis[13] reports beds of peat in southern Alaska from 15 to 20 feet deep and along the Arctic Ocean from 30 to 40 feet deep. It is possible, of course, that these may not have been formed exclusively of sphagnum.

YAKUTAT, MAY 17–22

There is a tundra perhaps more than 3000 acres in extent situated along the line of the Yakutat and Southern Railway. This railway extends from the salmon cannery on Montia Bay (about 1 mile east of Yakutat post office) to the Situk River at a point near its mouth. The road is about 12 miles long and is used for hauling salmon from the river to the cannery. The cannery is about 4 miles distant from the nearest point of the tundra. The region between Montia Bay and the tundra is densely wooded with spruce and hemlock. There was evidently considerable undergrowth in this forest, but little could be seen of it at the time of our visit, because of the snow.

This tundra is locally known as "the prairie" and much of it is treeless. The borders of it have scattered spruce trees and there

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[13] Davis, C. A., The preparation and use of peat as fuel. In Bulletin 442. U. S. Geological Survey.

are a few fairly dense clusters of these trees on raised places a few square rods in area, within the tundra. Many of the trees along the border of this heath are dead. There does not seem to be any evidence that they were killed by fire. The dead branchless trunks are still standing and only a very few of these trunks show any blackening or other fire injury and these are close along the railroad where the fires have evidently been purely local.

Fig. 2. Tundra at Yakutat.

The railway extends for a distance of about 5 miles across this tundra. The shallow ditches along the grade of this road bed offer good opportunity for studying the nature of the strata that make up the soil. The observations made on these ditches were supplemented by digging elsewhere. There was everywhere found to be about one foot of decayed or decaying organic matter. Beneath this is gravel, evidently glacial outwash.

What drainage there is for this region is furnished by Lost River and its small tributaries and the shallow ditches along the railway grade. There are numerous places of 100 acres or more in extent that have no drainage at all except seepage to small and distant streams.

Sphagnum is fairly common on the soil of this tudra but is dominant on only comparatively small areas. Several other mosses occur, forming the surface layer over considerable areas. A good deal of the surface layer of decaying organic matter is peaty in its nature. Where sphagnum is dominant it has formed peat bogs with their characteristic xerophytic flora.

The conditions that cause bogs here are, as usual, the presence of an abundance of sphagnum and the lack of drainage.

The following lists of plants are not complete, but include the ones that seemed most characteristic of these habitats at the time of our visit. Vegetation was in its late winter condition at that time. There was still much snow in the forest but none on the heath. No doubt many other plants would be found in midsummer.

Generally distributed: *Empetrum nigrum, Betula glandulosa, Viola* sp., Grasses, *Sphagnum,* other mosses.

Along streams and ditches: *Lysichiton camtschatkense, Caltha palustris, Alnus sinuata, Salix* sp.

In bogs: *Sphagnum* sp., *Ledum palustre, Kalmia glauca, Oxycoccus oxycoccus.*

Funston visited the Yakutat region in 1892 and made a collection of the plants found. The list of the plants in this collection (Coville and Funston) will be found interesting for comparison. It will be noted that none of the spermatophytes listed in the bogs are given in the Coville and Funston list.

It seems probable that Funston did not visit this tundra since he says: "The almost level country lying on the eastern side of the bay between Ocean Cape and the foothills of the mountains is covered with a forest growth practically impenetrable. The great amount of fallen timber together with the tangled and heavy undergrowth constitute such obstacles to travel that even the Indians who have lived here many years have never penetrated the forest of the mainland for more than a mile."

Much development has occurred in this region since Funston's visit twenty-one years ago, a good deal of it being due to the building of the cannery within the last few years and the necessity of transporting the fish to this cannery by rail because of the sand bar at the mouth of the Situk River.

Funston did, however, find small treeless areas in the forest which he describes as follows: "Scattered through the forests of the Yakutat Bay region are a number of small open treeless spots varying from a few square rods to an acre or two in extent. The larger of these glades are generally swampy and in some of them water is standing all summer, while others are well drained and there is no apparent reason for the lack of forest growth. These glades are few in number and occupy in the aggregate an extremely small percentage of the total forest area."

Kalmia glauca is much smaller here than it is in the Puget Sound bogs and does not form such dense growths. The same is true of *Ledum palustre* as compared with its congeners in the bogs of the Puget Sound region. The representatives of both of these genera are rather inconspicuous in the sphagnum bogs of the Yakutat region and also in the sphagnum bogs at Dixon Harbor.

An attempt was made to collect bog water here as had been done in the Puget Sound bogs,[14] but on digging down to the gravel no water at all had seeped into the cavity after a wait of fifteen minutes.

It seems quite possible that the treeless condition of this tundra as a whole is connected with its physiographic history. The gravelly glacial outwash, in its original condition evidently could furnish little opportunity for the growth of woody plants of any size. It seems possible that the mosses were the pioneers here, and that they early produced a condition on this gravelly flat where there was plenty of moisture but not enough drainage to permit the growth of trees. It would seem difficult, too, for trees to maintain their erect position with the poor anchorage for their roots afforded by the soft thin layer of soil, but they have done so in the case of the clusters referred to above. The mosses were actually found to be pioneers on a gravel plain in front of Grewingk

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[14] Rigg, G. B., The effect of some puget sound bog waters on the root hairs of *Tradescantia*. Bot. Gaz. **55**: 314–326. 1913.

glacier in Cook Inlet. Some very small seedlings of *Populus trichocarpa* were found growing in the gravel fronting Grewingk glacier, and this species with *Alnus sinuata* flourished where there was soil mixed with the gravel. *Picea sitchensis* grows abundantly on the neighboring mountain sides.

Heller ('12) in speaking of the vegetation of Prince William Sound says: "The tundra occupies wet swampy ground that the forest cannot invade, the complete saturation being fatal to tree growth. The forest occupies the drier ground. The tundra occurs as islands in the forest area and consists chiefly of a heavy covering of mosses and shrubs which hold much moisture."

Wind is certainly not a factor in the production of the Yakutat "prairie" (tundra), for it is wooded practically all around with trees that show no distorting effect of wind.

Sphagnum is very abundant in the Yakutat region outside of the bogs and even outside of the tundra. It is common around small ponds and is the dominant moss in much of the wooded region. It is by no means confined to forming a dense growth on the ground. It runs over fallen tree trunks and up-turned roots of trees. In one case a considerable growth of it was found with other mosses on the upturned roots of a fallen spruce at a height of 6 feet from the ground.

CORDOVA, MAY 26

At Cordova a small sphagnum bog was found that was closely bordered by a forest of spruce and hemlock. This is similar to the situation of bogs in the Puget Sound region and is quite different from the situation of the bogs at Dixon Harbor and at Yakutat Bay. This Cordova bog occupies all of the flat area and the bordering forest is on a steep hillside. *Empetrum nigrum* and *Kalmia glauca* are the characteristic woody evergreens of this bog. Sphagnum is dominant over its whole area. Beneath the surface is a mass of brown fibrous peat having a maximum depth of 3 feet. This bog is confined to an undrained place and is bordered by the hillsides and by the rocks that prevent the outflow of water. When a cavity was scooped out in this peat, water quickly accumulated in it just as it does in Puget Sound bogs.

SNUG HARBOR, KNIGHT ISLAND, MAY 29

Several small sphagnum bogs were found in a tundra occupying a somewhat level area on the mountain side. The bogs were confined to undrained places and were characterised by *Sphagnum, Empetrum nigrum,* and *Kalmia glauca. Harrimanella stelleriana* occurred along the borders of the bogs but not in them.

THREE SAINTS BAY, KODIAK ISLAND, JUNE 21

On the flat area just north of the sand spit on the east side of the bay there are numerous small sphagnum bogs varying in area from a few square rods to three or four acres. The covering of sphagnum is in many places so thin that I could feel the rocks beneath as I walked over it. In the middle of the larger bogs, however, the sphagnum and the underlying peat reached a depth of 2½ to 3 feet. These bogs occur wherever there is no drainage, the portions of the rocks that are steep enough to have good drainage, being covered with a thick carpet of mosses other than sphagnum, beneath which is humus formed by earlier vegetation. On this occur in profusion the flowers of the region—a *Viola,* a *Geranium,* an *Anemone,* a *Castilleja,* and others, but they do not extend into the bogs. *Veratrum viride* is also common in the humus of the region down to the edges of the bog, but it does not extend into them. Heller, in speaking of the bogs of Prince William Sound says that *Veratrum viride* is found about bogs. The writer has not found this species about Puget Sound bogs. It is, however, common on Mt. Rainier. *Alnus sinuata* also occurs along the borders of the bogs but not in them. *Betula papyrifera alaskana* reaches a height of 15 feet, and a diameter of 8 inches along the borders of some of these bogs, but in the bogs it is represented by a very few stunted sprawling specimens reaching a height of only 4 or 5 feet, and a diameter of only 2 or 2½ inches. There is also a prostrate *Betula* in the bogs, but it is evidently a different species. *Trientalis arctica* is found on the border of this bog, as it is in some Puget Sound bogs.

The following is a list of the plants that are most characteristic of these bogs:

Sphagnum sp., *Ledum palustre, Empetrum nigrum, Drosera rotundifolia,*[15] *Vaccinium vitis-idaea var minus, Andromeda polifolia, Eriophorum* sp., *Cornus suedetica, Betula glandulosa, Pinguicula* sp.

Other plants also found in this bog are: *Lycopodium* sp., *Vaccinium* sp., *Rubus chamaemorus, Carex* sp., *Equisetum* sp., *Arctostaphylos tomentosa, Cladonia rangiferina* and a few mosses other than *Sphagnum.*

LAZY BAY, KODIAK ISLAND, JUNE 23 AND 24

In the flat region lying between Lazy Bay and the ocean there are numerous small sphagnum bogs, all confined to undrained areas. Their characteristic flora is *Empetrum nigrum, Ledum palustre* and *Vaccinium vitis-idaea.* All of these species were also found on the very thin soil covering the rocks of the region. In one place they were found on the practically bare rocky surface of a cliff 60 feet above the level of the bay. All three of these species were prostrate when growing on rocks.

UZINKI, SPRUCE ISLAND, JULY 1

What was formerly a bog of several acres in extent bordering the village of Uzinki is now buried beneath a thick coat of volcanic ash from the eruption of Katmai volcano in June, 1912. Near the village a stream has cut through this ash deposit and sphagnum is exposed. Other than this all vegetation in the bogs was covered at the time that this bog was visited except a few plants at the center of the bog and there the deposit was still too soft to permit an inspection of these plants.

Superintendent M. D. Snodgrass, of the U. S. Agricultural Experiment Station at Kodiak told the writer that he had visited this place previous to the eruption and that it was a sphagnum bog.

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[15] The writer knows of only one place where *Drosera rotundifolia* is found outside of bogs. It was found by the members of the International Phytogeographic Excursion at Lake Kapowsin, near Tacoma, Washington. It occurs abundantly at the water line on the sides of floating logs used to support a foot bridge over the lake. It is not associated with sphagnum on these bogs. *Ledum groenlandicum* and *Kalmia glauca* also occur on top of some of these logs. The writer is now engaged in studying the vegetation of this lake.

Superintendent George A. Learn of the Baptist Orphanage on Wood Island also stated that there had been several sphagnum bogs of considerable extent on that island previous to the eruption but that they are now all covered deep with volcanic ash. From the fact that there are usually slopes draining into the bogs and that they have no outlet this loose volcanic material has soon accumulated in the bogs. No doubt many bogs on Kodiak Island, Afognak Island and the neighboring islands that received a heavy fall of ash from this eruption have been so completely buried that they are no longer recognizable as bogs. The bogs at Three Saints Bay and at Lazy Bay, Kodiak Island, described above are toward the western end of the island where there was no fall of ash from the Katmai eruption.

MITROFANIA BAY, JULY 20–25

There is a small bog perhaps 150 feet in diameter situated near Mitrofania village, on Alaska Peninsula. The bog is entirely confined to the undrained area and does not anywhere extend over the crest of the rocks that prevent drainage from it. The following are the dominant plants of the bog—*Sphagnum* sp., *Empetrum nigrum*, *Eriophorum* sp., *Vaccinium vitis-idaea*. *Iris setosa* also grew in the bog. The growth of sphagnum in this bog did not cover the surface so completely as in the other bogs described.

In a large meadow at another point in Mitrofania Bay there was a small patch of *Empetrum nigrum* with some mosses (not sphagnum) and lichens growing in it. The surrounding area was covered with grass and flowers but this empetrum-dominated area was entirely devoid of such vegetation. It was similar to empetrum-dominated areas that the writer has seen at Three Saints Bay and elsewhere in Alaska. It was slightly higher than the surrounding meadow and was soft and cushion-like to the step, much resembling a sphagnum bog. On pulling up the plants it was found that their lower portions were dead and a little farther down were decayed and had formed peat.

At an elevation of about 1500 feet on a mountain near Mitrofania village the writer found *Ledum palustre* growing on the rocks along with *Empetrum nigrum* and *Vaccinium vitis-idaea*.

FOX BAY, ALASKA PENINSULA, JULY 26-29

In a valley at the head of one of the arms of Fox Bay a good deal of sphagnum was found. Wherever there were undrained areas the sphagnum had formed bogs. *Empetrum nigrum*, *Ledum palustre*, *Oxycoccus* sp., and *Eriophorum* sp., were the characteristic plants of these bogs.

Ledum was found along with *Empetrum* to the top of the nearby mountain (about 1400 feet) on the rocks but never among the grass in the meadow-like places. *Ledum* when growing on the rocks was prostrate and showed a dorsiventral arrangement of the leaves.

Fig. 3. *Ledum palustre*, *Salix reticulata*, *Cladonia* sp., and other plants in the bog at Sand Point, Shumagin Islands.

SAND POINT, POPOF ISLAND, JULY 30-31

A long narrow sphagnum bog occupies the entire flat portion of the valley leading down to the village of Sand Point. It has been dammed near the lower end and the water supply for the village is piped from the pond thus created. The formation of this bog was not due to the presence of the dam. The bog was there long before the dam was constructed and there was no free drainage from it. The water escaped from it by seepage only.

Portions of the hillsides bordering the bog are covered with a growth of low alder (3 to 5 feet high) and there is some willow not quite so high as the alder. Both of these grow down to the edges of the bog but do not grow in it at all. Popof Island as well as the other islands of the Shumagin group is, as is well known, treeless except for these low alders and willows.

Sphagnum is dominant throughout practically all of the flat undrained area. Other plants of the bog are as follows:

Empetrum nigrum, *Ledum palustre*, *Loiseleuria procumbeus*, *Vaccinium vitis-idaea*, *Andromeda polifolia*, *Oxycoccus oxycoccus*, *Drosera rotundifolia*, *Betula* sp. (prostrate), *Eriophorum*, *Salix reticulata*, *Menyanthes trifoliata* (is pools), *Rubus chamaemorus*(?).

The first four plants in the above list were common on the very thin soil that partially covers the rocks on the sides and tops of the hills alongside this bog.

When a cavity a foot deep was scooped out in the peat, water quickly accumulated as it does in Puget Sound bogs.

UNGA ISLAND, AUGUST 1–4

Extensive bog areas were found on the neck of land between Zachary Bay and Popof Strait. The flora of both the bogs and the neighboring hills was like that observed a few days earlier at Sand Point.

SUMMARY OF FACTS ABOUT ALASKAN BOGS

1. Sphagnum grows in many localities and in a variety of conditions without forming bogs. Examples: on logs and in swamps—Juneau and Dixon Harbor; on upturned roots of trees—Yakutat Bay; on hillsides—Excursion Inlet; on sandy flat—Yakutat Bay; on soil in woods—Yakutat Bay; on soil in open places—Cape Douglas.

2. The establishment of a bog requires at least two conditions: (a) An abundant growth of sphagnum; (b) Lack of drainage. As is indicated above (a) frequently occurs without (b).

3. All Alaska bogs examined were comparatively thin deposits over rock, but cf. Davis ('13), while Puget Sound bogs are usually deeper deposits over soil, frequently glacial till.

4. Many Alaska bogs are occasional patches within tundras, (*e.g.*, Yakutat, Dixon Harbor, Snug Harbor); others are similar to Puget Sound bogs in being bordered by coniferous forest (*e.g.*, Cordova) while still others occur in forestless areas (*e.g.*, Three Saints Bay, Mitrofania Bay, Unga Island, Sand Point).

5. Many Alaska bogs were entirely buried by the accumulation of volcanic ash after the eruption of Katmai volcano in June, 1912. Examples: Uzinki and Wood Island.

6. *Kalmia glauca* is found commonly in bogs and occasionally outside of bogs in both Alaska and the Puget Sound region. For example it is found in Alaska on rocks at Lazy Bay and at Cape Douglas, and in the tundra at Snug Harbor. In the Puget Sound region it is found on Mount Rainier and on floating logs supporting a foot bridge over Lake Kapowsin.

7. *Ledum palustre* is found in Alaska both in bogs and outside of them. For example, it occurs on rocks at Mitrofania Bay, Fox Bay, Lazy Bay, Sand Point, and Unga Island. *Ledum groenlandicum* in the Puget Sound region occurs in sphagnum bogs and in the mucky soil on their borders and also on floating logs in Lake Kapowsin.

8. *Drosera rotundifolia* was not found by the writer in Alaska except in bogs. In the Puget Sound region he has found it growing on the floating logs supporting a foot bridge over Lake Kapowsin.

9. *Empetrum nigrum*, *Vaccinium vitis-idaea*, *Loiseleuria procumbens* and *Andromeda polifolia* are species that are common in Alaska, both in bogs and elsewhere in xerophytic habitats.

10. *Empetrum nigrum* in Alaska sometimes establishes bog conditions somewhat similar to the bog conditions elsewhere established by sphagnum. Examples: Mitrofania Bay, Three Saints Bay.

11. *Empetrum nigrum* is the most characteristic plant of Alaska bogs both as to the uniformity of its occurrence and as to its abundance in individual bogs.

12. *Kalmia glauca* is much smaller in Alaska bogs than in Puget Sound bogs and does not form so dense a growth. The same is true of *Ledum palustre* as compared with its congeners in Puget Sound bogs.

13. *Ledum* and *Betula* are usually prostrate in Alaska when they grow on rocks but not when they grow in bogs.

14. *Oxycoccus oxycoccus*, is the only plant that the writer has found common in the bogs of both Alaska and Puget Sound that he has not found also outside of bogs.

15. The plants most characteristic of Alaskan sphagnum bogs have been reported as follows, so far as the writer has had access to the literature:

Empetrum nigrum. Unalaska, Kellogg and Muir; without locality, Evans; Kotzebue Sound, Muir; Saint George Island, Macoun; Saint Paul Island, Macoun; Douglas Island, Grace E. Cooley.

Ledum palustre. Saint Michaels, Muir; Kotzebue Sound, Muir; without locality, Evans; Norton Sound to Point Barrow and Northern coast, Rothrock; abundant at Saint Michaels, common at Unalaska, Atka and Attu, Turner.

Ledum groenlandicum. Without locality, Evans; (under *Ledum latifolium*) Sitka, Kellogg; "Alaska," Kellogg; Sitka, Rothrock.

Ledum sp. Ounalaska Harbor, Muir.

Kalmia glauca. "Alaska," Kellogg; Douglas Island, Grace E. Cooley; Sitka, Rothrock.

Oxycocus oxycoccus. (Under *Vaccinium oxycoccus*) Fort Simpson, Kellogg; without locality, Evans.

Vaccinium vitis-idaea. Golvin Bay, Muir; Kotzebue Sound, Muir; Cape Prince of Wales, Muir; "Alaska," Kellogg; without locality, Evans; New Metlakatla, Grace E. Cooley; Point Barrow, Ray; Unalaska, Saint Laurence, Sitka, Norton Sound to Point Barrow and on the northern coast, Rothrock; abundant throughout the coast line of the mainland and on the eastern islands of the Alaskan chain, Turner.

Loiseleuria procumbeus. Saint Michaels, Muir; Cape Prince of Wales, Muir; Cape Lisburne, Unalaska, Chamisso Island, Rothrock; plentiful in small patches throughout the Aleutian Islands, Turner; mountain near Juneau, Grace E. Cooley.

Andromeda polifolia. Saint Michaels, Muir; Cape Prince of Wales, Muir; Sitka, Rothrock; Kotzebue Sound, Rothrock.

Drosera rotundifolia. Sitka, Rothrock; Fort Simpson, Kellogg; Douglas Island, Grace E. Cooley.

Pinguicula villosa. Ounalaska Island, Rothrock; Norton Sound, Rothrock; Chamisso Island, Rothrock; Golvin Bay, Muir.

It is a pleasure to the writer to acknowledge his indebtedness to Professor C. Schröter, Professor H. C. Cowles, Professor F. E. Clements, Professor A. Dachnowski, and Professor F. K. Butters for conferences in regard to bogs, during the visit of the International Phytogeographic Excursion to the Puget Sound region; to Mr. Hunt of the United States Forest Service at Cordova, Alaska, for a conversation with reference to bog conditions at Yakutat; and to Professor Robert F. Griggs for the identification of willows and some other bog plants.

AN IMPROVED COG PSYCHROMETER

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In the field and at experiment stations scientific observers have occasion to note the relative humidity. An instrument commonly used for this purpose is the sling psychrometer, as furnished by the United States Weather Bureau. To secure readings this instrument must be whirled.

The student of plant life often has occasion to ascertain the humidity conditions of restricted areas, as among foliage, or in small frames, etc. The sling type of instrument is useless under such conditions. Dr. F. E. Clements designed a small, portable cog psychrometer (see Research Methods in Ecology, 1905, p. 39) and later Prof. P. J. O'Gara designed one along very similar lines (see Monthly Weather Review, January 1909, pp. 22, 23). It is true of both these instruments that the necessity to whirl the entire instrument is avoided and that some protection is afforded the thermometers themselves, but both the protective device and thermometers are whirled, thus causing risk of entanglement with foliage. The mechanical parts of these instruments are not well constructed nor durable. In the design of Dr. Clements the thermometers are so short as to render rapid and accurate reading almost impossible, and in addition, the scale is Centigrade, whereas the conversion tables of the Weather Bureau are in Fahrenheit degrees. They also have the defect that both bulbs are made to whirl in the same plane. This may have the result that the "wet" bulb will leave a trail of vapor in which the "dry" bulb must travel—a condition that may influence the dry bulb to indicate incorrectly.

The writer has had occasion to study the humidity conditions of plants shaded by tents and glass covered frames, and among dense foliage in the open. Under these conditions it became neces-

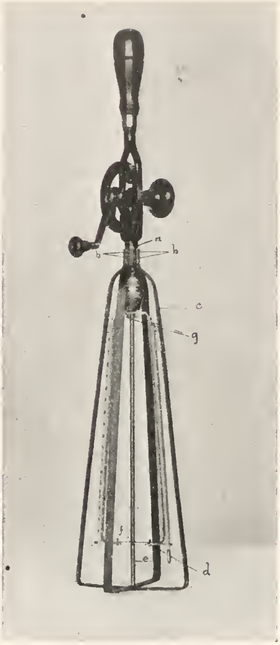

Fig. 1

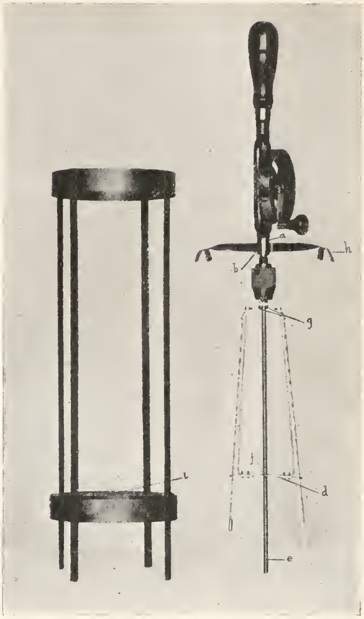

Fig. 2

Fig. 1. Psychrometer with protective cage attached. *a*, shank of drill; *b*, *b*, machine screws attaching protective cage to shank; *c*, protective cage; *d*, revolving frame supporting the thermometers; *e*, axis carrying the revolving frame; *f*, bent wire pin securing revolving frame to axis; *g*, machine screws engaging with projecting jaws of drill to assist in carrying the frame *d* around.

Fig. 2. Psychrometer with separate protective cage (left). *a*, shank of drill; *b*, machine screws attaching transverse arms, *h*, to the shank; *d*, revolving frame; *e*, revolving axis; *f*, bent wire pin securing frame to axis; *g*, machine screws engaging with jaws of drill to assist in revolving frame *d*; *h*, transverse arms to support instrument in cage (at left); *i*, hole in transverse strip of cage to steady the axis *e*.

sary to protect the whirling thermometers, therefore an outer, stationary cage was constructed to protect the inner, revolving parts of the instrument. Instead of the fragile and cheaply constructed commercial egg beaters, a substantial hand drill, such as may be obtained at any hardware store at a cost of about one dollar, was used. This is strong, not unduly heavy or large, runs very smoothly and is durable. The shank to which the chuck of this drill is attached is sufficiently long for the application of the outer protective frame or cage by means of small machine screws, as shown in the illustrations.

In figure 2 is shown a second and still more specialized form of cog psychrometer. This was designed and used for relative humidity studies among dense foliage, where it was desirable to avoid disturbing the foliage during a series of readings. The protective additions to both these instruments are made of strips of sheet brass of commercial sizes. In the second type of instrument the revolving supporting frame is identical with that of the first mentioned design, except that the axis is prolonged considerably at the lower or free end (*e*, fig. 2). In this case the protective cage is separate. Supporting arms, instead of the protective cage, are attached to the shank of the drill. The psychrometer is inserted within the cylindrical cage, the free end of the prolonged axis being inserted into a hole in the center of a strip (*i*. fig. 2) rivetted diametrically across the lower portion of the cage, while the ends of the supporting arms rest upon the upper rim of the cage.

To use this instrument, the cage is first set among the foliage whose humidity conditions are to be studied, care being taken that none of the leaves enter the cage; after moistening the "wet" bulb, the instrument is set into the cage as above indicated and the thermometers are revolved to obtain the reading. This operation may be repeated as often as desired without disturbing the foliage.

NOTES ON THE FLORA OF LOUISIANA. I

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The object of these notes upon the flora of Louisiana is to record various observations made during the past few years upon the distribution and occurrence of such plants as seem worthy of special notice whether on account of their rarity or because their presence in Louisiana would seem to be remarkable judging by their hitherto published range as set forth in Small's Flora of the Southeastern United States (1913) and Mohr's Flora of Alabama (1903), the only two publications which deal at all comprehensively with this region. In this present paper it is proposed to deal especially with the parish of West Feliciana which presents many features not found elsewhere in the state. The parish of West Feliciana is in the southeastern portion of Louisiana, using the term south as it is generally used in Louisiana to denote below the mouth of the Red River. On its northern boundary it adjoins the state of Mississippi and on its western side is bounded by the Mississippi River. From the state line of Mississippi extending southward there is on the eastern side of the river a belt of "bluff lands" running through West and East Feliciana and East Baton Rouge. In length the belt is about 50 miles, its width in West Feliciana about 18 miles. The bluffs on the Mississippi line rise to a height of 100 feet or more and are hilly and broken. Further south they flatten out, being only about 75 feet high at Port Hudson and 45 at Baton Rouge, continuing to fall eastward and southward until they reach the level of the pine flats and alluvial bottom lands. The parish of West Feliciana consists almost entirely of these bluff lands which lie between a small amount of alluvial land along the river and the so-called hill lands on the east. In West Feliciana the bluff lands are very hilly and broken with ridges rising sometimes several hundred feet, separated by very precipitous ravines or narrow valleys. In the southern portion of the parish the ridges are not so elevated and the level areas are more extensive. The parish affords a particularly inviting field for botanical investigation as unlike the similarly formed adjoining parish of East Baton Rouge, which is almost completely cleared and under cultivation, this parish still contains large tracts of undisturbed woodlands, explained by the fact that the large estates of the original owners who settled there in the latter part of the eighteenth century have never been broken up and subdivided into small farms. The forests of this region are unsurpassed anywhere. Perhaps their most striking feature is the magnificent growth of magnolia trees (*M. foetida*) which is in some places almost the exclusive tree, some of them attaining to a height of a hundred feet before branching. It is perhaps also worth recording that the jujube tree, *Zysiphus vulgaris*, is well naturalized in this region, occasionally forming extensive thickets. Other trees characteristic of the region are the following:

Ilex opaca, which here attains a size not approached elsewhere.
Celtis mississippiensis.
Carya cordiformis. Here conspicuous by its white bark.
Carya alba.
Carya porcina?
Quercus alba.
Quercus texana.
Quercus stellata.
Quercus Michauxii.
Quercus nigra.
Quercus phellos.
Quercus falcata.
Quercus pagodaefolia.
Quercus acuminata. Not common.
Liquidambar styraciflua.
Fraxinus americana.
Ostrya virginica.
Carpinus caroliniensis.
Platanus occidentalis
Tilia leptophylla.
Prunus caroliniensis.
Prunus sp.
Symplocos tinctoria.
Oxydendron arboreum.
Vaccinium arboreum.
Bumelia lanuginosa.
Bumelia lycioides.
Pinus glabra.
Cornus florida.
Cercis Canadensis.

In this paper I wish especially to record first the number of plants which are found here but no where else in Louisiana, second the large number of apparently mountainous species which occur here and have never been recorded in the intervening territory a distance of about five hundred miles.

FERNS

Adiantum pedatum L. Very abundant in the woods of West Feliciana and the adjoining parish of East Baton Rouge. Not found elsewhere in Louisiana. According to Mohr "rich shady woods of the mountain regions of Alabama."

Asplenium angustifolium Wild. In ravines West Feliciana, not elsewhere in the state. Range according to Small Quebec to Wisconsin, Virginia, Georgia and Alabama. According to Mohr mountain regions of Alabama.

Cystopteris fragilis (L.) Bernh. Very common in ravines West Feliciana. Not elsewhere in the state. According to Mohr mountain regions of Alabama to lower hills, south to central Georgia.

SEED PLANTS

Actaea alba (L.) Mill. Frequent in rich woods West Feliciana. Not observed in any other part of the state. According to Small's Flora it occurs in woods south to the mountains of Georgia and Missouri. According to Mohr along the mountains to South Carolina.

Magnolia Fraseri Walt. First collected about six years ago by Prof. C. S. Sargent and myself at Laurel Hill, West Feliciana. Since then the same tree has been observed at several other localities in the same parish but no where else in the state. Range according to Small chiefly in the mountains Virginia to Georgia and Alabama.

Celastrus scandens L. Very common in the woods of West Feliciana. Nowhere else in the state. According to Mohr its southern range is the mountain region of Alabama.

Panax quinquefolium L. Common in rich woods West Feliciana. Not elsewhere in the state. According to Mohr widely diffused over the mountain and hill country of Alabama.

Claytonia virginica L. Common in West Feliciana in open woods. Range according to Mohr from Virginia along the mountains to Georgia.

Carya laciniosa (Michx. f.) Loud. In woods subject to overflow West Feliciana. The distribution of this tree seems to be very imperfectly known. Small's Flora gives the distribution as New York to Iowa, Kansas, Pennsylvania, Tennessee and the Indian Territory. The tree is not included by Mohr in his Flora of Alabama but it is by no means uncommon in the so-called "black belt region" of Alabama, especially along the Alabama River near Selma. It is possible therefore that it has been overlooked in all the adjoining territory between West Feliciana and the Indian Territory.

Ilex longipes Chap. Rather rare, in wet places in woods West Feliciana. According to Small its range is "rocky banks North Carolina to Tennessee, Georgia and Alabama." According to Mohr mountain regions of Alabama it is however very common near Selma, Alabama, in woods rear the Alabama River. Neither near Selma nor in Louisiana does it ever grow on rocky banks.

Benzoin aestivale (L.) Nees. Very abundant in the woods of West Feliciana. Found also in swamps in the vicinity of New Orleans. The recorded range according to Small is Massachusetts to Ontario, Middle Georgia, Tennessee, and Kansas.

Frasera caroliniensis Walt. First collected in Louisiana in 1840 by Carpenter in West Feliciana as reported by Hale in his Notes on the Medical Botany of Louisiana published in the New Orleans Medical and Surgical Journal 1852. Rare in the woods of West Feliciana. No where else in the state. According to Mohr along the mountains from West Virginia to Georgia.

Asarum canadense L. Rich woods West Feliciana. Not seen elsewhere. According to Small an Alleghenian species, New Brunswick to Ontario, south to North Carolina.

Houstonia purpurea L. Dry woods West Feliciana. According to Small on or near the mountains Arkansas, Georgia and Alabama. This species is not confined to West Feliciana but is widely distributed over the state.

Circaea lutetiana L. In deep ravines West Feliciana. Not seen elsewhere in the state. Mohr gives its southern range as mountain regions of Alabama.

Hypericum lobocarpum Gatt. In swampy places West Feliciana. Very rare. The same shrub was also collected by Dr. Joor near

Madisonville, East Louisiana, in 1887. Range according to Small North Carolina and Tennessee.

Gillenia stipulata (Muhl.) Trelease. Widely distributed over Louisiana, very common in dry woods West Feliciana. Range according to Mohr along the mountains to South Carolina and Georgia.

Pachysandra procumbens Michx. Collected many years ago in West Feliciana by Carpenter. I have never observed the species but we have in the Tulane Herbarium Carpenter's original specimens labelled "woods West Feliciana." Range according to Mohr mountain regions of Alabama.

Antennaria solitaria Ryd. First collected many years ago by Carpenter near Jackson, Louisiana. I have collected the same species several times in different parts of West Feliciana. Range according to Small mostly in the mountains Pennsylvania to Middle Georgia and in Louisiana.

Taenidia integerrima Drud. In dry woods West Feliciana. Rare. Range according to Mohr mountain regions of Alabama and along the mountains to Georgia.

Cynoglossum virginicum L. In woods West Feliciana. According to Mohr another mountain species, ranging south to Florida and Louisiana. Small.

The following other mountainous species which are mentioned by Small as occurring in Louisiana have all of them been collected by me in West Feliciana and with one exception not elsewhere in the state:

Heuchera americana L.
Lappula virginiana (L.) Greene.
Myosotis virginica (L.) B.S.P. All over the state.
Lithospermun tuberosum Rugel.
Polygonatum commutatum (Roem and Schult). Dietr.

The following species are included on account of their rarity:

Amsonia loudiviciana. This is one of the rarest plants in Louisiana. It was first collected about 1840 by Carpenter in West Feliciana and I have collected it on several occasions close to the original station. So far as I know it has never been collected outside Louisiana nor anywhere else in the state. It is readily distinguished from other species of *Amsonia* by the woolly leaves.

Physalis carpenteri. This *Physalis* was first collected by Carpenter in West Feliciana in 1840 and was named in his honor by Riddell with whom he was associated in botanical work in Louisiana. The species is extremely abundant in ravines and rich woods in West Feliciana where it frequently occupies large tracts of ground to the exclusion of any other species. I have never observed it in any other parish in Louisiana.

Drymaria cordiformis Wild. This species which is as far as I can discover recorded here for the first time in the United States was identified for me by Dr. B. L. Robinson of Harvard University. It is widely spread over Louisiana, very rare in East Louisiana, extremely abundant near Opelousas, West Louisiana where it forms thick carpets in rich woods.

Ipomaea wrightii. This species is not included by Small in his Flora of the Southern States. It is widely spread in Louisiana having been collected by me on the edges of Lake Charles, in the swamps of New Orleans, and in swampy places West Feliciana. It is readily distinguished from all other species of morning glory in that the peduncle of the flower is transformed into a tendril by means of which it climbs round low shrubs and grasses.

BOOKS AND CURRENT LITERATURE

The Fungi which cause Plant Disease.—Among the multitude of books now appearing in all branches of botanical science it is rather rare to find one which meets a very definite need and meets it so well as Stevens' recent manual.[1] Heretofore we have had no book which has attempted to describe in a scientific manner the fungi which cause the diseases of our cultivated plants. Massee's Text Book of Fungi is much more limited in the number of species described and perhaps a little more extensive in the discussion of some of the larger groups than the manual under consideration, while Tubeuf and Smith's Diseases of Plants is scarcely more a manual of fungi than is Duggar's Fungous Diseases of Plants. Moreover the first two of those mentioned above apply to conditions in our country only in a general way. Hence a long felt want has been supplied. The title of the book is justified by its contents even if perhaps we might at first be led to expect that a larger number of species would be described.

It is evident from the opening sentence of the preface that the volume is intended to be limited to fungi which affect economic plants, yet in many instances sufficient reference is made to genera or even species of small economic importance to enable one to make use of the book in a study of those forms. Convenient keys are introduced to aid in the tracing of species, genera, families and larger groups and the classifications used are well chosen from the more widely accepted systems. The illustrations which represent nearly every genus described, and often several species from one genus, are helpful and tend to clarify doubtful points rather than becloud them as so often happens where "pictures" are introduced. A most valuable asset is the large number of references introduced supporting the statements made. The grouping of these at the ends of the large groups of fungi is a satisfactory arrangement. There is a total of over fifteen hundred references to articles, and over seventy-five titles of books and magazines useful in pathological work. Another device for convenience which could well be copied by many authors, is the constant cross reference by page numbers not only from the keys to the descriptions but also in the reverse direction to the keys where the name of the group first appears.

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[1] Stevens, F. L., The fungi which causes plant disease. Pp. 754, figs. 449. New York, The Macmillan Company, 1913.

There seem to be very few wasted words, and even fewer repetitions, thus giving the whole work, a business-like, crisp air well worth emulation in other works of reference. A long, useful glossary and a very complete index complete the volume of a little over seven hundred and fifty pages. The type is of good size and clear; and with one or two exceptions the illustrations are also very clear. With so many points in its favor one feels reticent about calling attention to a few points for improvement in the book. However, if offered in the spirit of helpfulness, and not of mere criticism, the suggestions may certainly not come amiss.

The reviewer can well understand that the present nomenclature of fungi is in so turbulent a condition that no really complete nor entirely accurate list of synonyms could be introduced, yet a free use of synonyms, particularly those which have been recently reduced to synonymy, would aid materially in locating descriptions and in using the volume as a reference work for inexperienced students. As all have experienced, a short definition of a scientific word in a glossary may give little information or even may give a wrong notion, so that the method of giving cross reference in the glossary to the place in the text where the term is defined more completely or illustrated, would be an improvement in any book where this device is lacking. Occasionally the cross reference from text to illustration is lacking and where, as in the case of *Botryosporium pulchrum*, a form is illustrated upon another page than it is described some confusion is likely to occur. A somewhat similar lack is noticed where the description under the illustration fails to clearly designate to which structure a certain term applies. Right here it may be said that the growing tendency to omit lettering from illustrations and to substitute a sentence of description beneath, may give a more artistic picture, but has led to a very vague explanation of the part shown. In the lists of references one would like to know the titles of the articles as well as the citations, which only are given. While it is true that this is a systematic treatise yet something more than a mere mention of the heteroecism of *Sclerotinia ledi* would be useful; while at least a page reference under "heteroecism" in the index would make the note available. Although on p. 323 we are told that the three genera, *Graphiola*, *Schinzia* and *Bornetina*, will be found under the heading "Genera of Unknown Affinity," on p. 663, only the first of these three is found there, and in its description we get no intimation that *Graphiola* has been referred to before, nor with which group it has been associated. Very few slips of this nature have been observed, however, and in closing the reviewer believes he is expressing the sentiment of a large number of pathologists when he states his appreciation of the excellences and value of the book.—Ernest Shaw Reynolds.

Acidity in Cacti.—The subject of the diurnal fluctuation of acidity in succulents has recently been treated from the chemical standpoint by H. A. Spoehr.[1] A number of conclusions are reached, among which the following are of most interest to botanists.

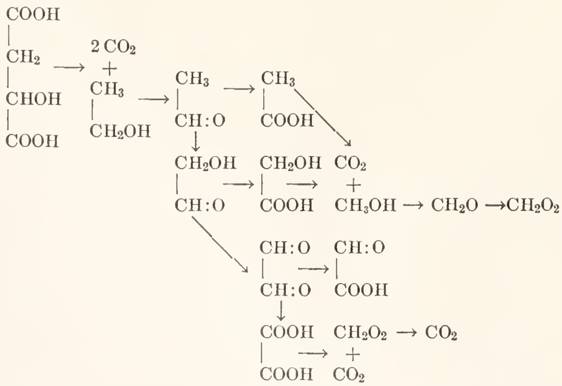
1. After oxalic acid, malic acid is of most frequent occurrence in plant tissues.

2. In *Opuntia versicolor* the highest acidity was found just before sunrise when 1 cc. of expressed juice was equivalent to 2.45 cc. $\frac{N}{10}$ potassium hydroxide, while the lowest was five hours after noon when 1 cc. of juice was equivalent to 0.31 cc. $\frac{N}{10}$ hydroxide.

3. The expressed juice of cacti showed decrease of acidity with evolution of oxygen, *in vitro* when placed in sunlight or in the light of a mercury vapor lamp.

4. Increase of acidity in plants takes place under conditions of oxygen scarcity. Succulents have poor aeration within their tissues and hence a greater accumulation of acid takes place in them than in other plants. The process, however, occurs in all plants.

5. The reactions concerned in the photolysis of malic acid were proved to be as follows:



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[1] Spoehr, H. A., Photochemische Vorgänge bei der diurnalen Entsäuerung der Succulenten. Biochem. Zeitschr. **57**: 95-111, 1913.

6. The formation of oxalic acid from acetaldehyde, as shown in the above diagram, is a possible explanation of the occurrence of large amounts of this acid in succulents, for although oxalic acid is easily decomposed in sunlight, it is, nevertheless, accumulated in the plant cells by the daily formation of stable compounds with calcium.

7. Malic, glycollic, and acetic acids all produce formaldehyde under the influence of light and hence the occurrence of formaldehyde in plant tissues gives no evidence either for or against the Baeyer assimilation hypothesis.

The paper closes with an interesting comparison of the results of this work with those obtained by Borowikow. The latter found that growth rate in plants is influenced in the same manner by the presence of acids, bases and salts as is the rate of swelling of colloids and deduced the generalization that growth is caused by the swelling of the colloids within the cell. Now, since the acidity of plants decreases in light and since a decrease of acidity would decrease the rate of colloidal swelling, a cause for the retardation effect of light on growth is found.—EDITH B. SHREVE.

MYCORHIZAS.—This study[1] is a distinct contribution to our knowledge concerning mycorhizas that has been gained from the sixty or more papers that have appeared on some phase of the subject. In addition to the ectotrophic and endotrophic mycorhizas the author reports a condition not previously recorded in which both forms appear on the same rootlet and are caused by the same fungus. For this condition he uses the term heterotrophic. Several different species of mushrooms may form mycorhizas on the same trees, the converse of which had previously been known. However, not all mycorhizal fungi are capable to relating themselves to all species of mycorhizal trees.

The fact that infection takes place through the root hairs in the formation of endotrophic mycorhizas is confirmed. In the case of infection in the formation of ectotrophic mycorhizas the fungous filament first penetrates the outer portion of the epidermal wall of the roots, dissolves the middle lamellae, and by continued growth a complete mantle is formed over the rootlet.

