upon a water-bath, it changed to a hard, vitreous mass. The determination of the strontium was made as described under the potassium salt.

Results:

	Theory.		Found. I.	Found. II.
	Per cent.	Per cent.	Per cent.	Per cent.
$3SrO$	311	7.79	6.80	....
$2Bi_2O_3$	930	23.30	23.07	23.42
$11WO_3$	2552	63.95	....	....
$11H_2O$	198	4.96	4.96	4.95

The purpose of this study will be to ascertain to what extent the more metallic sesquioxides can be introduced into such complexes as have been indicated in the preceding paragraphs, and to exhaustively investigate their derivatives before advancing to those compounds in which there will appear the additional pentoxide.

Columbo- and tantalo-tungstates of sodium and ammonium have been made and analyzed, but a description of them will be reserved for a later communication.

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THE INFLUENCE OF SOIL MOISTURE UPON THE CHEMICAL COMPOSITION OF CERTAIN PLANT PARTS.

BY JOHN A. WIDTSOE.

Received October 7, 1903.

THE great variation in the chemical composition of plants grown under the same climatic conditions and upon similar soils, has always been a somewhat mystifying phenomenon to students of plant chemistry. That plant composition is influenced by soil composition is beyond question; and it is quite generally believed that sunshine, temperature and soil moisture are factors in controlling the chemical composition of plants. However, the relative and absolute values of these soil, climatic and water factors have not been determined, even approximately; and the observed variation in plant composition has usually been beyond satisfactory explanation. In view of this lack of knowledge, it was most interesting to find a definite relation between the soil moisture and the chemical composition of plants.

In a series of exhaustive experiments on irrigation, carried on by the Utah Experiment Station, the water applied to plants was definitely controlled, and the quantity so varied as to determine the most economical use of water in an irrigated district. All the plants grown in the experiments were subjected to chemical analysis. The full report of the work, in the summer of 1901, is published in Bulletin No. 80 of the Utah Station, and it is upon some of the results there found that the present paper is based.

SOIL CONDITIONS OF THE EXPERIMENTS.

The farm upon which these experiments were conducted is located on the old fossil delta of the Logan River, in Cache Valley, State of Utah. The soil is very shallow—varying in depth from 9 to 59 inches, with an average depth of 28 inches. Below this thin layer of soil is a porous bed, nearly 300 feet deep, composed of coarse gravel, with occasional streaks of sand. It is most probable that this condition of shallow soil, with very porous subsoil, was a strong factor in producing the observed variation in the chemical composition of the crops grown upon the farm. The soil laye:: is, in most respects, similar to the soils that prevail within the Great Basin Region, as shown by the following physical and chemical analyses. The methods of analysis followed were those prescribed by the Association of Official Agricultural Chemists.

TABLE I.—PHYSICAL COMPOSITION OF THE SOIL.

Depth.	First foot.	Second foot.	Third root.
Medium sand (0.1 to 0.5 mm.)	28.1	29.7	31.6
Fine sand (0.032 to 0.1 mm.)	25.6	26.4	29.6
Coarse silt (0.01 to 0.032 mm.)	19.2	16.4	14.6
Medium silt (0.0032 to 0.01 mm.)	10.2	6.6	6.6
Fine silt (0.001 to 0.0032 mm.)	2.6	5.6	6.5
Clay (below 0.001 mm.)	8.4	8.8	8.6
Moisture	4.7	4.3	1.8
Soluble and lost	1.2	2.2	0.7
Total	100.0	100.0	100.0

Average weight of one cubic foot of dry soil ...... 88.9 lbs.
Average absolute water capacity .... 28.56 per cent.

TABLE II.—CHEMICAL COMPOSITION OF THE SOIL.

(All per cents. are referred to the water-free soil.)

