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A STUDY OF COLORADO WHEAT

By WM. P. HEADDEN

PART IV

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A STUDY OF COLORADO WHEAT

By WM. P. HEADDEN

PART IV

Bulletins Nos. 205, 208, 217 and 219 present the work previously reported in connection with our study of Colorado wheats. The general results in a more popular and less detailed manner have been given in Bulletin No. 237. In this bulletin we propose to record our further study of the properties of the wheats and flours produced in the course of our experiment, together with some flours produced from Colorado wheats by various mills in the State.

CHARACTER OF GRAIN DEPENDS ON RELATIVE SUPPLY OF PLANT FOOD

A brief statement of the conclsions reached may be advisable. The most important one is that, given conditions under which the plant will reach normal maturity, the character of the grain depends upon the relative supply of the respective plant foods.

In our case the important ones are nitrogen and potassium. If the latter predomintes, the character of the wheat will be mealy or soft, in which case the kernels will be large and plump. If the nitrogen present as nitrates be sufficient and in the right proportion to the potassium, the kernels will be flinty and of good size. If the nitrogen present as nitrates be excessive the plants will grow too rankly, will be susceptible to rust, will lodge, and will produce small flinty, hard and shrunken kernels. The crop will be smaller than in cases where less nitrogen in this form is present.

Organic or other forms of nitrogen than nitrates or ammonia salts whose nitrogen is easily converted into nitrates, is not sufficiently available to the wheat plant to affect the quality of the crop though it may increase the production of both straw and grain.

Phosphorus in our experiments produced no effects upon the yield or character of the grain that we could interpret as directly due to the effects of the element. The reason for this is probably that the phosphorus present in our soil is sufficiently available to procure a maximum effect and the addition of more phosphorus is at the present time useless. This condition may change with further cropping.

There is so near an approach to the desirable ratio between the nitric nitrogen and available potassium in our soil that comparatively small quantities of nitrates produce a big effect upon the growth of the plant and the character of the grain. The nitric nitrogen usually present in our soils is adequate to the production of good crops but not always adequate to the production of the best quality of grain. This is the reason why the application of sodic nitrate affects the character of the grain but in our experiments has not increased the yield to any marked extent; on the contrary, we have in many instances depressed it.

EFFECTS OF IRRIGATION

As irrigation is an indispensable portion of our practice, we have to determine the water supply necessary to produce the best crop and the effect of the water upon the character of the grain produced.

Our results show that if the plants be brought to the period of early head or to the time when they are well advanced in the boot in a healthy manner and are then irrigated liberally no further irrigation is, in ordinary seasons, necessary. Subsequent irrigation in our experiments proved to be useless in every respect, i.e., it neither increased the crop nor influenced the character of the grain, while the soaking of the ground exposed the crop to some danger.

The effects of water upon the quality of the grain depends upon conditions. Excessive water applied to the soil does not affect in any material degree the composition of the grain but if the plants be kept wet and the weather be dull and warm the crop will suffer greatly, in fact, will probably be ruined.

The leaching effects of water upon the soil may in some instance be a danger but in our experiments we could not discover any bad effects due to this cause.

As our soils contain a total supply of 2.25 to 2.5 percent of potash of which, roughly, one-quarter is soluble in dilute hydrochloric acid, we have an abundant supply of this element for many years. This means that we have from 22,500 to 25,000 pounds of potash in each million pounds of soil with from 5,600 to 6,250 pounds soluble in dilute acid at the present time. These quantities are so large that it does not matter whether we are quite right in tacitly assuming that being soluble in dilute hydrochloric acid is the same as being available to the plant or not. It is evident that the supply is very abundant.

NITROGEN OF PRIMARY IMPORTANCE

We have given the cultural reason for stating that the supply of phosphorous in this soil is adequate. As a matter of fact it is about three times as much as is considered adequate in a soil of similar composition. These analytical considerations indicate that the plant food of primary importance to us is the nitrogen. This is also the conclusion to which our experiments lead.

Availability, Not Quantity, Affects Grain.