The hypothesis that ectotrophic mycorhizas represent symbiotic associations in which the fungus serves as the conveyor of salts from the soil to the root has been quite generally accepted. McDougall

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[1] McDougall, W. B., On the Mycorhizas of Forest Trees. Amer. Jour. Bot. **1**: 51-74, pls. 4-7, fig. 1, 1914.

concludes, however, for the following reasons that ectotrophic mycorhizas are not to be regarded as symbiotic associations but as instances of parasitism by fungi on the roots of trees. (1) Healthy trees may grow entirely free from mycorhizas even in humus. (2) Mycorhizas are developed in late summer at a time when the tree is no longer active. (3) It is at this season too, that more food stored in the roots is available to the fungus than would be the case in spring. The parasitism is comparatively harmless, however, because only a few roots are attacked and only those near the surface. In the case of endotrophic mycorhizas the situation is more complex. Sufficient benefit may be obtained by the digestion of fungous hyphae to justify its being regarded as a symbiotic association.—Frederick A. Wolf.

NOTES AND COMMENT

The work carried out by Shantz in 1911 relative to the value of natural vegetation as an index of crop possibilities in the Great Plains region, has been extended, with the collaboration of Kearney, Briggs and others, to the Great Basin. The Tooele Valley, on the south shore of Great Salt Lake, has afforded a suitable location for the work, which has been reported in the Journal of Agricultural Research (vol. 1, p. 365). Seven distinct vegetations are found in the valley, including pure stands of *Artemisia tridentata*, of *Kochia vestita* and of *Atriplex confertifolia*, as well as mixed stands in which the above and other species are concerned. The physical texture of the soils underlying these vegetations was found to determine the acquisition and retention of water, and to determine the character of the vegetation when taken in conjunction with the amount and position of alkali in the soils. The existence of farming lands, with and without irrigation, in all parts of the Tooele Valley, has made it possible for the authors to make very specific recommendations as to the possibility of agricultural success on land occupied by the several vegetations.

There have been much more definite results in the study of natural vegetation as an indicator of whether agriculture is possible or is not possible, than there have been in its use to determine the particular crop which may best succeed where a given plant cover exists. There has also been a striking difference between the investigations of this character which have been carried out in semi-arid or arid regions, where the vegetations are strongly differentiated, and in humid regions, where they are more uniform even on soils which are widely dissimilar.

Mr. R. Lloyd Praeger, of Dublin, has written a booklet entitled Weeds (Cambridge, University Press), a popular and instructive account of the Irish "plants growing in places where man does not want them to grow." Much is said about the means of dispersal of weeds and the book is brought down to the last minute by the suggestion that aeroplanes may now become effective distributors of seeds over long distances. A large number of original field experiments on the behavior of weeds are suggested, offering an interesting line of work to the teacher of nature study. From first to last, however, the attitude of the author is one of hostility to weeds. He defines agriculture as "a controversy with weeds," and nowhere says a single good word for any one of the numerous handsome plants which may be gathered from the roadside for interior decoration or may be brought into the garden for its adornment, with many advantages over the less vigorous exotic. It may be the case, however, that as soon as we admire a weed it ceases to be a weed.

Over seventy of the Cambridge Manuals of Science and Literature have now been issued. They are authoritative in authorship, readable in style, and small enough for the coat pocket. One of the most interesting of the recent numbers is The Fertility of the Soil, by Dr. Edward J. Russell, Director of the Rothamstead Station, who discusses this subject in its scientific aspects and also tells the history of the notable agricultural progress made in Great Britain during the last forty years. Prof. Clement Reid has written on Submerged Forests, and Prof. George H. Carpenter on the Life-Story of Insects.

ON THE INFLUENCE OF THE ORDER OF DEVELOPMENT OF THE FRUITS OF PASSIFLORA GRACILIS UPON THE FREQUENCY OF TERATOLOGICAL VARIATIONS

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I. INTRODUCTORY REMARKS

Our knowledge of the proximate causes of teratological variations[1] is so meager that any definitely established facts bearing upon the problem are of value. Such facts are, because of the relatively great rarity of most abnormalities, very difficult to obtain.

In this note we show that the abnormalities in the fruits of *Passiflora gracilis* taken as a whole[2] are not distributed at random over the plant but that in their production there is a definite periodicity.

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[1] Strictly speaking teratological variations cannot be sharply marked off from any other kind. The term is, however, fairly well understood among botanists, and the distinction of this type of variation is perhaps convenient.

[2] Some years ago one of us (Harris, J. Arthur. Prolification of the Fruit in *Passiflora* and *Capsicum*. Ann. Rep. Mo. Bot. Gard. **17**: 133–145. 1906) discussed the phenomenon of prolification of the fruit in *Passiflora gracilis*. Besides prolification—the production of accessory fruits, or rather of a succession of whorls of incompletely closed, rarely ovuliferous carpels inside the fruit—a considerable series of meristic variations is to be found in the wall of the fruit. These consist for the most part of a tetramerous instead of the normal trimerous organization—that is, the production of eight external sutures, four dorsal and four placental, and four placentae, instead of six external sutures and three placentae. Pentamerous and even hexamerous fruits also occur, although very rarely. Transition stages between these various classes may occur, although these intermediate conditions are rare. These variations in the organization of the fruit wall may be combined in various ways with prolifications of fairly distinct types.

The morphological problems presented by these teratological fruits have been under investigation for several years and will be the subject of a forthcoming memoir by one of us. When that is made ready the subject of the distribution of the individual types of abnormality through the fruiting season will be taken into account.

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The discovery of this phenomenon was quite incidental.[3] The methods of demonstration are two: The comparison of the percentage of mature abnormal fruits in successive collections, and the comparison of the relative numbers of abnormal fruits in collections of fruits which are in a partially developed condition[4] with those which are fully matured and are consequently older. Numerically the results are therefore rough but quite sufficient for first approximations.

II. PRESENTATION OF DATA

Consider first two series of plants belonging to a strain which has been under cultivation at the Station for Experimental Evolution since 1908. These comprise 24 and 25 individuals which were transferred into 12-inch pots[5] plunged in the garden. The first lot contained garden soil. The second had in addition 175 grams of bone meal per pot.

TABLE 1

DATE OF COLLECTION	NUMBER OF FRUITS	NUMBER OF ABNORMALS	PERCENTAGE OF ABNORMALS
August 19	275	59	21.45
August 25	135	24	17.78
September 10–11	3,640	423	11.62
September 26–27	6,519	398	6.11
October 6	3,096	203	6.56

For the normal soil series the results for different collections of mature fruits are shown in table 1. There is a constant decrease in the percentage of abnormality from the first to the

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[3] These results were secured in a series of experiments initiated in the summer of 1913 to ascertain whether it is possible by the control of various external conditions to modify the percentage of abnormal fruits, either as a whole or with respect to some particular characters. This problem involves many technical difficulties which render it undesirable to draw any final conclusions at the present time.

[4] These would unquestionably show all the abnormalities of the fruit wall. We believe they are quite old enough to show prolification if it is to occur.

[5] All of the plants discussed in this paper were germinated under glass and allowed to make their first growth in three-inch pots.

last two collections[6] which show about the same proportion of abnormalities.

Comparing immature and mature fruits with regard to proportion of abnormalities as an additional check on the conclusions drawn from successive series of mature fruits, we find that for the collection of September 10–11, the percentage of abnormals is (126 × 100)/1655 = 7.62% as against 11.62% for the matured fruits. For the collection of September 26–27 the proportion is (75 × 100)/652 = 11.50% as compared with 6.11% for the matured series. Possibly the number in the immature series is not large enough to give a trustworthy percentage. For the final collection, October 6, the immature fruits have 121 abnormal out of a total of 3580, or 3.38% as compared with 6.56% for the mature fruits gathered at the same time.

For the combined collections of September 26–27 and October 6, the immature fruits show only 4.63% of abnormality as compared with 6.25% for the mature fruits.

The results for the plants grown with bone meal appear in table 2. In essentials the results are in agreement with those obtained from plants grown in ordinary soil.

TABLE 2

DATE OF COLLECTION	NUMBER OF FRUITS	NUMBER OF ABNORMALS	PERCENTAGE OF ABNORMALS
August 15–16	442	172	38.91
August 22	301	79	26.28
September 1–4	2,438	241	9.89
September 23–25	11,820	774	6.55
October 4	4,096	264	6.45

Comparing such series of immature and mature fruits as are available in this culture we find that for the collections of September 1, 3 and 4 there are 172 abnormals among 2310 immature fruits, or 7.45% as compared with 9.89% among the matured fruits. For the collections made after September 22 the mature

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[6] Since it was sometimes impossible to gather the fruits from all the plants of the culture on the same date, some of the groups in these tables contain those gathered on several different days.

fruits show 6.52% abnormality while the immature fruits show 5.31%.[7] Thus taken as a whole the results of the comparison of the mature and the immature fruits tend to confirm the conclusions drawn from fruits taken at different dates.

Table 3 gives the results from another culture made in a somewhat different manner from the same strain of seed as the two just described. The results agree with the preceding in all but numerical details.

TABLE 3

DATE OF COLLECTION	NUMBER OF FRUITS	NUMBER OF ABNORMALS	PERCENTAGE OF ABNORMALS
August 19–20	404	235	58.17
August 29	768	140	18.23
September 12–20	16,131	1,748	10.84
October 14–16	23,643	1,349	5.71

Comparing mature and immature fruits with respect to the occurrence of abnormality it appears that whereas in the mature fruits of the collection of September 12–20 there were 1748 teratological out of 16,131, or 10.84%, among the immature fruits there were 390 abnormals out of a total of 5443, or 7.17%. For the large collection of October 14–16, in which it was not so easy as in some other cases to distinguish between mature and immature fruits, there were 11,951 immature fruits among which were 242 or 2.02% abnormal as compared with 23,643 mature fruits among which there were 1349 teratological, or 5.71%.

The same condition is also illustrated by two cultures made from seeds imported from a German firm, although here only the mature and the immature fruits can profitably be compared.

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[7] For the collection of September 23–25 there are for the immature fruits 84 out of 808 or 10.40% abnormal as compared with 6.55% in the mature fruits. Here the production of abnormals in the immature collection is apparently higher than it is in the mature series. Possibly the number of abnormal fruits is too small to give a trustworthy percentage. Possibly the difference between the proportion of abnormals in the mature and in the immature series is statistically trustworthy and attributable to some unknown factor—perhaps to variations in temperature or soil moisture. For the final collection, October 4, the immature fruits have $(151 \times 100)/3618 = 4.17\%$ of abnormality as compared with 6.45% in the mature fruits.

For the first series the collection and dissection of all the 10,399 mature and immature fruits was carried out from September 29 to October 3. Of the 9570 mature fruits 1519 or 15.87% are abnormal, while of the immature fruits, only 96 or 11.58% are to be thus classified.

In the second culture only one gathering was made, that of October 6. Of the 8369 fully matured fruits which were dissected 1288, or 15.39% were in some degree abnormal, while of the 1896 immature fruits only 63 or 3.32% were abnormal.

III. CONCLUDING REMARKS

Concerning the factors immediately involved in the production of teratological structures comparatively little is known. This is in part due to the difficulty of obtaining adequate material. In *Passiflora gracilis* we have been able to secure rather large series of data bearing on this problem.

These definitely establish the fact that in successive collections of mature fruits from the same plant the proportion of abnormal fruits decreases. Furthermore collections of mature and immature fruits made at the same time generally show the greatest proportions of abnormality in the more mature, that is to say the older fruits. In short the proportion of abnormalities in the fruits decreases as the plant becomes older.

Thus there is in respect to this complex of variations a periodicity analogous to that which has been demonstrated in other forms by DeVries and others. The phenomenon here observed differs from the usual condition in that the maximum is an initial one.

NOTES ON THE ECOLOGY OF SAND DUNE PLANTS

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The dunes studied are those at Peck's Manhattan Beach, between Redondo and Venice, California. They are practically undisturbed, and therefore lend themselves readily to safe investigation of their flora. These dunes rise to a height of about 150 feet above sea level in a horizontal distance of three-quarters of a mile and descend abruptly 75 feet in about 100 feet of horizontal distance. The physiography is referred to as windward slopes, as summits, or as leeward slopes the configuration of the dunes having been determined by the sea winds.

Quadrat counts covering the dunes were made in March 1913, each quadrat being 10 meters square.

Quadrat No. 1

One-quarter mile from the sea on the windward slope

Gaertneria bipinatifida	30
Eriogonum parvifolium	12
Abronia umbellata	11
Lotus Junceus	1
Lupinus Chamissonis	1

Quadrat No. 2

One-half mile from the sea on windward slope, a ridge

Gaertneria bipinatifida	12
Lupinus Chamissonis	4
Abronia umbellata	3

Quadrat No. 3

One-half mile from sea, windward slope on edge of a blow-out

Gaertneria bipinatifida	17
Abronia umbellata	7
Lotus Junceus	5
Lupinus Chamissonis	1
Eremocarpus setigerus	1

Quadrat No. 4

Near summit, windward slope on slightly protected side of a ridge

Abronia umbellata	26
Eriogonum parvifolium	17
Lupinus Chamissonis	12
Cherianthus suffrutescens	3
Gaertneria bipinatifida	2
Phacelia Douglasii	1
Adenostoma fasciculatum	1
Lotus Junceus	1
Sphaerostigma viridescens	1

Quadrat No. 5

Summit of dune

Adenostoma fasciculatum	26
Cherianthus suffrutescens	23
Abronia umbellata	22
Eriogonum parvifolium	17
Lupinus Chamissonis	5
Lotus Junceus	2
Sphaerostigma viridescens	2
Eremocarpus setigerus	2
Phacelia Douglasii	2

Quadrat No. 6

Just below summit of dune on leeward slope

Cherianthus suffrutescens	29
Adenostoma fasciculatum	21
Eriogonum parvifolium	13
Lupinus Chamissonis	6
Phacelia Douglasii	5
Abronia umbellata	5
Ramona stachyoides	5

Quadrat No. 7

Foot of leeward slope

Lupinus Chamissonis	20
Gnaphalium chilense	7
Cherianthus suffrutescens	6

It is seen that the dominant plant in the first three quadrats is *Gaertneria*, which is the pioneer plant to encroach on moving sand. It establishes itself and is followed by *Abronia umbellata* in more or less protected places. As *Abronia umbellata* is secondary in the first three quadrats and dominant in the fourth it seems to rank second to *Gaertneria* as a sand binding plant.

In the fourth quadrat *Abronia umbellata* is the dominant plant with *Eriogonum* and *Lupinus* as secondaries. *Gaertneria* has lost its place and become a relict perhaps of former formations or is of accidental occurrence.

Quadrat number five shows *Adenostoma* as dominant and *Abronia umbellata* and *Cherianthus* as secondaries. *Adenostoma* appears suddenly and in so doing rather upsets the series of dominants and secondaries. It however is peculiar to the summit and leeward slope and occurs just as markedly as the quadrat count indicates. It does not occur on the windward slope. It is possible that *Eriogonum* should also be named as a secondary in this quadrat.

Quadrat six gives *Cherianthus* as dominant by numbers and *Adenostoma* and *Eriogonum* as secondaries. The size of the plants however place them in reverse order.

In quadrat seven the most conspicuous plant of the dunes in dominance is *Lupinus*. The land is so nearly occupied that to name a secondary would be stretching the meaning to apply to mere numbers.

The two kinds of competition exist, that between plants and their environment and that between plants themselves. In general the competition on the windward slope is environmental that of the summit a combination of environmental and vegetative and that of the leeward slope mainly vegetative. In both cases where the competition is greatest the number of species is the least. In case of environmental competition the plants do not cover the surface of the soil, but in the case of vegetative competition the surface is covered in proportion as the competition is close. In other words, open formation occurs on the windward slope and slightly so on the summit, while closed formations are the rule on the leeward slope and at the foot of the dune on that side. *Gaertneria* and *Abronia umbellata* seem to be the most successful in the environmental competition and *Lupinus* in plant competition. The regions giving greatest number of species in the

Fig. 1

Fig. 2

Fig. 1. General view of dunes near Redondo, California, showing hummocks and the encroachment of sand on new territory.

Fig. 2. Ripple-marked sand, with *Gaertneria* in center and distance.

Fig. 3

Fig. 4

Fig. 3. *Abronia,* in a characteristic situation, together with *Eriogonum, Cheiranthus* and *Eremocarpus.*

Fig. 4. *Cheiranthus* in a characteristic location, and of typical form.

counts seem to be where there is an intermediate stage in competition and stabilization. It will be noted that the greatest number species occurs in the counts taken on or near the summit of the dune. This is peculiar to dune formations. The combination of plant and vegetative competition is caused by the constant of sand and the tendency toward complete ecesis. The existence of this double condition tends to permit the gathering of representatives of all the species on the dunes near the summit excepting *Abronia maritima* which is limited to within about one-quarter mile from the sea.

The September aspect of the dune is very different from that of the spring. Most of the plants are in a drought resisting condition. Those flourishing in September are: *Eremocarpus*, *Sphaerostigma*, *Eriogonum*. The rest of the plants that made such a showing in the spring appear dead but still remain rooted for next season's growth. The leaves and stems of those growing are grayish in color and largely tomentose, a condition peculiar to the drought resisting plants of the dunes. The leaves of the *Eriogonum* are more revolute than in the spring, thereby reducing the synthetic and transpiring surface.

New dune regions where the above plants have not grown show the order of succession to be as given above. In evidence of this the fact may be stated that the owner of the sand spit connecting the mainland with Coronado near San Diego, California, sowed seeds of *Abronia umbellata* and *Gaertneria* on the barren spit and after two years all the plants that occur on the dunes are present in the same relations as have been given in the quadrats above.

ON THE DENSITY OF THE CELL SAP IN SOME DESERT PLANTS

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It is now well known largely because of the work of Fitting[1] that many of the longer lived desert plants may have a cell sap of great density. There also appears to be a direct relation between aridity of the habitat, or of the conditions surrounding the individual, and the osmotic power developed. Thus far the researches have apparently been limited to observations on the subaerial parts, in the present note, however, the results of a few tests on the roots as well as on the shoots of the same individual will be presented.

The plants studied in the present connection are one species with a water balance and two species of sclerophylls. The succulent is *Opuntia discata*, native on the domain of the Desert Laboratory, and one of the non-succulent species, *Fouquieria splendens*, is also endemic here. The third species, however, *Peganum harmala*, occurs in southern Algeria mainly along the flood-plains of the oueds or other situations where there is comparatively ample depth of soil. The *Opuntia* and *Fouquieria* are sufficiently well-known not to call for a special description, but it may be well, in a few words, to characterize *Peganum*. This species, related to *Covillea tridentata* of the American deserts, is a half shrub, with perennial subterannean parts. The shoots are 50 cm., more or less, in length, and, when growing under relatively favorable conditions as regards water supply, they bear dissected leaves which are comparatively large as well as abundant. In short, the species presents rather the appearance of a mesophyte than of a successful desert perennial.

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[1] Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen. H. Fitting. Zeitsch: f. Bonanik. **3**: 209. 1911.

The three species referred to were grown for experimental purposes in the glass house of the Desert Laboratory. *Opuntia* had been in the house for over one year and had been given water frequently. The specimens of *Fouquieria*, transplanted young plants, had also been in the glass house for several months. They were growing in glass tubes of different sizes, and, in order to bring about the formation of leaves, *Fouquieria* also was given water in fairly large amount. The specimens of *Peganum*, growing in glass tubes also, were raised from seed which the writer collected in southern Algeria in 1910–1911. At the time of the tests here reported the seedlings were about eight months old. The treatment of *Peganum* was somewhat different from that of the other species in that as little water was given as possible consistent with appreciable growth. For this reason the conditions of growth of this form may have approached, or possibly equaled, the aridity to which the species is subject in the proper habitat.

The general method employed in determining the approximate density of the cell sap of the plants used was to strip portions of the epidermis quickly from the leaves and plunge them at once into KNO_3 solutions of different densities. In case of the roots the procedure was of necessity somewhat different. The entire root-systems were washed out of the soil by the KNO_3 solution to be used in this particular test. This method, although apparently necessary, sharply restricted the number of tests. In both root and shoot the effects of the plasmolyzing solution were looked for in the epidermal cells. In all tests the temperature of the solutions was about 25°C.

Opuntia discata

In the latter part of May, when the tests were made, the specimens of *O. discata*, which were growing in soil beds of the glass house, were in leaf. The leaves of the species are ephemeral and of a surprisingly delicate structure. They wilt and fall away with the end of abundant moisture, as, in nature, at the close of the summer rains.

In a 0.25 N KNO_3 solution the leaves after ten minutes' immersion showed an occasional plasmolyzed epidermal cell.

A solution twice as strong, 0.5 N KNO_3 effected plasmolysis of all of the epidermal cells within ten minutes. This result accords very well with those of Livingston[2] who found plasmolysis of the epidermal cells of several cacti to take place in a 0.12 to 0.5 N KNO_3 solution.

Fouquieria splendens

The *Fouquieria* in the glass house was in full leaf. This species has the habit of forming leaves as a direct response to an improvement of the water relations. The leaves are retained as long as the water is sufficient in amount, but they wither and fall away with the return of drought. For this reason it is not feasible, as was done with *Peganum*, to attempt to increase the density of the cell sap directly through a limitation of the water supply.

In the test of the density of the cell sap the epidermis was stripped from the leaves and was plunged immediately into KNO_3 solutions of different strengths. Plasmolysis of the epidermal cells was seen to take place slowly in a 0.5 N KNO_3 solution, and after having been in the solution ten minutes all epidermal cells were plasmolyzed. The epidermal cells of young roots of the same plants, in a solution of the same density, plasmolyzed very quickly. It was concluded from the response of the cells of the roots that plasmolysis might have occurred in a less dense medium. The limitation of the material on hand at the time of the tests, however, did not permit further study of this point.

Peganum harmala

The specimens of *Peganum* employed in the tests were growing in glass tubes. The shoots were about 2 cm. long and bore relatively small leaves. The roots penetrated about 35 cm.

Portions of the leaves, mainly stripped epidermis, were placed in a normal solution of KNO_3 and after a short time, about ten minutes, showed plasmolysis of the epidermal cells—which had taken place very slowly. Tested in less dense KNO_3 solutions,

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[2] The relation of desert plants to soil moisture and to evaporation. Carnegie Institution of Washington. Publication No. 50. 1906.

plasmolysis of these cells did not occur. The epidermal cells of the young roots did not plasmolyze in 0.5 N KNO_3 solution, but a stronger solution, 0.75 N, brought this about.

On the following day the tests were repeated. At this time only occasional epidermal cells of the leaves were plasmolyzed with a normal solution of the salt, but plasmolysis of all of the epidermal cells was effected in a 1.5 N KNO_3 solution. The temperature of the solutions used on the two days was the same. The epidermal cells of the roots, on the other hand, were plasmolyzed in a 0.5 N solution. No explanation is attempted of the divergency of results with *Peganum.*

All of the material available was examined and, so far as possible, under parallel conditions. The results show that in the same individual cell sap of the roots is less dense, in the last instance much less dense, than it is in the shoots. The general result shows a somewhat less dense cell sap than Fitting found for the same species at Biskra. For example, specimens of *Peganum* from the Sahara showed the following reactions: An occasional epidermal cell on the upper side of the leaves was plasmolyzed in a 1.2 GM KNO_3 solution, while all of the cells of the epidermis of the upper portion of the leaf, anda few of the palisade cells of the leaf, were plasmolyzed in a 2 GM KNO_3 solution. Specimens from cultivated lands, at the moment not tilled, were affected by solutions varying from 0.7 to 0.9 GM KNO_3. Specimens from the dunes, on the other hand, had a somewhat heavier cell sap, as it required solutions varying from 1 to 1.2 GM KNO_3 to effect plasmolysis of the epidermal leaf cells.

A SUMMER'S RECORD OF EVAPORATION AND PRECIPITATION IN LANCASTER COUNTY, PENNSYLVANIA

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In the course of some experimental work in Martic Forge, Lancaster County, Pennsylvania, records were kept of the rainfall and evaporation during the growing season of 1913. The experimental plots where the work was done were in a chestnut orchard situated on the top of a rocky hill a little over 500 feet above sea-level, about 3 miles north of the Susquehanna River.

The rainfall was measured by means of a standard rain-gauge, the amount of precipitation being recorded after each rainfall. The evaporation records were made by means of the porous clay cups used by Livingston.[1] Six cups were used at a time in the plots, two of them always being installed in the same neighborhood. These were swung between the orchard trees by cords so as to be on a level with the center of the leafy crowns. The bottles to which the cups are attached were held by nets tied to the cords stretched between the trees. They swung in the wind with the branches, but were able to weather safely all the storms, although some of them were very severe. The cups were changed and restandardized during the season.

The evaporation records were measured in cubic centimeters, the rainfall in inches. In order to compare the two sets of records the cubic centimeters of evaporation are changed to centimeters of depth. The reductions are based on figures given by Livingston for this purpose.[2] For the same purpose of comparison the weekly averages of evaporation and rainfall are given in table 1, which was compiled by Mr. H. L. Van Buren.

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[1] Plant World **13**: 111, 1910.

[2] Plant World **14**: 214. 1911.

TABLE 1.

	MEAN WEEKLY EVAPORATION		MEAN WEEKLY RAINFALL	
	cc.	*cm.*	*cm.*	*inches*
April 22–27 inclusive	235	3.33		
April 28–May 4	220	3.13	6.1	2.4
May 5–11	201	2.84		
May 12–18	152	2.15	2.15	0.85
May 19–25	93	1.32	7.65	3.02
May 26–June 1	123	1.74	1.75	0.69
June 2–8	182	2.74		
June 9–15	204	2.89		
June 16–22	211	2.98	0.825	0.325
June 23–29	77	1.09	1.6	0.63
June 30–July 6	170	2.41	5.0	1.97
July 7–13	166	2.35	2.54	1.0
July 14–20	181	2.56	0.33	0.13
July 21–27	184	2.61		
July 28–August 3	170	2.41	6.8	2.68
August 4–10	179	2.54	6.35	2.5
August 11–17	95	1.34		
August 18–24	121	1.72	0.43	0.17
August 25–31	138	1.96	1.19	0.47
September 1–7	96	1.36	1.7	0.67
September 8–14	140	1.98	0.23	0.09
September 15–21	69	0.97	6.5	2.56
September 22–28	118	1.68		
September 29–October 5	97	1.38	4.15	1.63
October 6–12	41	0.58	1.7	0.67
October 13–19	147	2.07	2.56	1.05
October 20–26	44	0.62	3.25	1.19
October 27–31	98	1.39		
Totals		56.14	62.8	24.7

According to these figures, the average weekly evaporation is about 2. cm., the weekly precipitation 2.24 cm. During the year the total amount of rainfall was about 41½ inches. The hill sheds a great deal of this water. Twice in the period from April to November the meadows of the little valley draining the hill were flooded.

Between April 28 and 30, the buds on the chestnuts showed green leaves; throughout October the leaves yellowed and dropped off. These records, therefore, about cover the growing season of the chestnut in this region. It will be noticed that there was greater evaporation in the spring of the year than at any other season.

The hill was covered at the time of the American Revolution with a mixed growth of conifers and deciduous trees; a large percentage of the latter chestnut. The present orchard was grafted on the third generation of chestnuts since that time. At present a young, dense growth of coniferous and deciduous trees is appearing on the hill.

Judging by the growth, these climatic conditions appear to be nearly the optimum for deciduous trees of the temperate zone, especially for the chestnut tree.

BOOKS AND CURRENT LITERATURE

Influence of Humidity and Illumination on Transpiration.—Sir Francis Darwin[1] contributes two papers to the current volume of the Proceedings of the Royal Society, in which he emphasizes the importance of the relations holding between the transpiration rate from leaves and the relative humidity and light conditions of the surroundings. To avoid the influence of stomatal movement the stomatal surfaces of the leaves are thoroughly coated with cocoa-butter or vaseline, and knife incisions are then made through the leaf lamina, between the main lateral veins and parallel to these. These incisions of course put the external air into direct connection with the internal atmosphere of the leaf, in a manner comparable to that in which open stomata effect the same connection. Since the incisions do not open and close, as do the stomatal pores, with changes in the environmental complex, leaves so treated may be subjected to various kinds of conditions without danger that stomatal movements may seriously influence the rate of water loss. Thus, the most important varying internal condition is rendered approximately constant and the direct effects of external conditions are unmasked.

In the first paper the author presents the results of some studies of the relation of relative humidity to the magnitude of the transpiration rate and finds, in most cases, that this relation is actually a linear one, as was to be inferred from the physics of the conditions involved. In some cases there was a lag apparent, so that the experimental graph becomes a curve instead of an oblique straight line, but the simple linear relation appears to be usual, at least in the cases recorded. Darwin does not discuss the nature of this relation more in detail, but it is clear from his graphs that the straight line representing the relation in question does not vary far from the position giving it an angle of 45 degrees with the horizontal. The temperature varied but little during the experiments and is not seriously discussed. It is apparent from the general consistency of the results that the air currents and the form of the vapor blanket about the leaves must have been sensibly uniform in the different tests. If this had not been the case it would not be possible to bring out a definite relation between rate of transpirational water loss and relative

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[1] Darwin, F., On a method of studying transpiration. Proc. Roy. Soc. London B **87**: 269–80. 1914. Darwin, F., The effect of light on the transpiration of leaves. Proc. Roy. Soc. London B **87**: 281–99. 1914.

humidity, but in neither of these papers does the author appear to consider the importance of this consideration, which has been so clearly emphasized by Renner.[2] The external condition determining the rate of water loss from leaves is of course (aside from the intensity of impinging radiant energy) not the relative humidity of the air at all, but its *evaporating power* as has been repeatedly emphasized in the atmometric studies of the reviewer.[3] Only when the air currents and the radiant energy influx are maintained constant can relative humidity determine the rate of transpiration from a given leaf in a given condition.

If the rectilinear graph here discussed be produced downward and to the left it furnishes, where it intersects the axis of ordinates, an hypothetical value for the transpiration rate corresponding to 100 per cent of humidity, and this value, as has long been known from other sources, is always greater than zero. In other words, the line in question passes the y axis above the origin. By continuing the line still farther it finally cuts the horizontal axis at a point where the hypothetical humidity is about 105 per cent. This means, as Darwin well points out, that the vapor tension of the leaf is somewhat higher than that of a saturated atmosphere. Quantitatively, the vapor tension of the leaf is about what it should be if the leaf temperature were 0.8°C. higher than that of the surrounding air. Darwin concludes that such a higher degree of temperature may be supposed to be actually produced in the leaves of his experiments, through respiration, but it does not seem to the reviewer that such a supposition is at all necessary, for the vapor tension of the leaf as an evaporating object is determined by the temperature of the evaporating surface films rather than by the temperature of the entire leaf. Of course the incisions in the leaf may be expected to increase the rate of liberation of heat, by respiration, in their immediate neighborhood at least. But, in any case, is it not possible for heat set free by chemical processes or received by radiation to pass directly into the latent form, without any corresponding rise in the temperature of the leaf? What amounts to the same thing, may not the increased evaporation brought about by chemical processes cool the evaporating surfaces sufficiently so that a higher temperature may not be produced although kinetic energy is being liberated in the tissues? It seems safe to conclude that the coated and incised leaves give off water vapor *as though*

[2] Renner, O., Beiträge zur Physik der Transpiration. Flora **100**: 541–547. 1910. Renner, O., Zur Physik der Transpiration II. Ber. Deutsch. Bot. Ges. **30**: 572–5. 1912.

[3] Livingston, B. E., The resistance offered by leaves to transpirational water loss. Plant World **16**: 1–35. 1913.

they were water masses at a temperature about one degree higher than that of the surrounding air. Since the experiments were carried out at temperatures within about a degree of 15°C., it follows that these leaves should have had a water vapor tension surpassing that of liquid water similarly exposed, by somewhat less than 1 mm. of mercury (see tables of vapor tension of water at different temperatures).

The relation which Darwin found may be generally expressed by the equation $x = y + 5$ where x is relative humidity in percentage and y is a number proportional to the transpiration rate. It seems to the reviewer that this mathematical statement is hardly complex enough to necessitate the use of graphs at all in the discussion, though of course the graphs give a ready means of picturing the general extent of the departure of experimental from calculated rates of water loss.

In the second paper, Darwin presents measurements which seem to show that the lower ranges of light intensity (between darkness and strong diffuse light) affect the transpiration rate in a marked way, aside from any possible secondary effect brought about through stomatal movement; greased and incised leaves give off appreciably more water in weak light than in darkness. The acceleration due to light is shown to amount, frequently, to more than 50 per cent of the rate in darkness. No place is given to a discussion of the possible part here played by variations in air currents about the leaves, it being tacitly assumed that these are the same for both dark and light exposures. As to the causal conditions controlling the generally increased transpiration in diffuse light, Darwin writes, "we may either accept the view of Wiesner, viz., that in light the chloroplasts are warmed by absorption of radiant energy, or we may believe that light produces an increased permeability of the plasmic membrane to water." As has been pointed out above, the first alternative does not demand the supposition that the leaf is sensibly warmed, it is only necessary that some molecules be given greater kinetic energy (to resort to the kinetic picture), and these may escape as vapor without generally raising the temperature of the leaf. It is quite possible that the second alternative may prove to be a consideration worthy of experimentation; it has not been expressed before, so far as the reviewer is aware. Of course an increased permeability of the plasmic membrane to water must almost surely mean simply an increased swelling, with higher water content; for such colloidal membranes transmit water according to their content of this liquid and the more they resemble a simple aqueous layer the more rapidly can water pass through them.

These papers should stimulate further study of the physics of plant transpiration. It should be strongly emphasized that further work ought not to neglect air currents and ought to deal with light of known quality and intensity.—B.E.L.

Mutative Effects of Environic Agencies.—The comparative ease and accuracy with which pure cultures of moulds may be made and maintained and the marked changes which these organisms display under the influence of various factors makes them splendid material for the experimentalist concerned with permanent alterations in hereditary lines. Some notice has already been given to the results of Miss Elizabeth Schiemann who obtained atypic forms of *Aspergillus* by adding various substances to the nutritive media and obtained departures from the customary types by the use of unusually high temperatures (Plant World **16**: 123, 1913).

Dr. A. F. Blakeslee has recently reported upon preliminary trials including a large number of cultures of *Penicillium* in a series of nutrient media numbering over three hundred combinations, and in the examination of 22,000 colonies he found 25 or 30 aberrants. He says of these "Some of these variants are surely temporary conditions, for they eventually tend to revert to the normal type. Others may be more permanent but have not been sufficiently investigated. All, however tend, partially at least, to reproduce the new characters and some have for several sporangial generations kept their characters in gross cultures during the few months it has been possible to propagate them. Many of them would undoubtedly be described as distinct species by specialists in the group" (Ann. Rep. of the Director, Dept. of Exper. Evol. Carnegie Institution of Wash. for 1913, pp. 103 and 104).

Blochwitz has recently contributed further to our knowledge of the possibilities of the inductive action of external forces by some results concerning the origin of new species of *Aspergillus* by unusually intense light exposures. The effects were cumulative and the most striking feature was the gradual elongation of the conidiophores which finally increased to 10 mm. in length as contrasted with the average normal of 1 to 2 mm. The brief notice of this work (Berichte d. deut. bot. Ges. **32**: Hft 2. 100.1914) does not make it clear as to the permanence of the new forms or as to their behavior in illumination of intensity comparable to ordinary daylight. Some care was taken however to distinguish between light and heat effects.—D.T.M.

Sandhills of Nebraska.—An ecological study of the vegetation of the sandhill region of northern and northwestern Nebraska has been made by Pool.[1] The physiognomy and floristic content of the formations and associations are described, and much information is given regarding the habitats and ecological behavior of characteristic species. The prairie grass and short grass formations are given the most extended treatment, as their areal dominance deserves. The rôle of shrubs and trees in the vegetation of the region is also given extended treatment. Among the most striking phenomena described are the "pockets" of *Celtis occidentalis*, *Symphoricarpos occidentalis* and other species in the midst of the grassland, the occurrence of the northern *Betula papyrifera* in narrow ravines, and the extension of the western yellow pine along the northern boundary of the state on outcropping rocks of the Loup Fork series, and their derived soils, to a point at which it grows intermixed with eastern tree species. The physical features of the region and the chief soil and climatic factors are briefly treated. The illustrations are very effective aids to the descriptive text.

A few years ago Pool's paper would have been considered an eminently complete and satisfactory treatment of the sandhill region, but it is extremely gratifying to note that he alludes to it as a preliminary paper and promises a further study of the region, especially with respect to the operation of environmental conditions.—F.S.

FLORA OF WASHINGTON AND IDAHO.—Piper and Beattie have published a flora of southeastern Washington,[2] embracing an area of about 7500 square miles lying south of Spokane and east of Walla Walla, and an adjacent strip of Idaho approximately 2000 square miles in size. This region comprises sage-brush plains with *Artemisia* and *Chrysothamnus*, bunch-grass lands with *Agropyron spicatum* and *Poa sandbergii*, yellow pine forests and mountain areas rising to 6000 feet, with *Abies grandis*, *Pseudotsuga mucronata* and *Abies lasiocarpa*. The flora accompanying this range of vegetational conditions numbers 1139 species of ferns and flowering plants. There are keys to families, genera and species, as well as descriptions of the species. The taxonomic treatment of a small area affords an excellent opportunity for making specific statements regarding the habitats and local distribution of the plants concerned. The authors of this flora have, nevertheless, made it scarcely more satisfactory in this particular than are the floras of large areas.—F.S.

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[1] Pool, Raymond J., A Study of the Vegetation of the Sandhills of Nebraska. Minn. Bot. Studies **4**: 189–312, 30 pls., 15 figs. in text. 1914.

[2] Piper, Charles V. and Beattie, R. Kent, Flora of Southeastern Washington and Adjacent Idaho. 296 pp., with map. Lancaster, Pa. 1914. ($1.20; sold by The Auditor, State College of Washington, Pullman.)

NOTES AND COMMENT

Dr. O. D. Von Engeln, of Cornell University, has contributed two papers to the Bulletin of the American Geographical Society (April and May, 1914) on the effects of continental glaciation on agriculture. The modification of relief and deposition of soil which resulted from the glaciation of the northeastern United States are shown to have been of marked importance in increasing the agricultural value of that region. Only in New England has glaciation left the surface bare of soil deposits and strewn with boulders, whereas from New York to Wisconsin the glaciated area possesses a diversity of valuable soils and also an abundance of lakes which are often of horticultural value in lessening the amplitude of temperature changes.

Professor Emil Hatschek has collected a series of articles which he published in The Chemical World and issued them as a small book entitled An Introduction to the Physics and Chemistry of Colloids (Philadelphia, Blakiston, 1913). Although primarily addressed to chemists, the book will be a useful one to biologists who wish to acquaint themselves with the recent results in a field of work which is of increasing importance for the advance of general physiology. The several chapters discuss viscosity, adsorption, surface tension, emulsions, emulsoids, suspensoids and gels.

The fourth annual meeting of the Biological Society of the Pacific Coast was held on May 22 in the Science Hall of the University of Washington at Seattle. The botanical papers presented were: The Present Trend of Botany, by Professor T. C. Frye; The Life History of a new Pear and Quince Rust, by Professor H. S. Jackson; *Coryneum* and its Ascosporic Stage, by Professor J. G. Hall; and The Influence of Preceding Seasons on the Growth of the Yellow Pine, by Professor J. E. Kirkwood.

SPECIALIZATION IN VEGETATION AND IN ENVIRONMENT IN CALIFORNIA[1]

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To a person who is best acquainted with a country where the topography is monotonous, the climate the same over the region, and the species of general occurrence, a visit to California, where the opposite conditions largely obtain, must reveal many things which are at once novel and of much interest. It will be found, in short, that, in the state, there is a climate and a physiography, both very diverse, and, in harmony with this condition, a flora often exceedingly specialized.

The climate of California is a mild temperate one, due to a variety of causes, and it is modified in various ways by local conditions. The southern boundary of the state lies just below latitude 32°, and the northern boundary is 10° north of this. With so low a latitude, and with its situation on the western edge of the continent, the state is subject to drying trade winds in summer, and to the moisture laden prevailing westerlies in winter. As a result, the dry season is long, and, especially in the southern portion of the state, semi-desert conditions may prevail. Along the coast, however, due in part to a cold off-shore current, heavy fogs mitigate in a marked manner the severities of the summer drought as well as the summer heat.

In addition to the periodicity of the rainfall, the amount of rain may vary from year to year to a considerable extent, and, as a rule, where the mean annual rainfall is the least, the irregularity in precipitation is greatest. This feature, the variation in the amount of moisture available to the plants, is of undoubted great importance in shaping the character of the flora of the state. That

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[1] Given before the International Phytogeographic Excursion at Carmel, California, September, 1913.

this environmental characteristic is of moment will appear at once when it is recalled that California may be said to be the threshold to the desert, and, as for that, that much of the surface of the state is, in fact, as arid as one can find anywhere. We must bear in mind, therefore, that the capital response of the vegetation in much of this great state is in association with the water relation. As to the relative irregularity in the rainfall, the following ratios of lowest to highest annual precipitation, based on the Weather Bureau reports, are very striking. We find a variation of 1 to to 4.3 at Fresno, in the Great Valley; a variation of 1 to 2.5 at Eureka, on the northern coast. At Monterey the ratio is 1 to 4. At Paso Robles, in the upper Salinas Valley, it is 1 to 5.5. Finally at Indio, in the Colorado desert, the ratios is 1 to 26. Thus, in a large portion of the state, perennials must experience, during a not inconsiderable part of their life time, relatively severe droughts, and accordingly we see the xerophytic element strongly emphasized.

SPECIALIZATION IN TOPOGRAPHY

As we view the state as a whole, we see that the greatest modifying influences of the general climatic conditions are to be sought in the mountain masses, which attain an extreme height of 14,500 feet in the Sierras, and in the other ranges an altitude of 9000 feet, or less. In the mountains the temperature decreases and the rainfall increases with rise in altitude, and these changes, when not subject to the influence of local conditions, are fairly constant. The mountains, further, operate to determine the character of the climate of adjacent valleys. However, there are physiographic features other than the mountains which are of importance in bringing about specialized climatic conditions. A glance at the topographical map shows that this must be true from the state's physiographic complexity. Thus, there are isolated mountains, or mountain groups. There are valleys separated from other valleys by barrier ridges which have aspects in every direction, and which are inland, or by the sea. There are broad country-sides swept by the winds, which build up as well as modify and destroy. There are detrital slopes of varying texture and varying size and aspect, and in the larger valleys there are broad alluvial fans. There is a coast indented to some extent by bays, and made irregular by bold capes, promontories, or jutting peninsulas, all of which may have different, and possibly peculiar exposures to the winds, to the sun, and to the fogs. In brief the surface of the state is moulded and modified in numberless ways and the general result of this great diversity, from the present point of view, is to increase the specialization of the environment mainly, it may be, through its influence on the climate.

