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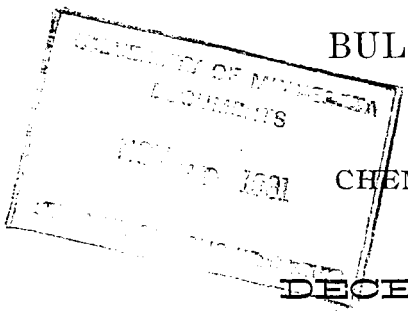

BULLETIN No. 29.

CHEMICAL DIVISION.

DECEMBER, 1893.

WHEAT.

I. HEAVY AND LIGHT WEIGHT SEED WHEAT.

II. THE VIGOR OF GROWTH OF THE WHEAT PLANT.

III. THE DRAFT OF THE WHEAT PLANT UPON THE SOIL IN DIFFERENT STAGES OF ITS GROWTH.

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I. HEAVY AND LIGHT WEIGHT SEED WHEAT.

BY HARRY SNYDER.

Experiments conducted at this station and elsewhere have shown that good, heavy weight wheat gives better results for seed purposes than light weight wheat of the same variety. Among the more important results that can be cited in this connection are those obtained by Hellriegel, who showed that the heavier the seed the more vigorous is the young plant, and where there was not an over-abundance of plant food in the soil the differences in vigor of the plants are traced even up to the time of harvest.

In order to determine in what way the causes of these differences are due to differences in chemical composition between the heavy and light weight wheat, twelve samples were secured ranging in weight from fifty-five to sixty-five pounds per bushel. These samples of wheat were all grown from one lot of seed, and in different parts of the state. They are some of the crops from the seed wheat donated by Hon. C. A. Pillsbury in 1891. The differences in grade and weight per bushel of these wheat samples are due to differences in soil, climate, and methods of cultivation, and not due to seed.

The important differences that are to be noted as to the amount of reserve plant food stored up in each kind of grain, are observed among the separate mineral matters that are found in the ash and taken from the soil. Every hundred pounds of wheat, whether light or heavy weight contains about two pounds mineral matter, but the separate compounds such as potash and phosphates are present in quite different amounts in the two cases, as will be seen from the table at the close of this article. The heavy weight wheat, pound for pound, contains more phosphoric acid and potash, and less of nearly all of the other elements than the light weight seed.

The differences from one sample to another are not in mathematical order, but there is the gradual tendency for the low-weight wheats to contain less potash and phosphoric acid, and more soda, silica, chlorine, and iron than the heavy weight seed. When the results of each are calculated to bushels, it will be found that the heaviest weight wheat yields 1.30 lbs of ash, containing .66 lbs of phosphates; while a bushel of the light weight wheat yields 1.15 lbs of ash containing .51 lbs of phosphates. There is nearly thirty per cent more phosphoric acid in the heavy weight wheat than in the light weight of the same variety. The heavy weight bushel also contains about a quarter of a pound more nitrogen than the light weight bushel.

Briefly stated; the heavy weight wheat seed contains more valuable food material for the young plant in the form of nitrogen, phosphates and potash than the light weight wheat. These reserve materials are more abundant in the heavy seeds by nearly thirty per cent, and are supplied to the young plants as just so much more reserve food, before the young plants are compelled to work for themselves, which accounts for the fact that the heavy weight seeds produce more vigorous plants than the light weight seeds. Independent of all this, the additional fertilizer material in the heavy weight wheat is worth about four cents per bushel.

TABLE I.—COMPOSITION OF THE ASH OF HEAVY AND LIGHT WEIGHT WHEAT.

This wheat was all ground from one lot of seed, in different parts of the state.