Our soils are only moderately well supplied with total nitrogen. The one on which our experiments were made carried about 0.145 percent. This is neither poor nor especially rich, still it is sufficiently available to produce, under ordinary tillage, abundant crops of wheat, 30 to 48 bushels, without the application of any kind of fertilizer. These results were obtained with wheat following wheat. The total amount of nitrogen present is not so abundant or necessarily of such a character as to assure us of a continued abundant supply of available nitrogen, and yet for five years in succession we have detected, so far as the crop indicated, no lack of nitrogen, while the addition of 10 lbs. of nitrogen in the form of sodic nitrate to a milion pounds of soil has not failed to change the character of the wheat produced without increasing the crop, except in a few instances and then only slightly. We can interpret these facts in only one way and that is that it is not the amount of total nitrogen but the amount present in an available form, in this case as nitrates, that is important. If the crop in our experiments had been increased and the character not changed the only inference that we could have drawn would have been that there was not enough of this form of nitrogen present in the soil to produce the best crop and its addition for this purpose would be advisable. This was not the case, but, the reverse. The size of the crop was not favorably affected but the quality of the crop was, which we have interpreted as proof that the supply of nitrogen in this form was sufficient to produce a maximum crop but not sufficient to produce a maximum quality.

It may be a question in the minds of some whether we have a sufficient basis for making the statement without any qualifications, that the results obtained were specifically due to the form in which the nitrogen was applied. The fact that we obtained this result more than 50 times without any exception when we applied the nitrogen in this form does not prove that organic nitrogen would not have produced the same results though it does prove that the results observed are uniformly the effects produced by nitrogen in the form of nitrates when present, in sufficient quantities. In our soil the addition of 10 pounds of nitrogen in this form to 1,000,000 pounds of soil is really too much, for in many instances there was no question about our having done injury. We have experiments in which we added nitrogen in the form of farmyard manure at the rate of at least 120 pounds of nitrogen to a million pounds of the soil or 12 times the amount added in the form of nitrates and it produced no effect upon the composition or physical properties of the wheat. This establishes the inference drawn from the uniformity of the results obtained in the use of nitric nitrogen, i.e., that the results observed were the specific effects of the nitrogen in the form of nitrates and not of organic nitrogen. Nitrogen in the form of ammonia has been shown by Ritthausen and Dr. R. Potts to produce the same effects that the nitrates do. The nitrogen in the ammonia salts, when these are applied to the soil, is readily converted into the nitrate form so their effects are really the effects of nitrates.

HARDNESS OR SOFTNESS DEPENDS ON RELATIVE SUPPLY OF NITROGEN IN THE FORM OF NITRATES

The question of the properties of our whaets whether they are hard or soft, flinty or mealy, depends upon the relative supply of nitrogen in the form of nitrates. If the supply of these in the soil is in the right proportion to the supply of potassium our wheat will be all that anyone could desire. It will be large-grained, plump and flinty, which is to say rich in protein.

The amount of nitrogen in our soil is not a fixed quantity but varies from time to time both in the total amount present and in the portion of it which may be present in the form of nitrates. Experimental proof has been adduced in preceding bulletins that in contiguous areas of 1 square foot the total nitrogen as well as that in the form of nitrates not only may, but actually does vary by significant quantities. Data obtained, both by laboratory experiments and on a larger scale in imitation of field conditions, establish it as an easily demonstratable fact that the soil in which we grew our wheats varies in its amount of total nitrogen from time to time. To establish this we made observations on 3,000 pounds of soil taken from the field and found that we had a maximum increase of 62 pounds per million of soil and that while the total nitrogen varied, it at all times showed an increase over the amount present at the beginning of the experiment. At the end of 40 days the total amount of nitrogen present exceeded that present at the beginning by 36 pounds per million. The nitrogen present as nitrates at the end of this experiment exceeded that present in this form at the beginning by 15.79 pounds per million. The increase in total nitrogen is due to fixation and the increase in the form of nitrates shows how actively the process of nitrification was going on. The 3,000 pounds of soil made a bed, as we prepaerd it, 6 inches deep Other and fuller data on the increase of the nitrogen present as nitrates will be found in Bulletin No. 217, pp. 42 and 43.

The significance in the increase of the total amount of nitrogen is that it is sufficient to maintain a reasonable supply and beyond question is present as living organisms, susceptible of rapid chang s. The nitric nitrogen is directly available to the wheat plant and the quantity formed during the 40 days of our experiment, 15.79 parts per million, is one and a half time the amount applied in some of our experiments, which was sufficient to determine the character of the growth of the plant and the physical and chemical characteristics of the wheat produced.