THE FLORAL PROVINCES

California is naturally divisible into a few provinces, which may be briefly characterized. These comprise in general the mountains the valleys, and the desert basins.

The mountainous provinces include the Sierra Nevadas, the Coast Ranges, and those of the southern portion of the state, of which the San Bernadinos and the San Jacintos are possibly, the most important,

The Sierras constitute an immense uplift 450 miles, or over, in length. Here the mean annual temperatures range according to altitude from 40° to 55°, or 60° F., and the mean rainfall 35 to 75 inches. In certain altitudes snow has been recorded in ten months of the year.

The mountains bordering on the sea extend from the northern boundary of the state for about two-thirds of the state's length. They are naturally divided into two sections, namely those to the north of the Golden Gate and those to the south. The climate of the northern mountains is colder and with a greater precipitation than those of the south. The rainfall at Eureka, on the North Coast, varies between 35.9 and 62.2 inches, and the mean temperature is 55° F. Taking a coast station to the south of San Francisco Bay, such as San Luis Obispo, we find that the annual precipitation varies between 16.9 and 28.1 inches. The temperature ranges between 26° and 106°F. At Carmel the rainfall varies between 13 and 28 inches as the extremes, and the usual temperature extremes range from 40° to 75°F. In the midst of the mountains, however, as at Boulder Creek, in the Big Basin, the amount of the annual precipitation may reach 95.76 inches, although the mean is 55.81 inches.

A very important climatic feature of the coast regions as a whole is the summer fog, although there appear to be little data on this subject. Fogs may cover the shore for days at a time and reach inland so far as 20 miles. They operate at once to lessen the evaporation and also, in forests, as will be mentioned again, to increase the precipitation through condensation by the trees.

The mountains of the southern portion of the state have, for parallel altitudes, less rainfall and higher temperatures than the other mountain groups mentioned. Thus with high temperatures, little rain, and no fogs, the southern mountains are relatively arid. Hence, here we find a large development of xerophytic perennials, and especially extensive areas covered with dwarf-forests, the chaparral.

THE VALLEYS

A second extensive physiographic province is made up of the larger valleys, which, holding many features in common, may, for convenience, be considered together.

The most important valley is the vast interior one, constituted by the Sacramento valley to the north and the San Joaquin valley, to the south. This, the Great Valley, is relatively arid. Nearer the coast, and separated from it as well as from the Great Valley by portions of the coast ranges, are also several important valleys. In these the climate, although not so dry as in the Great Valley, is nevertheless surprisingly arid. For example at Gilroy, in the Santa Clara valley, the precipitation extremes are 7.98 and 38.67 inches, which may be taken as being fairly representative of the rainfall of such valleys. One of the most striking features of the rainfall of the valleys, particularly those near the coast, is the great variation in amount which accompanies a relatively small distance between stations. Thus a difference of 1 to 2 may accompany a horizontal difference of stations not exceeding 4 miles. This feature is always in relation to the mountains, as might be supposed. Another characteristic of the valleys, particularly of such as are south of San Francisco bay, is the air movements. For example, in the morning the wind blows north, or down the valleys, which should probably be considered as cold air drainage from higher altitudes. But in the afternoons the prevailing westerlies, being deflected from their course, blow up the valleys with much force and with a decidedly dessicating effect. In certain instances, as, for example, near the head of the Salinas valley on the route to Los Angeles, the wind action is so effective that the general features of the topography are determined by it.

Another feature of the valleys may also be mentioned, although however important, it is at present but imperfectly known. I refer to the conditions of soil moisture. So far as superficial observations give an idea of such conditions, it would appear that the moisture utilized by shrubs and trees in the valleys lies either 3 to 6 feet from the surface or at a considerably greater depth, as for example 12 feet or more. In the first instance it is clearly derived directly from the rains, or from superficial runoff from higher ground, and in the second it owes its presence to a more deeply placed water table. The importance of a water table in semi-arid, or sub-arid regions (as many of the valleys may be considered to be), is to be found in connection with the presence of a forest, or of trees, of a more or less mesophytic nature. This relation with the environment will be referred to in more detail below.

THE DESERTS

To the south of the Sierra Nevadas and separated from the ocean by high mountains, lie two of the most arid areas of the United States, the Mojave and the Colorado deserts. The surface of these regions comprises about 14 % of the surface of the state. As is well known the leading climatic feature of the deserts are the low precipitation, which is also irregular in amount, the high summer temperatures, and the high rate of evaporation. The annual rainfall for several stations lies between 2.46 and 3.61 inches, all of which occurs in winter. Under so extremely arid conditions the vegetation partakes of a nature of great specialization, as is very well known.

GEOGRAPHICAL DISTRIBUTION OF THE FLORA

I have insisted somewhat upon the physiographic and the climatic features of California because some appreciation of these physical factors should assist in forming a proper background for the interpretation of many features of its flora. We may turn now and consider for a moment the geographical distribution of the vegetation of the state.

We have grouped the physiographic provinces, which are also climatic provinces, into mountains, valleys, and deserts. These regions, however, are commonly subdivided into life zones, which in certain ways is a convenience. In the mountains the life zones, each having characteristic rainfall and temperature, range from the Transition, through the Canadian and the Hudsonian to the Boreal. The annual precipitation is from 25 to 75 inches, as means, but it may greatly exceed this, as for example at Bowman's Dam, in the Sierras, 135 inches of rain has been recorded, and this does not take into account snow fall. The foothills, greater valleys, and the deserts are included in the Sonoran zone, and the mean precipitation is 15 inches or less. Since the Sonoran life zone may comprise the greatest part of the surface of California a xerophytic stamp to its flora, as remarked above, is to be expected.

In characterizing the life zones, it will be sufficient for present purposes, to mention categorically certain representative arboreal species. Of the Hudsonian, *Pinus albicaulis* is typical; of the Canadian, *Pinus monticola* and *P. jeffreyi;* and of the Transition, *Pinus lambertiana* and *P. ponderosa.* In the Sierras, the Big Tree occurs in the Transition, and in the coast ranges the redwood is in the same zone.

ENDEMIC SPECIES

The general outline of the features of the geographical distribution of plants in California does not make a special point of the large number of endemic species, some of which have a very limited range. This constitutes a very interesting phase of the flora of the state. For the present purpose it will suffice to mention some of the best known species of restricted distribution.

The Big Tree, *Sequoia gigantea*, is found only in the Sierras, where it occurs in isolated groves on western slopes over an area about 250 miles in length. The other species of the genus, *Sequoia sempervirens*, is found only in the mountains near the coast, north of San Luis Obispo County, and it covers an area about 450 miles in length and not over 20 miles in width. *Pinus muricata* is a coast species, also, but recurs outside of the state in Lower California. *Abies venusta*, the Santa Lucia fir, is found in the Santa Lucia mountains, where it grows in isolated groves over an area about 45 miles in length. *Pinus radiata*, the Monterey pine, occurs to the north and to the south of Monterey bay. *Pinus torreyana* is found near San Diego and on Santa Rosa island. *Cupressus goveniana* occupies an area about 200 yards long on the Monterey peninsula, but a varietal form occurs on the pine barrens 200 miles north. Finally, *Cupressus macrocarpa* is

Fig. 1. The Douglas oak, *Quercus douglasii*, growing on a high and arid bluff overlooking Putah Creek, in the Vaca Mountains. Here the structure of the substratum, as well as its height above the stream, is such as to preclude the possibility of the attainment of the water table by the plant's roots.

limited to Point Cypress and to Point Lobos near Carmel. There are, in addition, numerous other instances of limited distribution of the species in the state, which would be pointless to mention.

While the general distribution of these species may be accounted for in the surface and climatic changes which have gone on in the past geologic time, the actual limitations in distribution can possibly be explained in another manner, namely, in the specialization of physiography and of climate at the present day. Taking as an example of such specialization the Monterey peninsula we note the following characteristics which set apart this from the adjacent areas. The peninsula, about 4 miles square, is set out into the ocean so that it is exposed to the full sweep of the ocean winds, it is dominated by the temperature of the ocean, the evaporation is the minimum amount, the fogs are frequent, especially in summer. As opposed to this condition we find back from the shore, 2 miles or less, conditions surprisingly arid, and here the influence of the sea is not so immediate as on the peninsula. The peninsula is in effect a biologic island, with barriers on either side, but possessing within itself suitable conditions for the reproduction development, and survival of several endemic species. Analogous physiographic and climatic conditions obtain in many other localities, as already suggested, and one other instance of specialization, this time climatic, and its effect on the distribution of a species, will be referred to directly.

ADJUSTMENTS TO THE ENVIRONMENT

I wish now to present briefly a few instances where the relation between the species and the impinging environment is a fairly intimate one. It happens, also, that the point of each turns on the reaction of the species to the moisture relation, although in the first instance to be given the scene is laid in the Transition rather than in the Sonoran, the more arid zone.

The fitness of the conifers in general to life in high altitudes, where the evaporation rate is great and the absorption of water is retarded by a low temperature, and where the total heat received is relatively small in amount, is well known. Of the conifers, however, the redwood, *Sequoia sempervirens,* at low altitudes where it is native, shows a very special reaction to its environment which is characteristic of, if not peculiar to the species. As is well known, this species and others of the same genus were circumpolar in distribution in former geologic ages. At the close of the last ice age the species was marooned on the north coast mountains of California where today it enjoys the dampness and the fogs to which possibly its remote ancestors were accustomed.

Fig. 2. The Valley oak, *Quercus lobata,* by the side of Putah Creek. This specimen, and others in the vicinity of the river, are advantageously placed with respect to the perennial ground water which the deeply penetrating roots attain.

It is a moisture-loving species and its distribution, of a consequence, is limited by the breadth of the moisture belt, which in this instance is represented by the landward penetration of the ocean fogs. Where an adequate summer rain is wanting the dependence of the redwood on the fog is not difficult to understand. The feathery foliage, of which any individual carries an inconceivably large amount, is well adapted to condense the fog and in fact does so to so good purpose that a redwood grove in time of fog is as damp as a tropical forest. Water condenses on the leaves and twigs and drops from the branches incessantly, wetting the ground beneath. Moreover, the fogs operate in an indirect manner favoring the conservation of moisture by lowering the evaporation rate during the dry season. Contributory evidence that the fogs are of direct necessity is to be found in the southern limits of the species. The southernmost extensive growth of the redwood is in the Big Basin region. It is wholly lacking at Monterey and reappears again only in seaward facing valleys beginning near Carmel. The rainfall in the Big Basin averages 55 inches, that at Monterey about 16 inches. To the south of Carmel, gulches protected by their position from drying summer winds, are often filled with heavy fogs. In spite of the low rainfall here, the redwood is again found, either on the valley floors or on the southern side, with northern aspect, in moderate amount.

The arboreal species of the interior, especially of the foothills and the valleys, show also interesting adjustments to the environmental conditions under which they are placed. I refer more especially to the oaks which constitute a very important feature of the Californian forest flora. Three species only will be mentioned in this connection, namely, *Quercus agrifolia, Q. douglasii,* and *Q. lobata,* The first and last named species constitute the bulk of the forests of the coast valleys, while the Douglas oak frequents the foothills. *Quercus agrifolia,* the Coast Live Oak, retains its leaves until they are replaced by new ones each spring, but the other species mentioned shed theirs with the approach of the winter season.

The oaks in the valleys, as is well known, are widely scattered, forming a very open stand. This recalls at once the analogous condition to be seen in more arid regions where the shrubs are isolated the one from the other. In the last instance it has been learned that the root-systems of such species are widely extended and usually reach from one individual to another so that competition among them for soil moisture can, and probably does exist.

The distribution, therefore, is but an outward expression of the scarcity of water. With such facts in mind, it was suspected that there might be variation in the roots of the trees of the coast valleys in a similar direction which might account for the phenomena of species distribution already noted. Further than this, in the desert, where the shrubs are widely separated as already described, it is found that the water table is so deep as to be beyond the possibility of direct use to the plants of the areas in question. Therefore, from analogy, the relation of the tree distribution in the coast valleys to depth of perennial water was also a feature to be especially examined. The leading results of a preliminary survey can be briefly stated. The root system of *Quercus douglasii*, and the typical distribution of the species, will first be mentioned. As indicated by figure 1, as already stated, this species inhabits foothills which may be unusually arid. Not only is the water table at a great depth, but the denizens of such localities are subject to the drying influences of hot summers and are exposed to desiccating winds, as no other large species of the genus are. An examination of the roots of several specimens growing in widely separated localities shows that there is an unusually large development of superficial roots, which for the most part lie within 3 feet and often just beneath the surface. These roots are of large diameter also and serve as mechanical supports of the plant. The superficial laterals reach outward for a relatively long distance from their place of origin enclosing a large area surrounding the tree. The main root is usually not deeper than 12 feet, although at the crown it is often fairly stout. It seems fair to conclude, both from the character of the root development of the species and the fact that perennial ground water is beyond attainment by the roots, that, like the shrubs of the desert, the Douglas oak has become adjusted so that it depends wholly on the surface waters for its moisture supply.

The Coast Live Oak, *Quercus agrifolia*, together with the Valley Oak, *Q. lobata* make up the most of the open forest of the valleys of the Coast Range. The latter penetrates into the interior and occurs in portions of the Great Valley as well. It has been found[2] that in the latter valley the oaks are confined to

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[2] Jepson, W. L., Sylva of California. Mem. Univ. Cal., vol. 2, 1910.

the alluvial deltas where the soil is a loam, and hence fairly pervious to the rains.

The Coast Live Oak frequently occurs where the depth to the water table is considerable, 35 feet, or over, although it is found also where the perennial water is more shallowly placed. In certain situations, as where gravelly strata intervene between the surface and the water table, it is clear that the roots of this species do not penetrate to the zone of perennial water. A study of the roots of *Q. agrifolia,* in fact, shows that the species has a very strongly developed superficial system, most of the roots being within 3 feet of the surface. In this regard similar to the root-system of the Douglas oak, the roots of the Live Oak, however, are much more numerous and smaller and also very evidently adjusted to acquire practically all of its moisture in mature specimens, from the superficial water derived directly from the rains. Hence, where the rains are scant, or where there is no run-off from higher and adjacent areas, so that the superficial soils are not sufficiently moist throughout the year, the species is wanting.

The story of the Valley Oak, *Q. lobata,* is very different from that of the two species just mentioned. *Quercus lobata* finds its best development where the soil moisture is abundant, particularly where the depth to the perennial water supply is probably not great. Hence it is the Valley Oak by necessity, as it is the Valley Oak *par excellence.* In the coast valleys it appears often in association with the Coast Live Oak, but in the valleys further from the sea it is confined to the vicinity of streams or to other places where the moisture relations are relatively good. Under favorable circumstances this species develops into large trees. For example, one specimen was seen near Clear Lake which had a spread of top which was estimated to be 144 feet.

An examination of the roots of the Valley Oak shows that they have a type of development unlike that of the other oaks already mentioned. There is an especially well developed main root and numerous and large laterals. Both the main root and the laterals are apparently capable of deep penetration, and the laterals may extend widely as well. Therefore, the greatest development of the roots of this species does not occur near the surface of the ground, but on the contrary is relatively or actually deep. The species, therefore, is well adjusted by the characteristic type of root formation to grow where the zone of perennially moist soil can be attained, or where otherwise the conditions of soil moisture, at a considerable depth, are especially good,

Fig. 3. The Live oak, *Quercus agrifolia*, which often occurs where the water table is so deep as to be beyond reach of the roots, so that this species develops an extensive root-system within about 2 feet of the surface. In this situation the "feeding" roots take advantage of the penetration of the rains, or of runoff from higher ground, thus supplementing the more deeply penetrating portion of the root-system, to which such water is in large part not accessible.

It may be remarked that the dual type of root development, as exhibited by the Coast Live Oak, *Q. agrifolia*, and the Douglas Oak are not exceptional among the California trees, although its extent is not as yet known. A similar root type has been seen in the buckeye, *Aesculus californicus,* and in other forms. It may be concluded, therefore, that in regions of a fair but periodic, rainfall, as in California, the root-systems of the leading types of trees exhibit a two-fold habit—they may penetrate fairly deeply and at the same time they may have a large development near the surface of the ground It is probable that the condition of youth is characterized by deeply penetrating main roots, but that as the tree matures the superficial roots are the ones mainly formed. The end result is that the mature plants are adjusted to absorb the most of their water from the superficial soils, while at the same time a certain amount, which may be sufficient to tide them over during the droughts, is taken up from greater depths.

Without following the subject farther it will be quite clear, I suspect, that the fog relations of the redwood and the behavior of the roots of the different species of oaks, all point to this—that the moisture relation is of the first importance. We may say, therefore, that we needs must pay first attention to the moisture relation in seeking a key to explain many of the leading features of the California flora.

The leading idea in this paper can be characterized in a few sentences. It has been shown that the climate of California is a very diverse one and that its diversity is directly associated with the state's great physiographic complexity. Thus, the environment is highly specialized. In association, or possibly conformity, with such specialization the flora is likewise extremely diverse and may be highly specialized, as is exhibited in a number of ways. One of these is shown by the similar stamp put on the flora of areas over which some one environmental character is especially prominent, as, for example, the dwarf forest, or chaparral, which is the leading plant type in the moderately arid regions, especially of the south. Another floral specialization is shown in the limited distribution of many species some of which are restricted to a single locality. And, in yet another manner the response is seen in the individual adjustment to the impinging environment. This occurs in numberless ways, of which instances of the relation of the roots of several species of trees to the soil conditions were cited as examples.

Naturally, no attempt has been made to trace a causal relation between any special response and the environment, which is beyond the scope of this paper. It may be pointed out, however, that often the relation is apparently more accidental than otherwise. For example, the Big Tree represents, as is well known, a survival from earlier geologic times when its forebears had a circumpolar distribution. In such an instance the present day climate evidently closely resembles the climate to which the species was accustomed in those far away epochs. In another manner, however, the relation of climate and of plant may be more significant as leading to diversity of floral types. In brief it is this: Much variation is known to occur among the individuals of a collection of any species. Should the changing individuals be so situated that their environment is peculiar, survival of the type might take place, and the abundance of the new type would depend on several things which need not be discussed here. But the main point is that it would be the fortunate diversity in the environment which would make this possible, and this environmental diversity, as has been repeatedly stated, is precisely the *crux* of the situation, the single feature which looms big among those which occasion floral diversity in the state.

THE SAND DUNES OF COOS BAY, OREGON

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Wherever large areas of sand dunes are found, it is no uncommon sight to see the gradual advance of the dunes over herbaceous or even woody vegetation. In few places, however, is the destruction of forests by sand more impressive than among the dunes of Coos Bay, in southwestern Oregon.

My first view of the Coos Bay dunes was from the deck of the *Breakwater*, a small boat plying between Portland and Marshfield. The boat is locally and more popularly known as the "Corkscrew," possibly because of its habitual motion, and while on later voyages, I had abundant opportunity to pronounce its opprobrious appellation a descriptive one on this my first trip, the sea was mercifully calm, and approaching the entrance to Coos Bay the prominent physiographic features of the region impressed themselves upon my mind. To the south a series of bold headlands covered by forests of fir and spruce, to the north, miles of rolling sand dunes, stretching inland like a desert, with patches of willow and beach plants here and there, and in the distance clumps of trees and even large areas of forests making a last stand against the encroaching dunes.

My resolution to visit this sandy waste was accomplished a few days later, which was the first of several visits to this desolate but interesting tract.

Not alone has the wind and sand produced here an interesting geological phenomenon, but the shifting dunes have induced some unique ecological conditions, such as enclosed meadows formed where the wind has scooped out hollows, down to or below sea level, and which are always moist, even in the driest weather; enclosed lakes or ponds, apparently formed in the same way, or in some instances by the sand cutting off arms of the bay. The water in these ponds is fresh and they as well as their borders and the meadows possess a remarkably rich and interesting flora. *Nymphaea polysepala* is abundant on some of the ponds, while *Salix sitchensis* is to be found on their margins.

The destruction of the forests here by shifting sand is all the more remarkable when it is considered that this is a region of excessive humidity and that the coast is bathed almost continuously by the fogs which are produced when the warm moisture-laden winds strike the cooler land. During August and September I estimated that less than 20% of the time was dry enough, with the wind in the right direction and strong enough, to produce any visible movement of the sand particles.

When the wind is strong from the west, however, on a dry day, the movement of the sand is tremendous, covering a 6-inch log in the lee of a dune in less than an hour, and across the crests of the dunes coming with such force as to be almost unbearable to the uncovered face. Curious etchings are produced on sticks and timbers exposed to this blast, the usual effect being the eventual wearing away of all parts except the knots. On upright sticks, particularly severe wind storms are registered by transverse furrows, which indicated the level of the sand at the time of the storm, as the most effective work of the sand seems to be on or close to the level of the ground.

The forests of this region belong to the Humid Transition type and consist mainly of Douglas fir (*Pseudotsuga taxifolia*), Sitka spruce (*Picea sitchensis*), Port Orford cedar (*Chamaecyparis lawsoniana*), Western Red cedar (*Thuya plicata*), while the Western hemlock (*Tsuga heterophylla*), common inland is rarely seen on the dune sands of either past or recent origin. On the other hand the shore pine (*Pinus contorta*) entirely absent inland, is confined here to dune sand soil, and in some of the older depressions in the dune area, almost pure stands of it are to be found, and everywhere that the sand remains undisturbed for a few years dense thickets of the shore pine spring up. Some of these bear cones while they are still less than 5 feet tall.

Within the dune area the forests exist now only in patches, almost always in depressions, or in "ravines" formed by adjacent dunes, indicating the former level of the ground before the invasion of the dunes. At a former time the forests were apparently much more extensive here, perhaps during a period of greater humidity than the present, when the movement of the sand was reduced to a minimum and the forests had a chance to invade much of this sandy region. This is probably the case because dune sand in the form of hilly ridges is common much farther inland than the sand dunes now extend, and is covered by forests in character similar to those still remaining within the dune area, viz: Douglas fir, Sitka spruce, Shore pine, Port Orford cedar, etc. Nor has the lumbering operations on these inland dune areas caused any renewal of activity on the part of the sand, although it has had considerable effect upon the character of the second growth as compared with the second growth conditions farther inland on clay soils.

Thus one can imagine that this natural phenomenon works in cycles corresponding with the climate and that the present advance of the sand over the forests indicates a gradual decrease in the humidity of the climate within the past century, although some of the trees on the dune sand are easily over two hundred years of age. Certainly the hand of the lumberman has had little if anything to do with the advance of the sand here, for the forest on the dunes proper are too scattering and too poor, compared with others in this region, to tempt the lumberman, and have never been touched. Another possibility in this connection is that the force of the prevailing winds may have varied periodically.

The greatest height is attained by the dunes at a distance of three or four miles inland, where the advance of the dunes is checked by the accumulating height of the sand and by the north branches of Coos Bay, which lie here between the dunes and the mainland. Higher dunes, however, of a former period lie farther inland on the mainland side of the north and south branches of the bay but are now covered by forests or by second growth.

The undergrowth of the forests on the sand dunes is even more impenetrable than that on the mainland, consisting of a larger percent of the more rigid species of shrubs, such as Manzanita (*Arctostaphylos tomentosa*), Ocean spray (*Schizonotus ariaefolius*), Salal (*Gaultheria shallon*), Huckleberry (*Vaccinium ovatum* and *V. parvifolium*), Wax myrtle (*Myrica californica*), Blueberry (*Vaccinium ovalifolium*), Rhododendron (*R. californicum*), Pale laurel (*Kalmia polifolia*), Buckthorn (*Ceanothus thyrsiflorus*) and numerous smaller species such as the Thimbleberry (*Rubus parviflorus*), Menziesia, (*M. ferruginea*), Quinine bush (*Garrya elliptica*), Azalea (*A. occidentalis*), etc.

Around the borders of the ponds these thickets are particularly dense and often lack any overhead shade. The largest pond is nearly a mile in length and contains a rich aquatic and marginal flora, the common species being *Nymphaea polysepala, Juncus oreganus, Alnus oregana, Juncus bufonius, Carex mirata, C. magnifica,* and *C. oederi, Potamogeton natans, Salix sitchensis,* etc.

Fig. 1. Skeletons of a past forest in the foreground. The forest in the background is wedge shaped, with its apex toward the wind. Numerous indentations occur along its sides, due to advancing dunes or to undermining. The forest itself stands on dune sand with a general level of 15 to 25 feet below the surrounding sand.

The advancing crests of the dunes often open up small hollows, exposing the skeletons of a past forest (see fig. 1). Where these hollows are of large size there soon comes into existence a green grassy meadow, which is the home of numerous moist sand-loving plants, such as, *Eleocharis obtusa, Carex pansa, Allotropa virgata, Mimulus* (evidently several species), *Ibidium romanzoffianum, Trifolium fimbriatum, Orthocarpus castilleoides, Hydrastylus brachypus, Hypericum anagalloides, Fragaria chiloensis, Hookera pulchella, Epilobium* sp. *Ranunculus bongardi, Potentilla anserina, Viola adunca, Hosackia parviflora, Ranunculus unalaschensis, Aster douglassii, Lupinus* sp. *Carex hindsii, Lycopodium inundatum, Claytonia parviflora, Plantago purshii, Gentiana sceptrum, Eriophorum chamissonis, Juncus falcatus,* and several unidentified grasses and sedges, besides the species that probably occur there at other seasons of the year.

On the drifting sand, especially on the more level stretches and also near the shore where the moisture is evidently greatest, several unique sand-binding species occur, such as *Phellopterus* (or *Glehnia*) *littoralis* the large corky seeds of which are blown great distances along with the drifting sand, the corky coats soon almost entirely eaten away by the force of the drifting sand, *Abronia latifolia, Arctostaphylos uva-ursi, Cakile californica, Godetia quadrivulnera, Artemesia heterophylla, Tanacetum camphoratum, Gaertneria bipinnatifida, Carex macrocephala, Lupinus littoralis, Polygonum paronychia, Anaphalis occidentalis,* and *Elymus arenarius.* The *Abronia* seems to be especially effective as a sand binder, growing in large colonies and with a gigantic, deep going root, retaining the soil so firmly that the surrounding sand may be blown away for several feet below the colony, resulting in the production of curious green capped mounds, rather poorly shown toward the background of figure 1.

In the semi-meadow formations along the east sides of the sand dune area, where the influence of the salt or brackish water of the bay is felt, the vegetation is quite different from the meadow-like formation of the hollows within the dune area, which are all fresh water, and species occur which are characteristic of sandy brackish localities, such as *Salicornia ambigua* (largely infested by *Cuscuta squamigera*), *Orthocarpus* sp. *Scirpus microcarpus, Mimulus,* sp. *Rumex salicifolius, Baccharis pilularis, Atriplex hastata, Triglochin maritima, Muhlenbergia racemosa, Scirpus robustus,* and *Tissa marina.* The foregoing were the only plants identified at this season, although it was evident that the seashore marshes possess a much more varied flora.

Figure 2 shows the great height which the dunes attain and the "ravine-like" hollows in which the forests make their last stand. The trees in this photograph are being gradually overwhelmed by the dune barely showing in the foreground. Rarely, another method of destruction is seen when a hollow occurs near the windward side of a forest. These hollows seem to progress with the dunes and meeting the resistance of a surviving clump of trees destroys them by undermining, the sand blowing away from underneath the trees so that in time they topple over.

Fig. 2. A surviving body of forest being overwhelmed by the dune just visible in the foreground. This shows the frequent ravine-like formations caused by nearly contiguous dunes.

BOOKS AND CURRENT LITERATURE

The Effect of Light on Growth.—The results of the researches of the reviewer published in 1903 made untenable the inference that light acts as a retarding agent upon the growth of plants (The influence of light and darkness upon growth and development Mem. N. Y. Bot. Garden. 2: p. 307. 1903). This conclusion was reached after an extended study of the behavior of a hundred seed-plants in darkness as compared with their normal development. The ageworn inference, however, was convenient to use pedagogically and its vogue has continued up to the present, being embodied in most of the text-books, especially those in which no analysis is attempted of the complicated play of forces which contribute to the dimensional alterations constituting the external expression of growth. Now comes Dr. Blauuw of Haarlem who in the consideration of the "Primary photo-growth reaction and the cause of the positive phototropism in *Phycomyces nitens* (Koninkl. Akad. van Wetensch. te Amsterdam. 16; Feb. 26, 1914) finds that an eight-sided illumination of a sporangiophore of *Phycomyces* causes an acceleration after 3 or 4 minutes to two or three times the normal rate of elongation. The continuation of the illumination is accompanied by a lessening acceleration for as much as 16 minutes when the rate decreases and may even fall below the normal for a short time to return again to the normal. Incidentally the results of Blauuw show that the phototropic curvatures are the direct result of an asymmetrical modification of the growth of the different sides of the cylindrical cells. The actual direct effect of the light is taken by the author to include modifications of the stretching capacities of the cell walls, reëstablishing the old theory of De Candolle.—D. T. M.

Transpiration as Affected by Surface Films.—This paper[1] contains some strikingly significant and interesting results upon the influence of Bordeaux mixture of two different concentrations and of charcoal, lime, lime-sulphur, clay, etc., employed as dusts, upon the rate of water loss from castor beans and tomatoes. Both potted plants

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[1] Duggar, B. M. and Cooley, J. S. The Effects of Surface Films and Dusts on the rate of Transpiration. Ann. Mo. Bot. Gard. **1**: 1–22, Pl. 1. 1914.

and leaves in potometers were used in the experimentation, the technique of which is carefully described.

It is a matter of common observation that potatoes which have been sprayed with Bordeaux mixture exhibit a marked increase in yield and in vitality over those which have been unsprayed, and remain green for a longer time. This is generally considered to be due to some stimulative effect of the fungicide upon photosynthetic activity. Clinton ventured the logical explanation that it is due rather to the conservation of moisture in the leaves by clogging up the stomata and water pores with the sediment of the spray. The experiments reported in the present paper show that instead of conserving the moisture in the leaves the film rather facilitates water loss. A film of Bordeaux mixture was found to cause a greater water loss than a dust covering. No explanation is offered for this acceleration of transpiration, but some light may be thrown on the situation from work in progress looking toward the solution of the two questions which the authors raise: (1) "What is a physical or chemical basis of the increased evaporation from plant surfaces covered with Bordeaux mixture? (2) Is the increased evaporation in any way related to the increased vitality and longevity of sprayed leaves?"—FREDERICK A. WOLF.

NOTES AND COMMENT

We are in receipt of several recent numbers of the New Zealand Journal of Agriculture, a publication which betokens on every page the energy and sagacity that have given the antipodean Dominion a position such that its products must now be reckoned with in every other agricultural country. The importance of the grazing interests of the Dominion is underlaid by the suitability of the climate throughout the year for native and introduced forage plants. Much work is being done, chiefly at the Moumahaki Experimental Farm, for the further improvement of the grazing lands: proper seed mixtures are being worked out for the establishment of permanent forage in burned areas of forest and bush; breeding experiments are being made for the improvement of some of the best native grasses; rust inoculation has been successfully used in combating one of the troublesome pasture weeds; and experiments in the cultivation of alfalfa and lupines have been under way for several years.

It would appear that much of the future activity of foresters in New Zealand will centre about the management of the Monterey pine (*Pinus radiata*), which has proved to be extremely well suited to conditions there according to Mr. A. H. Cockayne. Trees 27 years old have been cut with a trunk diameter of 30 inches, and trees 40 years old have attained a height of 127 ft. It is estimated that plantations 30 years old will yield 100,000 superficial feet per acre, and cuttings have been made which are in excess of this yield. Although the wood is not of the best it is nevertheless capable of very general use, and is more durable than generally supposed.

There is no small interest attaching to the success of the Monterey pine in New Zealand. The nature of its distribution in its native home on the California coast is such as to suggest that it is a relict species, formerly of wider distribution, and perhaps a member of a vegetation most of the components of which are now extinct. The rate of growth is more rapid in New Zealand than in California, where diameters of 16 to 18 inches are attained in 28 to 35 years, according to Sudworth. The prolific seed production of California trees is maintained in New Zealand. The size of the New Zealand seeds is slightly greater and their viability is superior to that of California seeds. Two or three insects attack the young trees but their ravages are slight and fail to check the rapid growth. In other words the tree succeeds somewhat better in its new environment than in its native one, and this fact raises a host of questions as to the optimum requirements of the tree and the history of its present restriction to the fog belt of the Pacific coast.

It is encouraging to the forester to know of every success in finding a tree which will grow in a region remote from its natural range and will outclass the native trees of that region in rate of growth and in resistance to disease. The Monterey pine will doubtless be much more extensively planted in New Zealand than will the chief native timber trees, *Agathis*, *Podocarpus*, and *Dacrydium*, which have magnificent wood but are slow of growth. In the inland hills of British East Africa extensive plantings of Mexican highland conifers are being made, under the direction of Mr. C. E. Hutchins, and there is little doubt that successful species will be found for the replacing of the inferior native trees, which are mostly softwoods of tropical lowland origin.

Professor A. H. R. Buller has carried out some experiments on the fruit-bodies of the fungus *Schizophyllum* similar to those performed by Becquerel on various seeds, showing that the fungus is capable of retaining vitality after being kept dry for nearly three years, being then dried *in vacuo* and subjected to the temperature of liquid air for three weeks. Professor Buller finds it difficult to imagine how any metabolism can go on under these conditions and concludes that there must be a temporary suspension of vitality in the fungus. He says, "perhaps the machinery of metabolism in the fruit-bodies ceases to work under the conditions of our experiment but is uninjured and ready to resume its normal course when allowed to do so by a rise in temperature and access to moisture and air." It is altogether likely that there is no qualitative difference and only a slight quantitative difference between the behavior of *Schizophyllum* under the conditions of the experiment and under ordinary conditions of desiccation at normal temperatures and pressures.

THE RÔLE OF ASPEN IN THE REFORESTATION OF MOUNTAIN BURNS IN ARIZONA AND NEW MEXICO

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A characteristic feature of the timbered mountains in Arizona and New Mexico at altitudes above 8000 feet is the occurrence of extensive burns. The original forests below 9500 feet were composed mainly of western yellow pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga taxifolia*), limber pine (*Pinus flexilis*), Mexican white pine (*Pinus strobiformis*), and white fir (*Abies concolor*). As the altitude increases these species are gradually supplanted by Engelmann spruce (*Picea engelmanni*), bristle cone pine (*Pinus aristata*), and in some localities Alpine fir (*Abies lasiocarpa*). The greater portions of the burns have grown up to quaking aspen (*Populus tremuloides*), but extensive areas are practically bare. Scattering trees of the original forest usually remain, and where this condition exists or where the burn is comparatively small conifers are generally restocking the land. Douglas fir, white fir and Engelmann spruce thrive in the shade of the aspen and eventually overtop it, reëstablishing the original association or forest type. On burned areas not occupied by aspen or oak brush, which occasionally takes the place of aspen, coniferous reproduction is usually, though not always, deficient.

The absence of aspen on many of the burns within the natural range of the species is in some instances difficult to explain. On certain areas it is almost entirely wanting, and where it does occur the stands are broken by frequent openings. On exposed slopes and certain other sites the absence of aspen can be readily accounted for on the basis of unfavorable moisture conditions. Repeated fires have undoubtedly in some instances entirely exterminated the aspen, despite its great capacity for propagation by root suckers.

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The effect of fire has been aided by competition from grasses and in recent times by heavy grazing. Since aspen is extremely intolerant of shade, the prior establishment of other vegetation may preclude its reproduction.

The propagation of aspen at the present time seems to take place mainly by means of root suckers. Young aspens originating from seed are of rare occurrence. Undoubtedly reproduction from seed takes place under proper conditions; otherwise the wide range of the species and its rapid occupation of large burns could not be accounted for. But extension by means of root suckers is far more effective than is commonly supposed. It is quite possible that many of the largest aspen stands on burns owe their existence mainly to the activity of roots remaining alive after the coniferous forest was destroyed by fire. Despite their intolerance of shade, occasional aspens, probably remnants of a once thrifty stand, are scattered through many of the densest spruce forests. The tall, slender, usually crooked stems and scanty crowns of these individuals bear witness of their losing struggle for light. But if a fire should destroy the coniferous trees, the surviving aspen roots form the nuclei of numerous thickets which spread from year to year and tend to merge into one another. Sometimes the aspen may be entirely killed by its competitors before the fire occurs, or, if the fire is severe, it may destroy all the aspen roots.[1] Under such conditions the only way in which aspen can take possession of the land is through seed.

The failure of conifers to establish themselves satisfactorily on extensive burned-over areas of the national domain gives rise to the need for artificial reforestation, a task which is being undertaken by the United States Forest Service. A necessary preliminary step to so extensive an operation is a thorough investigation to determine under what conditions and by what means artificial reforestation can be most economically accomplished.

The fact that the most valuable of the high altitude trees, particularly Douglas fir and Engelmann spruce, apparently reproduce themselves best under a cover of aspen immediately suggests that

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[1] Weigle, W. G., and Frothingham, E. H., The Aspens, their Growth and Management. U. S. Forest Service Bull. 93, p. 18.

aspen covered areas are the most favorable for artificial reforestation and that such areas will therefore yield the best returns from a limited expenditure of funds. On the other hand, the fact that these conifers sometimes reproduce themselves on burns not covered by aspen, while in other instances they have failed to reproduce on aspen covered areas, has given rise to the opinion that the occurrence of conifers under aspen is merely a coincidence, due to a similarity of soil requirements. The idea has even been advanced that aspen through its shade, root competition and leaf litter hinders coniferous reproduction.

The effect of an aspen cover upon the establishment of Douglas fir has been under investigation at the Fort Valley Experiment Station since 1911. Both planting and direct seeding have been attempted in typical aspen thickets and adjoining openings. Due mainly to the activity of rodents in destroying the seed, the sowings have yielded negative results and, therefore, this article will deal only with the results of planting.

The area selected for this experiment occupies a level bench on the south slope of the San Francisco Mountains at an altitude of 8700 feet. No bed rock occurs near the surface but huge granite boulders lying on the surface or partially imbedded in the soil are much in evidence. The soil is a sandy to gravelly loam of granitic origin. Unlike the soil found in the lower altitudes of this region, it is fairly rich in humus.

A summary of meteorological records for the growing season, May 1–September 30, of the past three years follows: mean air temperature 11.5°C. (52.7° F.); mean soil temperature at a depth of 60 cm., 9.5°C. (49.1° F.); total precipitation 27.7 cm. (10.9 inches); total evaporation 39.9 cm. (15.7 inches); mean daily wind movement 58.4 kilom. (36.2 miles). The total annual precipitation is about 75 cm. (30 inches), of which approximately one-half comes in the form of snow. The early-summer dry season, while less prolonged than in the lower altitudes, is the critical period for the establishment of young plants. Practically no rain falls from April 15 to July 15. Moisture is undoubtedly the most important factor in determining the presence or absence of different types of vegetation.

The forest is typical of burned areas at this altitude. It is probably more than 25 years since the last fire occurred. Aspen thickets cover about two-thirds of the area and are separated by openings varying in diameter from 20 to 100 meters. Douglas fir, western yellow pine and limber pine occur singly or in groups in sufficient numbers to seed up the area, but nevertheless reproduction of these species is very meagre. Herbaceous growth is fairly abundant. Among the more conspicuous plants are *Frasera scabra*, *Pteridium aquilinum*, and *Verbascum* sp. Shrubby undergrowth is practically limited to occasional clumps of elder.

Fig. 1. A typical opening in an aspen stand. A Piche evaporimeter, anemometer, and thermograph are shown in the foreground.

In selecting the planting plots for a comparison of results in aspen thickets and openings, particular pains were taken to secure uniformity with respect to all physical conditions excepting the presence of aspen. Because of the reaction of the aspen stands upon the habitat, absolute uniformity cannot be obtained. The accumulation of leaf litter under the aspen adds humus to the soil. The herbaceous growth is invariably more luxuriant under the aspen than in the openings. In the former situations broad-leaved, more or less succulent types prevail, while in the latter there is a predominance of grasses. Minor variations in the original soil composition are sometimes unavoidable.

It may be argued that the fact that aspen occurs only on certain areas is in itself an indication of important differences in soil conditions, in other words, that aspen has occupied only the areas where certain soil conditions exist and that therefore we should expect to find a difference in the growth of coniferous trees in the aspen and in the open. This argument is answered by the presence of aspen root suckers throughout many of the openings, showing that they were once occupied by aspen. Grazing is and has for many years been responsible for keeping down these suckers which if undestroyed would develop into trees, thus obliterating many of the present openings. The area used in this experiment has been fenced and as a result aspen is springing up in all of the openings (see fig. 1). Grazing animals avoid the aspen thickets to a great extent and congregate in the openings where more desirable forage exists, with the result that the latter are closely grazed while the former are but lightly grazed. This is undoubtedly a factor to be considered in explaining the more common occurrence of coniferous reproduction in the aspen thickets than in openings.

The effect of aspen upon the establishment and growth of planted Douglas fir has been studied by comparing the percentage of loss and injury in aspen thickets and in openings, supplemented by a study of physical factors. Of the latter, moisture conditions were considered by far the most important. Soil moisture, evaporation, relative humidity, and wind movement were measured in the two situations at different times. A comparison of other physical factors, while of scientific interest, was not considered essential to this study.

The results of planting were observed on two plots under aspen and two in the open, each plot being 66 feet square and containing 100 plants, excepting in 1911 when smaller plots were used. The plantings were repeated each spring and examinations of the old plots were continued from year to year.

The methods used in measuring physical factors are as follows:

Soil moisture was determined from samples representing a depth of 5 to 25 cm. (4 to 10 inches) which is the stratum occupied by practically all the roots of planted trees during the first year. From 2 to 4 samples were taken on each plot at one time.

Fig. 2. A typical aspen thicket

Evaporation was measured by means of the Piche evaporimeter. Four instruments were placed in each of the two situations compared. The evaporimeters were suspended from an inclined stick (see fig. 1) so that the evaporating surface was about 8 cm. (3 inches) above the ground, in order to represent conditions in the air stratum occupied by the stems. Readings were made hourly for periods of from 8 to 24 hours in both clear and cloudy weather. The evaporimeters were thoroughly tested and are known to give reliable results for purposes of comparison.

Wind movement was measured by means of Standard United States Weather Bureau anemometers. The instruments were set in a hole so that the cups revolved about 8 cm. (3 inches) above the level of the ground.

The results of planting and measurement of physical factors are given in the following tables.

Some idea of the relative intensity of solar radiation in the open and under the aspen is furnished by the records of two thermographs exposed on the ground without shelters (see figs. 1 and 2). When the sun was under a cloud the records of the two instruments were practically the same, but when the sun shone the reading of the thermograph in the open was usually several degrees higher. This was not always the case, however, because at times the thermograph under the aspen, as well as the one in the open, received direct sunlight. The maximum temperatures recorded are as follows:

June 21, 1912	Open	30.0°C. (86.0° F.)
12 m. to 5 p.m. partly cloudy	Aspen	25.5°C. (77.8° F.)
July 8, 1912	Open	41.1°C. (106.0° F.)
10 a.m. to 4 p.m. clear	Aspen	36.2°C. (97.3° F.)