	Weight per Bushel.	Total Ash in Wheat.	Potash.	Soda.	Lime.	Magnesia.	Iron.	Phosphates.	Silica.	Sulphates	Chlorides.	Carbon Dioxide.
1	65 lbs.	2.00	30.44	.50	3.12	12.10	.41	50.83	.76	.11	.13	1.30
2	65 "	1.91	32.46	.67	2.55	12.39	.27	50.76	.37	.06	.11	.....
3	64 "	2.02	31.85	.86	3.16	12.54	.38	50.95	.09	.....	.04	.11
4	63 "	2.07	30.45	.06	3.00	12.10	.34	50.95	.24	.10	.10	1.64
5	63 "	1.94	31.29	.09	3.89	12.54	.29	50.60	.26	.07	10	.....
6	62 "	2.04	31.16	.62	3.16	12.62	.34	48.86	.85	.06	.11	1.96
7	61 "	1.92	30.02	.74	3.06	13.17	.62	48.04	.39	.09	.09	2.12
8	60 "	2.10	30.16	.26	3.02	12.86	.44	48.10	.27	.71	.07	2.86
9	59 "	2.08	29.01	.89	3.91	13.48	1.16	45.18	1.12	.16	.14	2.99
10	58 "	2.16	28 86	1.45	3.86	14.90	1.33	44.17	1.35	.10	.13	.....
11	57 "	2.05	28.41	.79	4.81	15.30	.81	43.52	1.67	.11	.47	3.04
12	55 "	2.09	28.77	.88	4.52	14.48	.86	43.07	1.92	.12	.42	3.02

Explanation of Table.—Under the head of total ash in the wheat is given the number of pounds of ash in every 100 pounds of wheat; the figures given for the potash, lime, etc., are the per cents of potash, lime, etc., that was found by analyses of each ash.

II. WHEAT PLANT—VIGOR OF GROWTH.

The differences between the heavy and the light weight wheat from the same seed source are so marked, that it is of great importance to know whether these characteristics can be traced to the plants, and what the differences in chemical composition are between the healthy and vigorous, and the poor and sickly wheat plants.

At harvest time a sample of thrifty, stocky, vigorous plants, straw four feet long, heads well filled and over four inches in length, was selected, and at the same time another sample of weak, sickly plants, straw about two feet long, heads two inches long, was sorted out from the same field. A complete chemical analysis was made of each sample.

900 thrifty plants gave about 3 pounds dry matter.

900 sickly plants gave about 1.2 pounds dry matter.

In the same weight of dry matter of each lot there was more nitrogen, phosphoric acid and potash in the healthy and vigorous plants than in the sickly ones, which contained more silica, soda and magnesia. These are the same general characteristics that are noted between the heavy and light weight wheat.

When the results are calculated to 900 entire plants, about the average yield per square yard of a good wheat crop, the differences are even more characteristic. The weak and sickly plants at maturity contained less total ash by nearly one half, than did the average wheat crop in the first fifty days of its growth. Some of the individual compounds of the ash show even greater differences.

In regard to the form of the nitrogen in both lots it is to be noted that in the healthy ones 87 per cent is in the form of gluten, while only 75 per cent is in this form in the sickly

ones. Evidently the plants did not possess enough vitality to reach full maturity and change the nitrogen from the amide to the gluten form.

In order to compare these two lots of wheat, it is necessary to note first the percentage composition, which gives an equal basis for comparison, pound for pound of the dry matter, and then consider the total amount that is present in an equal number of each kind of plants.

TABLE II.

	Percentage Composition.		900 Plants.	
	Healthy.	Sickly.	Healthy.	Sickly.
Total Dry Matter			1311.	5 40
Total Nitrogen	1.40	1.30	18.35	7.02
Crude Ash	7.22	6.46	94.65	34.88
Albuminoid Nitrogen	1.22	1.02	15.99	5.50
Fiber	25.90	26.44		
Chlorophyl, Fat, Etc.	2.55	2.69		
Silica	49.38	59.46	46.73	20.74
Potash	22.81	12.72	21.59	4.44
Soda	1.44	1.84	1.38	64
Lime	3.16	4.28	2.99	1.49
Magnesia	2.62	5.11	2.48	1.78
Iron	.30	.44	.28	.15
Aluminia	.05	.07	.04	.02
Phosphates	13.46	12.44	12.75	4.33
Sulphates	2.28	2.41	2.28	.56
Chlorides	.94	1.04	.98	.49

The absence of a normal amount of the essential ash elements in wheat is followed by weak, dwarfed, and sickly plants; these essential ash elements are furnished in greater abundance in heavy seeds than in light weight seeds.

III. THE DRAFT OF THE WHEAT PLANT UPON THE SOIL IN THE DIFFERENT STAGES OF ITS GROWTH.

In the growth of the wheat plant from the seed to full maturity, it is important to know at about what stages in the growth of the plant the various elements are taken from the soil and the air and put together in the form of gluten and starch, so as to have a definite idea as to what the soil must furnish to the crop at each stage of its growth. During the past two years work has been carried on in the chemical laboratory in order to obtain the necessary data upon this question.