EFFECT OF FALLOWING ON NITROGEN CONTENT

The bearing of these facts upon the fallowing of our land has been pointed out elsewhere, but we will point it out again. We have repeatedly given analytical data to illustrate this fact. Perhaps as good an illustration of the effect of fallowing upon the amount of nitrogen accumulating in the soil as we have, is an experiment made in 1915. On 3 August, 1915, we found that land cropped to wheat contained nitrogen as nitrates equal to 46.9 pounds of sodic nitrate in the top 4 feet of soil, whereas the same land from which the wheat had been removed as soon as it came up contained nitrogen as nitrates equivalent to 285.5 pounds per acre taken to the same depth. In this case there is 6 times as much nitrogen present as nitrates in the fallow land as in the cropped land.

We are by no means compelled to depend upon our analytical results to establish this fact, though they constitute more direct proof than the crops grown on ground fallowed the preceding year. In order to avoid the statement of several analyses I will state that the results of our experiments show that nitrate applied to wheat increases the nitrogen and depresses the phosphorus contained in the grain. With this explanation the following data will suffice for our present purpose.

A sample of Red Fife grown on land fallowed the preceding year, 1912, contained of nitrogen 3.008 percent and of phosphorus 0.414 percent. The same variety of wheat grown on a check plot which had been cropped the preceding year, 1912, contained of nitrogen 2.270 and of phosphorus 0.453 percent. The difference in the composition of these grains grown on plots of land separated by a 16-foot alley was due to the nitrogen accumulated in the one plot during its year of fallow, whereas the cropped land had been deprived of this advantage. This is probably the correct explanation for the flintiness of our dry-land wheats rather than a scanty supply of water. The dry-land practice is to cultivate fallow one year to facilitate the storage and conservation of moisture which at the same time increases the supply of nitrates.

There is another test which we can apply to these dry-land wheats which will lead us to the same conclusion. We have seen that the addition of nitrogen to the soil in the form of nitrates produces flinty berries and that the lack of it produces the condition designated as yellow-berry. Dry land planted to wheat continuously, produces wheat very badly affected by yellow-berry, which is the same effect that is produced on irrigated ground.

A TEST OF THE BREAD-MAKING QUALITIES OF VARIOUS WHEATS

These, briefly stated, are the most important conclusion presented in the previous statements of our work. We have further endeavored to ascertain whether the bread-making value of our flours and the milling qualities of these wheats have been as decidedly affected as the physical properties and the chemical composition of the kernels have been. It would have been almost impossible that it should be otherwise but as the whole subject of the bread-making quality of our flours has been an open question, concerning which a decided doubt has prevailed for many years, it seemed that to leave this feature of the study untouched would appear to be an evasion of a duty to avoid having to confirm the public in its bad opinion of Colorado flours for bread-making. This is the only weakness in Colorado flours of which I have ever heard complaint. At the beginning I had a lack of confidence in the representative quality of flour made by grinding small samples, especially when the grinding was done by a person who was not an experienced miller. I still entertain these misgivings and believe that samples should be ground only by an experienced and skillful miller on a commercial scale in order to determine the actual milling qualities of a wheat. I am convinced that the quality of the flour depends to a very large extent upon the judgment and skill of the miller. The college employee has no time to acquire this judgment and skill and he might at best make but a sorry job of milling. This was our situation and there has been no intention of establishing a Section of Cereals and Milling which would justify us in establishing a larger plant. We had a definite object in view which we have already stated but it has seemed advisable to extend it to include these additional features.

We actually had large samples milled on a commercial scale but we stored these samples in 50-pound lard cans without previously drying them. We had more analytical work to do than our force could get done in the time at our disposal, so these flour samples were stored in the sample room. The lard can kept out the mice and insects but the flours became musty and rancid before we could take up the study of their baking qualities. For these reasons we were after all compelled to grind small samples in an Allis & Chalmers mill. These samples answer the purpose of our study very well but the flours that we made do not represent the commercial flours produced from our wheats by the mills of the State; they are decidedly inferior. We, of course, milled the wheat representing the different fertilizers as separate samples and used the flour for baking. The flours on the market are not often made from a single variety of wheat and are seldom straight flours. Our home-ground samples are hardly comparable with the better-brands of flour on the market, but as stated, they serve our purposes. We milled the wheat with the rolls set too close all of the time and practically produced a straight flour.