	First foot.	Second foot.	Third foot.
Insoluble matter	68.42	65.66	56.49
Potash, K_2O	0.65	0.57	0.43
Soda, Na_2O	0.55	0.53	0.60
Lime, CaO	6.07	8.20	14.81
Magnesia, MgO	5.13	4.13	3.32
Alumina, Al_2O_3	3.13	2.36	2.39
Iron oxide, Fe_2O_3	2.33	2.65	1.72
Phosphoric acid, P_2O_5	0.20	0.15	0.24
Sulphuric acid, SO_3	0.10	0.11	0.08
Carbon dioxide, CO_2	10.00	12.74	17.90
Organic matter	3.86	2.99	2.12
Total	100.44	100.09	100.10
Humus	3.72	1.18	1.06
Nitrogen	0.149	0.100	0.072
Water at 100 C	1.85	1.91	1.69

The plats devoted to these experiments were one-twentieth of an acre in area, well ridged around the edges, so that the water applied would cover the ground to an approximately uniform depth. The depth of water applied at one irrigation varied, ordinarily, from 5 to 7.5 inches. All plants in the same experimental set were treated alike, except as to the quantity of water applied. The amount of water applied is expressed in the depth in inches to which the plats would have been covered had it been applied at one time.

MAIZE KERNELS.

The maize used was of unknown name, but had been grown for many years on the Station farm. It was sown on April 30th, and throughout its life exhibited no extraordinary characteristics, save the variation due to the application of varying amounts of water. The ripe maize was harvested on September 11th. The maize kernels were analyzed with the following results:

TABLE III.—PERCENTAGE COMPOSITION OF MAIZE KERNELS.

Irrigation water applied. Inches.	Water in fresh substance.	Water-free substance.				
		Ash.	Protein.	Ether extract.	Crude fiber.	N-free extract.
7.5	14.01	1.62	15.08	6.02	1.89	75.39
10.0	11.00	1.59	13.42	5.39	2.23	77.37
15.0	11.66	1.65	13.48	6.16	1.91	76.86
20.0	13.00	1.56	12.83	6.29	2.19	77.14
37.3	14.36	1.62	12.52	6.26	1.89	77.72

With one exception, the per cent. of water increased regularly with the increase in the amount of water under which the maize was grown. The per cent. of ash is not regularly affected by the quantity of water used. The protein content is strikingly influenced by the amount of water added to the soil. As the water increases, the per cent. of protein decreases—the difference between the protein content of maize which received 7.5 inches of water and that which received 37.3 inches being 2.56 per cent. The percentage of ether extract was also slightly affected by the soil moisture. As the water applied to the soil increases, the ether extract increases, also.

The per cent. of crude fiber does not seem to be regularly influenced by the soil moisture, but the N-free extract tends to increase on the well-watered plats. In general, the protein in the maize kernel decreases with increased applications of water, while the ether extract and N-free extract increase.

OAT KERNELS.

The variety of oats used in this experiment was "American Banner." The seed was placed in the ground on April 20th, and the ripe crop was harvested on July 30th. The composition of the oat kernel is shown in Table IV.

TABLE IV.—PERCENTAGE COMPOSITION OF OAT KERNELS.

Irrigation water applied. Inches.	Water in fresh substance.	Water-free substance.				
		Ash.	Protein.	Ether extract.	Crude fiber.	N-free extract.
6.98	8.00	3.26	20.79	3.91	9.02	63.02
13.20	7.73	4.52	17.29	4.19	10.76	63.25
14.89	8.11	4.97	15.48	4.21	15.40	59.55
30.00	8.40	4.49	15.49	4.59	10.92	64.51
40.00	8.62	4.55	15.80	4.56	10.38	64.71

As in the case of corn, the per cent. of water in the fresh substance is increased by an increased amount of water. The per cent. of ash does not seem to be affected by the soil moisture. As in the case of corn kernels, the relative amounts of protein are strongly affected by varying the amount of water applied to the soil. The larger the quantity of water, the smaller the per cent. of protein. The highest and lowest per cents. are 20.79 and 15.48—a difference of 5.31 per cent.

The per cent. of ether extract is highest in the well-watered plats, and the variation follows quite regularly the amounts of water used. The difference between the highest and lowest per cent. is 0.68. The highest per cent. of crude fiber is found on the plat receiving an intermediate amount of water. The N-free extract increases with an increase in the amount of water; this variation is regular, with one exception. As in the case of corn, increasing the water applied to oats, decreases the per cent. of protein, and increases the ether extract and N-free extract.