At various intervals during the growth of the wheat plant, a given area of ground was cut, and the entire plants, exeepting the roots were submitted to complete chemical analysis. The number of plants per square yard at each cutting was noted, and then the results were all calculated to a uniform basis of 900 plants per square yard, about the average yield of a good crop. This was found to be quite necessary in order to establish a uniform basis for comparison, since no two square yards of wheat always contain the same number of plants. The main points in the results recorded have been verified with two crops, that of 1892 and 1893. Taken as a whole the two crops represent fairly well the extremes in the conditions to which the wheat crop is subjected. Only those points that are common to both years and have a direct bearing upon the question, are discussed.

The time from seeding to maturity is arbitrarily divided into four periods: fifty, sixty-five, eighty-one and one-hundred and five days respectively from the date of seeding. At the close of this article a table is given in a condensed form setting forth all the important facts in regard to the rate of the growth of the wheat plant and its demands upon the soil.

First Period.—At the end of the first period of fifty days

the plants had reached an average height of eighteen inches. At this time a little less than one half of the total dry matter of the plant had been produced, and this dry matter contained nearly three quarters of the total mineral matters that were taken from the soil during the entire growth of the crop.

Second Period.—Fifteen days later, sixty-five days from the time of seeding, the plants were fully headed out and had made an additioual gain of about fifteen per cent organic matter; the mineral matters were taken up more slowly, showing an additional gain of about ten per cent. At the close of this period (July 15.) the wheat plant had taken up about eighty-five per cent of the total materials supplied by the soil.

Third Period.—At this time the wheat had reached that state as commonly known as "in the milk." During this period of fifteen days, from July 15 to about August 1, the plants showed rapid and marked gains in organic matter, over one third of organic compounds of the plant being produced during these dates. Along with this gain of organic matter, it is to be noted that practically all of the remainder of the mineral matters were taken from the soil.

Fourth Period.—In the last period of some twenty days prior to harvest there was an additional gain of ten per cent of organic matter, and no material increase in mineral matters. This is more of a period of rearrangement of the materials that are already in the plant rather than a period of increase in dry matter.

The important points to be noted from these various periods are, that the ash elements are assimilated quite in advance of the formation of organic matter, in fact the wheat plant makes its heaviest drafts upon the soil during the first fifty days of its growth, and takes but little mineral food from the soil during the last stages of its growth. This means that the food supplied by the soil to the wheat must be in such a condition so that the plant can readily take up over three-fourths of it before the first of July. There may be an abundance of phosphates, nitrogen, and potash in the soil, but if by poor cultivation, very late plowing, continued cropping without rotation, and poor general management

all of the available plant food is used up, the wheat plant cannot wait for more food to become available.

The separate compounds of the ash of the wheat plant that require consideration are: Silica (sand), potash, lime, magnesia, iron, aluminia, phosphates, sulphates, and chlorides. These compounds together with the nitrogen constitute the materials that are supplied by the soil. The essential ash elements as they are called, are not all taken up by the plant at the same time, some are taken up much more rapidly and at earlier stages than others.

Phosphates.—Nearly eighty per cent of the phosphates were taken up in the first fifty days. In the second period, a small amount, while in the third period nearly all of the remainder, about fifteen per cent, found its way into the plant. From eighteen to twenty-five pounds of phosphates are removed per acre of wheat, and about two-thirds of this amount is in the grain. The loss of phosphates by continuous cropping, becomes a serious question in time.

Silica.—In each period a little over half of the ash of the whole plant is silica (sand). A large portion of it, over seventy per cent, is taken up in the first period with marked additional gains in the second and third periods. From seventy-five to one hundred pounds of silica are removed in an acre of wheat, nearly all of it is in the straw and less than one per cent is in the grain. There is an abundance of silica in our soils, in fact it is the most abundant material that we have. Analysis of over one hundred typical wheat soils made in the laboratory of this station during the past year, have shown from five to forty per cent of hydrated silicates in addition to that which is present in the form of sand and clay. The lack of stiffness of straw, reported in so many cases, can not be due to a loss of silica from the soil, nor to its absence from the plant. Analysis of the straw from badly lodge grains have always shown as much silica, and in some cases even more, than in the grains that have not lodged. Whether this serious trouble is due to the absence of any material from the plant, is now receiving its due attention.

Sodium, Chlorine, Iron and Aluminia.—These

compounds are taken up in very small amounts and in the first period. Excepting the iron, these compounds are of far less vital importance to the plant, than the other ash elements. These compounds are found in the grain only in very small amounts, and there is always sufficient even in the poorest soils for all the demands of the crop.

