A Study of the Relation of Soil Moisture to Transpiration, Photosynthesis and Respiration in the Corn Plant.

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TRUMAN GEORGE YUNCKER.

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INTRODUCTION.

The object of the experiments covered by this paper was to determine the relation, if any, existing between the amount of transpiration, respiration and photosynthesis in corn plants grown under three degrees of soil moisture. The amount of transpiration was obtained by continuous weighings of potometers and a record was maintained of the water that was used by the plants. The amount of respiration was determined by measuring the amount of CO_2 evolved from the plants during a given period. The amount of photosynthesis was determined by measuring the weights of a given unit of area of the three series at different intervals during the day.

The plants were grown in the green-houses of the University of Nebraska during the fall and winter of 1914-1915 under normal green-house conditions. The particular room in which the problem was run was located in the south-west corner of the group and received the maximum amount of sunlight. The temperature of the house ordinarily never went below 50°F. or above 80°F. The humidity, while it varied somewhat, was constant at all times for the various series and no record of it was maintained. The location of the plants on the benches was changed frequently so that each potometer would not

be subjected to factors differing from the others.

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HISTORICAL.

Transpiration:

It has been stated, and with good reason, that plant physiology was 'born' with the advent of Hales' "Vegetable Staticks", but, even before this, we find a Frenchman by the name of Mariotte (1) carrying on physiological research in regard to plants.

In the year 1679 he ran experiments in an effort to arrive at some conclusions as regard the quantity of water "exhaled" from the plant. He placed a branch on which there were many leaves in a closed receptacle and collected two spoonsful of condensed vapor in two hours. While he did not, apparently, determine the exact amount of this transpiration vapor, at the same time it indicates the beginning of a line of inquiry which was to follow.

Woodward (2) in 1699 attempted to arrive at more exact amounts of transpiration by means of weighing a

(1) Essays de physique. I ess. de la veget. des pl.1679.
(2) Phil. Trans., 1699, Vol. XXI Nr. 253, p. 198.

plant from time to time, but little mention is made of his work and it is difficult to arrive at any definite conclusions regarding his results.

Stephen Hales (1), an Englishman, did the first really scientific work upon the subject and his data is readily accessible. His method of arriving at the amount of water loss was by weighing the plant at morning and night. He used a plant of sunflower about three feet tall, in a garden pot rendered evaporation-proof. He made weighings morning and night for fifteen days. He found that from an area of 5615 sq. in. that the plant transpired 1 lb. 10 oz. for the day and 5 oz. for the night. He also worked in a similar manner upon the cabbage. He found the area to be 2736 sq. in. and the transpiration for a twelve hour day was 1 lb. 9 oz.

Following these investigators was a line of others, not endeavoring, necessarily, to prove the fact of transpiration but rather the effect of various influences upon that phenomenon. The following brief list gives some idea as to who did the most important of some of the researches:

Guettard (1748): Daubeny (1836); Meyen (1838); Miquel (1839); Moll (1847); Garreau (1849); Sachs (1860); Unger (1861); Nägeli (1861); Hartig (1863); Knop (1864); Fleischmann (1867); Vesque (1868); Schlösing (1869); Baronetzky (1872); Barthelemy (1873); Eder (1875);

(1) Vegetable Staticks, 1727 p. 6.

Haberlandt (1875); Bonnier and Mangin (1884); Kohl (1886); Eberdt (1888); Aubert (1892); Noll (1893); Stahl (1894); and Stenström (1895).

Burgerstein (1904) published his "Die Transpiration der Pflanzen" which gives a comprehensive survey of the whole question of transpiration and includes an extensive and complete bibliography of all the work done up to 1904. Since 1904 extensive work has been done, especially by Livingston and Briggs and Shantz. Many others have also contributed to the general knowledge of the question, including Clapp, who ran quantitative studies on thirty or more plants under normal and standard conditions in the laboratory of Prof. Ganong at Smith College.