WHEAT KERNELS.

The variety of wheat used was "New Zealand." It was planted on April 13th, and harvested on July 29th and 30th and August 5th. Table V shows the results obtained from the chemical analysis of the wheat kernels from the different plats.

TABLE V.—PERCENTAGE COMPOSITION OF WHEAT KERNELS.

Irrigation water applied. Inches.	Water in fresh substance.	In water-free substance.				
		Ash.	Protein.	Ether extract.	Crude fiber.	N-free extract.
4.63	7.70	2.70	26.72	2.37	5.44	62.77
5.14	8.16	3.32	25.11	5.24	3.05	63.28
8.81	8.25	2.96	21.25	3.63	4.38	67.75
10.30	8.47	2.54	19.93	2.09	4.47	70.97
12.36	8.14	3.12	22.18	2.12	4.31	68.27
17.50	7.59	2.79	18.57	2.34	5.88	70.43
21.11	6.80	2.50	16.99	1.97	3.92	74.62
30.00	8.70	4.50	15.26	1.85	3.19	75.20
40.00	8.01	2.72	18.43	1.94	3.42	73.48

There seems to be no regular variation in the per cent. of water, held by the fresh substance, to correspond with the amounts of water applied to the soil; neither does the per cent. of ash show any definite connection with the soil water. The per cent. of protein increases very markedly in the wheat kernel as the amount of water applied to the soil decreases. The plat that received 30 inches of water yielded wheat containing 15.26 per cent. protein, while the wheat from the plat that received 7.70 inches, contained 26.72 per cent.—a difference of 11.46. It is to be noted that the variation did not follow regularly the amounts of water used.

The variation in the ether extract are very irregular. The kernels raised with 5 to 8 inches of water contain the highest per cents. of fat. The crude fiber is not strongly affected by the soil water, though the tendency is for the per cent. to decrease as the amount of soil water increases. The per cent. of N-free extract is highest in the wheat from the plats that received most water. As with corn and oats, increased watering of wheat decreases the per cent. of protein, and increases the per cents. of ether extract and N-free extracts.

POTATO TUBERS.

The variety of potatoes known as "Early Rose" was used in this experiment. They were planted on May 1st and 7th, and were dug on October 22d. They were immediately sampled and subjected to chemical analysis. Traces of reducing sugar were found in all the samples, and a trace of sucrose in one sample. The quantitative determinations are exhibited in Table VI.

TABLE VI.—PERCENTAGE COMPOSITION OF POTATOES.

Irrigation water applied. Inches.	Water in fresh substance.	In water-free substance. Ash.	Protein.	Ether extract.	Crude fiber.	Starch.	Undetermined.	N-free extract.
8.08	76.00	6.68	11.83	0.55	2.69	69.95	8.30	78.25
10.00	76.34	4.57	12.57	0.11	2.46	69.55	10.74	80.29
15.00	75.54	4.85	12.52	0.33	2.21	72.58	7.50	80.08
20.00	76.24	4.29	11.46	0.50	2.56	76.25	4.94	81.19
27.00	75.95	4.99	10.77	0.06	1.93	75.10	7.15	82.25
39.99	76.00	4.87	8.33	0.79	2.06	76.48	7.47	83.95

It is quite noteworthy that the variation in the amount of moisture in the fresh potatoes is very small. In fact, the soil moisture seems to have little, if any, effect on the water content of potatoes. The per cent. of ash does not vary with the amount of water applied. As in the case of the grains, the relative amount of protein becomes larger as the irrigation becomes smaller. The one exception to this rule is the plat which received least water. The difference between the maximum and minimum per cents. is 4.24—sufficient to affect, materially, the food value of the potatoes. The variation of the ether extract is very irregular and does not follow the variation in the amount of water applied to the soil. The crude fiber shows a tendency to decrease on the well-watered plats. The per cent. of starch, on the other hand, increases very regularly with the increased irrigation. The difference between the highest and lowest per cents. of starch is 6.93—also quite sufficient to affect the food value of the tubers. The undetermined portion does not vary regularly with the soil moisture, but there appears to be a tendency for it to decrease as the watering becomes more liberal.