Lime and Magnesia.—The lime is taken up at comparatively much earlier periods than the magnesia. The magnesia, it is to be noted, is stored up in the seed more liberally by three fold than the lime. From eight to ten pounds of lime are removed per acre and about eight-ninths of it is removed in the straw crop. The magnesia, which is found largely in the seed is assimilated more slowly and at later periods. The question as to the amount of lime in our soils and the use of lime fertilizers is too long to be discussed in this bulletin.

Potash.—About three quarters of the potash finds its way in the plant at the end of the first fifty days. The rate of the assimilation of the potash is, to a great extent, a measure of the degree of vigor of the plant. The gains in potash in the second and third periods are gradual and uniform. It is to be noted in particular that there is more potash in the plant at the end of the third period by six and one half per cent than at harvest time. In the growing plant potash is found largely in the upper extremities, and when the plant matures there is a gradual downward movement of the potash from the seed into the straw. More potash is carried off in the straw crop than in the grain crop. It appears that this well established retrograde movement of the potash is carried even further, some of it even to the roots. In both trials this point was distinctly marked. In similar work on the oat plant by *Ardent*, and particularly in the corn plant work by *Schweitzer* these same points are observed in the analysis. This appears to be a characteristic of these crops so as not to exhaust the soil too rapidly, and means that a larger working supply of potash must be in the soil than the mere amounts taken off in the crop.

Gluten.—The most essential building materials of which the gluten is composed are assimilated in the early

stages of growth, although they are not put together by the plant in the form of gluten until the end of the third period. The nitrogen—the important building material of the gluten—is assimulated even more rapidly than the mineral matters taken as a whole; about eighty-six per cent of nitrogen was taken up at the end of the first fifty days. Next to the nitrogen the phosphates were assimilated the most rapidly. In the third period the formation of the gluten is distinctly marked. At the time the wheat was head-out about sixty-five per cent of the nitrogen was in forms allied to gluten, about the same amount as at the end of the first period, but in the third period there is a change of over twenty per cent of the nitrogen from amide to gluten forms.

Of all the food that the soil supplies to the wheat plant the nitrogen must be in the most available form. The chief benefits of summer fallow are due to the additional time and more favorable conditions given for the process of rendering the nitrogen available. In the wheat soils that have been under cultivation for ten years or more there is about a quarter of one per cent of nitrogen present, but it is not safe to count on more than one per cent of this as being available at any one time for crop purposes. From thirty-five to fifty pounds of nitrogen per acre are required for an average crop of wheat.

The opinion is held by many that our wheat producing soils are practically inexhaustible—that this is not the case a simple calculation will show. The average prairie and wheat producing soils weigh about 3,260,000 pounds per acre to the depth of one foot, and contains about 6,500 pounds of nitrogen; at least 50 pounds per year of nitrogen is lost either in the crop or in various other ways. So that only one hundred and twenty-five or thirty crops can be counted upon if all of the nitrogen in time was to become available and none lost, which can not be expected to occur in either case. Allowing the largest factor admissable—that only one per cent of this nitrogen can be counted upon for grain crop purposes, and it will be seen that the time when the nitrogen ceases to be present in sufficient available quantities is not such a great way off. This question will

receive a more thorough discussion in the following bulletin on the chemical composition of our soils.

Fiber.—The fiber (woody material) is formed largely in the first and second periods, and none in the last period; in fact the last period shows a slight loss which is probably due to the transformation of the fiber into other allied forms of carbhydrates, such as starch.

The chlorophyl, fat and gums, designated as the ether extract, forms such a hetrogeneous mixture that nothing definite can be said about them.

Starch.—The starch that is stored up in the seed is formed mainly in the second and third periods, a small portion being formed well along in the last period.

The wheat plant is capable of doing a certain amount of work and procuring its own mineral food, provided it is present in the soil; and it is not dependent upon the mineral food that is simply offered to it in solution. The wheat plant is to be looked at as a working organism and not as having its food "pumped into it." One of the best proofs that we have as to this point is the fact that the soil in which this wheat was grown contained more soluble lime, magnesia, and soda, than it did of either potash, nitrogen and phosphates, but notwithstanding this fact the wheat plant took up much larger quantities of these three elements than of any of the others that were present in the soil in larger and more soluble amounts. In order to accomplish this, the wheat plant must certainly have performed a certain amount of work, not only to procure the food required, but also to reject what was not required.