In comparing the aspen-covered and open plots in tables 1, 2 and 3, it should be borne in mind that the counts and measurements in the various years were on entirely different plots; thus the variation due to peculiar local conditions is to a large extent overcome. It will be noted that the measurements of physical factors are confined largely to the month of June or early July. This period represents the early summer dry season which is considered the critical period for plants not fully established.

The results of the planting (table 1) furnish convincing evidence of the superiority of the aspen-covered areas over the openings. The dead or injured plants almost invariably have the appearance of suffering from drouth. The tops turn brown and

TABLE 1

Results of planting

CHARACTER OF PLOT	PLOT	NUMBER PLANTED	PER CENT OF PLANTS IN GOOD CONDITION			
			October, 1911	August, 1912	October, 1912	August, 1913
		1911 Planting				
Open	A, C, F	45	82		75	
Aspen	B, D, E	91	91		88	
		1912 Planting				
Open	7	100		95.0	83	63.0
	17	100		83.0	73	60.0
Average				89.0	78	61.5
Aspen	5	100		95.0	90	70.0
	10	100		91.0	86	78.0
Average				93.0	88	74.0
		1913 Planting				
Open	1	100				78.0
	10	100				84.0
Average						81.0
Aspen	53	100				92.0
	59	100				83.0
Average						87.5

usually the entire plant dies, although plants which begin to fail toward the close of the dry period frequently revive after the beginning of the summer rains.

The relation with respect to soil moisture varies in different years (table 2). The plots planted in 1911 show the same average moisture content in the open as under the aspen. In 1912 the relation is variable, with a margin in favor of the aspen-covered plots during the months of May and June and September which are typical of the two dry periods of the growing season. The 1913 plots, however, show a noticeably higher moisture content in

TABLE 2

Soil moisture on planting plots

CHARACTER OF PLOT	NUMBER PLOT	SOIL MOISTURE, PER CENT OF DRY WEIGHT				
			June 8			
		1911 Planting				
Open	A, C, F		19.7			
Aspen	B, D, E		19.7			
		1912 Planting				
		May 24	June 21	July 19	Aug. 16	Sept. 20
Open	7	37.2	18.9	15.9	16.7	7.9
	17	21.7	14.4	11.3	14.9	5.4
Average		29.5	16.6	13.6	15.8	6.6
Aspen	5	38.7	24.1	11.9	14.3	7.9
	10	35.4	24.3	12.9	15.5	9.2
Average		37.5	24.2	12.4	14.9	8.6
		1913 Planting				
		May 17	June 18			
Open	1	29.2	23.9			
	10	29.3	23.6			
Average		29.2	23.7			
Aspen	53	23.6	14.9			
	59	19.9	13.6			
Average		21.7	14.2			

the open than under the aspen. This appears to be due partly to subsurface seepage in the open plots from higher ground in the near vicinity, and partly to the fact that the ground is practically bare of native vegetation as a result of heavy grazing previous to fencing in 1913.

The varying relation between the aspen-covered and open plots in 1912 when samples were taken monthly through the growing season is explained as follows: Practically no rain fell in May, June and the first half of July. At the beginning of the

TABLE 3

Evaporation, wind and relative humidity

CHARACTER OF PLOT	SKY	TOTAL WIND (KILOM.)	MEAN RELATIVE HUMIDITY %	TOTAL EVAPORATION (CC) (MEAN OF 4 INSTRUMENTS
1912 Planting				
(June 21, 1912, 12 m. to 5 p.m.)				
Open	part cloudy	10.7	65.0	7.9
Aspen		4.2	58.2	5.2
(July 8, 1912, 10 a.m. to 4 p.m.)				
Open	clear	23.1	36.0	29.4
Aspen		9.4	40.1	18.0
1913 Planting				
(June 26, 1913, 11 a.m. to 4 p.m.)				
Open	clear	31.6		18.5
Aspen		15.8		9.7
(June 26, 1913, 4 p.m. to June 27, 10 p.m.)				
Open	June 26 clear	79.0		18.0
Aspen	June 27 cloudy	47.6		13.3
(June 27, 1913, 11 a.m. to 4 p.m.)				
Open	cloudy	48.4		14.4
Aspen		24.0		9.0

spring season the soil in both situations was thoroughly saturated. By June 21, owing to heavier water loss, the moisture content in the open had been reduced considerably below that in the aspen thickets. The July and August determinations, however, show the reverse relation. This is principally due to the fact that in the aspen stands a considerable portion of the rain was intercepted by the foliage or absorbed by the dry leaf litter on the ground, while in the open it went directly into the soil. In a season of heavy rainfall there would be more run-off in the open than in the aspen, but since the summer of 1912 was an exceptionally dry one the run-off was not great. By September

20 the aspen covered plots again showed a higher percentage due to the smaller water loss after the summer rains ceased.

The effect of the aspen on soil moisture appears to be about as follows: Other conditions being equal, the greater humus content of the soil in the aspen stands should increase its water holding capacity, and therefore at the end of the spring thaws when the soils are fully saturated we should expect to find a higher moisture content in the aspen than in the open. Direct evaporation from the soil is undoubtedly less under the aspen because of the protection afforded by the tree crowns and the leaf litter. On the other hand, the loss by transpiration through the aspen foliage may more than offset the difference in direct evaporation from the ground.

The records of evaporation (table 3) show that this factor is in every instance decidedly more active in the openings than under the aspen. This is due partly to higher solar radiation and partly to greater wind movement in the openings. That wind alone has an appreciable effect is shown by the fact that on June 27, 1913, when the sky was overcast all day but the wind velocity in the open was twice as great as in the aspen, the evaporation was 60% greater in the open (see table 3). The combined effect of wind and sun is shown on June 26, 1913, when the evaporation in the open was 90% higher than under the aspen. The records show no constant relation with respect to relative humidity.

CONCLUSIONS

The success of Douglas fir under aspen as compared with the open situations may be attributed mainly to a reduction in transpiration. Abundant soil moisture, while important, can only in a measure compensate for excessive transpiration. It is necessary to maintain the proper balance between water absorption and expenditure. As shown in the open plots of 1913, heavy losses may take place despite the presence of an abundant moisture supply in the soil if transpiration is not controlled. The same condition has been experienced in nurseries where Douglas fir transplants exposed to full sunlight, though well watered, suffered severely while partially shaded plants in the same bed escaped injury.

It is believed that the whole question resolves itself into one of moisture, although it has not been proven that certain solar rays do not exert an injurious effect upon the young plants by other physiological action than that of increased water loss. It has been established that aspen stands, despite the fact that the trees and the usually luxuriant herbaceous growth underneath them use up a large portion of the moisture in the soil, create conditions more favorable to the establishment of planted Douglas fir than are found in open situations. Undoubtedly this conclusion has certain limitations. As the young Douglas firs grow older they demand more light, and the densest aspen thickets will have to be thinned to permit the best development of the planted trees. The lack of sunlight results in a spindly form accompanied by pale and poorly developed needles. This, rather than arbitrary rules based upon mathematical expressions of the requirements of the species, must guide the forester in determining when more light is needed.

Although results in open situations will as a rule be less satisfactory than where the ground is occupied by aspen, reforestation, in the smaller openings at least, is by no means to be despaired of. Possibly the problem can be solved by the use of plants specially developed to meet these conditions. Yellow pine, because of its lower moisture requirements and greater demands for light will probably prove more suitable than Douglas fir for openings within the natural range of the former.

In altitudes above the range of Douglas fir and yellow pine, Engelmann spruce is the species to plant in aspen thickets. Engelmann spruce seedlings are even more sensitive to strong sunlight and drought than are Douglas fir seedlings, and therefore the results of the foregoing experiments may be expected to apply in a greater degree to Engelmann spruce than to Douglas fir. Spruce will grow in the densest aspen thickets, but in openings particularly of southerly exposure it establishes itself with difficulty. Bristle cone pine (*Pinus aristata*) grows on such sites, and can doubtless be planted successfully where Engelmann spruce fails.

A NOTE ON THE REVERSIBILITY OF THE WATER REACTION IN A DESERT LIVERWORT

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The longer lived plants native to southern Arizona are exposed each year to great variations in the water relation. The responses on the part of the plants, although extremely varied, are, however, so sharp as to permit the classification of the plants on this as a basis. We have, thus, (1) species with a reversible water relation and succulent,[1] (2) species with a reversible water relation and not succulent, and (3) species with an irreversible water relation and spinose or sclerophyllous. The first class is represented in southern Arizona by the cacti, and the last class by the woody plants in general, while the second group consists mainly, or wholly, of certain mosses, ferns and liverworts. The last are the so-called "resurrection" plants, which become dormant on drying and which revive on being moistened. It is proposed in the present note to add another species to the last class, and, especially, to present in a quantitative manner the amount of water lost, when the form becomes dormant, and, the amount regained, when it revives.

The observation by others on species from the more moist, as well as from semi-arid regions, indicate that a fairly large number have to a greater or less degree a reversible water relation, as defined in the preceding paragraph. For instance, Schröder[2] found that *Corsinia marchantioides* revived after having been kept in an herbarium seven months, and *Gymnostorium rupestre* and *Dicranum longirostre* were not killed after having been kept two years in an herbarium. Pfeffer[3] states that all turgid plants

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[1] The water-balance of succulent plants. D. T. MacDougal and E. S. Spaulding. Carnegie Institution of Washington, Publication No. 141, 1910.

[2] Quoted in Goebel's Pflanzenbiologische Schilderungen, 1 Pt., 174.

[3] Physiology of plants. Eng. tr., **2**: 250.

can withstand considerable loss of water, as, for example, the vegetative organs of some flowering plants which were not killed by a loss of 90%. Quoting Schröder, Pfeffer says that the succulent *Sedum elegans* survived a water loss of 90%, but *Parietaria arbona* succumbed from a loss of 70 to 76%, and was partly killed when the loss was 50%. The "lace lichen," *Ramulina reticulata*, air-dry, according to Peirce, can absorb so much water that its wet weight is 2.04 times its air-dry weight.[4] At the end of a long dry summer, Peirce[5] found, by drying the lichen in an oven until constant weight was achieved, that there had been 13.9% water in the air-dry condition. Although following desiccation the plant naturally would not recover, it is not unlikely that it could withstand a greater water loss than that experienced by it as a result of the summer's drought. At least such is true of certain liverworts as established by Humphrey[6] who found that certain species, air-dry, could yet lose from 4.57 to 12.3% of water and survive. Such forms, therefore, have a considerable, although varying, margin of safety which would stand them in good stead in unusually dry seasons.

In comparing the leading climatic features of the region inhabited by the liverworts studied by Humphrey with the region, to be characterized directly, in southern Arizona where the liverwort, of which the present note especially treats, is indigenous, we find certain points of agreement, although in other points, which are definitive, they are unlike. For example, in both regions, the rainfall is periodic, with a season of drought between the seasons of rain. In California there is no regular rainy season in summer. The California summers, however, in regions near the sea, are visited by fogs, or dew, which probably serve to mitigate to a degree the severity of the drought. The dry seasons in Arizona, especially the foresummer, are without dew or fog, and,

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[4] On the mode of dessimination and on the reticulation of *Ramulina reticulata*. Bot. Gaz. **25**. 1898.

[5] The nature of the association of alga and fungus in lichens. Proceed. Calif. Acad. Sci. 3d Ser. Botany, **1**: 7. 1899.

[6] Studies in the physiology and morphology of some California Hepaticae. Proceed. Washington Acad. Sci. **10**. 1908.

although not so long, are possibly more intensely arid than the dry season in the portion of California to which reference is made. The response of a liverwort to the more arid desert region, therefore, has an especial interest.

THE HABITAT AND HABIT OF PLAGIOCHASMA[7]

No liverworts have been reported from the domain of the Desert Laboratory, which is probably too arid for these forms, but one species, *Plagiochasma* sp., was found by the writer on the southern face of the Santa Catalina mountains at an altitude of approximately 5000 feet. The rainfall at the altitude is 18–22 inches and occurs periodically, being about equally divided in amount between winter and summer. At the time when the liverwort was seen, October, there was no rain but the humidity was probably not so low as in the foresummer. It was mainly for this reason that the species was fully expanded, although there was the additional one that it was growing in a protected situation among some mosses at the northern base of a cliff.

Material of the liverwort was brought in the active condition to the glass house of the Desert Laboratory. It was given water frequently through the winter and remained fully expanded. Early in the following spring the plants were somewhat neglected, water was not given for a few days, and they promptly rolled up, losing their characteristic color and form, becoming as lumps of the soil on which they were resting. Upon being given water, however, they expanded within a few minutes and assumed their familiar appearance.[8]

When opportunity offered, some experiments were made on the liverwort for the purpose of learning the amount of water lost on drying. Separate thalli were removed from the group of plants, the soil particles were brushed away, and the moist weight was determined. Afterward, when the thalli had become air-dry and had assumed the appearance described above, the weight

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[7] The determination of the liverwort was by the kindness of Prof. A. W. Evans.

[8] See, also, Resistance of drought by liverworts, D. H. Campbell, Torreya, 4. 1904.

was again determined. Finally the air-dry plants were allowed to absorb water freely, when the plant was again weighed. The two following tables report typical results with separate thalli.

Experiment I

Weight of moist plant	0.0367 gr.
Weight of air-dry plant	0.0085 gr.
Percentage of water lost to weight of moist plant	76

Experiment II

Weight of moist plant	0.0499 gr.
Weight of dry-air plant	0.0147 gr.
Percentage of water lost to weight of moist plant	70

For the purpose of learning how much the same plants would absorb they were given water, and after having become air-dry, the superficial water was removed, as much as possible, with blotting papers. In addition to this the plants were permitted to remain in the dry room-air for a few moments. The thalli absorbed water at once and assumed their customary color and form. Upon being weighed again it was learned that the plant used in the first experiment had gained 38 mgm., or 10 mgm. more than it had lost on becoming air-dry. The thallus of the second experiment gained 50 mgm., or 15 mgm. more than it had lost by drying out.

The experiment was repeated with several thalli together for the purpose of making less the probable errors which were unavoidable when single thalli were employed. The results, in tabulated form, are as follows:

Experiment III

Weight of moist plants	1.048 gr.
Weight of dry-air plants[9]	0.203 gr.
Amount of water lost	0.845 gr.
Percentage of water lost to weight of moist plants	80

The thalli used in the last experiment were returned to the glass house and were left for twenty-five days, or until May 23, without having been given water. During this period the humid-

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[9] After weighing, the moist plants were allowed to become air-dry by standing exposed for twenty hours in a dry, warm room.

ity of the house was very low, and the temperature very high, so that the exposed plants were subjected to conditions of extreme aridity. Without doubt the glass house at the time was much more arid than the habitat of the liverwort even in unusually dry seasons. It was of interest, therefore, to watch the behavior of the liverwort when its water fast was ended. Upon being given water, it promptly unrolled, and assumed its active condition. Although it was not determined, it is very evident, from such responses of the plant, that it possesses a margin of safety by which it can withstand conditions in nature almost inconceivably arid. For this reason it seems doubtful whether aridity in itself is the definitive factor limiting its lower distribution.

BOOKS AND CURRENT LITERATURE

Ecology of Plants.—It is something from the scientific standpoint to be in the botanic succession, to be the successor of a worthy line of predecessors, whose work has been recognized by the scientific world. Professor Drude the author of this attractive volume,[1] was a student of Grisebach's, one of the earliest and greatest of plant geographers and he comes well equipped for the presentation of the subject of plant ecology by years of study and travel. Dr. Drude has lived during the entire period which has witnessed the rise and progress of plant ecology, and he has taken no mean place in that progress. As one of the editors of Die Vegetation der Erde he has had unexcelled opportunities of acquainting himself with the vegetation of the world.

The first chapter of the book after the introductory preface deals with the physiognomic life forms of plants. Professor Drude gives a short historic account of ecology, written in a trenchant manner, which betrays a personal acquaintance with the men who have been the prime movers in this new department of botanic science. Many interesting side lights are thrown upon terms and matters which are considered axiomatic by plant ecologists. We have in this chapter interesting details as to the views of Grisebach, Reiter, Warming, and others and we are introduced to Raunkiaer's fruitful classification of plant types. A statement is given of the principles upon which a classification of life forms depends. The author's arrangement of physiognomic life forms is then set forth in detail, under the head of three principal groups: Aerophytes, Aquatic Plants and Cellular Plants. A total of 55 life forms are recognized, with brief descriptions and the citing of examples. In the delimitation of these growth forms Drude does a real service to the working ecologist, as he puts upon a scientific basis many forms which have been chaotically treated by other students of the subject. It is impossible in a review to give more than a general idea of the richness of details presented in the 54 pages devoted to this classification and to the notes and references cited in connection with it. Some of the groups considered are: Monocotyledonous Crown Trees, Tree Ferns and

[1] Drude, O., Die Oekologie der Pflanzen. Die Wissenschaft, Bd. 50. Pp. 308. figs. 80. Braunschweig, F. Vieweg und Sohn, 1913 (Mk. 11.00).

Cycads, Dicotyledonous Woody Lianes, Grass-trees, Dicotyledonous Stem-succulents, Perennial Grasses, Dicotyledonous Cushion Plants, Geophilous Bulbous Plants, Saprophytes, Parasites, Amphibious Plants, etc. Following this systematic presentation the author considers it important to discuss the whole subject in a section devoted to explanations and additions, where the preceding argument is clinched by descriptive matter treated under vegetative propagation, effective distributional power of plants by means of seeds, and the exhibition (*Schaustellung*) of flowers.

The second section of the book treats of climatic influences, periodicity and leaf characters. It deals with the physiognomic effect and organization of the leaf, as well as with matters of plant nutrition. Here the author deals with the duration of the leaf, bud formation and protection, light and leaves, transpiration, etc. In the pages devoted to climatic periodicity the author recognizes 18 climatic groups or climatic geographic zones. This classification is intensely scientific and lends itself to use in discussions of phytogeography amongst the botanic *élite*, but for ordinary use in the class room and for other ordinary purposes, the system is too cumbersome and the names are too long and bulky for general acceptance. However, Drude has done ecologists a service in drawing attention to the facts that he has presented in this section of his work. The climatic groups are arranged under four series with the prefixes iso–, tropo–, etesial–, and helio–. The first has uniform annual light, temperature and rainfall, the second an alternation of wet and dry seasons, the third a dry hot summer and a winter with little light, while the fourth has a winter with little light, effective in the production of a rest season. Phenology and other matters of climatic influence are presented in this section, together with Professor Drude's views on the general phenomenon of periodicity in relation to climate. He holds that periodicity is inherent to plants, and that this inherent periodicity is the result of the exposure of plants to millions of years of climatic periodicity.

The third section is devoted to physiographic ecology. The ecologist must deal with the difficult problem of why species unite into certain communities and why they have the physiognomy which they possess. The author treats of the edaphic influences of soil, ground water, bacteriologic soil content and the influence of lime and acids. The work of G. Kraus published in 1911 (Boden and Klima auf kleinstem Raum) is mentioned specifically. He quotes Jaccard's law on the distribution of species in alpine meadows and pastures and deals with the much discussed question of association and formation. The last chapter presents his classification of 13 vegetation types, under each of which examples are given.

The fourth section is devoted to matters of evolutionary interest and is headed ecologic epharmony and phylogeny. The several divisions of this part of the book treat of phylogeny and growth forms (life forms,) eurychory and stenochory, the behavior of closely related races in the struggle for space, the behavior of representative species of a eurychoric genus, the generic coefficient, evolution of new forms by correllation, epharmony, species mutation, and present day theories of heredity. The third chapter of this section deals with an extension of the migration hypothesis of Moritz Wagner, that specifically rich genera colonize different formations with different species. Drude holds that closely allied races of a species either grow in separate areas or are heterochoric, *i.e.* grow in different ecologic habitats within the same area. The fourth chapter, on the behavior of representatives of eurychoric genera, which are equivalent ecologically but are found in different geographic areas, is illustrated by a number of such cases as are afforded by *Asarum*, *Monotropa* and *Larix*. In conclusion Professor Drude discusses the scope of ecology and enunciates his philosophy, which appears to be a blending of Neo-Lamarckianism and Darwinism.

Ecologists the world over will be indebted to Professor Drude for a lucid exposition of some of the most important principles of plant ecology philosophically considered. He has presented many old facts in a new form, and many new facts, which he has worked out in a study of the vegetation of the globe. The book is well printed and systematically arranged. The figures are good and many of them new, representing typic species as grown in the Dresden Botanic Garden—JOHN W. HARSHBERGER.

PHYSIOLOGICAL ANATOMY—Three German editions of Haberlandt's well-known Physiological Plant Anatomy have been issued since the original one of 1884. From the last of these an English translation has just been made by Mr. Montagu Drummond, of the University of Glasgow.[1] The familiar features of the third German edition (1904) have been retained in respect of the subdivisions of the subject matter,

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[1] Haberlandt, G. Physiological Plant Anatomy. Translated by Montagu Drummond. 778 pp., 291 figs. London, Macmillan and Company. 1914 ($6.50).

the illustrations and the general manner of treatment, at the same time that the appended body of notes has been very greatly augmented, and the number of references to recent literature increased. The translation has been made with freedom but with fidelity to the original and the resulting volume will take a place as one of the most important texts for instruction and reference in botanical establishments.

The aim of the physiological anatomist is to discover and describe the interrelations of structure and function in plants, but the extent to which anatomy has outrun physiology in the assemblimg of its facts makes physiological anatomy chiefly an attempt to "explain" the findings of anatomy in the terms of physiology. Haberlandt regards the discovery of a correlation as an explanation: "Denn Zusammenhänge aufdecken heisst erklären" (German Ed. p. 1). A correlation may suggest the ground for an explanation or it may not. All depends upon the extent to which the correlated facts may be determined in common by a third fact or factor, and upon the extent to which the correlation is exclusive as well as inclusive. The whole structure of physiological anatomy appears to have been erected on a foundation of belief that a correlation constitutes an explanation. The actual performance of physiological anatomy has been to describe a large number of correlations between structure and function and to classify them. Many of the interpretations of functional value that have been made are so obvious that no one would contradict them, many others have already been backed by experimentsl evidence. The number of cases in which suppositions have been made is large, but the future development of the subject may witness an increasing support of physiological evidence for these suppositions.

The anatomical facts of Haberlandt's volume are presented in a helpful manner. The classification of the tissue systems is natural and excellent, and the great bulk of the explanations of function are very suggestive, even when they have not been substantiated by experiment. There can be no gainsaying the fact that Haberlandt has done much to enliven anatomy and something to steady physiology. The field that he has outlined will be none the less important if it is eventually incorporated into the domains of ecology and physiology.

Haberlandt holds a frankly teleological view-point, and states again and again that this or that structure has been developed "for" this or that function. We read that "many shade plants in particular are satisfied with a somewhat scanty supply of light. Nevertheless, every plant endeavors to arrange its photosynthetic tissues in such a manner they that will obtain the most favorable illumination." In the very next sentence we read, however: "Hence light intensity is the factor which primarily determines the location of the photosynthetic system . . . . " a statement which is just as free from objectionable flavor as the previous one is full of it. It is perhaps unreasonable to object to the use of teleological language by a man who holds a teleological philosophy, and it would be still more unreasonable to blame a translator for retaining what he might consider to be an essential feature of the original upon which he was working. It is not a very difficult thing to brush aside the teleology as one reads a book like Haberlandt, but it would be very pleasant not to have to do it. There is scarcely a field of botanical science which lends itself more pliantly to teleological thinking than this very one, in which structures are having functions cut to fit them. On the other hand there is no lack of much clean, logical deduction in Haberlandt's work, and on the whole it is difficult to overestimate the importance of this botanical field which he has done so much to develop. In it anatomy, physiology, ecology, and the study of evolution unite in a collective consideration of plant tissues and organs, each of these disciplines guarding the others from errors of fact and interpretation.—F. S.

NOTES AND COMMENT

Professor Robert F. Griggs has made some observations on the Sitka spruce (*Picea sitchensis*) at the northern limit of forest on Kodiak Island, Alaska (Bull. Torr. Bot. Club, July, 1914), and he is able to confirm the statement of Fernow that this tree is now advancing northward onto the tundra. Griggs states that the edges of forests have been used more than have any other vegetational lines in showing the correlation of plant ranges with climatic factors, and that they have afforded the "evidence upon which most of the assumptions of static plant ranges have been based."

It is necessary here to ask who it is that has assumed plant ranges to be static. Biology, in fact science in general, was formerly full of static phenomena, but they have been kineticized at a rapid rate during the last fifty years, and there are surely few plant geographers who still maintain that plant ranges belong in the ancient limbo of things not yet discovered to be unstatic.

Griggs holds that the correlation of plant ranges with climatic factors is based on an assumption of complete adjustment of plants to climate and loses its significance wherever such adjustment does not exist, *i.e.* wherever the ranges are not fixed but changing. To say that plants are adjusted—or adapted (old style)—to climatic conditions is to state an incontrovertible fact. To maintain that they are in a state of complete adjustment is to say more than any worker has ever had the temerity to claim or the evidence to disprove.

The relation of plants to climate is one which involves three variables: the amplitude of the physical requirements of each species, the acquisition of new requirements or endurances by a plant stock, and the minor and major variations of the climate. The ecological work of the last fifteen years has centered in a study of the most unstable plant communities, and little has been done until recently to correlate the successional phenomena in these communities with the physical conditions. The observation of plant successions has been an easy task and has afforded much aid in the classification of the communities involved. The regions in which relatively stable vegetational conditions obtain are merely the ones in which a more stable physical environment has brought about a closer relation of plant occurrence to the physical factors. These stable communities have been little studied, and chiefly because they require attack from a very distinct point of view. The theory of successional plant ecology has now been thoroughly elaborated, even if the work which it suggests has not been finished. The study of the relatively stable communities resolves itself into an investigation of the relation of plant distribution and plant activities to climatic factors. The abeyance of successional phenomena and the immanence of physiological problems combine to make the investigating of stable communities take a different course from that which has commonly been pursued in ecological field work. To state that the correlation of plant ranges with climatic factors is based on assumption is merely to emphasize the need for work on stabilized vegetations from a physiological point of view.

EVAPORATION AND PLANT SUCCESSION IN SOUTHEASTERN WASHINGTON AND ADJACENT IDAHO

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During the summer of 1913, while a study of the ecological conditions in Southeastern Washington and adjacent Idaho was being made, measurements of the physical factors of the habitat, including the evaporating power of the air, were made in many of the more important plant associations. It is the purpose of this preliminary paper to point out briefly the sequence of succession, and to give the comparative rates of evaporation in each of the major associations. A detailed discussion of the development and structure of the various stages in the succession has been reserved for another time.

The physiography and geology of the region in which these investigations were carried on will be outlined, since both play an important rôle in influencing plant distribution. Pullman, the base station, in Whitman County, Washington, lies near the eastern edge of the great lava sheet which forms the Columbia Plains. Fifteen miles eastward, in Idaho, the lava rests upon the flanks of a low range of mountains known as Thatuna Hills. From these mountains two chains of buttes extend westward into the lava, each for a distance of about eighteen miles. These, with the mountains, enclose a peninsula of the igneous rock approximately two hundred square miles in area. The base station occupies a position near the neck of this peninsula. The enclosed area, and that extending northwestward for fourteen miles, together with the buttes and mountains, comprise the region under consideration. It has an average altitude (exclusive of the mountains) of about 765 m., and lies mostly in the life area known as the Arid Transition. Thatuna

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Hills are composed of old crystalline rocks, quartzites and granite, while the appended chains of buttes are almost wholly quartzite in composition. All represent great elevations in the former rough topography, which in rather recent geological time has been flooded and mostly buried by the lava. The buttes are islands of quartzite in a sea of basalt. The disintegrated basalt, now a fine silt loam, has been moulded by the action of water, and especially by the work of the prevailing southwest wind, into a topography not unlike that of sand dunes. The rolling hills with a height of 30–110 m. are characterized by much steeper north and northeast leeward slopes. The soil is usually deep, and only where the streams have cut channels among the hills is the basaltic rock exposed. The wind likewise has played an important rôle in carrying the finer particles of the more sandy loam of the decomposed quartzites and granite to the sheltered sides of the buttes and mountains.

The more important plant associations occupying the basaltic soil are few in number. The hills and narrow valleys were formerly covered with a characteristic prairie formation, only relatively small areas of which now remain, while along the exposed banks of the canyons this gives way to the bunchgrass-rimrock association, and only on the more sheltered slopes of the deeper canyons does the yellow pine occur. A poorly developed shrub association consisting of *Symphoricarpos racemosus*,[1] *Rosa nutkana*, *Rosa pisocarpa*, dwarfed specimens of *Prunus demissa*, *Crataegus brevispina*, and *Amelanchier* spp. and sometimes *Opulaster pauciflorus*, and small trees of *Populus tremuloides*, occupy areas on the more mesophytic slopes of the treeless hills. These shrubs are better developed in the canyons and are usually forerunners (especially *Opulaster pauciflorus*) of the pine association. Along the stream margins they give way to flood plain thickets of *Crataegus brevispina*, *Salix* spp., *Cornus stolonifera*, *Amelanchier* spp., and *Alnus tenuifolia*, or to small groves of *Populus tremuloides*, or, less frequently, *Populus trichocarpa*.

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[1] The nomenclature throughout this paper is according to Piper's Flora of the State of Washington. Contributions from the U. S. National Herbarium. **11**: 1906.

The major plant groups of the buttes and mountains, in which evaporation was measured, in a succession extending from the prairie to the climax mesophytic forest, are: the prairie, open yellow pine association, Douglas fir-tamarack association, and the cedar association. This list, however, is not complete. For example, pure associations of yellow pine and Douglas fir (*Pseudotsuga mucronata*) often occupy a position intermediate in succession between the yellow pine and Douglas fir-tamarack association; while the white fir (*Abies grandis*) may come in with or even precede the tamarack.

Livingston,[2] in his researches with his porous cup atmometer, has shown that the evaporating power of the air is a rather satisfactory summation of the atmospheric factors which determine the growth of plants during that portion of the season free from frost. Accordingly, in the spring of 1913, a number of observation stations were established in various plant associations and by means of the Livingston porous cup atmometer the rate of evaporation was determined during the ensuing growing season. The cups were mounted in bottles of convenient capacity, closed with tightly fitting cork stoppers that were perforated for the atmometer tubes and for bent capillary tubes which served to equalize the atmospheric pressure within the bottles with that of the external air, without causing loss by evaporation or permitting rain water to enter the reservoir. The bottles were sunk into the soil so that the evaporating surface of the cups was in all cases 17–23 cm. above the surface of the soil. Readings were taken at weekly intervals, or more frequently except at the distant stations, which were visited on alternate weeks. At each reading the bottles were refilled with a weak (2% solution) of formalin from a 100 cc. graduate to a file scratch on the neck. New instruments were employed, all of which were standardized to the same unit before using and restandardized at the end of the season. In correcting the readings a gradual alteration was assumed and interpolations were made for the coefficients to apply to the various readings. At most of

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[2] Livingston, B. E., Evaporation and Plant Habitats. Plant World, **11**: 1-10. 1908.

the stations cups were run in duplicate and careful record was made between atmometers near each other to see that they were changing in a parallel manner. The data obtained from 9 of the 31 cups used are not recorded in this paper. One or two showed irregularities in their operation, while two disappeared one week before final collecting.

Fourteen stations were established in the various associations, care being taken in all cases to select spots which possessed the average amount of herbaceous, shrubby, or tree vegetation characteristic of that specific association as a whole. To facilitate comparison of the evaporation between the various stations and to exhibit the progress of evaporation during the season, the average water loss per day between the readings has been calculated and shown in graphs with the ordinates representing the number of cc lost per day by a standard atmometer; the abscissae being the intervals between the readings. Because of the difference of rainfall, exposure, and soil, it is deemed best, at least in this preliminary report, to consider the plant associations and evaporation on the plains separately from those on the adjacent buttes and mountains.

The first group of stations was established near Colfax, Washington, fourteen miles northwest of Pullman. Here the south fork of the Palouse River has cut a canyon in the basalt to a depth of 90 m. Along the north bank of this canyon the bunchgrass-rimrock association has its best development in the region, while the well protected south bank is covered with an open yellow pine (*Pinus ponderosa*) association above which, still on the north slope, lies the prairie.

The most characteristic plant of the bunchgrass-rimrock association is *Agropyron spicatum* (including var. *inerme*). In the shallow soil, often only a few centimeters deep, the bunches are well developed, averaging 20 cm. in diameter at the base and reaching a height of one meter. An actual count in twenty-seven square meter quadrats in the vicinity of station No. 1 showed these bunches to average 6 per quadrat. Forty-five per cent of the ground was bare or very sparsely covered with mosses and lichens, relicts from a preceding association. Between the bunches occurred the low annual, *Festuca pacifica*, averaging 150 individuals to the quadrat, while small bunches of *Poa sandbergii*, and single plants of *Plantago purshii* averaged 10 per sq. m. each. Dwarfed specimens of *Epilobium paniculatum* and *Clarkia pulchella* were represented by 18 and 28 plants per sq. m. respectively. *Polygonum majus* gave an average of 2; while *Madia exigua* with 3 plants per quadrat and *Allium acuminatum* with 2, were the only other plants represented by an average of more than one specimen per unit area

Fig. 1. Station No. 1, in the bunchgrass-rimrock association near Colfax, Washington.

At station No. 1, half way up the north bank of the canyon, an atmometer was installed on May 7 (fig. 1), and on the same day another was placed in the pine association on the opposite side of the canyon. Two weeks later a second porous cup was placed near each of these respectively, and at the same time one was installed in the prairie. These were kept in constant operation until September 10.

The atmometers at station No. 1 were on the south slope and exposed fully to the heat of the sun and the prevailing south-west winds. The graphs for these instruments have been plotted on the chart in figure 2. The rainfall for Colfax is shown for periods corresponding with those of the intervals between evaporation readings, and each vertical space on the chart represents 1 cm. of rainfall. It should be noted in this connection that the average annual precipitation of 56 cm. occurs mostly during the months when vegetation is dormant; the average annual rainfall for June (a wet month in 1913) being only 2.54 cm. The graphs indicate that the maximum evaporation occurred during the latter part of July. At this time the water content of the soil to a depth of 25 cm. had reached the non-available point[3] and the vegetation, including the deep crevice-rooted bunchgrass, was rapidly drying up. The average daily evaporation for the two instruments at station No. 1 during the 126 days of observation was 28 cc. The mean of the readings of these two instruments is believed to express quite accurately the measure of the evaporating power of the air and is therefore plotted and used in comparison with similar graphs in figure 5.

The prairie replaces the bunchgrass-rimrock type of vegetation as one passes up over the sides of the canyons. The chief factors causing the transition are the increased depth and increased water holding capacity of the soil. The first invaders are *Balsamorhiza sagittata, Lupinus ornatus, Antennaria luzuloides, Achillea millefolium lanulosa, Festuca ovina ingrata* and *Lithospermum ruderale* Other prairie species appearing early in the succession are *Helianthella douglasii, Hoorebekia racemosa, Potentilla blaschkeana, Hieracium scouleri, Castilleja lutescens, Koeleria cristata, Gaillardia aristata, Siversia ciliata,* and species of *Aster*; while *Epilobium paniculatum, Clarkia pulchella, Polygonum majus, Festuca pacifica,* and *Madia exigua*—all characteristic rimrock plants—tend to drop out. *Agropyron* under the new conditions abandons its characteristic bunch habit, in part, and breaks up into smaller clumps which may spread by

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[3] Wilting coefficient determinations were made by Dr. L. J. Briggs, of the Bureau of Plant Industry, to whom the writer is indebted.

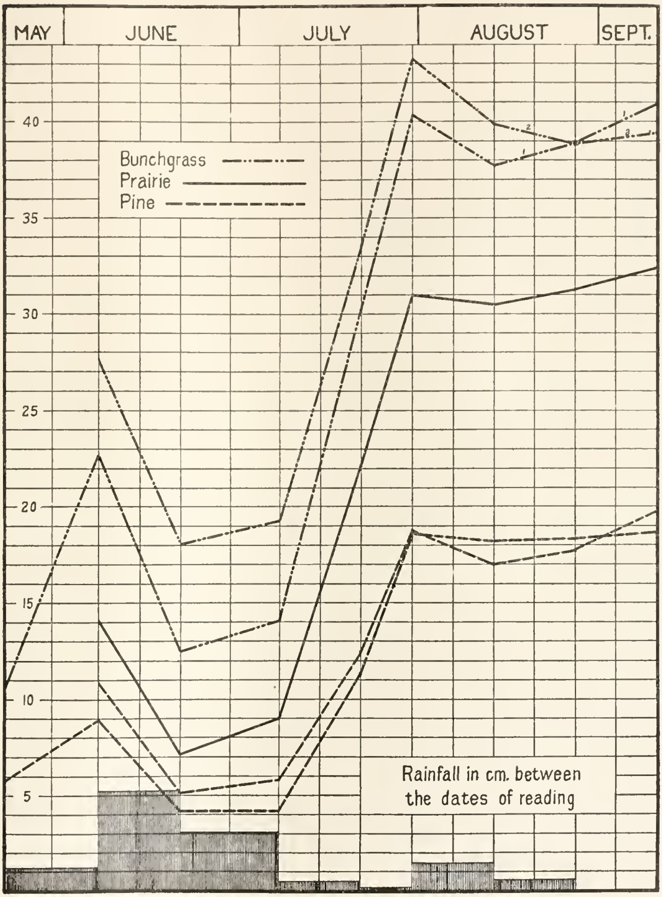

Fig. 2. Evaporation rates in the bunchgrass-rimrock association, the prairie, and in the pine association, near Colfax, Washington.

rhizomes, and thus it becomes a partial sod former. The difference between prairie vegetation occupying exposed and sheltered slopes is so marked that it will be given special consideration when comparing the results obtained at the base station where evaporation was determined in both situations.

The graph representing the evaporation at the prairie station (fig. 2) shows a great similarity in its general course and in its simultaneous maxima and minima to that of the preceding. The markedly smaller average daily evaporation of 21 cc. (from May 21 to September 10) is due to the slightly lower temperature and greater humidity, and the less wind velocity brought about both by the position of the atmometer on the leeward slope and by the vegetation which completely covers the ground.

An open yellow pine forest occupies the more sheltered part of the protected side of the canyon from which vantage ground it is slowly invading the prairie. That these pines are relatively recent invaders is shown both by the age of existing trees and the almost entire absence of the remains of former generations. The characteristic under-shrub is *Opulaster pauciflorus*. Important herbaceous relicts from the prairie are *Potentilla blaschkeana*, *Siversia ciliata*, *Galium boreale*, *Trillium petiolatum*, *Viola adunca*, *Synthyris rubra*, and *Heuchera glabella*; while the presence of such plants as *Cytherea bulbosa*, and *Pterospora andromedea* indicate decidedly mesophytic conditions. The pine grass (*Calamagrostis suksdorfii*) and *Deschampsia calycina* are also important species here. The former often covers the ground completely, while in other places a carpet of pine needles nearly excludes vegetation. In carefully chosen typical areas, about 20 m. below station No. 2, and near the upper edge of the pines, station No. 3 was maintained. An examination of the graphs here obtained (fig. 2) shows again a general conformity to those preceding; but the average rate of evaporation for the whole period was only 11.8 cc. per day.