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Water Requirement:

Following is a list of people who have worked upon the question of the water requirement of various crops, when the work was done and also the crop with which they worked:

Il'enkov, 1865, Buckwheat; Fittbogen, 1873, Oats: Hellriegel, 1883, Barley; Maercker, 1896, White Mustard; Schroeder, 1896, Barley; Von Seelhorst, 1899, Oats; Wilms, 1899, Potatoes; Daszewski, 1900, Potatoes; Fortier, 1903, Oats; Von Seelhorst and Bünger, 1907, Spring Wheat; Ehlmer, 1908, Wheat; Wimmer, 1908, Carrots and Grasses and Preul, 1908, Wheat.

Some of the results that have been obtained by investigators who have worked upon the corn plant are as follows:

Widtsoe in 1908 obtained the following data:

Satur-ation.	Water Requirement				Ratio of water req. low to high				
	1902	1903	1904	1905	1902	1903	1904	1905	Average
10%	490	280	424	697	1.31	1.09	1.54	2.28	1.53
20%	406	256	276	306					

Leather in 1910 at Pusa, India obtained the following data:

Year	No. Pots	Saturation	Water Requirement
1907	9	10%	414
		15%	404
		20%	436

Kiesselbach, 1910, at Lincoln, Neb., obtained the following figures:

Satur'n	Avg. Dry Wt. no roots	Water req. based on dry wt.	
		with roots	without roots
98%	91.1	242	270
80%	93.1	239	272
60%	100.6	227	256
40%	92.9	233	270
20%	85.2	201	239

Kiesselbach and Montgomery in 1911 continued Kiesselbach's experiments with the following results:

Saturation	Dry Weight	Water Requirement
100%	373	290
80%	484	263
60%	442	239
45%	297	230
35%	112	261

Briggs and Shantz, 1913, worked out the water requirement at Akron, Colo. of many crops. They worked on three varieties of corn with the following results:

Variety	Water Req.	Average
Iowa Silvermine	420	369
Northwestern Dent	368	
Esperanza	319	

They did not use varying degrees of soil moisture, but, rather to obtain a comparison between different varieties and between various crops with the idea of determining certain drought resistant varieties.

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Respiration:

The discovery of oxygen by Priestly in 1774 would appear to be the earliest date at which investigations would be carried on regarding respiration, but Malpighi (1) in 1767, seven years before oxygen was discovered, proved the necessity of air for germinating seeds. Shortly

(1) Opera Omnia 1767 1 p. 108.

after this, Scheele (1), in 1777, showed that during this process oxygen was consumed and CO_2 produced, as in animal respiration. Ingenhousz (2), 1786, showed that all living tissues exhale CO_2 in darkness and that non-chlorophyllous parts do the same even when illuminated. Huber (3), 1801, described the giving off of CO_2 by germinating grains. De Saussure's work (4) in 1804, is some of the most important done at this period. He showed that growth was dependent upon respiration; that respiration was more active in growing parts than elsewhere, and also that both water and CO_2 are produced during respiration. Meyen (5) was probably the first to show that the respiration and assimilation of CO_2 are two distinct and independent processes. Dutrochet (1837), Garreau (1850) and Mohl (1851) held correct views with regard to the relationship between respiration and photosynthetic assimilation. Sachs, (1865) pointed out that only the processes concerned in the product of CO_2 can be correctly termed respiration or breathing. The continued exhalation of CO_2 in the absence of oxygen was first observed by Rollo in 1798 (6). Pasteur (7) was the first to show that yeast and certain bacteria can respire in the absence of oxygen. The fact

(1) Chem. Abh. von d. Luft, übers v. Bergmann, 1777.
(2) Versuche mit Pflanzen 1786.
(3) Memoire sur l'influence de l'air sur la germ. Geneve, 1801
(4) Recherches Chimiques sur la Vegetation, 1804.
(5) Pflanzenphysiologie t. II p. 162, 1838.
(6) Ann. d. Chim. 1798 T XXV, p. 724.
(7) Jahresb. d. chem. 1861, p. 42.