SUGAR-BEETS.

The German Kleinwanzlebener seed was used in these investigations. Seeding was done on April 25th and 26th. The beets were harvested on October 22d. The composition of the beets on the date of harvesting is shown in Table VII.

TABLE VII.—PERCENTAGE COMPOSITION OF SUGAR-BEETS.

Irrigation water applied. Inches.	Water in fresh substance.	In water-free substance.								
		Ash.	Protein.	Ether extract.	Crude fiber.	Reducing sugars.	Sucrose.	Starch.	Undetermined.	N-free extract.
12.32	76.23	4.76	9.68	0.29	5.37	1.22	60.85	6.33	11.51	79.91
15.57	75.95	5.14	8.15	0.31	5.24	1.17	63.20	6.33	10.43	81.13
17.64	75.34	4.38	10.51	0.32	4.80	1.24	61.62	6.19	10.96	80.01
20.06	76.46	4.89	10.42	0.36	5.06	0.94	60.83	6.91	10.59	79.27
21.00	78.67	4.98	7.50	0.18	6.02	1.53	57.21	7.46	15.12	81.32
25.31	75.69	4.69	8.98	0.36	4.98	0.64	62.93	7.10	10.13	80.80
40.82	77.58	4.69	5.63	0.45	5.68	1.18	62.01	7.05	13.31	83.55
53.96	73.39	3.79	6.10	0.36	4.79	1.89	60.65	7.07	15.35	84.96

The per cent. of water in the fresh substance does not vary, in general, with the variation in soil moisture. The per cent. of ash is irregular and does not follow the soil moisture. The per cent. of protein tends to increase with increased applications of water, until 20 inches have been applied; from then on there is a distinct decrease. The difference between the highest and lowest per cent. is 2.92. The per cents. of ether extract, crude fiber and reducing sugars are so irregular that they cannot well be connected with the variation in the soil moisture. The sucrose, which is the most important constituent of the sugar-beet, constitutes from 57.21 per cent. to 63.20 per cent. of the water-free substance. Regular changes in the soil moisture do not seem to cause corresponding regular variations in the sucrose content. This is surprising, in view of the comparative regularity with which the nitrogen-free extract in the crops, previously studied, has increased with the increase in soil moisture. The per cent. of starch increases somewhat with the increase in soil moisture.

From these data, it would seem that the relative proportions of the constituents are not markedly affected by variations in soil moisture. The great regularity in variation that has prevailed in other crops leads to some doubt concerning the correctness of this view. The plats on which the sugar-beets were grown were very different in depth and in the proportion of gravel, and they had been manured differently. Further, the accurate sampling of beets is a matter of great difficulty. It must also be remarked that the beet was dried and ground before analysis, which is not the best method to be followed in making carbohydrate determinations in sugar-beets. While the per cent. of total carbohydrates may be very near the truth, the sucrose and other single constituents may have suffered change during the process of drying. These questions must be left, however, for future investigations.

To obtain fuller and more accurate data on the effect of soil moisture upon the sugar content and purity of the juice, the plats were sampled and the beets analyzed weekly, from August 19th to October 16th. The average results for the sugar in the juice are found in Table VIII.

TABLE VIII.—PER CENT. OF SUCROSE IN THE JUICE FROM SUGAR-BEETS.

Irrigation water applied. Inches.	August 19th to September 3rd.	September 10th to September 25th.	October 2nd to October 16th.
11.16 to 17.78	11.35	13.14	14.83
19.95 to 26.66	12.58	13.72	15.86
40.82 to 53.96	13.40	14.62	15.25

It is quite evident, from the above table, that during the first two periods, the per cent. of sugar in the juice increases with the increase in the amount of water applied. During the last period, the beets grown with more than 40 inches of water contain 0.61 per cent. less sugar than do those grown with an average of 23.31 inches of water. The general conclusion to be drawn from this table is, that increasing the soil moisture tends to increase the per cent. of sugar in the juice of sugar-beets.