A second set of stations was maintained on the basaltic soils near Pullman, in the prairie formation. Preliminary investigations in the spring and autumn of 1912 showed that the evaporation on the two hillsides was markedly different; accordingly

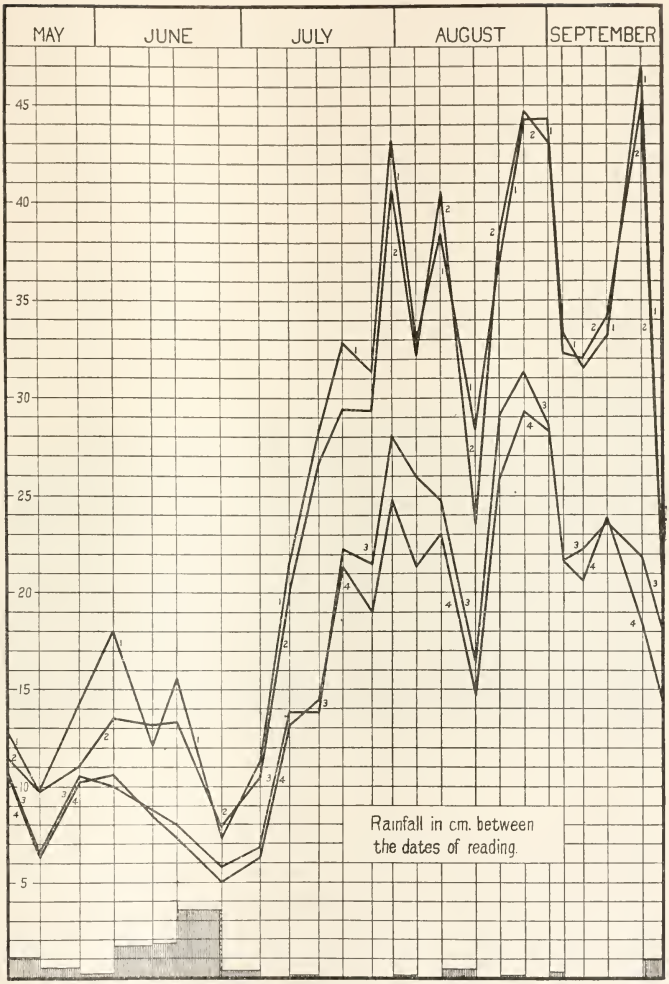

Fig. 3. Evaporation rates in the prairie formation near Pullman, Washington. Graphs 1 and 2 on a southwest exposure, and 3 and 4 on a northeast exposure.

a station with two atmometers was established on the southwest slope about 20 m. from the crest of a hill somewhat less than the average height, and another station with two instruments was placed at an equal distance from the hilltop on an average northeast slope. These atmometers were read at intervals of a week or less from May 5 to September 23, as shown in the graph (fig. 3), on which chart the rainfall at Pullman is also recorded in cm. An inspection of these graphs shows a remarkable similarity in their general course throughout the season, but the difference in the amount of evaporation is just as striking. The average daily evaporation on the north slope is 16 cc., which is only 64% of that (25 cc.) on the south slope. The greatest factor in causing this difference is the same one that has so profoundly influenced the topography, namely, the wind. During the 141 days of observation, the wind was from the southwest 43% of the time;

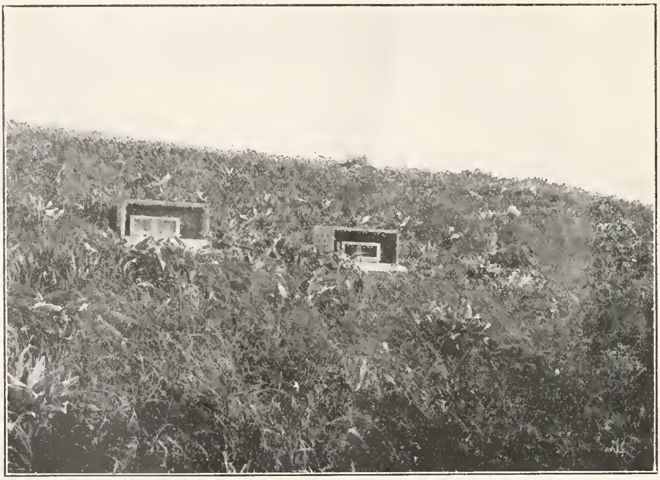

Fig. 4. Station No. 4, in the prairie formation near Pullman, Washington. The atmometers are to the left and not shown in the picture

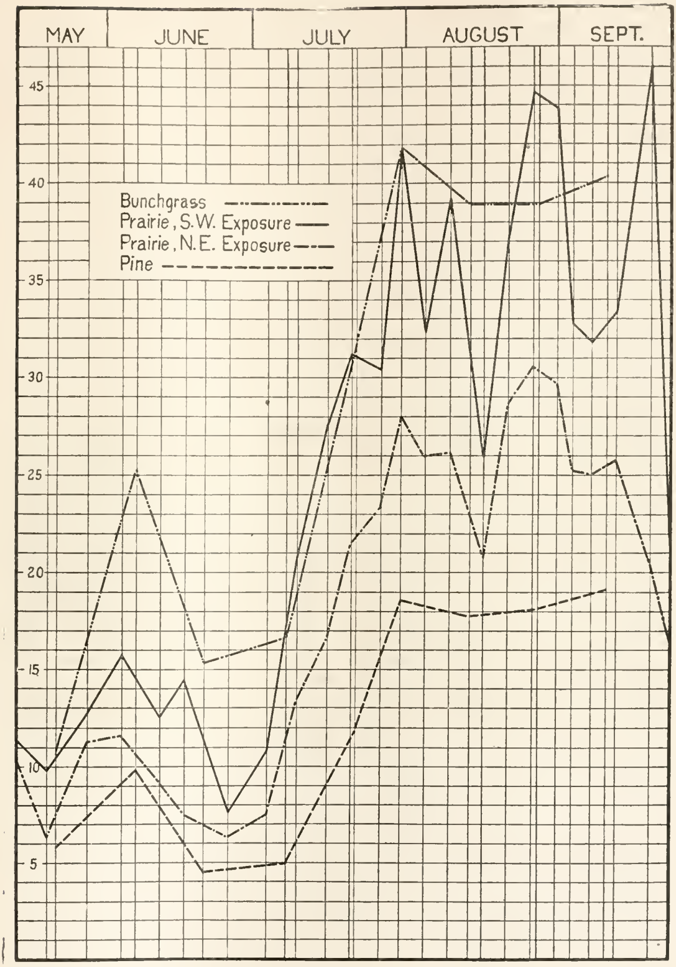

Fig. 5. Mean daily evaporation in the bunchgrass-rimrock association, the more xerophytic and less xerophytic types of prairie, and in the pine association.

while during 68% of the time it was from some southerly direction which struck the southwest slopes. Readings from anemometers placed at these prairie stations (fig. 4) showed, for example, that during the period from May 2 to June 3, 1120 miles of wind passed over the northeast slope at a distance of 50 cm. from the ground while 3.1 times as much (3497 miles) passed over the southwest exposure. In this region, where the annual precipitation is only 56 cm., most of which falls in the winter and early spring, were it not for the high water-holding capacity of the silty loam soil, the drying winds would convert the prairies into a semi-desert. In fact the prairies may be divided into the more xerophytic and less xerophytic types, the former occupying exposed south and southwest slopes, the latter north and northeast slopes and the narrow intervening valleys. An examination of 70 sq. m. quadrats, carefully selected at Pullman, Colfax, and Whelan, to represent typical conditions on exposed and protected hillsides, reveals marked differences in the floristic composition. In table 1 the first horizontal group includes plants equally or nearly equally represented on the exposed and sheltered slopes. It will be noted that the grasses—*Festuca ovina ingrata*, *Agropyron spicatum*, and *Koeleria cristata*—are not only about equally distributed but occur in all the quadrats, while *Poa sandbergii* has a tendency to drop out on the north slopes. The second group (A) shows plants which, while occurring on the north slopes are more abundant in the drier situations. It also includes plants (B) that (with the exception of *Wyethia amplexicaulis*) rarely occur on the moist hillsides. Group 3 lists those plants which are more abundant in the less xerophytic situations; and the last group includes plants which rarely occur except on sheltered north and northeast slopes. While the area here considered is very limited in extent, the floristic conditions which it reveals bear out in the main those repeatedly observed in the various prairie areas of the region.

The atmometers at station No. 4 on the southwest slope were operating in a situation where the plants averaged 112 individuals per sq. m. with 19% bare ground, while at station No. 5, 200 plants occurred in each unit area with only 3% of the soil surface

TABLE 1

Showing the average number of plants per sq. m. quadrat and the per cent of quadrats in which they occur, on N.E. and S.W. exposures, respectively, in the prairie formation

	AVE. NO. PER SQ. M. N.E. EXPOSURE	PER CENT OF QUADRATS IN WHICH IT IS REPRESENTED	AVE. NO. PER SQ. M. S.W. EXPOSURE	PER CENT OF QUADRATS IN WHICH IT IS REPRESENTED	LIST INCLUDES NO PLANTS AVERAGING LESS THAN 0.5 PER SQ. M.
Per cent of bare ground	3	29	19	100	Each bunch of grass or Carex is counted as an individual
Koeleria cristata	9	100	8	100	Bunches seldom more than 2.5 cm. in diameter
Festuca ovina ingrata	10	100	13	100	Bunches from 2–10 cm. diameter. Best developed on S. side
Agropyron spicatum (including var. *inerme*)	9	100	9	100	Bunches often less than 3 cm. diameter
Poa sandbergii	2	29	4	62	Clumps always small, often less than 3 cm. diameter
Achillea millefolium lanulosa	6	90	6	100	Much better developed on S. side.
Rosa spp	2	71	2	72	Each clump counted as one plant
Symphoricarpos racemosus	3	84	3	82	Each clump counted as one plant
Lupinus ornatus	4	64	7	92	
Solidago missouriensis	2	29	3	31	
Hoorebekia racemosa	1	26	2	31	
Lithospermum ruderale	1	39	1	51	
Collinsia tenella	1	13	3	31	A
Epilobium paniculatum	2	26	5	64	
Bromus hordeaceus	4	16	16	23	
Balsamorhiza sagittata	1	29	3	85	
Helianthella douglasii	2	6	6	46	
Agoseris heterophylla			1	28	
Allium acuminatum			7	10	
Alyssum alyssoides			1	3	B
Wyethia amplexicaulis			1	5	
Antennaria luzuloides			1	18	Each mat counted as one plant
Potentilla blaschkeana	14	100	3	60	
Siversia ciliata	5	81	2	80	Each cluster of rosettes counted as one plant
Aster spp. and *Erigeron corymbosus*	4	58	0	3	
Hieracium scouleri	3	67	2	64	
Castilleja lutescens	2	61	1	36	
Synthyris rubra	9	80	1	44	
Galium boreale	9	71	1	15	
Geranium viscosissimum	7	84		33	
Gaillardia aristata	2	68		10	
Bromus brizaeformis	6	23		13	
Carex geyeri	6	67		3	This list does not include a few plants that occur very early in the spring. Of these *Erythronium grandiflorum*, confined to N. hillsides, is alone important
Lupinus leucophyllus	1	26			
Viola adunca	13	71		3	
Sidalcea oregana	1	10			
Heuchera glabella	2	39			
Drymocallis convallaria	1	39			
Gentiana oregana	3	42			
Arnica pedunculata	1	32		3	
Epilobium angustifolium	1	35			
Silene douglasii	1	29		3	
Carduus palousensis	2	32		8	

unoccupied. At the time of the third maximum period of evaporation during the last week in July, the vegetation near station No. 4 (except *Hoorebekia racemosa* and *Solidago missouriensis*) was rapidly drying up, and the soil moisture for a depth of 25 cm. had been reduced to its non-available point; while on the north slopes similar conditions were not reached until the second week in September, and, indeed, several plants, such as *Gentiana oregana*, *Aster fremonti*, *Carum gairdneri* and others, remained in blossom until the frosts of late September.

For comparison, the mean average daily evaporation graphs of all instruments in the bunchgrass-rimrock association, the more xerophytic and less xerophytic prairies, and the pine association are plotted upon the same chart in figure 5. All show a maximum in early June and another in July after which time evaporation is high until the middle of September. The greater regularity in the highest and lowest graphs is due in part to the longer intervals between readings, and this same explanation probably accounts for the overlapping in places of the bunchgrass and dry prairie graphs. With this exception, however, the evaporation in each association is decidedly lower than that of the association which it replaces in the normal succession. In figure 6 is shown a comparison of the evaporation rates in the different associations on the basis of the average daily amount from May 7 to September 10, a period of 126 days. This gives the same result, only expressed in a different manner.

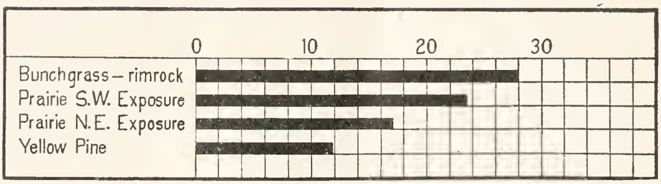

Fig. 6. Diagram showing the comparative evaporation rates in the different plant formations and associations of the plains on the basis of the average daily amount from May 7 to September 10.

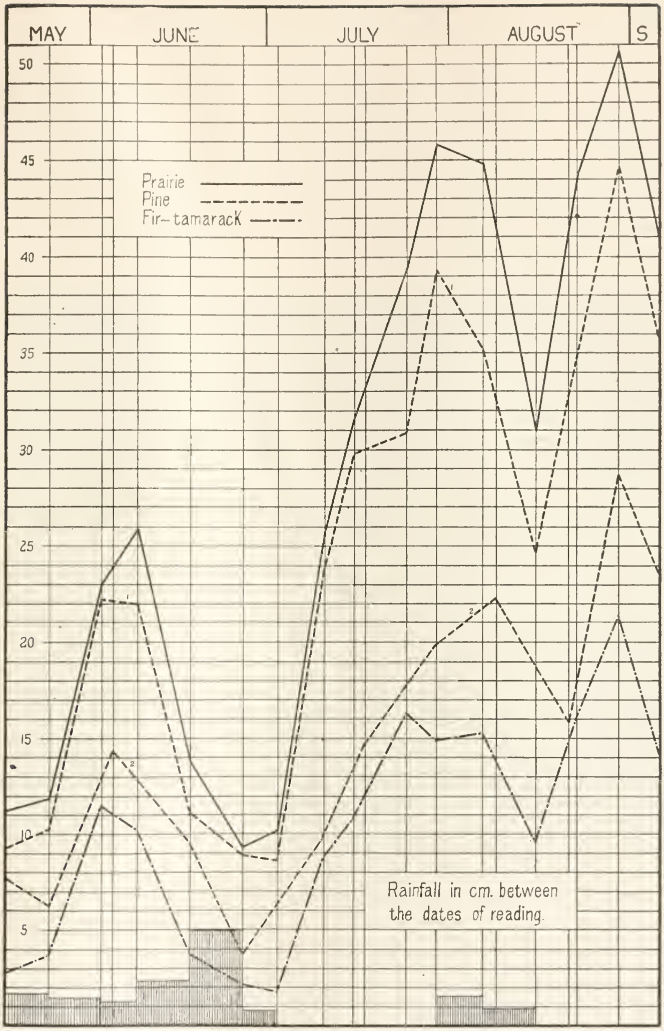

Fig. 7. Evaporation rates in the plant formations and associations on Kamiak Mountain and in the pine association (graph 2) at Viola, Idaho.

We shall next consider the plant associations and evaporation on the buttes and mountains. The factors causing evaporation—humidity, temperature, and wind—are all so much greater in degree upon the exposed south and southwest sides of the buttes that they have exerted a marked effect upon plant distribution. The conditions on Kamiak Mountain, a bold butte lying nine miles north of Pullman, and one of the series extending in a westerly direction from Thatuna Hills, illustrates this condition very well. This butte, running from east to west for a distance of over two miles and reaching an elevation of 300 meters above the surrounding hilltops, is covered on the south side with the prairie formation, while the steeper north slope bears a dense forest of Douglas fir (*Pseudotsuga mucronata*) and Western larch (*Larix occidentalis*). On the south side trees occur only near the summit, where outcropping rocks furnish in their crevices a sufficient shelter and water supply for the establishment of the seedlings. Here is a very open growth of yellow pine (*Pinus ponderosa*) which flanks the fir and tamarack on both ends of the butte and occupies the less sheltered north base below the fir-tamarack zone.

Eight miles east, near Viola, Idaho, is another butte slightly lower than Kamiak, but with plant associations very similarly distributed. Here again the south side is prairie, which the pines, occupying the crest and northwestern slope, are gradually invading. The sheltered northeast sides are clothed with a forest of Douglas fir and tamarack. These conditions are representative of numerous other situations. Only as the mountains become higher and rainfall increases, does the prairie give way to a forest growth, but in all places areas of prairie occur near the summits on the exposed slopes.

The butte prairies at Kamiak and Viola are not very unlike those upon the basalt as far as kinds of species and their distribution are concerned; but, owing in part to the more open soil and consequent smaller water-holding capacity, combined with greater exposure to the wind, the vegetation bears a more xerophytic stamp and there are fewer plants per given area and, consequently, more soil surface is exposed.

Occupying a place in the succession between the prairie and the fir-tamarack stages, is the yellow pine. This tree is able to invade the prairie even without the protection of an intervening shrubby stage, although often a growth of *Opulaster pauciflorus*, *Prunus emarginata*, *Spiraea corymbosa*, or *Ceanothus* spp. precede it in the ordinary course of succession. Likewise the Douglas fir closely follows the pines and, as already pointed out, the white fir may sometimes precede the tamarack, thus giving rise to a mixed association of pine, Douglas fir, and white fir. When conditions become more meseophytic, the Douglas fir-tamarack stage is followed by the climax cedar association This last association is not represented either at Kamiak or Viola.

Fig. 8. A view in the cedar association on Cedar Mountain near station No. 10

During the first week in May, four atmometers were placed in the prairie formation on Kamiak Butte and two in the same formation at Viola. Owing to accidents and the loss of some readings, complete data from only four instruments were obtained. The two sets of readings from the Kamiak atmometers, which were placed only a few meters below the pine zone, are shown combined in figure 7. The rainfall on the chart in this figure is given in cm. for a station near Viola at an altitude of approximately 1000 m. The readings of the Viola atmometers (not shown here, but combined with those from Kamiak in fig. 9) were very similar.

Just within the edge of the pine zone and 20 m. above station No. 7, station No. 8 was maintained. Here the ground is covered with pine needles which almost exclude undergrowth and the atmometer was shaded only indifferently by the open growth of the trees. That this was a decidedly xerophytic habitat is shown by the evaporation graph (fig. 7, graph 1) which closely follows that of the prairie. The evaporation data in the more typical yellow pine habitat located on the northwest slope of the butte at Viola is plotted on the same chart for sake of comparison (fig. 7, graph 2).

Station No. 9 was located on the north side of Kamiak butte nearly opposite No. 7 and No. 8, about 20 m. from the top, in the fir-tamarack association. The mountain side having been cut over about 35 years ago, the trees of this association are chiefly second growth. Douglas fir and tamarack are nearly equally distributed with a mixture of about 3% white fir. The pines are almost excluded. The chief shrubs of the undergrowth are *Rubus parviflorus, Rosa gymnocarpa, Pachistima myrsinites, Vaccinium macrophyllum,* and half-dead bushes of *Opulaster pauciflorus.* Other important plants of the undergrowth are *Linnaea americana, Arnica cordifolia, Vagnera amplexicaulis, Anemone quinquefolia, Calamagrostis suksdorfii, Cytherea bulbosa,* and *Fragaria platypetala.* In most places the undergrowth is poorly developed and often the forest floor is nearly bare.

The station in the fir-tamarack association at Viola was located two-thirds of the way down the northeast slope of the

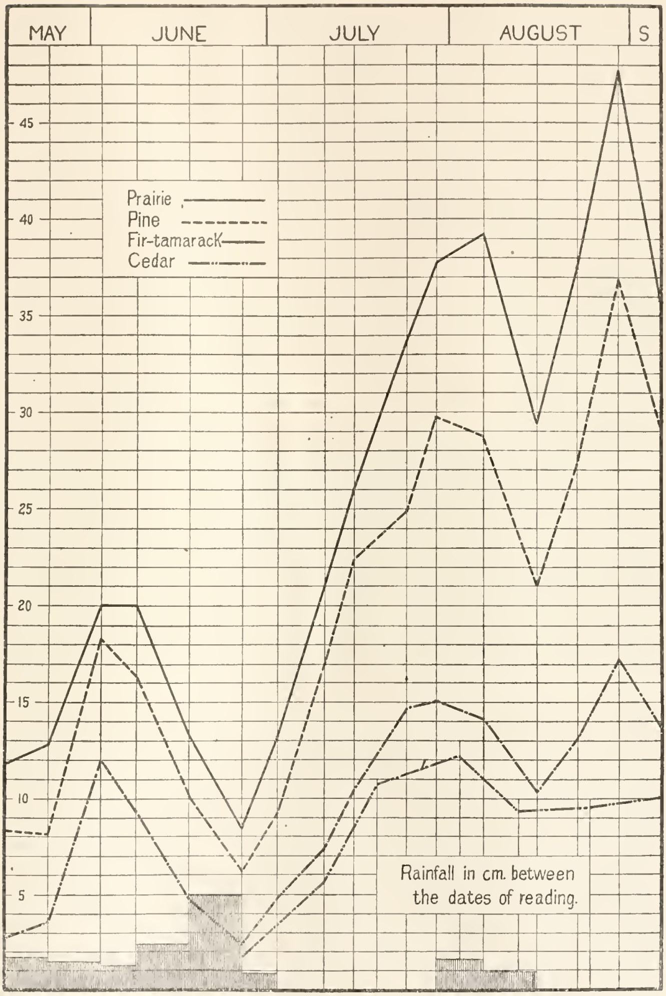

Fig. 9. Mean daily evaporation rates in the butte-mountain plant formations and associations.

butte on the side opposite the station in the prairie. Here, as at Kamiak, the forest is second growth. Actual count showed the trees to be mostly 32 years old. They are principally Douglas fir and tamarack, among which the Western cedar (*Thuja plicata*) is coming in, while the numerous dead yellow pines tell the story of the lost struggle for light. The rather sparse undergrowth is very similar to that in the fir-tamarack forest on Kamiak Butte. The graph representing evaporation here corresponds in general with that obtained at Kamiak (fig. 7) and like it shows without exception a continuous lower daily rate of evaporation than that in the pine association. All the graphs plotted show three periods of extreme evaporation, one in early June, another in late July and the first week in August, and still another the last week in August. At the time of the second maximum, the prairie and pine soils at both Kamiak and Viola had lost all of their available water to a depth of 25 cm., while in each of the two fir-tamarack stations a margin of only about 12% above the nonavailable point was left on July 24.

Thatuna Hills extend southeast from Viola and reach their culmination in Cedar Mountain, a point about 1500 m. high, lying eighteen miles east of Pullman. Here we find in the cedar association the climax type of forest of the region. On June 14, as soon as the snow had melted away, stations were established on the north slopes of this mountain about 200 m. from the summit, one in the cedars and one over a ridge about 250 m. eastward in the fir-tamarack association.

The cedar association (station No. 10) occupies a north slope and a ravine, through which flows a small stream. This forest is over 95% pure cedar, mostly large trees from 70 cm. to more than a meter in diameter (fig. 8) while the rest of the trees are large white firs which are mostly dead. Near the stream the forest floor is covered with *Athyrium cyclosorum* which gives way further back to a rather dense growth of *Rubus parviflorus, Vagnera amplexicaulis, Tiarella unifoliata, Trillium ovatum, Clintonia uniflora, Disporum majus, Pyrola* spp, *Actaea spicata arguta,* and *Coptis occidentalis.* These with *Viola* spp., and *Streptopus amplexifolius* together with *Phegopteris dryopteris,* and the seedlings of the cedar, make up the characteristic undergrowth, while further up the slope the ground is almost bare. Three instruments were installed here on June 14 and readings were taken on alternate weeks until September 19. All of the atmometers were placed in situations rather free from undergrowth, so that the readings are perhaps higher than representative conditions warrant. During the same period two atmometers were maintained at station No. 11 in the fir-tamarack association. This association also occupies a north slope somewhat above and east of the cedar association. The Douglas fir and tamarack are the principal trees, but a considerable amount of white fir and some spruce (*Picea englemanni*) are also present. The undergrowth is very sparse. The few species represented include some of those enumerated at station No. 10. Unfortunately one instrument was taken a week before the end of the season so that only a single graph was obtained from data taken here. This together with those obtained in the cedars is represented in figure 9 where all readings on the prairies, in the pines, in the fir-tamarack association and in the cedars are respectively combined. Inspection of these combined graphs together with figure 10, where the average daily rate of evaporation is shown for each association, bears out the former finding that plant succession is closely related to evaporation.

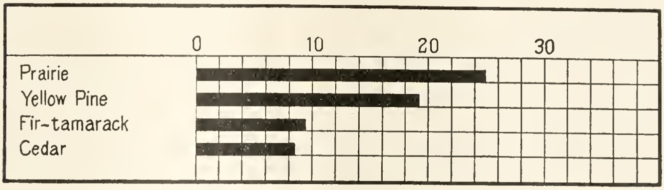

Fig. 10. Diagram showing the comparative evaporation rates in the butte-mountain plant formations and associations on the basis of the average daily amount from May 7 to September 5 (except in the cedars, which is from June 14 to September 19).

The plant formations and associations, their order of succession, and the various rates of evaporation, while determined for a relatively local region, are probably representative of a much larger area—perhaps several thousand square miles in Eastern Washington.

Following the valuable suggestion of Fuller[4] "that a plant association of wide distribution (such as the beech-maple forest of the Eastern United States) be used as a basis for comparison (of evaporation), and that the conditions in other associations be expressed in the same units," we find that evaporation in the cedar association from June 14 to September 21 is only .5 cc. per day greater than in the beech-maple forest. In the fir-tamarack association from May 10 to September 5 atmospheric conditions in the lower stratum are 120% as severe; in the average prairie formation of the plains 250%; and in the bunchgrass-rimrock association 345% as unfavorable for plant life, as regards the evaporating power of the air. While these data represent the evaporation in the lower strata only, yet this is the critical one for the establishment of seedlings and therefore the most important ecologically.

Evaporation at different stations in the same plant association exhibits variations similar both in character and degree, and these variations in the rate of evaporation gradually become less and less as the climax type of vegetation is approached.

The great amount of evaporation in the earlier stages of succession seems a sufficient cause for the xerophytic character of the vegetation.

A study of the differences of the rates of evaporation in the various plant formations and associations shows that these differences are sufficient to be important factors in causing succession, at least through the earlier stages, where light values are usually high.

The writer hopes to continue and extend these investigations during coming seasons.

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[4] Fuller, George Damon, Evaporation and Plant Succession. Bot. Gaz., **52**: 193–208, 1911.

ANTAGONISM BETWEEN ANIONS AS RELATED TO NITROGEN TRANSFORMATION IN SOILS

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When a subject of biochemical research is of absorbing interest from the purely scientific point of view it deserves the most earnest consideration at our hands, but when it is of potential practical value as well, it becomes fascinating. Such is the subject of salt effects in all its ramifications, as applied to the domain of biology and it is probably conservative enough to state that nothing in recent work in biological science has engendered greater activity and interest in research than the splendid series of investigations of Loeb and his co-workers on the rôle of salts in animal life. Of no smaller interest and significance, have been the researches of modern plant physiologists in their application, to the realm of plants, of the principles established by Loeb.

The writer has attempted during the past five years not only to point out through his investigations the remarkable rôle of salts in the physiological efficiency of soil bacteria in pure and mixed cultures, but also the additional tasks of applying Osterhout's findings to the growth of plants in soils rather than in solutions, and to correlate these effects with those noted for the soil bacteria. The latter work was of course based on the fact that the soil bacteria are admittedly one of the essential factors in soil studies and of importance at least tantamount to that of any other single factor in soil fertility.

My first work[1] dealt with pure cultures of *Bacillus subtilis* and their ammonifying power in peptone solutions as affected by the presence of various salts, singly, in combinations, and in various concentrations. The effects of the positive or kation were studied here exclusively, the chlorine ion being uniformly the anion

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[1] Bot. Gaz., vol. 48, p. 105 and vol. 49, p. 41.

employed. The kations studied were sodium, potassium, calcium, and magnesium. When used alone these chlorides were found to be toxic in the following order: calcium, magnesium, sodium, and potassium. In a variety of combinations of these salts it was found that the toxicity of all of them for *B. subtilis* could be very much reduced by mixing any one of them in the same concentrations with a certain other salt even though the latter itself be toxic at that concentration. It was thus found that antagonism existed between sodium and magnesium, between sodium and potassium, and between potassium and calcium. Likewise it was found that no antagonism existed between sodium and calcium and none between calcium and magnesium.

It was further found in later researches[2] that Loeb's conception of the physiologically balanced solution for animals and plants was also valid for bacteria and that sea water which Loeb had looked upon as a natural balanced solution for other organisms also proved to be a perfectly balanced solution for *B. subtilis* as obtained in pure cultures from a soil.

Up to this time, however, but very little attention had been given to the study of the rôle of the anion in antagonistic salt effects. Loeb in fact as well as Osterhout and other students of this most interesting subject had declared the anion to be of but little significance in antagonistic salt effects and believed the kation to be of greatest importance in that connection. The work of Miss Moore and of Neilson had received therefore but scant attention but is mentioned in Robertson's review[3] of the researches carried out on the rôle of salts in life processes. The writer had believed for some time prior to reading the work above mentioned that antagonism between anions was, *a priori*, to be expected. Moreover, realizing the fact, when the subject is viewed from the practical standpoint, that the salts occurring in alkali soils are mostly those of sodium combined with hydrochloric, sulphuric, and carbonic acids, it appeared of the greatest practical significance as well as of scientific interest to determine whether or not

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[2] Bot. Gaz., vol. 49, p. 207.

[3] Ergebn. d. Physiol., vol. 5, p. 216.

antagonism existed between the anions of those salts and whether it existed for both soil bacteria and for the higher plants. The results of researches which were inaugurated to test these points have been most gratifying and some very striking examples of existing antagonism under the conditions named have been obtained in the cases both of the plants and of the bacteria. For the purposes of this paper only the latter phases of the subject can be dealt with.

ANTAGONISM BETWEEN ANIONS AS AFFECTING AMMONIFICATION

Ammonification, which is the process by which organic nitrogen is transformed to the ammonia form in soils, is carried out by many different species of bacteria working at the same time but not necessarily in the same direction. However, since organic nitrogen must be transformed into nitrates through the agency of the nitrifying bacteria it was deemed wise to study the effect of salt antagonisms as between anions first with respect to ammonification and then with respect to nitrification so as to determine how the general process of nitrogen transformation in soils is affected by them.

The method employed in the ammonification experiments was as follows: To 100 gram portions of a light sandy soil with a good ammonifying and good nitrifying power, placed in tumblers, were added 2 grams of dried blood and the different salts (as indicated in the tables given below). Enough sterile distilled water was added to make optimum moisture conditions and the mixture stirred with a sterile spatula. The tumbler was covered with a Petri dish cover and allowed to incubate for a week at 28° to 30°C. At the end of the incubation period the soil was transferred to copper distilling flasks, 300 to 400 cc. of distilled water and an excess of magnesia added, and the ammonia was distilled into standard acid, the excess of the latter being titrated against standard ammonia. The salt additions were made on the basis of their toxicities which were determined in investigations described elsewhere.[4] All determinations were run in

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[4] Cent. für Bakt., vol. 32, p. 58; vol. 33, p. 305; vol. 35, p. 647, 2te abt.

duplicate and the tables below give such duplicate determinations, as well as the averages and other necessary data.

The data given in Tables I, II and III leave no room for doubt as to the genuineness of antagonism between anions. Moreover, they constitute the most striking of such antagonisms thus far published. We see, therefore, that not only can we induce

TABLE I

NaCl *versus* Na_2SO_4

NO.	PER CENT NaCl IN DRY SOIL	PER CENT Na_2SO_4 IN DRY SOIL	N AS AMMONIA PRODUCED MGS.		AVERAGE N AS AMMONIA PRODUCED MGS.
			1	2	
1	0	0	55.16	53.76	52.46
2	0.20	0	30.52	30.94	30.73
3	0.20	0.10	31.78	31.78	31.78
4	0.20	0.20	30.80	33.46	32.13
5	0.20	0.30	37.66	36.54	37.10
6	0.20	0.40	28.84	30.24	29.50
7	0.20	0.50	28.28	26.60	27.44
8	0.20	0.60	28.28	25.90	27.09
9	0.20	0.70	26.88	25.48	26.18
10	0.20	0.80	22.82	24.64	23.73

TABLE II

NaCl *versus* Na_2 CO_3

NO.	PER CENT NaCl IN DRY SOIL	PER CENT Na_2CO_3 IN DRY SOIL	N AS AMMONIA PRODUCED MGS.		AVERAGE N AS AMMONIA PRODUCED MGS.
			1	2	
1	0	0	40.25	43.26	41.75
2	0.20	0	22.61	21.49	22.05
3	0.20	0.20	38.29	37.31	37.80
4	0.20	0.30	39.69	38.99	39.34
5	0.20	0.40	44.17	46.69	45.43
6	0.20	0.50	49.91	50.61	50.26
7	0.20	0.60	68.95	66.15	67.55
8	0.20	0.70	69.37	72.03	70.70
9	0.20	0.80	53.13	54.25	53.69
10	0.20	0.90	41.09	42.63	41.86
11	0.20	1.00	45.29	43.19	44.24
12	0.20	1.20	34.23	35.77	35.00

TABLE III

Na_2SO_4 *versus* Na_2CO_3

NO.	PER CENT Na_2SO_4 IN DRY SOIL	PER CENT Na_2CO_3 IN DRY SOIL	N AS AMMONIA PRODUCED MGS.		AVERAGE N AS AMMONIA PRODUCED MGS.
			1	2	
1	0	0	55.89	51.27	53.58
2	0.90	0	27.82	29.36	28.59
3	0.90	0.30	19.19	19.90	19.55
4	0.90	0.40	20.80	20.66	20.73
5	0.90	0.50	31.67	31.25	31.46
6	0.90	0.60	46.31	44.45	45.38
7	0.90	0.70	32.16	26.00	29.08
8	0.90	0.80	27.82	24.74	26.28
9	0.90	0.90	27.12	25.22	26.17
10	0.90	1.00	25.58	21.03	23.31
11	0.90	1.20	18.65	16.41	17.53

antagonism between Na_2CO_3 and NaCl and Na_2SO_4 in which cases the first named salt is a stimulant to ammonification even at high concentrations, but that even between two definitely toxic salts like NaCl and Na_2SO_4 a distinct antagonism obtains so far as the ammonifying flora are concerned. That these results are not accidental is attested to by the large amount of data above submitted and by the excellent agreement which obtains between duplicate determinations.

In the above data, therefore, we are confronted by the singular and most interesting fact that marked improvement for ammonia production in alkali soils by biological means may be effected by the proper balancing of salts, and what is more striking, that such balancing of salts may actually mean a doubling or even tripling of the total salt content which involves enormous changes in the osmotic pressures of the soil solution in which the organisms work.

No further discussion is necessary to emphasize the results which are so clearly set forth in Tables I, II and III. The writer only wishes to add the observation that regardless of the attitude one may take with reference to what constitutes antagonism between ions there are given data in the foregoing tables which testify to the existence of antagonism between anions when the latter are both toxic, as well as when one of them is toxic and the other stimulating. Thus, the undoubted antagonism shown to obtain between NaCl and Na_2SO_4 gives an unequivocal reply to the assertion which might be made, on the basis of the other two tables, to the effect that antagonism between the ions only exists when one of them exercises a stimulating effect, which, to a considerable degree, is true of Na_2CO_3 in respect to ammonification.

ANTAGONISM BETWEEN ANIONS AS AFFECTING NITRIFICATION

The experiments dealing with this phase of the subject were even more elaborately arranged than the foregoing work in that reciprocal series were run in all cases. In other respects the cultures were prepared like those in the ammonification series except that 1% of dried blood instead of 2% was used. All other explanatory data are given in the following tables.

Nothing can be more convincing proof of the existence of antagonism between anions than the foregoing figures obtained from the nitrification experiments. Not only does antagonism between the anions prevent injury to the nitrifying flora in the case of salts which are only moderately or slightly toxic, but it does so most markedly in cases in which extremely toxic salts are employed.

TABLE IVA

Na_2SO_4 *versus* NaCl

NO.	PER CENT NaCl IN DRY SOIL	PER CENT Na_2SO_4 ADDED TO DRY SOIL	N AS NITRATE PRODUCED MGS.		AVERAGE N AS NITRATE PRODUCED MGS.
			1	2	
1	0	0	23.52	23.24	23.38
2	0.20	0	10.08	10.92	10.50
3	0.20	0.05	29.96	29.40	29.68
4	0.20	0.10	28.56	29.26	28.91
5	0.20	0.15	28.00	28.56	28.28
6	0.20	0.20	28.00	27.58	27.79
7	0.20	0.25	23.80	22.96	23.38
8	0.20	0.30	20.44	20.72	20.58
9	0.20	0.35	17.08	18.48	17.78

TABLE IVB

NaCl *versus* Na_2SO_4

NO.	PER CENT Na_2SO_4 IN DRY SOIL	PER CENT NaCl ADDED TO DRY SOIL	N. AS NITRATE PRODUCED MGS.		AVERAGE N AS NITRATE PRODUCED MGS.
			1	2	
1	0	0	23.52	23.24	23.38
2	0.35	0	19.04	19.88	19.46
3	0.35	0.05	20.72	21.56	21.14
4	0.35	0.10	21.56	22.40	21.98
5	0.35	0.15	23.52	23.80	23.66
6	0.35	0.20	18.48	12.60	15.54
7	0.35	0.25	9.80	lost	9.80

TABLE VA

Na_2SO_4 *versus* Na_2CO_3

NO.	PER CENT Na_2CO_3 TO DRY SOIL	PER CENT Na_2SO_4 ADDED TO DRY SOIL	N AS NITRATE PRODUCED MGS.		AVERAGE N AS NITRATE PRODUCED MGS.
			1	2	
1	0	0	23.52	23.24	23.38
2	0.05	0	6.44	5.60	6.02
3	0.05	0.025	10.92	lost	10.92
4	0.05	0.050	11.20	10.64	10.92
5	0.05	0.100	17.08	20.72	18.90
6	0.05	0.200	25.76	29.69	27.72
7	0.05	0.300	28.84	26.88	27.86
8	0.05	0.400	28.56	30.80	29.68
9	0.05	0.500	25.20	26.60	25.90
10	0.05	0.600	19.60	22.68	21.14

TABLE VB

Na_2CO_3 *versus* Na_2SO_4

NO.	PER CENT Na_2SO_4 IN DRY SOIL	PER CENT Na_3CO_3 ADDED TO DRY SOIL	N AS NITRATE PRODUCED MGS.		AVERAGE N AS NITRATE PRODUCED MGS.
			1	2	
1	0	0	23.52	23.24	23.38
2	0.35	0	19.04	19.88	19.46
3	0.35	0.010	26.60	29.40	28.00
4	0.35	0.025	31.64	34.72	33.18
5	0.35	0.050	32.48	22.68	27.58
6	0.35	0.100	15.68	16.80	16.24
7	0.35	0.150	13.44	16.52	14.98
8	0.35	0.200	15.40	lost	15.40

TABLE VIa

$NaCl$ *versus* Na_2CO_3

NO.	PER CENT Na_2CO_3 IN DRY SOIL	PER CENT NaCl ADDED TO DRY SOIL	N AS NITRATE PRODUCED MGS. 1	N AS NITRATE PRODUCED MGS. 2	AVERAGE N AS NITRATE PRODUCED MGS.
1	0	0	23.52	23.24	23.38
2	0.05	0	6.44	5.60	6.02
3	0.05	0.05	7.84	8.96	8.40
4	0.05	0.10	16.80	19.60	18.20
5	0.05	0.15	22.12	22.96	22.54
6	0.05	0.20	29.40	22.40	25.90
7	0.05	0.25	14.84	15.82	15.33

TABLE VIb

Na_2CO_3 *versus* NaCl

NO.	PER CENT NaCl IN DRY SOIL	PER CENT Na_2CO_3 ADDED TO DRY SOIL	N AS NITRATE PRODUCED MGS. 1	N AS NITRATE PRODUCED MGS. 2	AVERAGE N AS NITRATE PRODUCED MGS.
1	0	0	23.52	23.24	23.38
2	0.20	0	10.08	10.92	10.50
3	0.20	0.010	17.36	20.44	18.90
4	0.20	0.025	33.60	30.24	31.92
5	0.20	0.050	30.80	26.88	28.84
6	0.20	0.100	23.80	29.12	26.46
7	0.20	0.150	26.88	22.40	24.64

Taking up a consideration of the most striking features of each of the tables above given, we find in Table IVa in which a uniformly toxic quantity of NaCl (0.2%) was employed and varying quantities of Na_2SO_4 the following interesting facts. When NaCl is used alone at the concentration indicated considerably less than 50% of the amount of nitrates is produced that results normally from the activities of the same flora in the same soil that is free from salts. Yet any quantity of Na_2SO_4 from 0.05% to 0.2% inclusive may be added to 0.2% NaCl, in the latter case doubling the alkali content of the soil, and nitrification is not only not depressed further but is much improved over that of the normal soil. Even when 0.3% Na_2SO_4 is added to 0.2% NaCl, thus making a total alkali content of

0.5% of the dry weight of the soil, nitrification is only slightly below the normal.

Considering Table IVb the reciprocal of IVa in which a constant toxic quantity of Na_2SO_4 namely 0.35% is employed we find the following. When 0.35% Na_2SO_4 is added alone, the nitrifying power of the soil is depressed by about 15%. When however varying quantities of NaCl are added thereto ranging from 0.05% to 0.15% inclusive nitrification is gradually improved as the amount of the latter salt is increased until at the last named concentration nitrification is again brought back to the normal.

Table Va and its reciprocal, however, show what are probably the most striking results owing to the acutely toxic nature of Na_2CO_3. Considering each of the two tables separately we find that an addition of 0.05% Na_2CO_3 depresses nitrification to a point approximately 75% below the normal. When however, varying amounts of Na_2SO_4 are added with the Na_2CO_3 nitrification is gradually improved as the amount of Na_2SO_4 is increased until it reaches the very high concentration of 0.5%. Even at that very high salt concentration nitrification is superior to that of the normal soil and even an addition of 0.6% Na_2SO_4 to the 0.05% Na_2CO_3 allows the latter to lower nitrification only very slightly. It is difficult to conceive of anything more striking than these data in support of the theory of antagonism between ions.

In Table Vb the reciprocal of Table Va in which 0.35% Na_2SO_4 is used as the constant toxic salt concentration we find that 0.35% Na_2SO_4 alone as in some of the foregoing tables lowers the nitrifying power of the normal soil by approximately 15%. When, however, varying quantities of Na_2CO_3 ranging from 0.01% to 0.05% inclusive are added to it nitrification is most markedly stimulated and increased by about 40% in excess of the normal soil.

Considering briefly the last two reciprocal tables we find again most striking evidence in support of antagonism between anions. Thus, for example in Table VIa in which the constant toxic salt Na_2CO_3 is used again at a concentration of 0.05% of the dry weight of the soil we find the latter salt concentration alone depresses the nitrifying power of the normal soil by about 75%. When, however, we add to it varying quantities of NaCl ranging from 0.05% up to 0.2% inclusive, nitrification is not only very much improved but at the last concentration mentioned is superior to that of the normal salt. Yet one of the salts alone depresses nitrification by about 75% and the other alone by about 50%.

Still more amazing than the data of Table VIa are those of its reciprocal Table VIb. Indeed the latter presents in many respects the most striking data in all the experiments described herein. Thus 0.2% NaCl alone depresses the normal nitrifying power of the soil by considerably more than 50%, and 0.05% Na_2CO_3 alone depresses it by about 75%. Yet when the two are added to the soil together the nitrifying power is increased by more than 25% above that of the normal. Even greater stimulations are obtained when smaller quantities of Na_2CO_3 are added to the 0.2% NaCl. The fact, however, which is most striking in this last table is that amounts of Na_2CO_3 two or three times as large as that which alone depresses nitrification by about 75% can be made absolutely innocuous, and even allow of a stimulating effect on nitrification, if 0.2% NaCl is added to them.

SUMMARY AND CONCLUSIONS

The data above submitted dealing with the antagonism between anions as related to the production of ammonia and nitrates in soils through biological agencies forms the most striking evidence thus far adduced in investigations of this kind. Indeed, more narrowly considered, it represents to date only the third set of experiments which testify to the genuineness of antagonism between anions, and it sets forth the evidence in hand in support of the principle under discussion in a much more striking and convincing manner than the others mentioned.

These results therefore testify 1st to the general nature of Loeb's conception of physiologically balanced solutions, 2nd to the relatively new or obscure fact that anions are as effective in antagonism between salts as kations, and 3rd, to the promising probability of employing the principle of salt antagonisms as a formidable weapon in the solution of alkali problems in soil management as well as in other problems of practical value which are related to the physiology of plants. Briefly stated the conclusions flowing from these investigations are as follows:

1. Antagonism exists to a more or less marked extent between the anions of alkali salts when the ammonifying powers of soils are employed as criteria in the study of that problem.

2. Marked antagonisms have been found to obtain between NaCl and Na_2SO_4, Na_2CO_3 and Na_2SO_4 and between NaCl and Na_2CO_3.

3. Evidence is given that there is antagonism between toxic concentrations of salts as well as between stimulating concentrations of them.

4. Antagonism between anions is most strikingly proven when the nitrifying power of a soil is employed as a criterion.

5. Such antagonism has been shown to obtain between fixed quantities, known to be toxic, of each of the alkali salts and varying quantities of every one of the other salts.

6. Not only improvement in the ammonifying power, and nitrifying power of soils can be induced by addition of salts to toxic salts already contained in them, but antagonism between anions may be made to improve very markedly the nitrogen transforming powers of soils over those characteristic of the normal soils which are wholly free from alkali.

7. These facts possess profound significance for the reclamation of alkali lands, especially since similar ones have been obtained by us as regards the growth of higher plants with which the effects on the soil bacteria of alkali salts must always be correlated.

To Prof. L. T. Sharp who assisted me in the ammonification work above described and to Prof. P. S. Burgess who likewise did valuable analytical work in connection with the nitrification studies, my sincere thanks are due and this opportunity is gladly taken to express them.