In the following table is given the average draft of the wheat crop upon the soil at the rate of eighteen bushels per acre, and the compounds that are removed separately in the straw and chaff, and in the grain. Lessened yields, as during the past year, would of course remove correspondently less amounts.

TABLE III.

	Grain.	Straw.	Total.
Total Mineral Matters	22.	178.	200.
Silica (sand)	.1	114.	114.1
Potash	6.5	26.5	32.
Soda	.1	3.	3.1
Lime	.7	6.3	7.
Magnesia	2.8	2.7	5.5
Phosphates	12.40	7.6	20.
Chlorides	.1	1.6	1.7
Sulphates	(2.)	2.8	4.8
Total Nitrogen	25.	10.	35.

In the table on the following page is given the comparative drafts of the wheat plant upon the soil at each of the four periods of its growth. In the first column of figures for each period is given the total weight in grams of each of the organic compounds and ash elements found in nine hundred plants at the end of that period. In the second column headed "Gain" is given the gain in grams of weight for that period, and is obtained by subtracting the total of the previous period from the total of the period in question. Finally in the last column headed "Per cent", is given the percentage amount of the total, of each element and compound, assimilated up to the close of that period. For comparative purposes the reduction to ounces per square rod is unnecessary. One ounce equals 28.3 grams.

TABLE IV.—WHEAT. ANALRSES OF ENTIRE PLANT.

Nine hundred entire wheat plants, the average yield per square yard of a good crop. All of the weights in the column headed "Total" are in grams.

	50 Days.		65 Days.—Headed Out.			81 Days.—In Milk.			Harvest Time		
	Total	Per Cent.	Total	Gain	Per Cent.	Total	Gain	Per Cent.	Total	Gain	Per Cent.
Total Dry Matter	486.2	45.85	650.	163.8	58.77	1012.	362.	95.45	1106.	94.	100.
Total Nitrogen	13.12	85.97	13.52	.40	88.60	14.56	1.04	95.42	15.26	.70	100.
Gluten Nitrogen	8.26	63.50	8.78	.52	67.33	12.34	3.56	94.63	13.04	.70	100.
Chlorophyl, Fat and Gum	41.46		21.12			36.12			34.38		
Fiber	134.44	44.88	209.48	75.04	69.96	299.46	89.98	100.	294.64	4.82	98.37
Dry Organic Matter	440.35	43.48	579.11	138.76	57.16	916.53	337.42	90.47	1013.12	96.59	100.
Silica (sand)	32.40	72.48	35.34	2.94	79.24	43.96	8.62	98.34	44.7	.74	100.
Potash	14.20	74.71	16.84	2.63	88.54	19.02	2.18	100.	17.8	1.22	93.6
Soda	.94	94.	1.02	.08	100.	.96	.06	.96	.86	.14	86.
Lime	2.86	67.77	3.86	1.00	91.47	4.22	.36	100.	4.06	16	95.7
Magnesia	1.88	56.97	3.12	2.24	67.88	3.28	.16	99.4	3.30	.02	100.
Iron (oxide)	.06	100.							.04		
Aluminia	.04	100.							.04		100.
Phosphates	8.10	79.57	8.48	.38	83.30	10.16	1.68	97.87	10.18	.02	100.
Sulphates	.64	59.26	.96	.32	88.89	.96		88.89	1.08	.12	100.
Chlorides	.81	84.38	.96	.15	100.	.91	.05	94.80	.82	.09	85.5
Pure Ash	61.94	74.10	70.89	8.85	84.83	83.56	12.67	100.	82.88	.68	99.2

SUMMARY.

1. Heavy weight seed wheat contains a larger quantity of more valuable food materials for the young plant in the form of nitrogen, phosphoric acid and potash, than light weight wheat of the same variety. This additional reserve food is supplied to the young plants, and produces a more vigorous growth.

2. The additional fertilizer material that is present in a bushel of heavy weight wheat is worth from three to five cents more per bushel.

3. The same characteristic differences that are noted between heavy and light weight seed wheat are observed between healthy and vigorous, and poor and sickly wheat plants even at the time of harvest.

4. The wheat plant takes up over three-fouths of its food from the soil before heading out.

5. The soil must be cultivated and managed in such a way so as to supply the growing wheat crop with at least three fourths of its mineral food and seven-eights of its nitrogen before the first of July.