TABLE IX.—PER CENT. PURITY IN JUICE FROM SUGAR-BEETS.

Irrigation water applied. Inches.	August 19th to September 3rd.	September 10th to September 25th.	October 2nd to October 16th.
11.16 to 17.78	77.0	77.9	81.1
19.95 to 26.66	80.6	81.1	82.7
40.82 to 53.96	80.5	82.7	84.2

Table IX shows very clearly that the purity of the juice is highest with sugar-beets grown with large amounts of water but that the differences are so small as to have little practical value.

DISCUSSION.

A study of the preceding tables confirms the belief that the soil moisture influences strongly the chemical composition of plants and plant parts. To what extent the compositions of different plants and plant parts are affected by soil moisture, cannot, of course, be determined from this preliminary investigation. However, it may safely be concluded that the protein and nitrogen-free extract are influenced more than any other chemical group contained by plants. It may further be concluded that withholding water from the plant increases the per cent. of protein, and diminishes the per cents. of nitrogen-free extract and fat; increasing the supply of water decreases the per cent. of protein and increases the per cents. of nitrogen-free extract and fat.

That the variation is far greater than that ordinarily assumed to be possible is shown by Table X, in which the differences between the lowest and highest per cents. of protein, fat, nitrogen-free extract and starch are given, due regard having been had for the variation due to the application of different amounts of water.

TABLE X.—DIFFERENCE BETWEEN HIGHEST AND LOWEST PER CENTS. DUE TO VARYING SOIL MOISTURE

Substance.	Protein.	Fat.	N-free extract.	Starch.
Corn kernels	2.56	0.90	2.33	...
Oat kernels	5.31	0.68	1.69	...
Wheat kernels	11.46	1.78	12.43	...
Potatoes	4.24	...	5.70	6.93
Sugar-beets	4.88	...	5.05	...

While the power to control the composition of plants by varying the soil moisture is of immense practical value to all irrigated countries, yet its higher theoretical importance must not be overlooked. To the plant physiologist it opens a large field of research, which promises to result in light being thrown on some of the obscure parts of our knowledge of plant growth and plant life. The temptation to theorize, even with the meager data of this paper, is very great, but as considerable material on this subject has been gathered since 1901, the discussion of the physiological relations of the data, here presented, has been left for future reports. However, it may be said that the soil moisture is only one of many factors controlling the composition of plants, and that the great variations, recorded in this paper, were partly due to the peculiar soil conditions prevailing on the Station farm.

This investigation has been continued since 1901, and is still being continued.

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[CONTRIBUTION FROM THE NEW YORK AGRICULTURAL EXPERIMENT STATION.]

RENNET ENZYME AS A CAUSE OF CHEMICAL CHANGES IN THE PROTEIDS OF MILK AND CHEESE.

BY L. L. VAN SLYKE, H. A. HARDING AND E. B. HART.

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INTRODUCTION.

THE object of the work described in this article was, primarily, to ascertain to what extent the proteolytic phenomena, observed in cheese-ripening, are due to the action of an enzyme contained in the rennet extract used in cheese-making. It was also our purpose to learn how the proteolytic action of rennet compares with that of commercial pepsin.

It has been quite generally believed that the rennet extracts used in the manufacture of cheese contain not less than two enzymes or ferments, called rennin and pepsin, one ferment coagulating milk-casein and the other converting milk-casein and paracasein, under favorable conditions, into soluble forms of nitrogen compounds. The present tendency, however, is in the direction of the belief that both kinds of action are due to the presence of only one enzyme. The presence of a proteolytic ferment in rennet extract is readily understood, when we consider its source, which is the stomach of a suckling calf.

For years the weight of opinion was against the belief that rennet has any other function in cheese-making than simply to coagulate milk-casein. In some work[1] done by one of us in 1892, it was shown that cheese, made with larger amounts of rennet, furnished greater quantities of soluble nitrogen com-

[1] New York Agr. Expt. Sta. Bull. No. 54, p. 267 (1893).