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BOOKS AND CURRENT LITERATURE

Botanical Features of the Sahara.—Cannon has published an amply illustrated account of the geography and vegetation of the Algerian Sahara,[1] instituting comparisons of that region with the deserts of the United States. His route lay southward from Algiers across the Tellian Atlas and Saharan Atlas mountains, and the plateau by which they are joined, and then south-eastward over the Saharan desert to Ghardaia and Ouargla. The Tellian Atlas bears forests of pine (*Pinus halepensis*), cork oak (*Quercus suber*), and juniper (*Juniperus oxycedrus* and *J. phoenicea*) with cedar (*Cedrus atlantica*) at the highest elevations. The Saharan Atlas, which lies further from the Mediterranean, is more lightly forested with the same species of trees. The intermontane plateau is largely occupied by saline depressions and possesses a scant vegetation.

To the southward of Laghouat lies the Sahara, with its monotonous topography: alternating flat stony areas, rolling sandy areas or dunes, and occasional depressions which offer more favorable soil moisture conditions. Some of the depressions are highly saline (*chotts*), while others possess good agricultural soil (*dayas*).

The dunes present a very scant vegetation (*Aristida, Tamarix, Retama, Acanthyllis, et al.*), while the plant cover of the stony plains may be extremely light or may consist of considerable numbers of plants, mostly small in size. No trees are found outside the *dayas* and oases, and the only conspicuous plants of the plains are: *Haloxylon, Zizyphus, Ferula, Zollikoferia, Deverra, Ephedra* and *Aristida.* Ephemeral herbaceous plants are also found in some places on the stony desert plains.

In the *dayas* the pistache tree (*Pistacia atlantica*) is found at certain localities, and there is a relatively abundant vegetation, including *Peganum, Retama, Henophyton, Capparis* and *Zizyphus.* The *chotts* are without vegetation in their most alkaline portions, but *Nollctia, Halocnemon* and other shrubs are abundant about their edges.

The author has described some of the climatic conditions of the regions visited. The rainfall decreases from 19.8 cm. (7.79 in.) at

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[1] Cannon, W. A., Botanical Features of the Algerian Sahara. Carnegie Inst. Wash. Publ. **178.** Pp. 81, pls. 36. Washington, 1913.

the inner base of the Atlas ranges to 4.7 cm. (1.85 in.) at El Golea, in the heart of the Sahara. The annual evaporation is nearly 400 cm. (157 in.), as averaged for three stations in the Sahara. The annual ratio of rainfall to evaporation is 1:46.5 for the three desert localities.

The results of an extended examination of the root systems of characteristic plants of the Algerian desert is given. The soils vary in depth as well as in texture, and the deep soils are found to support the densest plant populations, at least where grazing does not interfere. Some of the desert shrubs are found to have a definite type of root system, with a long tap, and such plants are restricted in distribution by the depth of the soil. Other plants have variable or generalised root systems and are more ubiquitous in occurrence. The absence of succulents and the general scantiness of the vegetation render the Algerian desert very unlike the deserts of southern Arizona and western Texas. The relation of root types to soil conditions is, however, very similar in Africa and America.—F. S.

NOTES AND COMMENT

At the annual session of the Iowa Academy of Science a paper was presented by L. A. Kenoyer on a floral variation which had been discovered in *Saxifraga texana.* Instead of exhibiting the usual bicarpellate condition of the genus some 1800 flowers were found to be predominantly tricarpellate, with 17% fluctuating around that condition. The phenomenon is not quite so striking as it would be if we knew something about the variation of the same species in other localities, nevertheless such behavior on the part of any plant is very interesting and is well worthy of the fullest investigation. It is almost impossible for a keen student to make a sound observation or to perform a well-conceived experiment without securing results which are *interesting,* but everyone who has attended a scientific meeting or followed botanical literature knows how few of these results are made *valuable* by having enough thought and energy put into them after they are first featured on the screen of publicity.

The Third International Congress of Tropical Agriculture recently held at London was attended by over four hundred men, representing forty-two nationalities or colonies. The key note of the meeting was the need of providing better facilities for education and research along the lines of tropical agriculture.

Announcement has been made of the publication of the third German edition of Jost's Lectures on Plant Physiology. The entire book has been revised and brought up to date, especially with respect to the subjects of hybridisation and breeding.

We learn from the Züricher Zeitung that Dr. Eduard Rübel has given the sum of 25,000 francs to the Swiss Natural History Society, as the nucleus of a fund for the advancement of plant geography in Switzerland.

TRANSPIRATION OF SILPHIUM LACINIATUM L.

L. A. GIDDINGS

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The observations here recorded were performed in an effort to determine the relation of transpiration to evaporation and to other factors affecting it in one of our common prairie plants, *Silphium laciniatum* L. Evaporation and transpiration experiments were carried on simultaneously under various conditions for the purpose of making a direct comparison of the amount of loss due to each of the two processes. One set of experiments was carried on in the plant physiology laboratory of the State University of Iowa, and another series was carried on in the field at the Macbride Lakeside Laboratory on West Lake Okoboji during the summer of 1912. The detached leaves of the plant were used in the transpiration experiments.

Thanks are due Professor Shimek at whose suggestion the work was undertaken and under whose directions it was carried on.

HABIT AND STRUCTURE OF *SILPHIUM LACINIATUM* L.

The reason for selecting *Silphium* for the transpiration experiments was because of its xerophytic nature. It grows in places where the exposure to the agents of evaporation is extreme. In spite of the fact that it inhabits such unfavorable regions, it grows to a height far exceeding most of the native plants of the prairie regions, some specimens being found that were a little over nine feet high. The leaves, especially the lower ones, are very deeply incised, thus reducing the actual leaf area very greatly. With the exception of the very lowest leaves, those borne below the general level of surrounding vegetation, the leaves decrease in size upward until the upper ones are but little more than bracts. The lower leaves are long-petioled, but the

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upper ones are sessile and clasping. This arrangement gives the plant a broad, spreading surface below, but an exceedingly reduced one above.

THE STOMATA

Microscopic observations were made on the number of stomata per unit area at different heights and of different parts of the same leaf. It was found that as a rule the number of stomata increased with an increase in the height of the leaf and also toward the tip of the leaf. In the following observation, which serves as a type, three leaves were used; one from a height of 18 cm., one from a height of 65 cm., and one from a height of 100 cm. In examining the leaves for stomata, pieces of the epidermis were shaved off from both the upper and lower surfaces near the base, near the middle, and near the tip of the leaf. To bring out more clearly the comparison of the number of stomata in the leaves at different heights and in different parts of the same leaf, table 1 has been compiled. In this table the maxima, the minima, and the average number of stomata per square centimeter of leaf area, as determined by ten counts in each place, are given. The area of the lowest leaf in this case was 379.7 sq. cm., of the second leaf 215.2 sq. cm., and of the third leaf 65.1 sq. cm. These areas include both surfaces of the leaf.

The average number of stomata per square centimeter of surface for the lowest leaf was 10,634; for second leaf 12,775; and for the highest leaf 13,487. The data obtained in this observation correspond very closely with those from other similar observations though there were minor variations as would naturally be expected. The smallest average number found on the upper surface of any leaf was 7825 per square centimeter, and the greatest average number was 12,966. The smallest average number found on the lower surface was 9258, and the greatest average number was 16,220. In the specimens studied there was practically no difference in the size of the stomata of the different leaves.

Transverse sections of the leaves showed that the epidermis was always heavily cutinized; the stomata were not sunken to any marked degree, but the guard cells were strongly cutinized on the outside; the palisade cells were greatly elongated; and water storage cells were abundant.

In an effort to determine the condition of the stomata during the long hot afternoons, pieces of leaves at different heights were plunged into absolute alcohol between 2 and 3 p.m. to fix the stomata for later examination. Subsequently, upon shaving off pieces of the epidermis and examining them under the microscope, it was found that all the stomata were more or less closed, most of them completely so. This would suggest that during the afternoon the stomata are practically closed, but the use of rather large pieces of leaves renders the observation of somewhat doubtful value.[1]

TABLE 1

The number of stomata per square centimeter in leaves of Silphium from heights of 18, 65 and 100 cm.

		LOWER SIDE			UPPER SIDE		
		Max.	Min.	Aver.	Max.	Min.	Aver.
18 cm.	Base	12,992	8,129	10,039	9,744	6,472	8,380
	Middle	14,616	9,744	11,693	11,368	8,120	9,582
	Tip	16,240	9,744	12,730	12,299	9,744	11,378
65 cm.	Base	14,616	11,368	12,505	12,992	9,744	11,368
	Middle	16,240	11,368	13.154	12,992	11,368	12,180
	Tip	17,864	12,992	14,941	16,240	9,744	12,505
100 cm.	Base	16,240	9,744	12,988	16,240	9,744	12,118
	Middle	16,240	12,992	13,804	14,616	11,368	12,830
	Lower	19,488	14,616	16,220	16,240	12,992	13,966

EVAPORATION AT DIFFERENT HEIGHTS

For the purpose of determining what effect height above the ground has on evaporation, an experiment was performed at a station set up on the laboratory grounds with Piche evaporimeters at different heights. The lowest evaporimeter was hung so that the bottom was 10 cm. from the ground. In this position it was somewhat protected by surrounding vegetation. The

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[1] See Lloyd F. E. The Physiology of Stomata. Carn. Inst. Wash. Publ. 82, p. 28. 1908.

second evaporimeter was suspended at a height of 114 cm. from the ground; and the third evaporimeter at a height of 237 cm. from the ground. Wind velocity and psychrometric readings were taken beside each evaporimeter. The experiment was run ten hours, beginning at 7.30 a.m. The data for the experiment are given in table 2.

TABLE 2

Rates of loss from Piche evaporimeters (in cubic inches) at different heights, with the concurrent wind velocity (in miles per hour) relative humidity, and temperature (Fahr.). September 8, 1912

	HOURS	EVAPORATION	WIND	HUMIDITY	TEMPERATURE
Lower	7.30	0.045	1.74	67	78
	9.30	0.090	1.66	64	80
	11.30	0.120	1.46	38	94
	1.30	0.120	2.91	34	95
	3.30	0.070	3.29	35	92
	5.30	0.445	2.09	36	89
Middle	7.30	0.060	4.73	59	77
	9.30	0.110	6.04	45	86
	11.30	0.160	7.47	37	91
	1.30	0.165	11.27	31	94
	3.30	0.105	9.70	33	93
	5.30	0.600	6.85	36	90
Upper	7.30	0.075	7.48	59	77
	9.30	0.135	8.00	36	87
	11.30	0.190	9.68	35	92
	1.30	0.200	17.42	29	94
	3.30	0.160	14.29	31	93
	5.30	0.760	9.21	31	90

From the data for this experiment it seems very evident that elevation played a very important part in the rate of evaporation. The variation in the amount of evaporation during the day was very much the same at the three heights, but the total amount of loss increased regularly with an increase in height. Wind velocity also increased with height, but the increase was greater between the two lower positions than between the two higher ones. This was probably due to the fact that the lower position was somewhat protected by vegetation while the two upper ones were not thus protected. Relative humidity was highest at the lowest position and decreased with increasing height, while there was but slight difference in temperature at the three different heights.

In the graphs for this experiment (fig. 1, fig. 2) the curves are numbered in order from the lowest position to the highest. In the first graph the solid lines represent evaporation, and the broken lines represent wind velocity.

From these data it appears that evaporation increases more or less regularly with an increase in height, for moderate heights at least. Taking the lowest evaporimeter as the standard or 100%, the loss of the next evaporimeter was 130.3%, and that of the highest evaporimeter was 170.7%. Since there was not much difference in temperature at the different heights, the increase in the rate of evaporation with an increase in height must have been due to an increase in wind velocity more than to any other one cause.

TABLE 3

Evaporation (in cubic inches) from Piche evaporimeters at different heights (in centimeters).

DATE 1912	NO. I		NO. II	
	Height	Loss	Height	Loss
July 11	6.0	0.240	26.5	0.280
July 13	5.5	0.240	20.5	0.360
July 16	4.0	0.220	37.0	0.375
July 18	9.0	0.165	15.5	0.180
July 23	9.0	0.365	25.0	0.605
July 25	10.0	0.145	26.0	0.230
July 29	10.0	0.130	26.0	0.220
August 6	7.0	0.170	29.0	0.245
August 19	5.0	0.200	22.0	0.240
August 20	6.0	0.210	25.0	0.260
August 21	6.0	0.195	25.0	0.260
August 22	6.0	0.190	25.0	0.240
August 25	16.0	0.340	25.0	0.390
August 26	6.0	0.165	25.0	0 190
September 1	6.0	0.305	25.0	0.360
September 2	6.0	0.275	25.0	0.300
September 5	6.7	0.450	30.0	0.600
September 7	6.7	0.290	30.0	0.330

As it might be claimed that one experiment is not conclusive,

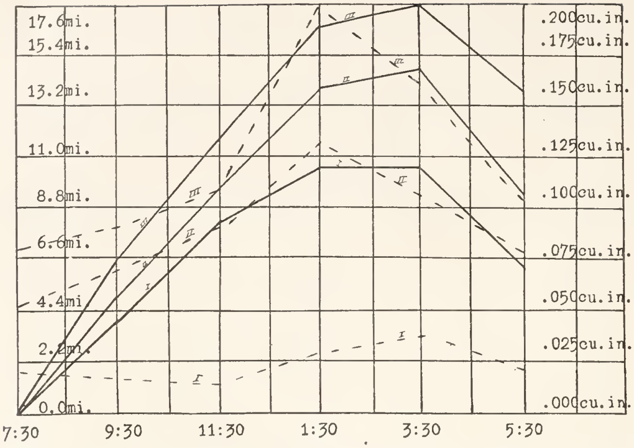

Fig. 1. Curves of evaporation (solid lines) and wind velocity (broken lines) for experiment of September 8, 1912. The curves are numbered in order from the lowest to the highest position.

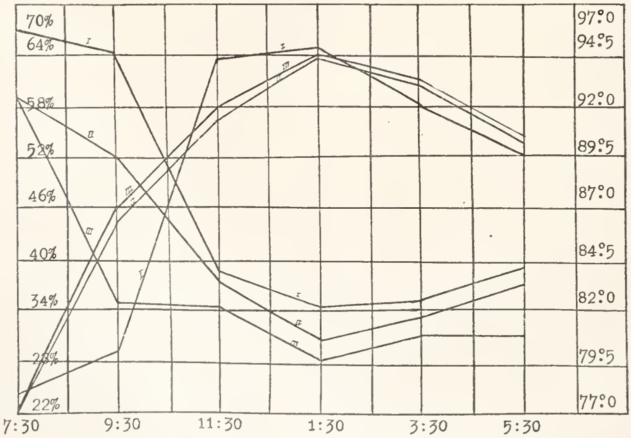

Fig. 2. Curves of temperature and relative humidity for experiment of September 8, 1912.

further evidence is given to substantiate the above conclusion. The data for the evaporimeters used in a series of experiments, herein mentioned and others, have been brought together in table 3 and presented as further proof that the rate of evaporation increases with an increase of height.

Since in a series composed of as many experiments as this, the evaporimeter at the greater height lost the greater amount without a single exception, the natural conclusion is that evaporation increases with an increase in height. The importance of these variations in relation to height will be noted later.

LABORATORY EXPERIMENTS

The chief purpose in view in these experiments was the determination of the effect of different wind velocities on the rate of evaporation and transpiration. This particular problem was undertaken in the laboratory rather than in the field because in the laboratory by using an electric fan the experiment could be kept more nearly under control than was possible in the field. The fan was placed in one end of an elongated box, and part of the evaporimeters and leaves were placed side by side in the box and part of them outside of the box. In selecting the leaves for these experiments care was taken to get them from about the same height, of about the same age, and of approximately the same size. As it would be undesirable to give the details for a whole series of experiments, the details of only one will be given, with the final results of a few others for comparison.

In these experiments Piche evaporimeters were used to determine the rate of evaporation. These instruments were very convenient to handle, and trial tests showed that they gave very accurate results if properly adjusted and used by the same individual. In the experiments of July 8 (table 4) the first evaporimeter and leaf were within the box at a distance of 60 cm. from the fan; the second set was within the box at a distance of 95 cm. from the fan; and the third set outside the box at a distance of 140 cm. from the fan. The experiments were run twelve hours, beginning at 7.30 a.m. The instruments and leaves are numbered in the order of their distance from the fan. The leaves were

TABLE 4

The rates of water loss of Silphium (in grams), and of evaporation from Piche evaporimeters (in cubic inches) at different wind velocities, together with the temperature (Fahr.) and relative humidity. July 8, 1911

HOURS	TEMP.	HUMID.	WIND VELOCITY 7.2 MI.		WIND VELOCITY 5.3 MI.		WIND VELOCITY 4.8 MI.	
			Transp.	Evap.	Transp.	Evap.	Transp.	Evap.
7.30	84	63						
9.30	87	57	6.7	0.09	4.2	0.05	5.0	0.05
11.30	89	58	2.3	0.12	3.7	0.06	1.3	0.07
1.30	91	52	1.9	0.15	6.4	0.08	1.3	0.11
3.30	92	47	1.5	0.14	6.1	0.09	0.4	0.10
5.30	92	49	1.2	0.14	6.5	0.08	0.4	0.09
7.30	92	49	0.7	0.14	6.9	0.08	0.9	0.10
Totals			14.3	0.78	32.9	0.44	8.4	0.52

placed in bottles of water which were carefully sealed, and the loss determined by weighing.

In the graphs for these experiments the curves for the leaves and evaporimeters are numbered in the order of distance from the fan. The temperature and relative humidity were those of the laboratory and not for any one of the positions occupied by the leaves and evaporimeters (fig. 3, fig. 4).

In table 5 are given the totals for three other experiments. From these data it is evident that there is a close relation between

TABLE 5

The relation of wind velocity (in miles per hour) to the transpiration of Silphium (in grams) and to the evaporation (in cubic inches). 1911

DAY	WIND	TRANSPIRATION		EVAPORATION	
		Plant	Amount	Inst.	Amount
		no.		*no.*	
July 1	8.3	I	9.7	I	0.66
	6.8	II	9.4	II	0.56
	5.5	III	7.9	III	0.50
July 15	8.5	I	11.3	I	0.68
	5.9	II	11.7	II	0.61
	5.0	III	10.4	III	0.59
July 23	8.4	I	5.2	I	0.51
	6.7	II	7.2	II	0.36
	6.0	III	3.5	III	0.26

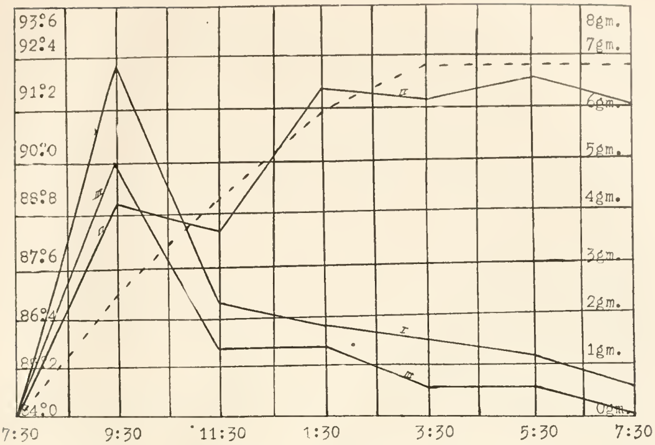

Fig. 3. Curves of transpiration and temperature for experiment of July 8, 1911, with electric fan, showing influence of wind velocity. The curves are numbered in order from the fan outward.

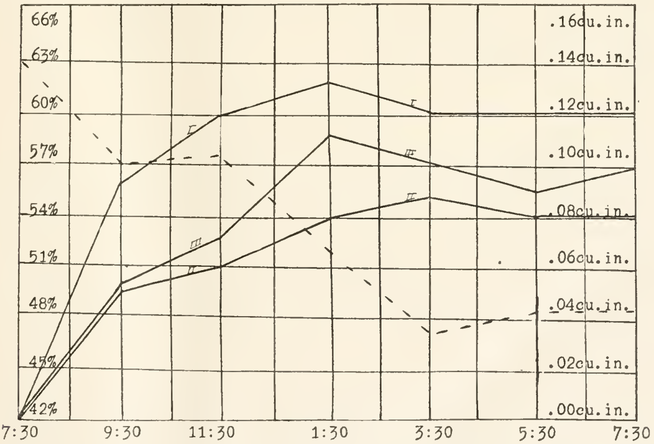

Fig. 4. Curves of evaporation and relative humidity for experiment of July 8, 1911, with electric fan, showing influence of wind velocity. The curves are numbered to correspond with the transpiration curves of figure 3.

the rate of evaporation and the rate of transpiration, but it is equally clear that there is a distinct difference also. The rate of evaporation increased in an almost direct ratio with an increase in wind velocity. This was not true for transpiration. The rate of transpiration increased with an increase in wind velocity up to a certain point after which it did not continue to increase in proportion to the increase in wind velocity. This is well brought out by the fact that as a rule the second leaf lost the greatest amount of water, the leaf having the greatest wind velocity being second. From these and similar experiments it seems that the wind increased the activity of the leaves until a velocity of about 8 miles per hour was reached, but that if the velocity rose above this the activity of the leaves was impaired and the rate of transpiration became less.

In the experiment given in detail the evaporimeter farthest from the fan lost more than the one next closest. This happened in some of the other experiments, but may be accounted for because of currents of air circulating through the room as the doors and windows of the laboratory were open. Since the results from the two instruments closest to the fan were constant, these occasional variations would not invalidate the results of the experiments.

FIELD EXPERIMENTS

The field experiments discussed in this paper were carried on at the Macbride Lakeside Laboratory during the summer of 1912. The detached leaves of *Silphium laciniatum* were used as in the laboratory experiments. The stations were set up in the open field where the plants naturally grew so that the plants used in the experiments were subjected to the same meteorological conditions as were those growing in the prairies of the surrounding country.

In these experiments two problems were studied. One was the relation between evaporation and transpiration, and the other was the rate of transpiration of leaves from different heights when placed under similar conditions. To bring the leaves from different heights under the same conditions, they were removed from the plant, placed in bottles as already described, and placed side by side during the experiment. While this gives the action of the leaves under similar conditions, it does not show what would be their action at their own respective heights. This of itself furnishes an interesting problem for a series of experiments, but is not discussed in this paper.

In the experiment of August 19 (table 6) four *Silphium* leaves were used. The leaves were all taken from the same plant at different heights. No. 1 was taken from a height of 13 cm., No. II from a height of 47 cm., No. III from a height of 71 cm.; and No. IV from a height of 100 cm. The leaves being of such unequal size, the results given in the table are on the basis of 100 sq. cm. of leaf area, both sides of the leaf being included.

TABLE 6

The transpiration (in grams per 100 sq. cm.) of four leaves of Silphium from different heights and the evaporation (in cubic inches) from two evaporimeters at different heights, with the concurrent relative humidity and wind velocity (in miles per hour). The anemometer was at a height of 54 cm. August 19, 1912

HOURS	TRANSPIRATION				EVAPORATION		HUMID.	WIND
	I 13 cm.	II 47 cm.	III 71 cm.	IV 100 cm.	I 22 cm.	II 5 cm.		54 cm.
7.30	0.18	0.26	0.28	0.20	0.00	0.00	95	3.42
8.30	0.21	0.44	0.24	0.21	0.01	0.01	86	2.75
9.30	0.48	0.70	0.66	0.36	0.01	0.01	82	2.61
10.30	0.53	0.82	0.59	0.47	0.02	0.02	74	2.97
11.30	0.51	0.74	0.62	0.52	0.02	0.02	74	2.79
12.30	0.67	0.85	0.81	0.53	0.02	0.02	72	4.06
1.30	0.83	1.35	1.16	0.78	0.03	0.03	68	4.26
2.30	0.77	0.75	0.97	0.88	0.04	0.03	64	4.11
3.30	0.76	0.49	0.39	0.94	0.03	0.02	62	4.85
4.30	0.74	0.33	0.29	0.22	0.03	0.02	62	6.62
5.30	0.29	0.22	0.21	0.14	0.03	0.02	64	4.94
6.30	0.18	0.13	0.18	0.11	0.01	0.01	66	4.40
Totals..	6.18	7.08	6.40	5.36	0.25	0.21		

From the data for this experiment it will be seen that three of the leaves showed the greatest amount of loss at the same time that one of the evaporimeters showed a maximum loss, but an hour before the other evaporimeter indicated a maximum loss.

This was before temperature or wind velocity had reached a maximum and also before relative humidity was lowest. The third leaf showed the greatest loss at the time when temperature was the highest and relative humidity the lowest, but an hour before wind velocity was highest. The leaves all became somewhat wilted before the end of the experiment, but there was no apparent wilting until 2.30 p.m., when No. II was slightly wilted. Since these leaves came from the same plant at different heights it is of interest to note how they compare with each other in the amount of water lost. Taking the lowest leaf as the standard or 100%, the loss per 100 sq. cm. of leaf surface for the other leaves was 114.5%, 103.5%, and 86.5%, respectively.

This experiment indicates that the upper leaves transpired less actively than did the lower ones when placed under like conditions. A tall plant is thus protected from the dangers of greater loss of water at the greater heights, due to greater evaporation, not only by the diminished size of the leaf, but also by the check upon transpiration which they are able to effect. In the graphs for this experiment the leaves are numbered in order from the lowest to the highest. The evaporimeters are numbered in order from the ground up (fig. 5, fig. 6).

In the experiment of August 21 (table 7) four *Silphium* leaves were used. No. I was taken from a height of 16 cm., No. II from a height of 50 cm., No. III from a height of 71 cm., and No. IV from a height of 85 cm.

Evaporimeter No. I was at a height of 25 cm., and evaporimeter No. II at a height of 6 cm. above the ground. Here, as in the other experiments where the evaporimeters were at different heights, the one at the greater height lost the greater amount of water. The anemometer was at a height of 54 cm. from the ground. It will be noticed that both evaporimeters showed a maximum loss at the time when relative humidity was the lowest, but at a time prior to that of highest temperature and greatest wind velocity.

In this experiment the leaves showed the greatest loss from one to three hours before the time of greatest evaporation. In this experiment, as in practically all the rest of the series, the second

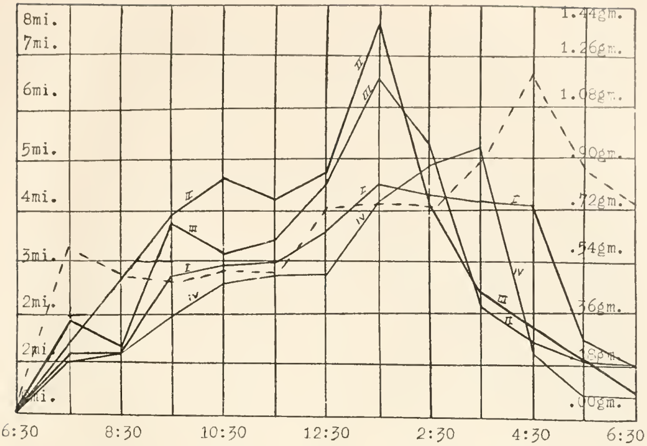

Fig. 5. Curves of transpiration of leaves of Silphium from four different heights (solid lines, numbered as in table 6) and of wind velocity (broken line) in experiment of August 19, 1912.

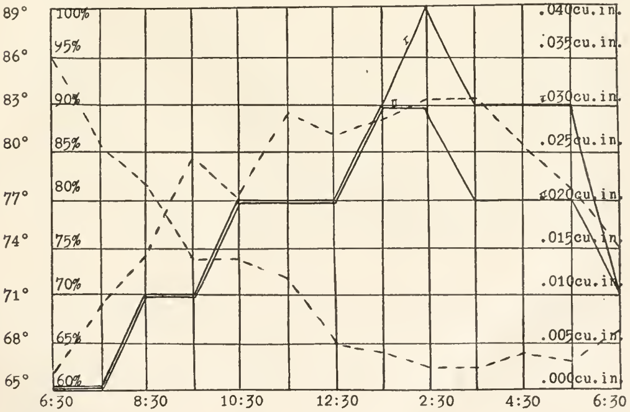

Fig. 6. Curves of evaporation at two different heights (solid lines, numbered as in table 6), and of temperature and relative humidity in experiment of August 19, 1912.

TABLE 7

The transpiration (in grams per 100 sq. cm.) of four leaves of Silphium from different heights, with the concurrent evaporation (in cubic inches) from two Piche evaporimeters at different heights, the relative humidity and the wind velocity (in miles per hour). August 21, 1912

HOURS	TRANSPIRATION				EVAPORATION		HUMID.	WIND
	I	II	III	IV	Piche No. I	Piche No. II		
	16 cm.	50 cm.	71 cm.	85 cm.	25 cm.	6 cm.		
7.30	0.29	0.49	0.21	0.19			94	3.84
8.30	0.46	0.54	0.62	0.38	0.010	0.010	89	4.45
9.30	0.62	0.83	0.75	0.82	0.020	0.010	85	4.28
10.30	0.72	0.98	0.90	1.05	0.020	0.020	69	4.52
11.30	0.74	1.11	0.77	0.71	0.030	0.025	69	4.95
12.30	0.76	3.23	0.84	0.68	0.030	0.025	61	5.98
1 30	0.68	0.44	0.79	0.74	0.040	0.030	58	5.82
2.30	0.38	0.42	0.52	0.44	0.020	0.015	57	5.85
Totals. .	4.65	6.04	5.40	5.01	0.170	0.135		

leaf lost the greatest amount of water, above the second leaf the loss invariably became less with the increased height of the leaves above the ground. Again taking the lowest leaf as 100%, the loss of the other leaves was 129.8%, 316.6%, and 107.07%. In the graphs for this experiment the leaves are numbered in order from the lowest to the highest. The evaporimeters are also numbered from the lower to the higher (fig. 7, fig. 8).

In table 8 are given the totals for two other experiments with leaves from different heights. From these data it is evident that leaves from different heights do not behave in exactly the same manner when placed under similar conditions.

TABLE 8

The transpiration (in grams per 100 sq. cm.) of leaves from different heights (in centimeters.) 1912

DAY	HEIGHT	TRANSPIRATION	HEIGHT	TRANSPIRATION
August 20....................	30	6.44	80	5.54
August 22....................	43	6.34	58	5.95

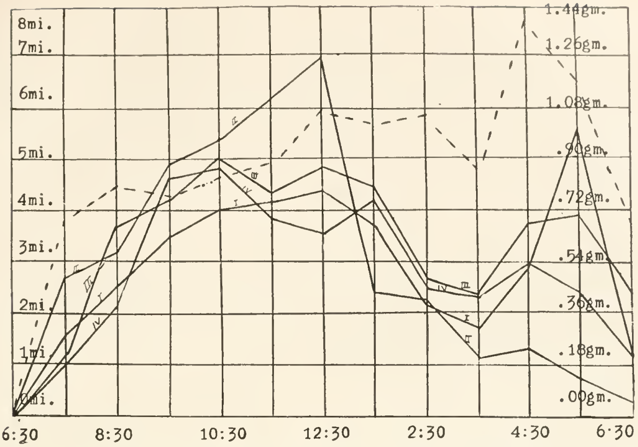

Fig. 7. Curves of transpiration of four leaves of Silphium from different heights (solid lines, numbered as in table 7) and of wind velocity for experiment of August 21, 1912.

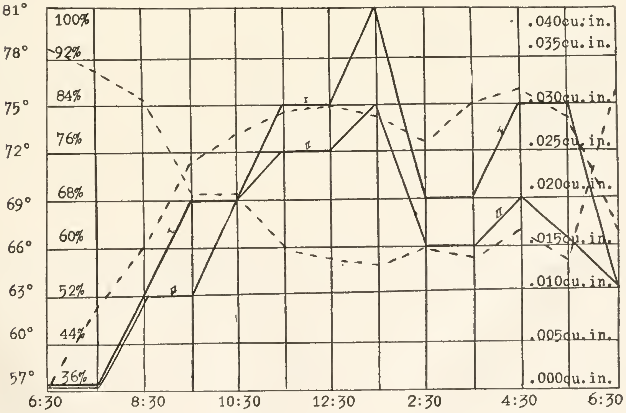

Fig. 8. Curves of evaporation at two heights (solid lines, numbered as in table 7) and of temperature and relative humidity for experiment of August 21, 1912.

TRANSPIRATION FROM DIFFERENT SURFACES

Another problem, not directly connected with the preceding, was studied in the field experiments. For the purpose of making a comparison between the amount of transpiration from the upper and lower surfaces of *Silphium* leaves, vaseline was placed on the upper surface of part of the leaves and on the lower surface of the others. In the experiment given in detail the leaves were taken from the same plant at different heights. No. 1 was taken from a height of 20 cm., No. II from a height of 32 cm., No. III from a height of 53 cm., and No. IV from a height of 72 cm. No. I had vaseline on the upper surface; No. II on the lower surface; No. III on the upper surface; and No. IV on the lower surface. A number of experiments were performed with leaves arranged as described, but the details for only one are given in table 9.

TABLE 9

Transpiration (in grams per 100 sq. cm.) from upper and lower surfaces of leaves of Silphium taken from different heights, with concurrent evaporation (in cubic inches) from two Piche evaporimeters at different heights, relative humidity, and wind velocity (in miles per hour). At the head of each transpiration column is stated the height from which the leaf was taken and the surface which was transpiring. September 1, 1912

HOUR	TRANSPIRATION				EVAPORATION		HUMID.	WIND
	20 cm. lower	32 cm. upper	53 cm. lower	72 cm. upper	25 cm.	6 cm.		
7.45	0.15	0.14	0.15	0.11	0.010	0.005	95	4.95
8.45	0.33	0.34	0.43	0.29	0.015	0.015	86	4.43
9.45	0.49	0.40	0.52	0.35	0.020	0.020	79	6.15
10.45	0.57	0.52	0.55	0.41	0.040	0.039	72	5.82
11.45	0.55	0.64	0.57	0.52	0.040	0.040	66	5.61
12.45	0.51	0.47	0.63	0.43	0.040	0.035	63	5.09
1.45	1.14	0.68	1.25	0.74	0.045	0.400	60	5.55
2.45	1.11	0.76	1.19	0.71	0.050	0.945	58	5.65
3.45	0.73	0.85	1.34	0.67	0.035	0.030	55	5.35
4.45	0.37	0.90	0.75	0.66	0.035	0.025	64	5.70
5.45	0.19	0.36	0.34	0.51	0.020	0.015	63	4.85
6.45	0.08	0.13	0.11	0.08	0.010	0.005	74	1.45
Totals. .	6.22	6.20	7.83	5.49	0.369	0.305		

Evaporimeter No. I was at a height of 25 cm., evaporimeter No. II at a height of 6 cm. The anemometer was at a height of 54 cm. The evaporimeter at the greater height lost the greater amount of water. Both instruments showed a maximum loss an hour before relative humidity was lowest.

In this experiment two leaves showed the greatest loss before the time of greatest loss by the evaporimeters and two of them after. In this experiment the loss of water by the leaves did not run the same as in the experiments where the leaves were not covered with vaseline. Taking the lowest leaf as 100%, the loss of the other leaves was 98.2%, 125.8%, and 88.2%. Instead of the second leaf losing the greatest amount it lost next to the least. By comparing these figures with those of other experiments it becomes very evident that there is a difference in the rate of transpiration from the upper and lower surfaces of the leaf of *Silphium*. In a leaf which assumes a more nearly horizontal position the difference would probably be much greater. In the graphs for this experiment (fig. 9, fig. 10) the leaves are numbered in order from the lowest to the highest. The evaporimeters are numbered in order from the lower to the higher.

In table 10 are given the total transpiration results for two experiments with *Silphium* leaves, part of which had vaseline on the upper and part on the lower surface. In these experiments the leaves were taken from the same height from different plants. The loss here given is on the basis of 100 sq. cm. of surface. In both of these experiments the leaf with the vaseline on the lower surface lost the least.

TABLE 10

Transpiration (in grams 100 sq. cm.) from the upper or lower surfaces of leaves of Silphium taken from different heights and coated with vaseline. 1912

DAY	HEIGHT	SURFACE TRANSPIRING		
		Lower	Upper	Lower
	cm.			
August 25	20	7.71	2.64	4.17
August 26	26	2.36	1.02	3.05

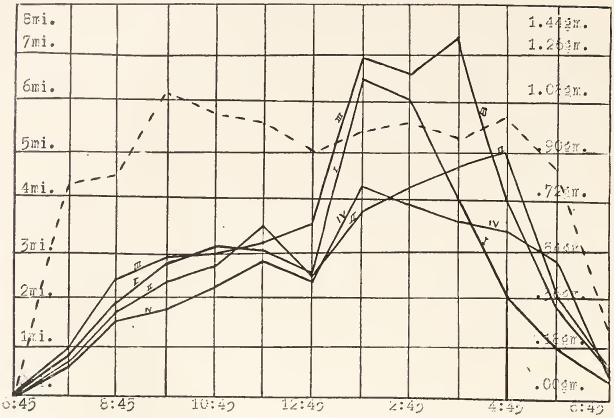

Fig. 9. Curves of transpiration of vaselined leaves of Silphium (solid lines, numbered as in table 9) and of wind velocity (broken lines) in experiment of September 1, 1912.

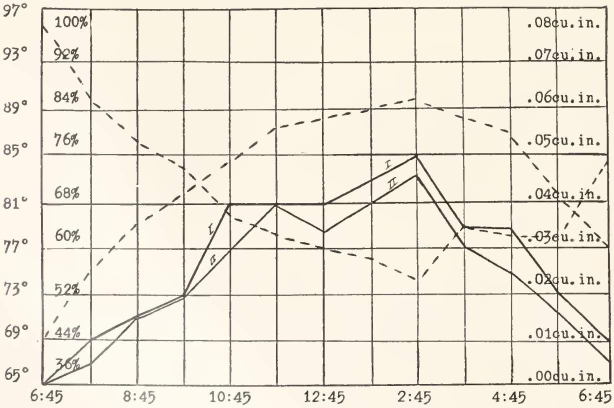

Fig. 10. Curves of evaporation at two heights (solid lines, numbered as in table 9) and of temperature and relative humidity for experiment of September 1, 1912.

DISCUSSION

The experiments carried on in the field indicate that the greatest amount of evaporation usually occurs between 1.00 and 3.00 p.m. This period is also the one when temperature is usually the highest and relative humidity the lowest. On a clear day the rate of evaporation usually rose more or less regularly until a maximum was reached after which there was a regular but more rapid decrease in the amount of loss until evening or the end of the experiment. The experiments in the laboratory brought out the fact that the rate of evaporation varied in an almost direct ratio with an increase in wind velocity.

By comparing the tables and graphs for evaporation with those for transpiration, it is seen that transpiration usually reached a maximum from one to three hours before the time of greatest evaporation.

The data on the rate of evaporation at different heights show very conclusively that the rate of evaporation increases very much with an increase in height. This increase was due more to the influence of increased wind velocity than to any other factor. Since it was shown in the laboratory experiments that the rate of transpiration increases with an increase of wind velocity within certain limits, and in view of the fact that transpiration, up to a certain point, increases with an increase in the rate of evaporation, it becomes apparent that the upper portion of a tall plant is exposed to very unfavorable conditions. How a plant meets these conditions by a reduction of its leaf area in the upper portion of the stem is well illustrated by *Silphium laciniatum.* In one case two leaves were taken from the same stem, one at a height of 12 cm. and the other at a height of 93 cm. The one taken from the lower position had an area of 304 sq. cm., while the one from the upper position had an area of only 63 sq. cm. In another instance a leaf taken from a height of 18 cm. had an area of 379 sq. cm. while another leaf from the same plant taken from a height of 100 cm. had an area of 65 sq. cm.

CONCLUSION

From the foregoing experiments it seems evident that there exists a very close relationship between transpiration and evaporation. The same agents that are active and efficient in evaporation are also active in transpiration, but in transpiration there are evidently other factors than those concerned in evaporation. The plant itself apparently has the power of influencing transpiration to a certain extent. It seems to be able to exercise a regulative influence whereby it can check transpiration even though the rate of evaporation continues to increase. Outside of the plant itself, the chief agents concerned in transpiration are wind velocity, temperature, and relative humidity. Transpiration, up to a certain point, increases with increased wind velocity, increased temperature, and decreased relative humidity. In this respect it agrees very well with evaporation, but evaporation is entirely dependent upon outside factors. Transpiration seems rather to be governed by the activity of the plant which may be influenced largely by external factors, but does not correspond throughout with the fluctuations produced by the agents of evaporation. Transpiration and evaporation are not entirely the same thing though more or less related.

THE LONGEVITY OF SUBMERGED SEEDS

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The durability of protoplasm, when packed away in condensed form in seeds, has interested several generations of botanists, and a number of statements are now on record, having various degrees of probability, indicating that under certain conditions certain seeds may have retained their vitality even for centuries. I need not enter into an enumeration or discussion of these cases, but refer the reader to papers by de Candolle[1] and Kunzé,[2] in which a considerable number of these instances are brought together. It is generally recognized that conditions favorable to great longevity are dryness, moderate and uniform temperature, and the partial or complete exclusion of oxygen.

Some fully authenticated cases and one definite experiment[3] show that seeds of certain species can grow after at least a quarter

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[1] De Candolle, C., The latent vitality of seeds. Pop. Sci. Monthly **51**: 106–111.

[2] Kunzé, R. E., Germination and vitality of seeds. Read before the Torrey Botanical Club, December 13, 1881. Published by subscription of members of the Club. No date.

[3] This very interesting and instructive experiment of Prof. W. J. Beal was begun at the Michigan Agricultural College in the autumn of 1879, and the results have been reported from time to time in the Proceedings of the Society for the Promotion of Agricultural Science. The following brief statement taken from the Report of the 31st Annual Meeting of that Society, may sufficiently explain the details of the experiment:

"I selected fifty freshly grown seeds of each of twenty-three different kinds of plants. Twenty such lots were prepared with the view of testing them at different times in the future. Each lot or set of seed was well mixed in moderately moist sand, just as it was taken from three feet below the surface, where the land had never been plowed. The seeds of each lot were well mixed with the sand and placed in a pint bottle, the bottles being filled and left uncorked and placed with the mouth slanting downward so that water could not accumulate about the seeds. These bottles were buried on a sandy knoll in a row running east and west, and placed fifteen paces northwest from the west end of the big stone set up by the class of 1873. A boulder stone barely even with the surface soil was set at each of a century of rest. This capacity to rest during considerable periods of time prevents the extinction of a form under severe competition, or temporarily unfavorable conditions, allowing the organism to take advantage of any event which reduces or removes the competition or restores conditions favorable to growth, and in many cases it is also an important condition for successful introduction into new areas.

Darwin recognized the importance of the durability of seeds in water as a condition favorable to the stocking of the islands of the sea, and experimentally determined that some seeds could withstand the action of artificial sea water for 137 days, and if they should possess at the same time the ability to float, they might be carried over long stretches of ocean and lodged under favorable conditions for development on some distant strand. Other European investigators performed similar experiments and are said to have extended the time of submergence to 13 months.

In the spring of 1904 an event occurred which raised in a striking manner the question as to the length of time during which a seed might remain submerged and still germinate. Nachaquatuck Creek, whose submerged lower course forms Cold Spring Harbor on the north shore of Long Island, was dammed in three places about the fourth decade of last century, in order to supply water-power for the turning of two woolen-mills and a flour-mill, all of which have been long since abandoned, the mills having either disappeared or fallen into decay. The mill-ponds remain as delightful features, biologically and scenically, of Cold Spring Harbor. The lowest and largest of the three ponds, known as St. John's pond, has a length of about 400 meters, a maximum width of 265 meters and includes an area of approximately 8 Ha. (about 20 acres).

end of the row of bottles, which were buried about twenty inches below the surface of the ground. I should make an exception in the case of the acorns, which were placed in the soil near the bottles and not inside the bottles. At the end of five, ten, fifteen, twenty, twenty-five and now thirty years, sets of these seeds were tested for vitality."

After thirty years burial, seeds of the following species germinated: *Amaranthus retroflexus*, *Brassica nigra*, *Capsella bursa-pastoris*, *Lepidium Virginicum*, *Oenothera biennis*, *Rumex crispus*, *Setaria glauca*, *Stellaria media*.

In February 1904, a freshet carried away a section of the lower dam, and the bed of St. John's pond was laid bare for the first time in over seventy years. With the opening of spring there came into existence a covering of vegetation, remarkable alike in quantity and diversity, over nearly the entire pond-bed. The higher portions of the pond-bed, which were quickly drained, soon became hard like sun-dried bricks, and deeply fissured and on these portions the phaenogamous vegetation was sparse (fig. 1), but in the lower portions, which remained moist throughout the summer, the carpet of vegetation became quite dense as seen in the background in figure 1 and in figure 2. An enumeration showed the presence of more than 140 species of flowering plants, besides many mosses and at least one liverwort, whose small circular mat-like thalli were not specifically identified. A small portion of the plants which came to bloom during the summer were perennials, including, for example, several species of *Aster* and *Solidago*, which must have developed from fragments of rootstocks which had been carried into the pond by the tributary streams. A fine cluster of *Utricularia gibba* which had not been previously listed from Cold Spring Harbor was also included. Its vegetative fronds had been found in the waters of the pond but had not been identified because the descriptions of this species in the manuals have been written from the flowering specimens and do not correctly represent the vegetative stage. The great majority of the species, however, were annuals, and must have developed from seeds lying in the mud.

In view of the emphasis which is generally laid upon the necessity of keeping seeds dry in order to maintain their vitality, the question immediately arose as to whether the millions of seeds represented by this dense herbaceous carpet might have lain in the mud since the preceding autumn or even longer, or whether they must have been brought in by various distributing agents after, or at any rate not long before, the draining of the pond in the spring.

To get an experimental answer to this question, seeds of 58 species representing a wide relationship, were collected on November 5, 1904, and placed in a large glass jar which had been filled

2 dm. deep with soil taken from the pond-bed. The jar was filled with ordinary tap water which was replenished from time to time as it evaporated. The jar was wrapped in several thicknesses of brown paper, and the top covered with a piece of wire gauze. It was placed in an unused room on the second floor of the Laboratory where it was kept relatively cool, though rarely cold enough to freeze a little, and moderately lighted, throughout the ensuing winter.

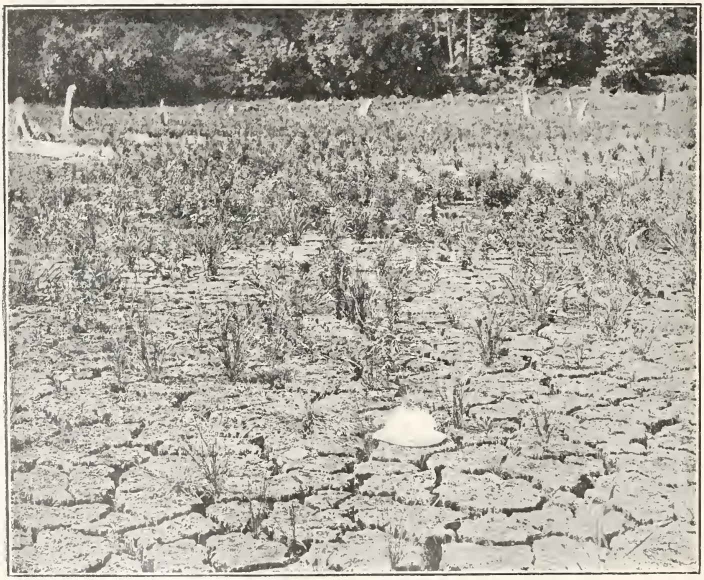

Fig. 1. The bed of St. John's Pond, at Cold Spring Harbor, Long Island, five and one-half months after the breaking of the dam. Photographed by Forrest Shreve, July, 1904.

The following species supplied the seeds involved in this experiment, and as the soil had not been sterilized, other species whose seeds had been in the mud of the pond-bed were doubtless also included.

Andropogon scoparius
Asclepias pulchra
Aster juncea
Aster lateriflorus
Aster multiflorus
Aster patens
Aster salicifolius
Aster sp.
Bidens cernua
Bidens frondosa
Chenopodium anthelminticum
Chrysanthemum Leucanthemum
Cuscuta Gronovii
Cyperus diandrus
Cyperus esculentus
Daucus Carota
Eleocharis acicularis
Epilobium adenocaulon
Erechtites hieracifolium
Eupatorium perfoliatum
Euthamia graminifolia
Festuca sp.
Gratiola aurea
Gnaphalium sp.
Hypericum mutilum
Isnardia palustris
Juncus bufonius
Juncus Gerardi
Juncus tenuis
Lappa minor
Leptilon Canadense
Linaria Canadensis
Ludwigia alternifolia
Lycopus rubellus
Mimulus ringens
Muhlenbergia diffusa
Oenothera biennis
Panicum capillare
Panicum Tennesseense
Phytolacca decandra
Plantago major
Plantago Rugelii
Poa compressa
Polygonum Hydropiper
Potentilla Monspeliensis
Rosa sp.
Rumex crispus
Rumex obtusifolius
Scirpus atrovirens
Solanum Dulcamara
Solidago rugosa
Triadenum Virginicum
Trifolium pratense
Urtica gracilis
Verbascum Thapsus
Verbena urticaefolia
Veronica serpyllifolia
Viola papilionacea domestica

On March 27, 1905, the jar was removed to the skylight room of the laboratory which was being used at that time as a propagating house. The water was carefully drained off, exposing the seeds to an abundance of free oxygen, after 130 days of submergence. In three days numerous germinations appeared and samples of the different kinds of seedlings were reset, from time to time, to boxes of soil, to grow until their identity could be determined without question. The following 24 species were represented among the seedlings thus secured.

Aster 2 spp.
Bidens cernuum
Bidens frondosa
Chenopodium anthelminticum
Cuscuta Gronovii
Cyperus diandrus
Cyperus sp.
Daucus Carota
Eupatorium perfoliatum
Isnardia palustris

Juncus sp.
Lycopus rubellus
Plantago major
Plantago Rugelii
Polygonum aviculare
Polygonum Hydropiper
Potentilla Monspeliensis
Rumex crispus
Rumex obtusifolius
Solanum Dulcamara
Triadenum Virginicum
Trifolium pratense
Verbascum Thapsus

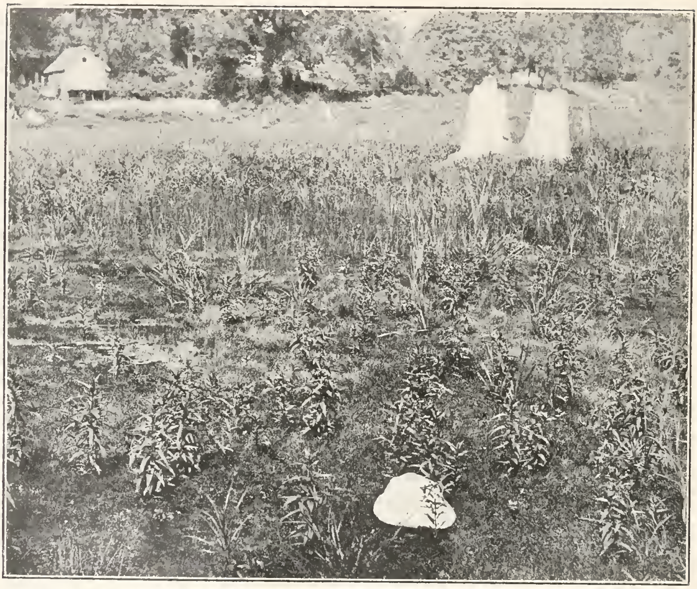

Fig. 2. The lower-lying portion of the bed of St. John's Pond. Photographed by Dr. Shreve on the same day.

Surprised at the large proportion of germinations, I planned to repeat the experiment, using still longer submergence. To this end seeds of the following 22 species were collected in considerable quantities and the seeds of each species were divided into six approximately equal lots:

Agrimonia hirsuta
Asclepias Syriaca
Chenopodium album
Circaea Lutetiana
Geum Carolinianum
Hieracium sp.
Juncus bufonius
Juncus tenuis
Lappa minor
Muhlenbergia diffusa
Phryma leptostachya
Plantago Rugelii
Polygonum arifolium
Polygonum Virginianum
Rhus glabra
Sanicula Marylandica
Sium cicutaefolium
Solidago rugosa
Sparganium androcladum
Unifolium Canadense
Verbena urticaefolia
Washingtonia longistylis

One lot of seeds of each species was deposited on a layer of soil in each of six large glass jars on December 13, 1905, and placed in a dark room in the basement of the laboratory, where there is relatively little fluctuation in temperature. The water was replenished from time to time so that submergence was continuous. During the last year of the experiment the jars were subjected to diffuse light during the day, owing to the cutting of an open doorway leading into a skylighted cave-room.

The first of these jars was removed to the greenhouse and drained July 1, 1907, after a submergence of 565 days or 18½ months. In several days numerous seedlings appeared, not all of which were identified before my departure for California in September, but the following were recognized:

Cyperus spp.
Juncus tenuis
Muhlenbergia diffusa
Plantago Rugelii
Sium cicutaefolium
Verbena urticaefolia

A second jar was drained 11 months later, May 31, 1908. Among the large number of seedlings which appeared in a few days, occurred the following species. With the exception of *Chenopodium album* and *Lappa minor*, all appeared in considerable numbers.

Chenopodium album
Lappa minor
Muhlenbergia diffusa
Plantago Rugelii
Sium cicutaefolia
Verbena urticaefolia

On March 7, 1910, the soil in a third jar was laid bare, and in five days numerous seeds were seen germinating after a continuous submergence of nearly $4\frac{1}{4}$ years. The following species were noted:

Asclepias Syriaca
Juncus tenuis
Muhlenbergia diffusa
Phalaris sp?
Plantago Rugelii
Polygonum sp.
Sium cicutaefolium
Solidago rugosa
Sparganium androcladum
Syntherisma sanguinalis
Verbena urticaefolia

Besides these Angiosperms, the little mat-like liverwort which had been noted in abundance on the pond-bed, also made its appearance in the jar.

It was decided to keep the remaining three jars for longer periods but the experiment was brought to a sudden and unexpected close early in December 1912, when under a pressing need for jars for other experiments, the three jars containing the submerged seeds were mistaken for waste, notwithstanding the attached labels which stated the character of the experiment in which the jars were being used. The soil was emptied into a small pile on the grass near the laboratory, where it remained for about a fortnight before I discovered what had taken place. During the interval there were two sharp freezes, the minimum temperature reaching −8.3°C. on December 9, and −7.8°C. December 12. As soon as the absence of the jars was noticed a search was made for the soil, which was readily identified by the fact that many of the small fragments of soil still showed plainly the stratification due to the method of its deposition in the bed of the pond from which it had been taken. As soon as discovered, the top part of the pile of soil was carefully removed and scattered over the surface of sterilized soil in several seedpans. In a few days numerous seedlings of *Sium cicutaefolium* and *Juncus bufonius* appeared, as well as one each of *Juncus tenuis, Syntherisma sanguinalis* and *Trifolium* sp. The last two could have been introduced to the soil after the jars were emptied, though it will be noted that one specimen of *Syntherisma* had appeared in the jar which was emptied in 1910 in which no contamination had been possible. The rest of these seedlings must have developed from seeds which had been continuously submerged a fortnight less than seven years, and then subjected in their supposedly supersaturated condition, to two sharp freezes. Whether other species kept their vitality through the seven years' submergence and were killed by the frost can not be known.

Thus, while the experiment did not fully reach the goal which was planned, the question suggested by the vegetation on the bed of the drained pond has received a partial answer. Nearly half of the species whose seeds were used in the longer experiment gave some germinations after a submergence of more than four years and at least three species or 13.6% of those used in the experiment were still represented by viable seeds at the end of seven years' continuous submergence. Consequently it may be inferred that no such strain is placed upon the efficiency of the various distributing agents as was involved in the suggestion that the seeds which germinated in the bed of the drained pond must have been transported thither in the course of a few months' time at longest.

BOOKS AND CURRENT LITERATURE

A Flora of the Rocky Mountains.—A manual of the Colorado mountain flora has just been published by Prof. Frederic E. Clements and Dr. Edith S. Clements.[1] The book is designed to be a particularly useful one to the amateur who wishes to become acquainted with the plants of the Rocky Mountains. It is furnished with keys, and a large number of characteristic plants are illustrated in color, from the brush of the junior author. There are no descriptions of the species, no synonymy is given, and there are no localities nor statements as to habitat and range, all of which are features that will limit the usefulness of the book.

Rocky Mountain Flowers is of particular interest to botanists by reason of the fact that it is written, as the authors state, "from the standpoint of the experimental ecologist," being "concerned primarily with the relationships of 'species' and their subdivisions as an organic expression or measure of habitat differences, and of the competitive relations of the various formations."

A tangible evidence of the viewpoint from which the flora has been elaborated consists in the greatly reduced number of species which it enumerates as compared with other works covering the same territory. Rydberg credits 2872 species of flowering plants to Colorado; Nelson describes 2689 species for Wyoming, Colorado and adjacent portions of the neighboring states, while Clements and Clements embrace only 1878 forms in Rocky Mountain Flowers. This is to say that 25 per cent of the species in Rydberg's Flora of Colorado are omitted from the work under notice. The authors state in their preface that they have omitted many of the recent segregates from long-known species, and that they have done so on the evidence of experimentation and field study which have demonstrated that the groups of closely related segregates are expressions of habitat effects upon a single specific stock. The authors have thus reduced their presentation to "units

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[1] Clements, Frederic E., and Clements, Edith S. Rocky Mountain Flowers: An Illustrated Guide for Plant-lovers and Plant-users. 392 pp., 47 pls. The H. W. Wilson Company, White Plains, N. Y. 1914.

which can be recognized with some readiness and certainty," and have promised an early publication of the evidence upon which their simplification of the flora has been based. It appeals to the reviewer as an unfortunate circumstance that some of these experimental evidences were not published in advance of the appearance of this flora in which 994 species have been placed in the category of habitat variants.

The history of taxonomy for many years has been that finer and finer lines are being drawn between stocks or races of plants, and that the characters by which related species are separable are becoming fewer and more tenuous. The taxonomist maintains that it is his business to make species, and that any sheet of dried herbarium material is entitled to become a type specimen if it presents a very small group of distinctive characters. Some taxonomists know their new species in the field, know the range of their variability, know the influence of habitat differences upon them, and know many distinguishing features of habit, gross appearance or seasonal behavior—all of which they are afraid to incorporate in their technical descriptions for fear of being considered too informal. In many cases, on the other hand, the taxonomist knows only the one shapeless herbarium specimen which he designates as the type, and nothing can be done to increase his acquaintance with the plant, because it would delay the publication of the species.

Those who have occasion to use the technical names of plants can do much to encourage the taxonomist to gain a wider field knowledge of the plants with which he deals, or even to cultivate them or experiment with them. Nothing can be done, however, to check the man who is about to describe a new species, and it would be manifestly unfair to the man and stifling to the progress of botany to attempt to check him, even if his work is manifestly doomed to be undone by his colleagues.

It is to be feared that the majority of taxonomists think little about the aspects of their work in which the experimental ecologist or geneticist is interested. A great deal of taxonomic work has been overthrown by later taxonomists, but no real test of the value of the ultimate units of taxonomy can come by pitting the judgment of one man against the judgment of another. Extremely little has been done, as yet, by ecology or genetics that is calculated to overthrow taxonomic work—in fact the student of genetics is apt to outrun the taxonomist in the recognition of new types, forms, elementary species or what not.

The decision as to whether it is desirable to "split" or to "lump" is made by the taxonomist on a basis which is largely subjective. Such a decision should be made on the evidence of precise quantitative and statistical work, or on the evidence of accurately known environmental conditions. It is on such evidence that it will be necessary for future workers to scrutinize the acts of the taxonomist. Professor Clements has begun this scrutiny and botanists will await with interest a full presentation of the results of his cultures and experiments. —F. S.

NOTES AND COMMENT

Thirty-four doctorates are credited to botany during 1914 by the Editor of Science (**40**: 256–264. 1914) as against 28 for 1913. Seven of the 34 properly belong in 1913, however, (see Plant World **17**: 56. 1914) so that the doctorates on the basis of the discussion in science would number 35 in 1913 and 27 in 1914. Accepting the current figures in Science, however, the total number of interest to botanists in 1914, which would receive notice in the botanical reviewing periodicals, is 45 as against 39 in 1913, as given in the following list:

CORNELL UNIVERSITY

Paul Johnson Anderson: The Morphology and Life History of the Chestnut Blight Fungus.
Harris Miller Benedict: Senile Changes in Leaves of *Vitis Vulpina* L. and certain other Plants.
Forest Milo Blodgett: Perithecial Development of *Sphaerotheca humuli*.
Jean Broadhurst: A Study of the Habitats and the Morphological and Physiological Characters of Streptococci.
Jehiel Davidson: A Comparative Study of the Effect of Cumarin and Vanilin on Wheat Grown in Soil, Sand, and Water Cultures.
Howard Brett Frost: The Relation of Temperature to Variation in *Matthiola*.
Charles Truman Gregory: The Downy Mildew Disease of Grapes.
Lexemuel Ray Hesler: Black-rot, Leaf-spot and Canker of Pomaceous Fruits.
Robert Andrew Jehle: Brown Rot of Orchard Fruits.
Emmeline Moore: Potamogetons in relation to Pond Culture.
William Howard Rankin: Field Studies on the Endothia Canker of Chestnut in New York State.

UNIVERSITY OF CHICAGO

Winfred McKenzie Atwood: A Physiological Study of the Germination of *Avena fatua*.
George Smith Bryan: The Archegonium of *Sphagnum subsecundum*.
George Damon Fuller: Evaporation and Soil Moisture in Relation to the Succession of Plant Associations.
Edward Maris Harvey: Some Effects of Ethylene on the Metabolism of Plants.

John Benjamin Hill: The Anatomy of Six Epiphytic Species of *Lycopodium.*
Lee Irving Knight: A Study of Dormancy in Buds of *Liriodendron tulipifera.*
John Nathan Martin: Comparative Morphology of some Leguminosae.
Loren Clifford Petry: The Anatomy of *Ophioglossum pendulum.*
Norma Etta Pfeiffer: Morphology of *Thismia* (*Bagnisia*) *americana* n. sp.

HARVARD UNIVERSITY

William T. Bovie: The Action of Ultra-Violet Light on Protoplasm.
Walter Palmer Thompson: The Anatomy and Relationships of the Gnetales. I. The Genus *Ephedra.*

COLUMBIA UNIVERSITY

Fred Denton Fromme: The Morphology and Cytology of the Aecidium-cup.
Louis Otto Kunkel: Physical and Chemical Factors Influencing Toxicity of Inorganic Salts to *Monilia Sitophila* Mont. Sacc.

UNIVERSITY OF ILLINOIS

Philip Augustus Lehenbauer: Growth in Relation to Temperature.
John Hamilton Whitten: The Effect of Kerosene and other Petroleum Oils on the Viability and Growth of *Zea mais.*

UNIVERSITY OF WISCONSIN

Elbert T. Bartholomew: Physiological Changes causing Black Heart in Potatoes.
Howard Austin Edson: Damping Off and Root Decay of Sugar Beets.
Edward Martinius Gilbert: Cytological Studies on the Tremellineae.
Martin Perry Henderson: Studies on the Black Leg Disease of Cabbage.
Aaron Guy Johnson. The Helminthosporium Diseases of Barley.
George Wannamaker Keitt: Peach "Scab" (*Cladosporium carpophilum* Thüm) and its Control.
Gilbert Morgan Smith: Organization of the Colony in Certain Form-celled Coenobic Algae.

YALE UNIVERSITY

Joel Andrew Sperry: A Biochemical Study of the Behavior of Bacteria towards Pure Unchanged Animal and Vegetable Proteins.

UNIVERSITY OF MICHIGAN

John Henry Ehlers: Winter Temperature of the Leaves of the Pine.

UNIVERSITY OF PENNSYLVANIA

Charles Blizard Bazzoni: The Destruction of Bacteria through the Action of Light.

BROWN UNIVERSITY

Harold William Lyall: A Contribution to the Study of the Streptococci.
George Henry Robinson: Isolation, Identification and Serum Reactions of Typhoid and Paratyphoid Bacilli.

UNIVERSITY OF MINNESOTA

Harry Vaughn Harlan: Some Distinctions in Our Cultivated Barleys with Reference to their Use in Plant Breeding.
Julius Valentine Hofmann: Natural Reproduction of Coniferous Forests.

GEORGE WASHINGTON UNIVERSITY

Hartley Harrad Thompson Jackson: The Biota of Ridgeway Bog, Wisconsin: A Study in Ecology and Distribution.

UNIVERSITY OF MISSOURI

William Henry Chandler: The Killing of Plant Tissue by Low Temperature.

UNIVERSITY OF NEBRASKA

Melvin Randolph Gilmore: On the Uses of Plants by the Indians of the Nebraska Region.

WASHINGTON UNIVERSITY

Jacquelin Smith Cooley: A Study of the Physiological Relations of *Sclerotinia cinerea* (Bon.).

UNIVERSITY OF CINCINNATI

Emma Lucy Braun: The Physiographic Ecology of the Cincinnati Region.

D. T. M.

THE FREEZING POINTS OF TOTTINGHAM'S NUTRIENT SOLUTIONS[1]

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In Tottingham's[2] recent work upon the properties of nutrient solutions for plant cultures, the osmotic concentrations or diffusion tensions[3] of the solutions used were approximated by a method of calculation, which considered that each salt of a complex mixture ionizes to the same degree as though the other salts were not present. Tottingham calls attention to the possibility of considerable error in the making of this assumption that other salts in the same solution are without influence upon the ionization of each particular salt, but notes that the assumption leads to a closer approximation of the conditions actually existing than can any other method of calculation, considering our present ignorance of ionization phenomena in complex salt mixture. The author just mentioned employed three series of 84 solutions each, all of the solutions of each series having the same calculated diffusion tension but differing in their proportions of the four nutrient salts. The same salts occurred in all the

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[1] Botanical contribution from the Johns Hopkins University No. 42.

[2] Tottingham, W. E., A quantitative chemical and physiological study of nutrient solutions for plant cultures. Physiol. Res. **1**: 133–245. 1914.

[3] As has been pointed out by Livingston (The role of diffusion and osmotic pressure in plants. Chicago, 1903, pp. 30–31) and later by Findlay (Osmotic pressure. London, 1913, pp. 3–4) a solution does not, in itself, exert osmotic pressure. Such pressure results only when a solution is separated from the pure solvent, or from a weaker solution, by a membrane permeable only to the solvent, or at least more permeable to it than to the solute. The term diffusion tension as used by Livingston seems suitable to denote the condition existing in the solution itself. This tension is numerically equal to the osmotic pressure which would result if a solution were separated from the pure solvent by a membrane perfectly permeable to the solvent and not at all to the solute. In the present paper the term osmotic pressure will be avoided, since no membranes are here to be considered.

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252 solutions, these being monopotassium phosphate, potassium nitrate, calcium nitrate and magnesium sulphate. The three series were calculated to have diffusion tensions, or osmotic concentrations, of 0.05, 2.50 and 8.15 atmospheres, respectively.

For the weakest of these series of solutions there can be little doubt that the method of calculation used by Tottingham must give calculated values very close to those of the actual diffusion tensions. For the remaining two series the method of calculation becomes somewhat more questionable, and it seems probable that the error introduced in the case of the strongest medium may be considerable. It is therefore desirable, as was indeed indicated by Tottingham, that the diffusion tensions of his numerous solutions be determined experimentally. With this determination the present paper has to deal.

The simplest method available for determining the diffusion tensions or osmotic concentrations of such solutions as these, and the one generally used in such cases, is that of cryoscopy, and this was here employed. By this method the diffusion tension is derived from the observed depression of the freezing point of the solution by use of the formula,[4] $P_f = \Delta \left(\frac{22.4}{1.86}\right) = 12.06\ \Delta$, where P_f denotes the diffusion tension (in atmospheres) of the solution at 0°C., and Δ stands for the depression of the freezing point (in degrees Centigrade) below that of the pure solvent. The freezing points of the solutions were determined by means of the Beckmann apparatus, accounts of which are to be found in text books of physical Chemistry. Since the values given by the application of the formula are for 0°C., and since Tottingham's calculations refer to a temperature of 25°C., it is necessary to apply a temperature correction to the value P_f. This was accomplished in the usual manner, by using the formula for Gay Lussac's principle, $P_{25} = P_f\ (1 + 0.00366 \times 25)$, where P_{25} denotes the diffusion tension at 25°C.

Of course, the temperature just prior to the formation of ice in an aqueous solution is usually several degrees lower than the

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[4] Jones, H. C., Elements of physical chemistry. New York, 1910, p. 256.

freezing point of the solution. When such an undercooled solution freezes, a sufficient amount of pure solvent crystallizes out to raise the temperature of the remaining solution to its freezing point. Thus the solution actually frozen is more concentrated than the original one, and it becomes necessary to apply a correction for this increase in concentration due to the separation of ice from the solution. Such a correction was applied in these determinations, the method used being well stated by Harris and Gortner.[5] If v denotes the volume of the solvent and u the undercooling of the solution in degrees Centigrade, $\frac{uv}{80}$ (or $0.0125\,uv$) represents the total volume of the solvent removed, since for each degree of undercooling one-eightieth of the total weight of the solvent is removed from the solution as ice. It then follows that $v - 0.0125uv$ represents the volume of the solvent remaining in the solution after the formation of ice due to undercooling. Hence $\Delta = \Delta' (1 - 0.0125u)$, where Δ' is the *apparent* lowering of the freezing point and Δ is the corrected lowering. For facility in computation the value of u was taken as 2.5°C.; since the undercooling was never much more than 3°C. and never much less than 2°C., the error thus introduced is not greater than that attributable to slight inconsistencies in experimentation.

The structure of the Beckmann thermometer is such that a considerable column of mercury is exposed to temperature conditions external to the freezing apparatus, and the mercury column so exposed is of course, subject to contraction and expansion with fluctuations in the temperature conditions under which the determinations are made. This renders it necessary either to apply a correction for variation in length of the mercury column with fluctuations in room temperature, or to redetermine the apparent freezing point of the solvent whenever such fluctuations may occur. The latter is by far the simpler procedure. There is no definite point in the mercury column where the in-

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[5] Harris, J. A., and Gortner, R. A., Notes on the calculations of the osmotic pressure of expressed vegetable saps from the depression of the freezing point, with a table for the values of P for $\Delta = 0.001°$ to $\Delta = 2.999°$. Amer. Jour. Bot. **1**: 75–78, 1914.

fluence of the freezing mixture ceases and that of the external temperature conditions begins, and a correction for the variation in the mercury column can be only roughly approximated. The thermometer employed in the present work exposed, to temperature conditions external to the freezing chamber, a mercury column somewhat more than 25 cm. in height.

Since the influence of external air temperature upon the reading of the Beckmann thermometer seems not to have been emphasized in connection with this sort of work, the data of table I are here presented to show the nature of this influence, these data being representative of a much larger number of determinations. The value of the freezing point of the solvent, as used in the computations of the table, was determined with a room temperature of 20°C., and the corresponding values for the solutions were determined with varying air temperatures, the apparent depressions being, in each case, the difference between the freezing point of the pure solvent (air temperature 20°C.) and that of the solution. Similar variations of the apparent from the true depression must, of course, result in every case where the air temperature at the testing of the solvent differs from that at the testing of the solution. When pure water is tested with two different air temperatures an apparent depression of its freezing point is evident, and this well emphasizes the point here under discussion. It should be noted that none of the diffusion tensions given in the last column of table I are correct, since none of them were determined from freezing point determinations with air temperature at 20°, the air temperature prevailing at the determination of the freezing point of pure water here used in calculation. These numbers represent only *apparent* diffusion tensions at the freezing point.

From table I it is clear that air temperature is not to be neglected in such determinations as are here undertaken. It was impracticable to maintain the room temperature constant, and the difficulty was obviated by reading the freezing point of pure water at the beginning of each day's operations and repeating this determination at intervals of an hour or two, according to fluctuations of the air temperature. The depression was determined in each case by reference to a reading of the freezing point of the pure solvent, made with approximately the same external temperature as obtained at the freezing point determination of the solution itself.

The solutions to be tested were prepared in the same manner as were those employed by Tottingham, "Baker's analyzed" chemicals being again used. The distilled water was obtained from the same still as was employed by that writer. Thus the results here obtained from cryoscopic determinations are quite comparable with Tottingham's calculated diffusion tensions.

TABLE I

Data showing the relation of external temperature to the magnitude of the depression of the freezing point, as determined with the Beckmann apparatus, and to that of the depression corrected for undercooling, and the derived diffusion tension at the freezing point.

	External air temperature	Apparent depression of freezing point, (Δ')	Δ' corrected for undercooling, (Δ)	Diffusion tension at freezing point
	Deg. C.	*Deg. C.*	*Deg. C.*	*Atmospheres*
Solution 1	31	0.205	0.199	2.40
	21	0.215	0.210	2.40
	18	0.220	0.216	2.61
	12	0.235	0.226	2.73
	− 4	0.245	0.241	2.91
Solution 2	23	0.180	0.175	2.11
	10	0.195	0.191	2.30
	5	0.207	0.202	2.44
Pure water	20	0.000		
	14	0.010		
	5	0.017		
	2	0.020		

All of the solutions in Tottingham's optimal series (calculated diffusion tension 2.50 atmospheres, calculated total concentrations 0.6%) were subjected to cryoscopic test, as were also those solutions of his supra-optimal series (calculated diffusion tension 8.15 atmospheres, calculated total salt concentration 2.0%) which produced no precipitation on standing.[6] A sufficient number of the solutions in the remaining sub-optimal series (calculated diffusion tension 0.05 atmospheres, calculated total salt concentration 0.01%) were studied to demonstrate practical agreement between Tottingham's calculations and the present

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[6] Tottingham (*loc. cit.*, p. 222) calls attention to the fact that precipitates occurred in 19 of these solutions, and these were therefore omitted in the present study.

determinations; in no case tested was the difference greater than 0.004 atmospheres. The data for the two most concentrated series are given in tables II and III. In these tables the numbers of the solutions are those employed by Tottingham. The partial, volume-molecular, concentrations and the total salt concentrations are given for each series. These are followed by the actual depressions of the freezing point (after correction for undercooling of 2.5°C.) and by the diffusion tensions at 25°C. Finally, the last column of each table gives the plus and minus percentage variations of the diffusion tensions here determined, from the corresponding calculated values as given by Tottingham.

It will be observed that the results obtained by the method of calculation and those here set forth are in very close agreement for the optimal series of solutions. The greatest deviation above 2.50 atmospheres of diffusion tension (calculated for Tottingham's series 5) is 6.4%, and the greatest below this calculated value is 5.6%. The average for this whole series is 2.508 atmospheres of diffusion tension, which represents a deviation, from the calculated value, of only 0.32%. For the more concentrated series on the other hand, the results obtained by the two methods are not in nearly as complete accord. In every instance the values obtained by the cryoscopic method fall markedly below the calculated value (8.15 atmospheres of diffusion tension), the smallest deviation from the calculated value being 6.7%, and the greatest 20.0%. The average diffusion tension for the whole series is 7.22 atmospheres, which represents a minus deviation from the calculated value of 8.9%. It is of interest to note that the whole range of variation between the highest and lowest values of diffusion tension for the optimal series is only 0.30 atmospheres, while the more concentrated series shows a corresponding range of 1.08 atmospheres.

As has already been remarked, a number of tests made with solutions from Tottingham's least concentrated series showed practically perfect agreement between his calculation and the diffusion tension values derived by cryoscopy; variations were so small as to make it appear unnecessary to test the entire series. From what has just been said it is clear that the optimal series

TABLE II

Data for Tottingham's optimal series
(Calculated diffusion tension 2.50 atmospheres)

Solution number	Partial concentrations, volume-molecular				Total concentration	Depression of freez'g point	Diffusion tension 25° C.	Variation from calculated diffusion tension
	KH_2PO_4	KNO_3	$Ca(NO_3)_2$	$MgSO_4$				
					Per cent	*Deg.C.*	*Atmospheres*	*Per cent*
T1R1C1	.0052	.0049	.0036	.0406	.66	.202	2.66	6.4
C2	.0052	.0049	.0072	.0348	.65	.148	2.42	-3.2
C3	.0052	.0049	.0108	.0290	.64	.199	2.62	4.8
C4	.0052	.0049	.0144	.0232	.63	.188	2.48	-0.8
C5	.0052	.0049	.0174	.0116	.62	.180	2.37	-5.2
C6	.0052	.0049	.0216	.0116	.61	.184	2.42	-3.2
C7	.0052	.0049	.0252	.0058	.60	.191	2.51	0.4
R2C1	.0052	.0098	.0036	.0348	.64	.201	2.64	5.6
C2	.0052	.0098	.0072	.0290	.63	.188	2.48	-0.8
C3	.0052	.0098	.0108	.0232	.62	.189	2.49	-0.4
C4	.0052	.0098	.0144	.0174	.61	.191	2.51	0.4
C5	.0052	.0098	.0180	.0116	.60	.202	2.66	6.4
C6	.0052	.0098	.0216	.0058	.59	.188	2.48	-0.8
R3C1	.0052	.0147	.0036	.0290	.62	.179	2.36	-5.6
C2	.0052	.0147	.0072	.0232	.61	.188	2.48	-0.8
C3	.0052	.0147	.0108	.0174	.60	.202	2.66	6.4
C4	.0052	.0147	.0144	.0116	.59	.180	2.37	-5.2
C5	.0052	.0147	.0180	.0058	.58	.191	2.51	0.4
R4C1	.0052	.0196	.0036	.0232	.60	.188	2.48	-0.8
C2	.0052	.0196	.0072	.0174	.59	.198	2.61	4.4
C3	.0052	.0196	.0108	.0116	.58	.196	2.59	3.6
C4	.0052	.0196	.0144	.0058	.57	.193	2.54	1.6
R5C1	.0052	.0245	.0036	.0174	.58	.200	2.63	5.2
C2	.0052	.0245	.0072	.0116	.57	.192	2.53	1.2
C3	.0052	.0245	.0108	.0058	.56	.196	2.59	3.6
R6C1	.0052	.0294	.0036	.0116	.56	.198	2.61	4.4
C2	.0052	.0294	.0072	.0058	.55	.188	2.48	-0.8
R7C1	.0052	.0343	.0036	.0058	.54	.188	2.48	-0.8
T2R1C1	.0104	.0049	.0036	.0348	.66	.190	2.50	0.0
C2	.0104	.0049	.0072	.0290	.65	.195	2.57	2.8
C3	.0104	.0049	.0108	.0232	.64	.200	2.63	5.2
C4	.0104	.0049	.0144	.0174	.63	.198	2.61	4.4
C5	.0104	.0049	.0144	.0174	.62	.191	2.51	0.4
C6	.0104	.0049	.0216	.0058	.61	.184	2.43	-2.8
R2C1	.0104	.0098	.0036	.0290	.64	.182	2.40	-4.0
C2	.0104	.0098	.0072	.0232	.63	.184	2.43	-2.8
C3	.0104	.0098	.0108	.0174	.62	.185	2.44	-2.4
C4	.0104	.0098	.0144	.0116	.61	.191	2.51	0.4
C5	.0104	.0098	.0180	.0058	.60	.190	2.50	0.0
R3C1	.0104	.0147	.0036	.0232	.62	.185	2.44	-2.4
C2	.0104	.0147	.0072	.0174	.61	.174	2.41	-3.6
C3	.0104	.0147	.0108	.0116	.60	.188	2.48	-0.8
C4	.0104	.0147	.0144	.0058	.59	.189	2.49	-0.4
R4C1	.0104	.0196	.0036	.0174	.60	.188	2.48	-0.8
C2	.0104	.0196	.0072	.0116	.59	.189	2.49	-0.4
C3	.0104	.0196	.0108	.0058	.58	.185	2.44	-2.4
R5C1	.0104	.0245	.0036	.0116	.58	.191	2.51	0.4
C2	.0104	.0245	.0072	.0058	.57	.189	2.49	-0.4
R6C1	.0104	.0294	.0036	.0058	.56	.188	2.48	-0.8
T3R1C1	.0156	.0049	.0036	.0290	.67	.186	2.46	-1.6
C2	.0156	.0049	.0072	.0232	.66	.186	2.46	-1.6
C3	.0156	.0049	.0108	.0174	.65	.201	2.65	6.0
C4	.0156	.0049	.0144	.0116	.64	.200	2.63	5.2
C5	.0156	.0049	.0180	.0058	.63	.196	2.59	3.6
R2C1	.0156	.0098	.0036	.0232	.65	.193	2.54	1.6
C2	.0156	.0098	.0072	.0174	.64	.191	2.51	0.4
C3	.0156	.0098	.0108	.0116	.63	.193	2.54	1.6
C4	.0156	.0098	.0144	.0058	.62	.196	2.59	3.6
R3C1	.0156	.0147	.0036	.0174	.63	.184	2.42	-3.2
C2	.0156	.0147	.0072	.0116	.62	.184	2.42	-3.2
C3	.0156	.0147	.0108	.0058	.61	.188	2.48	-0.8
R4C1	.0156	.0196	.0036	.0116	.61	.196	2.59	3.6
C2	.0156	.0196	.0072	.0058	.60	.197	2.59	3.6
R5C1	.0156	.0245	.0036	.0058	.59	.182	2.40	-4.0
T4R1C1	.0208	.0049	.0036	.0232	.67	.184	2.42	-3.2
C2	.0208	.0049	.0072	.0174	.66	.180	2.37	-5.2
C3	.0208	.0049	.0108	.0116	.65	.182	2.40	-4.0
C4	.0208	.0049	.0144	.0058	.64	.189	2.49	-0.4
R2C1	.0208	.0098	.0036	.0174	.65	.184	2.42	-3.2
C2	.0208	.0098	.0072	.0116	.64	.194	2.55	2.0
C3	.0208	.0098	.0108	.0058	.63	.191	2.51	0.4
R3C1	.0208	.0147	.0036	.0116	.63	.191	2.51	0.4
C2	.0208	.0147	.0072	.0058	.62	.191	2.51	0.4
R4C1	.0208	.0196	.0036	.0058	.61	.191	2.51	0.4
T5R1C1	.0260	.0049	.0036	.0174	.67	.188	2.48	-0.8
C2	.0260	.0049	.0072	.0116	.66	.188	2.48	-0.8
C3	.0260	.0049	.0108	.0058	.65	.192	2.53	1.2
R2C1	.0260	.0098	.0036	.0116	.65	.191	2.51	0.4
C2	.0260	.0098	.0072	.0058	.64	.188	2.48	-0.8
R3C1	.0260	.0147	.0036	.0058	.63	.192	2.53	1.2
T6R1C1	.0312	.0049	.0036	.0116	.67	.191	2.51	0.4
C2	.0312	.0049	.0072	.0058	.66	.194	2.55	2.0
R2C1	.0312	.0098	.0036	.0058	.65	.189	2.49	-0.4
T7R1C1	.0364	.0049	.0036	.0058	.67	.191	2.51	0.4

TABLE III

Data for Tottingham's supra-optimal series
(Calculated diffusion tension 8.15 atmospheres)

Solution number	Partial concentrations, volume-molecular				Total concentration	Depression of freez'g point	Diffusion tension, 25° C.	Variation from calculated diffusion tension
	KH_2PO_4	KNO_3	$Ca(NO_3)_2$	$MgSO_4$				
					Per cent.	*Deg. C.*	*Atmospheres*	*Per cent.*
T1R1C1	.0168	.0163	.0120	.1393	2.25	.497	6.52	-20.0
C2	....	....	....	....	....	...	....	....
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	....	....	....	....	....	...	....	....
C6	....	....	....	....	....	...	....	....
C7	.0168	.0163	.0840	.0199	2.00	.572	7.53	-7.6
R2C1	.0168	.0326	.0120	.1194	2.18	.521	6.86	-15.8
C2	....	....	....	....	....	...	....	....
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	....	....	....	....	....	...	....	....
C6	.0168	.0326	.0720	.0199	1.97	.570	7.50	-8.0
R3C1	.0168	.0489	.0120	.0995	2.11	.538	7.04	-13.6
C2	.0168	.0489	.0240	.0796	2.06	.557	7.34	-9.9
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	.0168	.0489	.0600	.0199	1.94	.570	7.50	-8.0
R4C1	.0168	.0652	.0120	.0796	2.03	.538	7.04	-13.6
C2	.0168	.0652	.0240	.0597	1.99	.550	7.24	-11.2
C3	.0168	.0652	.0360	.0398	1.95	.572	7.54	-7.5
C4	.0168	.0652	.0480	.0199	1.91	.570	7.50	-8.0
R5C1	.0168	.0815	.0120	.0597	1.96	.544	7.16	-12.2
C2	.0168	.0815	.0240	.0398	1.92	.558	7.35	-9.8
C3	.0168	.0815	.0360	.0199	1.88	.558	7.35	-9.8
R6C1	.0168	.0978	.0120	.0398	1.89	.539	7.10	-12.9
C2	.0168	.0978	.0240	.0199	1.85	.549	7.23	-11.3
R7C1	.0168	.1141	.0120	.0199	1.81	.560	7.38	-10.6
T2R1C1	.0336	.0163	.0120	.1194	2.24	.517	6.81	-10.5
C2	....	....	....	....	....	...	....	....
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	....	....	....	....	....	...	....	....
C6	.0336	.0163	.0720	.0199	2.03	.573	7.55	-7.4
R2C1	....	....	....	....	....	...	....	....
C2	.0336	.0326	.0240	.0796	2.13	.531	7.00	-14.1
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	.0336	.0326	.0600	.0199	2.00	.563	7.42	-9.0
R3C1	.0336	.0489	.0120	.0796	2.10	.533	7.02	-13.9
C2	.0336	.0489	.0240	.0597	2.05	.533	7.02	-13.9
C3	.0336	.0489	.0360	.0398	2.01	.552	7.27	-10.8
C4	.0336	.0489	.0480	.0199	1.97	.559	7.36	-9.7
R4C1	.0336	.0652	.0120	.0597	2.02	.533	7.02	-13.9
C2	.0336	.0652	.0240	.0398	1.98	.552	7.27	-10.8
C3	.0336	.0652	.0360	.0199	1.93	.554	7.30	-10.4
R5C1	.0336	.0815	.0120	.0398	1.95	.554	7.30	-10.4
C2	.0336	.0815	.0240	.0199	1.91	.569	7.50	-8.0
R6C1	.0336	.0978	.0120	.0199	1.87	.562	7.40	-9.2
T3R1C1	....	....	....	....	....	...	....	....
C2	.0504	.0163	.0240	.0769	2.20	.535	7.05	-13.5
C3	....	....	....	....	....	...	....	....
C4	....	....	....	....	....	...	....	....
C5	.0504	.0163	.0600	.0199	2.07	.548	7.22	-10.2
R2C1	.0504	.0326	.0120	.0796	2.16	.526	6.93	-15.2
C2	.0504	.0326	.0240	.0597	2.12	.543	7.15	-12.3
C3	.0504	.0326	.0360	.0398	2.08	.546	7.19	-11.8
C4	.0504	.0326	.0480	.0199	2.04	.567	7.46	-8.5
R3C1	.0504	.0489	.0120	.0597	2.09	.536	7.06	-13.4
C2	.0504	.0489	.0240	.0398	2.05	.565	7.44	-8.7
C3	.0504	.0489	.0360	.0199	2.01	.548	7.22	-10.2
R4C1	.0504	.0652	.0120	.0398	2.02	.509	6.70	-17.8
C2	.0504	.0652	.0240	.0199	1.97	.565	7.44	-8.7
R5C1	.0504	.0815	.0120	.0199	1.94	.562	7.04	-9.2
T4R1C1	.0672	.0163	.0120	.0796	2.23	.523	6.89	-15.5
C2	.0672	.0163	.0240	.0597	2.18	.538	7.08	-13.1
C3	....	....	....	....	....	...	....	....
C4	.0672	.0163	.0480	.0199	2.10	.562	7.40	-9.2
R2C1	.0672	.0326	.0120	.0597	2.15	.533	7.02	-13.9
C2	.0672	.0326	.0240	.0398	2.11	.577	7.60	-6.7
C3	.0672	.0326	.0360	.0199	2.07	.557	7.34	-9.9
R3C1	.0672	.0489	.0120	.0398	2.07	.541	7.12	-12.6
C2	.0672	.0489	.0240	.0199	2.04	.548	7.22	-10.2
R4C1	.0672	.0652	.0120	.0199	2.00	.548	7.22	-10.2
T5R1C1	.0840	.0163	.0120	.0597	2.22	.538	7.08	-13.1
C2	.0840	.0163	.0240	.0398	2.18	.572	7.53	-7.6
C3	.0840	.0163	.0360	.0199	2.13	.548	7.22	-10.2
R2C1	.0840	.0326	.0120	.0398	2.14	.541	7.12	-12.6
C2	.0840	.0326	.0240	.0199	2.10	.555	7.31	-10.3
R3C1	.0840	.0489	.0120	.0199	2.07	.550	7.24	-11.2
T6R1C1	.1008	.0163	.0120	.0398	2.21	.538	7.08	-13.1
C2	.1008	.0163	.0240	.0199	2.16	.548	7.22	-10.2
R2C1	.1008	.0326	.0120	.0199	2.13	.552	7.27	-10.8
T7R1C1	.1176	.0163	.0120	.0199	2.19	.538	7.08	-13.1

also exhibits satisfactory agreement between the present determinations and the calculations of Tottingham. As that writer employed the optimal series, the diffusion tensions apparently varied from a minimum of 2.36 to a maximum of 2.66 atmospheres, while he assumed this value to be constant throughout the series and to possess a magnitude of 2.50 atmospheres. Considering the relatively low sensitiveness of ordinary plants to slight variations in the total diffusion tensions of the medium in which they are rooted, it appears that Tottingham's calculations are satisfactory for the preparation of nutrient solutions not more concentrated than his optimal series. For the weakest and for the medium concentrations, then, Tottingham's method of calculation (which assumes ionization of each salt to proceed independently of any influence of the other salts) proves reliable.

As has been emphasized, the highest concentration employed by Tottingham exhibits much more serious departures from his calculation of diffusion tension. The supra-optimal series shows, by the cryoscopic method, a range of diffusion tension from a minimum of 6.52 to a maximum of 7.53 atmospheres, while Tottingham's calculation placed this value at 8.15 atmospheres. Whether such a variation may be important in culture experiments, with plants at best sickly from such high concentrations, has not been determined, but it appears probable that an osmotic influence may sometimes enter as an uncontrolled condition if Tottingham's strongest solutions are prepared according to his formulae.

Since no concentrations were studied between the optimal and the supra-optimal of Tottingham's experiments, since the former of these concentrations proves reliable as he prepared the series, and since the latter seems somewhat unsatisfactory, it can not be stated how concentrated such a series may be made without introducing considerable variation from the diffusion tensions derived by cryoscopy. It seems perfectly clear, however, that Tottingham's method of calculations should prove satisfactory for series of somewhat higher concentration than that of his optimal solutions.

EXPERIMENTS IN FORCING NATIVE PLANTS TO BLOSSOM DURING THE WINTER MONTHS

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The problem of obtaining sufficient and suitable material for class work in taxonomy during the winter months, especially of flowering plants, is often a very perplexing one to those giving instruction in schools and colleges of the northern states. Dried and pressed specimens are generally unattractive and uninstructive to the average college student of systematic botany, and it is only the occasional person with a predilection for taxonomic work who can sustain his enthusiasm on this kind of material alone and derive benefit from it. Material preserved in alcohol or formalin, though much better for dissection purposes, is bound to be both sloppy and smelly, and on the whole not much more desirable or satisfactory than the first mentioned kind. Formalin material becomes particularly objectionable if the plants are large and a considerable quantity of it has to be given out at one time.

If one is fortunate enough to have extensive greenhouse space for growing plants that blossom during the winter season, these difficulties can be lessened to a considerable extent by supplementing with fresh flowers and plants. However, this kind of material is not wholly satisfactory either, for the reason that most of the winter-blooming hothouse plants are strange exotics and frequently are not representative of families and genera with which the average student comes in actual practical contact. They also present often the additional difficulty of being double or filled to such an extent that they prove of little or no value for systematic work.

Finally, our manuals and floras, available as handbooks for students of taxonomy, include but a very few of the hothouse plants, and consequently the training of running down and determining species has to go by default. This undoubtedly is the most serious objection to exotic material for I believe that it must be generally conceded that one of the chief values of a course in taxonomy is the training afforded by continual practice in the independent determination and classification of genera and species. If manuals were available with good keys and brief diagnostic descriptions, covering the majority of the plants usually grown in our greenhouses, then there would be less objection to using these plants very largely as regular material throughout the time of the year when native vegetation is dormant.

In looking about for a way of obviating, at least in part, the various difficulties pointed out above, the feasibility of forcing native plants to blossom during the winter months suggested itself to the writer. When this plan was first suggested to the head gardener, an Englishman of long experience, it met with considerable skepticism and was looked upon with more or less disfavor as a waste of valuable time and greenhouse space. After considerable persuasion and delay, the experiment was undertaken and carried through according to the plans and suggestions of the writer. Naturally after the authoritative discouragement of the gardener, little or no success was really anticipated from it, but it proved on the whole so successful that a brief account of the methods employed and an enumeration of the plants used are deemed justifiable.

All the plants used were found growing naturally in and around Minneapolis. They were dug late in the fall of the year, after the growing season was over, and replanted at once in pots and flats of suitable size and depth. The pots and flats were used more or less indiscriminately, largely for the reason that it was not known which would prove the most satisfactory. After a year's trial it was demonstrated that for most of the plants, the flats were the best, mainly because they afforded the roots more space in which to spread out and take hold. Furthermore, the flats can be frozen without danger of breaking, and therefore in the end save both time and expense. No definite attempt was made to transplant into the same kind of soil as the plants were found in, and rich sandy loam was used for practically all.

Most of the plants as soon as they had been potted and put into flats were divided into two sets, one of which was put into the forcing house at once, the other was left outside to freeze. This work was completed about the middle of October. A few of the plants left outside, were given only a slight freezing—28°F. for about four days—and then transferred to the forcing house. The remainder were kept outside until December 16 to 18, and thoroughly frozen. They were then all taken in and left in the potting room to thaw out for two days. After this they were transferred to the forcing house and placed alongside the others, so that throughout the forcing period they were all under the same light, temperature, and moisture conditions.

The following observations and data are copied from the notes kept, and for convenience will be set down in tabular form. It should be stated that there was no intention at the outset of gathering these data for publication and that the notes were taken only in a fragmentary manner. Only such facts as might prove of interest and value in individual cases were recorded and hence no uniformity or consecutiveness runs through the notes. They are given here in the brief disconnected manner in which they were recorded.

The temperature of the forcing house throughout most of the period ranged from 60° to 65°F. during the day, while the night temperature averaged 15° less or 45° to 50°. Towards the end of the period—March 15 to April 15, the day temperature rose considerably higher than 65°.

In those cases where the plants were put into the greenhouse without any previous freezing, results were almost wholly negative as far as flowering was concerned. The plants made considerable growth although uniformly slower than in the cases where they were thoroughly frozen. Only occasionally were flowers produced and then only in limited numbers and sometimes intermittently. It would seem from this, together with the results shown in table II, that the stimulus of thorough freezing

TABLE I

Plants potted and left outside to freeze until December 16. After two days in potting house taken into forcing house

NAME OF SPECIES	FIRST SIGNS OF GROWTH	OBSERVATIONS ON GROWTH	FIRST FLOWER BUDS	OPENING OF FIRST FLOWER	MAXIMUM BLOSSOMING	NORMAL TIME OF BLOSSOMING	REMARKS
Aquilegia canadensis......		3 to 6″ high January 13	January 20	2 flowers January 26	January 29	May 6 to June 3	Flowers deficient in red color
Actaea rubra............	January 13	Leaves 10 to 12″ January 20	January 20			May 15 to June 10	Most of the flowers withered unopened
Asarum canadensis.......				January 13	January 20	May 15 to 30	Blossomed freely, vigorous growth
Caltha palustris..........	Leaves visible January 8	Leaves 4 to 6″ high January 20	January 12	January 25	January 30	April 25 to May 20	Several flower buds did not open
Caulophyllum thalictroides.................	Leaves unfolding January 13 to 20	Sterile plants full grown January 30			February 12	May 8 to 20	Grew and blossomed vigorously
Cornus canadensis........		Flowering shoots 2″ high January 20				June 1 to 20	Buds blasted, leaves appeared frozen January 20
Hepatica acuta...........				December 30	January 4	April 10 to May 1	Blossomed freely
Heuchera hispida.........		Leaves 5 to 7″ January 20		March 10		June 10 to 30	1st scape withered, 2nd blossomed freely
Geum ciliatum...........			January 13	January 20		May 1 to 15	Only a few flowers opened
Lithospermum canescens.		Stems 3 to 5″ January 20	January 20		January 25	May 15 to June 10	Blossomed freely
Liatris scariosa...........	January 12	Leaves 6″ January 20	March 25			August 6 to 30	Blossomed freely, date lost
Mitella diphylla..........		Active growth January 20	January 20	January 27	January 30	April 26 to May 20	Flowered freely several weeks
Pulsatilla hirsutissima....		Leaves unfolding January 5 to 8		January 3	January 10 to 20	April 10 to May 1	Blossomed very freely
Pyrola elliptica...........		2″ high January 20	January 13	January 25		June 25 to July 15	Blossomed normally
Pedicularis canadensis....	January 15	Flowering shoot visible January 20				May 25 to June 15	Flower buds did not open
Zizia aurea...............	January 5	8 to 10″ high January 20	January 13	January 25	January 30	May 10 to June 1	Blossomed freely

TABLE 11

Plants subjected to freezing temperature 2 to 4 days; a temperature of about 28° F. obtained during this time. Brought into the greenhouse November 4, 1912

NAME OF SPECIES	FIRST SIGNS OF GROWTH	OBSERVATIONS ON GROWTH	FIRST FLOWER BUDS	OPENING OF FIRST FLOWER	MAXIMUM BLOSSOMING	NORMAL TIME OF BLOSSOMING	REMARKS
Allium tricoccum.........	Leaves visible January 1	2 to 3″ high January 20				June to July 1 ?	No blossoms by the end of May
Anemonella thalictroides.				January 4	January 20	April 25 to May 25	Flowered for a long time, irregularly
Claytonia virginica.......	Leaves visible December 20		December 23	December 30	January 1 to 10	May 1 to 10	Many flower buds did not open
Hydrophyllum virginicum....................			January 20	January 25		May 20 to June 15	Blossomed fairly well
Isopyrum biternatum....						May 1 to 20	Blossomed intermittently for some time
Lithospermum canescens.					December 25 to 30	May 15 to June 10	Many flower buds did not open
Mitella nuda.............		3 flowering scapes March 1		March 8 to 9	March 15	May 20 to June 15	Grew very slowly

TABLE III

Plants left out from the time of potting and frozen until December 18; taken directly into the forcing house

NAME OF SPECIES	FIRST SIGN OF GROWTH	OBSERVATIONS ON GROWTH	FIRST FLOWER BUDS	OPENING OF FIRST FLOWER	MAXIMUM BLOSSOMING	NORMAL TIME OF BLOSSOMING	REMARKS
Aralia nudicaulis.........		Scapes 6″ January 24			February 6 to 12	May 15 to June 1	Blossomed freely
Anemonella thalictroides.	January 8		Numerous buds January 15	January 20	February 1 to 5	April 25 to May 25	Same plants as previous year
Agrimonia hirsuta........	Basal leaves expanded January 20	Stems 2 to 4″ March 1	March 20		April 5 to 8	June 15 to July 15	Blossomed very freely
Arisaema triphyllum.....					February 14	May 15 to June 10	Blossomed normally

Caltha palustris			Fully out January 8	January 15	January 25 to February 1	April 25 to May 20	Blossomed profusely
Cornus canadensis					February 5 to 15	June 1 to 20	Blossomed freely. Same plants as previous year
Cardamine bulbosa		Stems 2 to 4″ high January 8	Numerous buds January 8		January 25 to February 1	May 15 to June 10	Blossomed freely
Geum ciliatum		Scapes 1 to 2″ January 8	January 8			May 1 to 15	Flower buds blasted
Geum canadense		Stems 6 to 8″ March 1	March 1	March 15	March 26 to April 1	June 25 to July 10	Blossomed very freely
Hepatica acuta	Buds showing January 5	Leaves unfolding February 1 to March 1	January 12	January 15	January 20 to February 10	April 10 to May 1	Blossomed freely
Hydrophyllum virginicum	January 10	Many leaves January 20	February 10	March 1	March 9	May 20 to June 15	Blossomed freely
Isopyrum biternatum	December 28	Many leaves January 3	January 3	January 5	January 12	May 1 to 25	Blossomed freely a long time
Liatris scariosa	January 15	Stems 1 to 1.5′ March 1	March 6	March 28	April 10	August 6 to 30	Blossomed very freely
Mitella diphylla		Scapes 1 to 2″ January 8	January 8	January 15, 2 flowers	January 21 to February 10	April 26 to May 20	Same plants used as previous season
Panicum sp.		Growing actively January 10		Several spikelets March 8			Blossomed normally
Pyrola uliginosa		Leaves unfolding January 10	February 14	March 1	March 8	June 20 to July 10	Blossomed normally
Phlox divaricata	January 8	Stems 1 to 3″ January 15	February 5		February 25	May 10 to June 10	Blossomed freely
Polygonatum commutatum	January 20		February 7		March 1	June 5 to 20	Blossomed freely
Sanguinaria canadensis			January 10	January 15	January 20	April 15 to May 1	Blossomed normally
Smilacina racemosa	January 30	2 to 3″ February 5	February 12	February 20	March 1	June 5 to 20	Same plants as previous year; vigorous
Senecio aurens	January 10	Full growth of leaves January 30	January 24	February 21	February 28	May 28 to June 15	Blossomed moderately
Uvularia grandiflora					February 6 to 15	April 25 to May 15	Somewhat abnormal
Viola pedata	January 5	Leaves 1 to 2″ January 8	January 8	January 24	February 1 to 5	May 10 to 30	Blossomed very freely

for several weeks is essential to successful forcing of native perennials.

The experiment has been carried on for a second time during the present season (1913–1914), partly on the same plants that were used last year, partly on new plants dug and potted during October and November of 1913.

In view of the fact that slightly different treatment has been employed, the results obtained during the second season are interesting for comparison.

In the first place, nearly all the plants were obtained later in the season than in the previous year. They were all left out to freeze completely and the freezing period lasted considerably longer than the year before. Finally, the temperature in the forcing house was kept uniformly much higher, ranging from 55° to 60°F. at night and often going as high as 80°F. during the daytime.

In comparing table III with table I it will be noticed that it contains a number of species not included in the first one and that most of the species used in both cases were the same plants kept over from the previous year. The object of using the same plants again was to determine if a thorough rooting and establishment in the pots and flats during a season of growth would have a beneficial effect on their blossoming. In all cases this proved to be the case, for the plants all grew more vigorously and blossomed more freely than during the previous season.

That the increased temperature may have been partly responsible for this is possible, yet in the light of other facts, it may have been only of secondary importance. On some of the early blooming species the effect of higher temperature was to cause spindling of growth and sometimes impairment of flowering, while on the somewhat later blooming species the effect was beneficial in both respects, as was naturally to be expected. In this latitude (45°N.) the temperature that obtains during the time of blooming of *Sanguinaria, Uvularia, Hepatica, Dicentra* and other spring flowers does not average more than 48°F., whereas the greenhouse temperature maintained in this experiment averaged about 20° higher. It is therefore obvious that these plants will force the best in a temperature that more nearly approximates that in nature.

An inspection of the column of the normal time of blooming for this locality (Minneapolis) will show that the species tried out can be forced to bloom anywhere from 11 to 17 weeks ahead of time under the treatment given.

It is reasonable to expect that better and more uniform results could be obtained with proper adjustments of temperature, watering, potting, etc., for in all cases tried very little effort was made to take into account the different habitat and soil conditions to which the plants have become adapted. The results in one or two specific instances will illustrate the importance of taking these things into careful consideration.

The first year the experiment was tried, a flat planted with *Asarum canadense* gave very satisfactory results. In this case the plants were put in with the rhizomes practically on the surface of the ground and only slightly covered with leaf mold. During the second year a new set of plants was brought in, and in planting, the rhizomes were covered with 1 to 2 inches of soil. Only two blossoms came out and very few leaves were unfolded. In the case of *Pulsatilla* very good results were obtained the first year, but during the second year no flowers opened. In the latter case, the flower buds were covered with a thin layer of soil and in addition, the plants were watered too freely. Several similar instances could be cited in addition to these, but this is enough to show that care and judgment in potting and subsequent treatment must be exercised in order to insure success.

The foregoing experiments are not comprehensive enough to draw from them the conclusion that all our native perennials can be successfully forced in the greenhouse during the winter season. However, it has been clearly enough demonstrated that a goodly proportion of them under proper treatment lend themselves to successful forcing and that a wealth of fresh material can thus be obtained with little effort and expense.

BOOKS AND CURRENT LITERATURE

Essentials of College Botany.—Though announced as the eighth edition of "The Essentials of Botany," by the senior author, this book[1] bears little if any resemblance to the earlier one. In fact, as stated on the title page, the revision has amounted to complete rewriting. Of twenty-two chapters, the first five, written by the junior author, deal with the fundamentals of morphology (Chapters I–III) and physiology (Chapters IV and V). Chapter VI treats of the general principles of classification, and each of the remaining sixteen chapters (except XXI, "Special Adaptations") is devoted to a plant phylum, discussed in evolutionary sequence, the last chapter being a key to the phyla of plants, with their classes, orders, families, and illustrative genera.

Laboratory directions alternate with reading matter. The implication would seem to be that the study of the text should precede that of the specimen in the laboratory. Whether this or the opposite order is best, is of course one of the many points on which teachers differ. Another one of these points of controversy is illustrated by the nature of many of the laboratory directions, where the student is told in advance what he is to see in his specimen; *e.g.* p. 12, "Examine the cells of various fungi . . . . and note the absence of chloroplasts."

The pupil is frequently directed to begin his study of a form by a trip for collecting it in the field. Query: How can a pupil "Look for Riccias" (p. 248) in the field, who has never seen a Riccia in his life?

Technical terms are quite frequently used before they have been defined, and before the student may reasonably be expected to know what they mean (p. 20, gametes, ascus, ascospore; p. 21, karyokinesis, mitosis; p. 29, cambium; p. 50, osmotic action; p. 31, apothecium of cup-fungi; etc.). This tends to make the text, in places, very tough reading for a beginner. Would a freshman appreciate the statement (p. 245) that the Riccias possess no "elaters," when this term is not really explained until five paragraphs further on?

The paragraph (p. 106) on the effect of light on growth, gives the impression of perpetuating the idea, shown to be erroneous by careful

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[1] Bessey, Charles E., and Bessey, Ernst A., Essentials of College Botany. Pp. 409, figs. 206. New York, Henry Holt and Company, 1914.

experiments over ten years ago, that light exerts universal and invariable influence on growth in length or thickness.

Chapter V., The Chemistry of the Plant, consisting of a list of the commoner plant constituents and products, giving the name, chemical formula and occurrence of each, so far as these are known, while containing important information, most certainly could not be used with either intelligence or interest, by the average beginner of the study of botany, especially by college freshmen, or high school students, who, as often as not, have never studied chemistry.

In the systematic chapters the plant kingdom is divided into fourteen phyla, the "Thallophytes" being separated into seven phyla. For the first time in an elementary text (so far as the reviewer knows) fossil plants receive the attention to which their importance and their relation to living forms entitle them.

There is not, in the entire book, any reproduction of a photograph, the 206 illustrations being confined to diagrams such as the teacher would place on his blackboard during the course of his lecture. This, as the authors suggest, removes the temptation to "grave abuse" of elaborate drawings in the laboratory, and may doubtless have other good arguments to recommend it, but the restriction of all illustrations to this type tends to take the life out of the book, and to make absolutely necessary an inspiring teacher and a rich abundance of living material for laboratory study. Perhaps, after all, any feature of a book that operates to insure the two latter desiderata may be regarded as one of its strong points.

The tabular statement of the steps in the progressive development of plants from the Myxophyceae to the Anthophyta (p. 317–318) is admirable, giving a summary, as illuminating as it is concise, of the main forward steps in the evolution of plants. In fact, though the book is rather Spartan in point of illustrations and condensed statement, the result of its use, in the hands of stimulating teachers, such as its authors are known to be, would be to make the pupil *know plants*—a kind of knowledge often conspicuous for its meagerness as a result of some introductory courses.

The senior author was a pioneer in raising botanical instruction in this country above the level of merely collecting, pressing, and naming "the wild flowers," and it is both instructive and gratifying, on comparing this new book with its predecessor, to note the great advances that have taken place in the method and content of botanical instruction since the first edition appeared. One of the factors contributing in large measure to this change has been the influence emanating from his laboratory. The present book must be regarded as embodying the kind of course and the type of instruction that, combined with the personality of the author, has resulted in winning possibly more first class men to botany as a life work than may be credited to any other laboratory in America.—C. S. G.

ELEMENTS OF FORESTRY.—This is the title of an attractive volume[1] which appears to be exactly what the authors claim: viz., "an up-to-date textbook broad in its scope, and containing general information on all phases of the subject." In the preface the authors call attention to the remarkable growth of public interest in forestry. Departments of forestry have been established in 31 states; forestry associations have been organized in 23 states; conservation commissions have been created in 17 states; courses leading to a degree in forestry have been added to the curricula of 23 educational institutions, and short courses in forestry are offered in 42 other schools.

Part one of the text contains chapters on the tree, silvics, silvicultural systems of management, improvement cuttings, artificial regeneration, forest protection and mensuration, lumbering; wood utilization, technology and preservation; forest economics and finance. Part two takes up the location and boundaries, characteristics, silvicultural treatment, protection, utilization, special problems and future of each of the forest regions of the United States.

Among the interesting problems discussed are ownership of forest lands, state control of forest lands, and methods of forest taxation. In connection with the ownership of forest lands, some rather startling facts are brought out. One-twentieth of the land area of the United States, exclusive of Alaska and colonial possessions, is owned by 1694 persons. Their holdings amount to 105,600,000 acres, an area four-fifths of that of France. Sixteen of these speculators hold an area ten times that of New Jersey. In 900 timbered counties investigated by the Bureau of Corporations the 1694 own one-seventh of the land. National control of forest lands is declared preferable to state control, for favorable laws, once enacted by Congress, are repealed with difficulty, whereas state legislatures reverse themselves with ease; the power to settle interstate questions pertaining to forestry is important; the

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[1] Moon, F. F., and Brown, N. C., Elements of Forestry. John Wiley and Sons, 1914.

facilities of the national government for developing a trained corps of men for management of forest reserves are better than those of any state government. Taxation on the basis of yield, and collection of taxes at the time of cutting the crop, are advocated as inducements to owners to handle tracts for a perpetual supply of timber.

The value of the text is considerably enhanced by a conservative number of well-chosen and carefully reproduced photographs, a bibliography at the end of each chapter, and a comprehensive glossary of forestry and logging terms.—J. G. **Brown.**

NOTES AND COMMENT

A method for the detection of reducing sugars which is decidedly more exact than the use of the customary Fehling's solution and at the same time better adapted for the use of elementary students, certainly deserves wide-spread adoption in botanical laboratories. The reagent devised by Dr. Stanley R. Benedict, professor of chemistry at Cornell Medical College, and described by him in the Journal of Biological Chemistry (1909, vol. 5, p. 485 and 1911 vol. 9, p. 57) is so superior to Fehling's in every way that it should entirely supercede it. Benedict's reagent is made in one solution, keeps indefinitely even in half-filled colorless cork-stoppered bottles, gives a more obvious reaction and is ten times as sensitive as the other.

It is prepared as follows:

Copper sulphate crystals 17.3 grams, dissolve in 100 cc. distilled water and make up to 150 cc.

Sodium citrate—173.0 grams.

Sodium carbonate crystals—200.0 grams (100.0 grams anhydrous).

Dissolve these two together in 700 cc. of hot water and make up to 850 cc.

Pour the copper sulphate solution into the other while stirring, filter and the reagent is ready for use.

To 5 cc. of this reagent add 8 or 10 drops of the solution to be tested and boil vigorously for one to two minutes. If a reducing sugar be present the whole mass of the fluid will become opaque because of a red, yellow or brown precipitate. If the amount of sugar present be minute the precipitate may not be visible until the reagent is allowed to cool slowly. The bulk, not the color, of the precipitate is the basis of the test. Since alkalinity in this reagent is produced by sodium carbonate the test is more specific than when hydroxides of the alkali metals are used, since these may exert a destructive action on carbohydrates present before reduction.

Benedict's reagent may be employed to give valuable demonstrations of sugars in plant cells. A fresh portion of a leaf or other plant tissue when boiled in the solution and then examined under the microscope, reveals the characteristic precipitate in the cells in the local areas where the sugar occurs.

A modification of this solution which gives accurate quantitative determinations is described in the second paper cited above. This solution is prepared as follows:

Copper sulphate crystals—18.0 grams, dissolve in 100 cc. distilled water.

Sodium carbonate crystals—200.0 grams.

Sodium citrate, 200.0 grams.

Potassium sulphocyanate, 125.0 grams.

Dissolve these three with heat in enough water to make about 800 cc. of solution and filter.

Potassium ferrocyanide, a 5% solution.

Pour the copper sulphate solution into the hot triple solution with constant stirring, add 5 cc. of the 5% potassium ferrocyanide solution, dilute to exactly 1000 cc. and the solution is ready for use and will keep indefinitely without any special precautions.

Only the copper salt need be weighed with exactness.

Twenty-five cc. of the reagent are reduced by 0.050 gram of glucose by 0.053 gram of levulose.

"Sugar estimations are conducted with the solution in the following manner: Measure 25 cc. of the reagent into a porcelain evaporation dish (25–30 cm. in diameter) and add 10–20 grams of crystallized sodium carbonate (or one-half the weight of the anhydrous salt) and a very small quantity of powdered pumace stone. Heat the mixture to vigorous boiling over a free flame and run in the sugar solution quite rapidly until a heavy white precipitate is produced, and the blue color of the solution begins to diminish perceptibly. From this point the sugar solution is run in more and more slowly, with constant vigorous boiling, until the disappearance of the last trace of blue color, which marks the end point." When solutions rich in sugar are tested they should be diluted 1:10. Toward the end of sugar solution should be added a drop or two at a time with intervals of half a minute. Chloroform must not be present.

I hope that this note may be the means of eliminating one of the many sources of trouble upon which the directors of botanical laboratories are compelled to keep a watchful eye.—H. M. Benedict.

Dr. H. Brockmann-Jerosch, Dr. E. Rübel and Prof. C. Schröter, all of Zürich, form a committee which was charged with the plans and arrangements for an International Phytogeographical Excursion, to be held in Switzerland in the summer of 1915. A prospectus has been issued by the committee outlining a most attractive excursion of thirty-seven days through representative parts of the Alps. A circular letter accompanying the prospectus states, however, that the plans for the excursion will have to be indefinitely postponed on account of the European war.

Announcement has been made of the formation of an International Palaeobotanical Society, of which one of the chief objects will be the establishment and support of a *Palaeobotanisches Zentralblatt.* This organ will be a monthly, published by Gebrüder Borntraeger, and edited by an international committee, the members of which are Scott, Berry, Zeiller, Jongmans, Zalessky, Nathorst, Engler, Krasser and Gothan. The subscription is Mk. 10 per annum.

The following papers will appear in early forthcoming issues of The Plant World: Notes on the Relations between the Floras of Subantarctic America and the Dominion of New Zealand, by Carl Skottsberg; The Relative Transpiration of White Pine Seedlings, by George P. Burns; Atmometry and the Porous Cup Atmometer, by B. E. Livingston; The Flora of the Williams Division of the Tusayan National Forest, Arizona, by A. D. Read; A Manometer Method of Determining the Capillary Pull of Soils, by W. A. Cannon; Observations in the Colorado Desert, by S. B. Parish; and Natural Reforestation in the Mountains of Northern Idaho, by H. B. Humphrey and J. E. Weaver.

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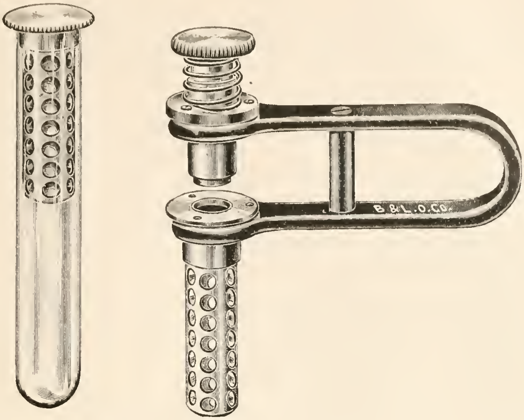
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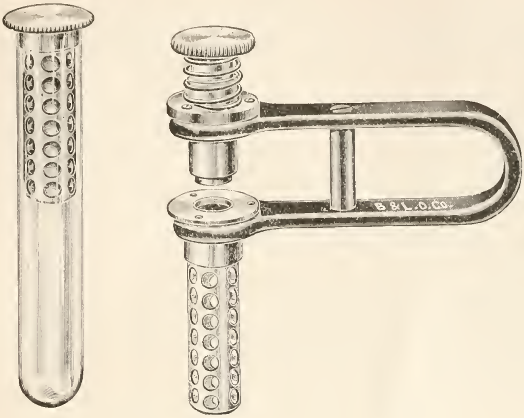
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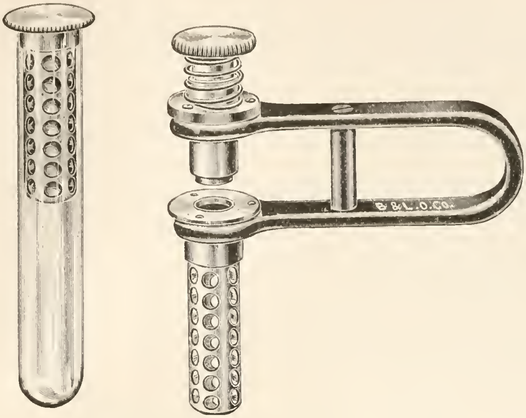
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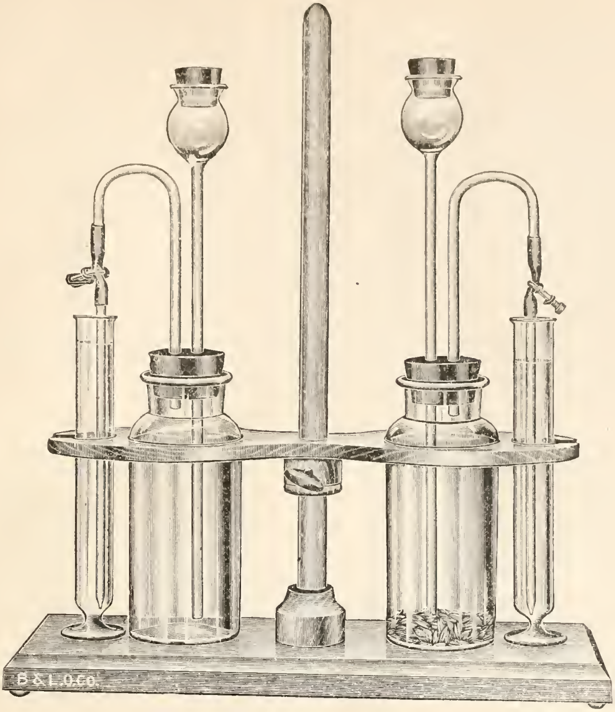
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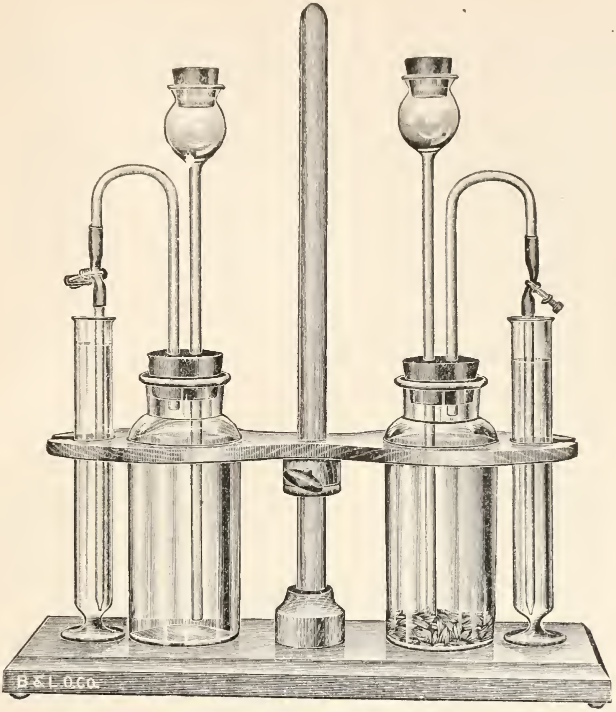
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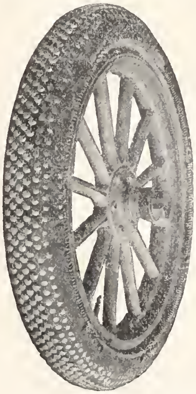

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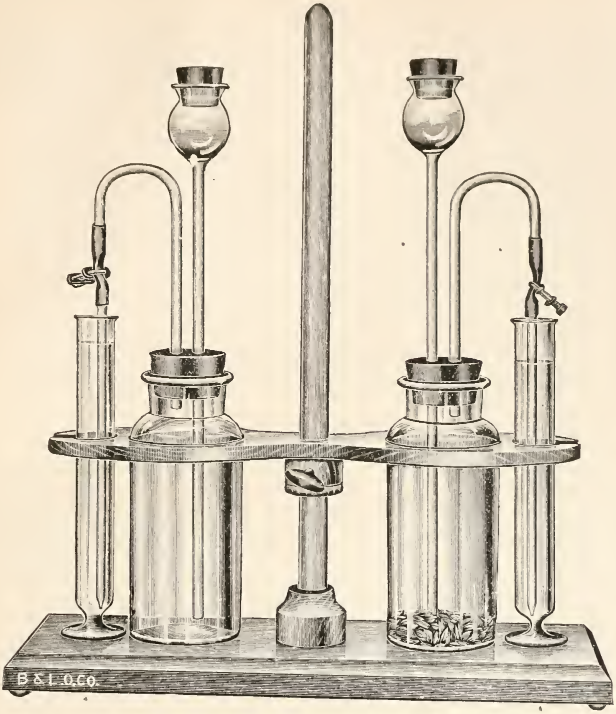
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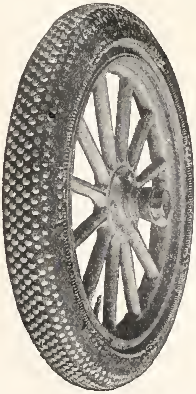

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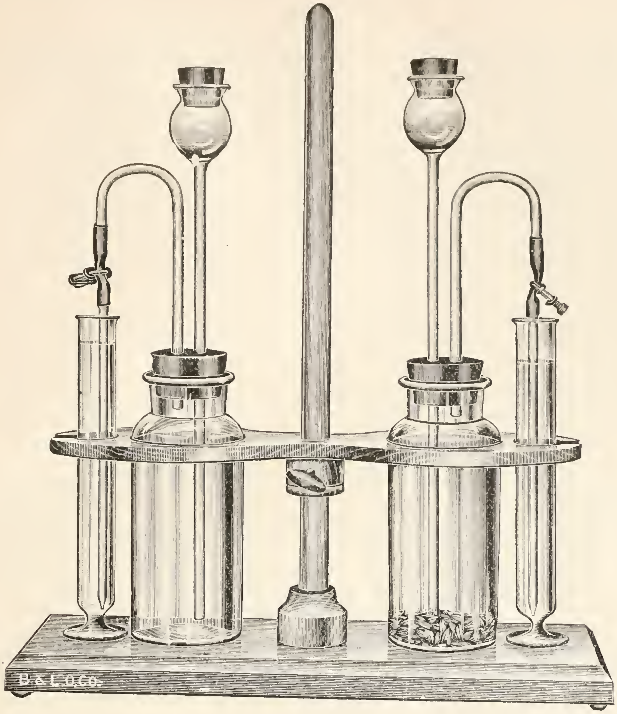
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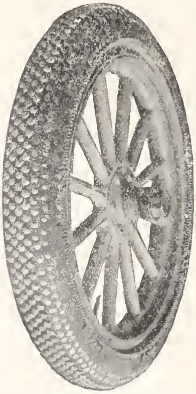

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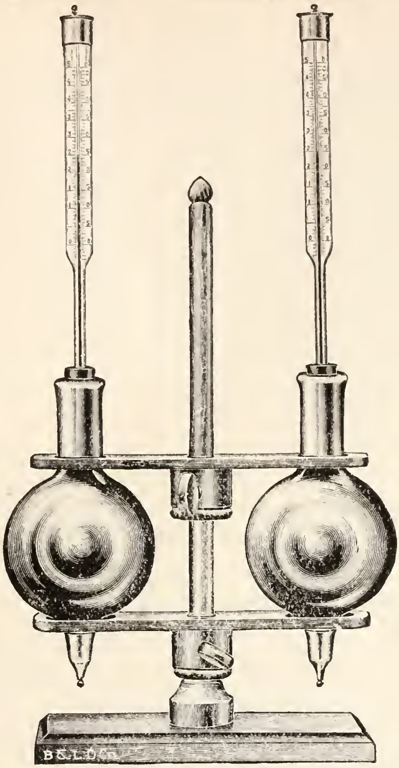
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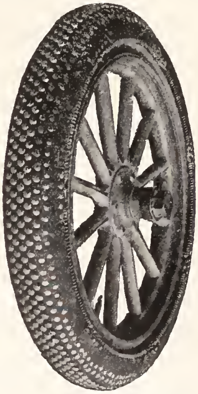

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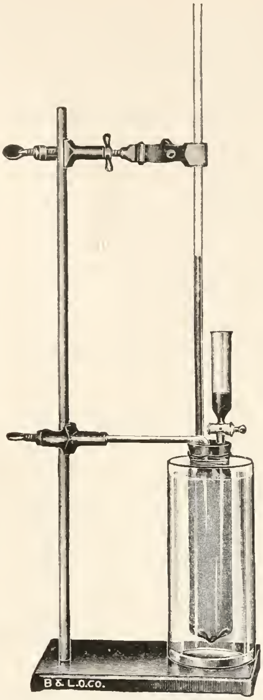
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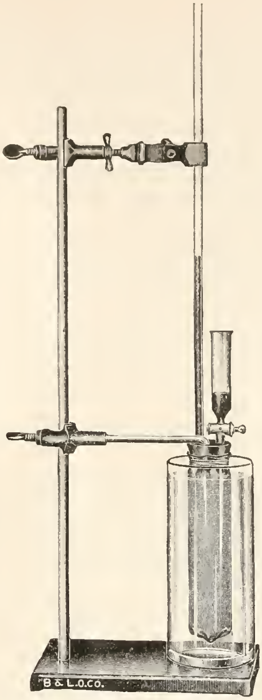
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THE PLANT WORLD, Tucson, Arizona

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The Plant World

A Monthly Magazine of General Botany

Established 1897

Edited by
FORREST SHREVE

Published by

The Plant World Association

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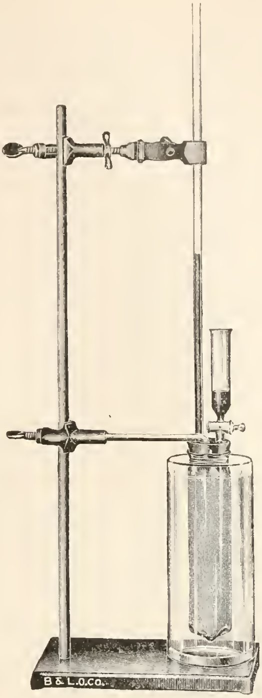
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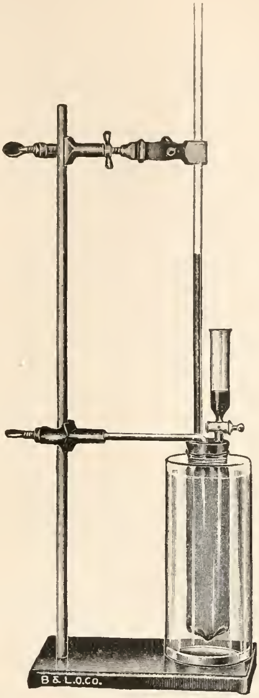
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