The wheats yielded in our different crops varied in their composition as is set forth in detail in Bulletin No. 219 but for any given year they are clearly and naturally divided into two classes those grown with and those grown without the application of nitrogen in the form of sodic nitrate. Any attempt to distinguish any differences between the wheats grown with the application of phosphorus, potassium and the check plots would be based upon small and irregular differences to such an extent as to have no value. This is not true of the physical properties of these samples; the differences in this respect being usually very plain, even strikingly so. The wheat grown with the application of nitrogen in the form of nitrates on the other hand differed in an easily recognized manner both physically, in that it was always flinty and often more or less shrunken, and in its chemical composition in that it was always higher in protein and lower in starch and phosphorus but fully as rich as the other samples in potassium. While the differences in the amount of starch present may be less than the differences in the physical appearance of kernels might lead one to expect, they are marked and constant enough to justify their mention as distinctly characteristic effects, attributable to the nitrate applied. These differences are shown by the average composition of the general samples for the three years, 1913, 1914 and 1915 which follow:

AVERAGE COMPOSITION OF WHEATS INCLUDING THE THREE VARIETIES

	1913		1914		1915	
	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent
Protein	12.530	14.170	9.416	11.607	8.950	11.500
Starch	62.190	60.930	64.020	61.960	61.350	58.070
Wet Gluten.	25.850	31.240	23.900	30.280	21.340	29.890
Dry Gluten.	10.650	12.550	9.910	12.430	8.840	11.870
True Gluten	7.580	9.110	6.910	8.670	5.670	7.870
Phosphorus.	0.453	0.413	0.398	0.368	0.383	0.369

AVERAGE COMPOSITION OF THE INDIVIDUAL VARIETIES GROWN IN 1913*

	Defiance		Red Fife		Kubanka	
	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent	Without Nitrogen Percent	With Nitrogen Percent
Moisture ...	11.338	11.469	10.372	10.200	11.047	11.568
Ash	1.893	1.873	2.047	1.904	1.937	1.771
Fat	1.771	1.685	1.790	1.809	1.903	1.984
Fibre	2.614	2.634	2.588	2.609	2.557	2.550
Nitrogen ...	2.045	2.452	2.392	2.608	2.158	2.401
Protein, Nx5.7	11.656	13.493	13.632	14.863	12.302	13.719
Starch	62.558	61.179	62.108	60.717	61.961	60.492
Sucrose	1.256	1.166	1.319	1.339	1.438	1.60[illegible]
Wet Gluten.	23.790	30.343	27.780	32.780	26.160	30.610
Dry Gluten.	9.770	12.150	11.250	12.980	10.950	12.540
True Gluten	6.863	8.934	8.146	9.465	7.743	8.931
Phosphorus .	0.446	0.423	0.479	0.445	0.432	0.399
Potassium .	0.449	0.454	0.452	0.485	0.473	0.455

*Analyses of the wheats grown in 1913, 1914 and 1915 may be found in Bul. No. 219.

NOTE.—Succeeding pages, in pairs, give complete results, including composition of flour, milling results, and baking tests for the years 1913, 1914, and 1915. The composition of wheat for 1917 is given, thus requiring three pages to complete the results for that year.

COMPOSITION OF FLOURS—CROP OF 1913—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos phorus	Potas- sium
Defiance													
Nitrogen	10.910	0.834	0.666	0.331	1.8055	10.2914	67.949	0.360	32.50	12.086	9.483	0.1196	0.1465
Phosphorus ...	10.444	0.761	0.602	0.309	1.6888	9.6262	69.911	0.406	29.43	11.023	8.471	0.1251	0.1422
Potassium	10.798	0.817	0.920	0.329	1.6707	9.5233	68.788	0.396	29.83	11.451	8.807	0.1213	0.1533
Check	10.218	0.840	0.984	0.302	1.7242	9.8518	68.067	0.351	29.90	10.966	8.523	0.1146	0.1418
Red Fife													
Nitrogen	7.750	0.740	1.045	0.335	2.1801	12.4267	69.820	0.347	40.07	15.219	11.361	0.1190	0.1533
Phosphorus ...	7.688	0.797	0.961	0.293	1.9793	11.2820	70.083	0.370	32.73	13.022	10.345	0.1217	0.1426
Potassium	8.304	0.824	1.206	0.362	1.9732	11.2474	70.292	0.408	35.33	13.565	10.436	0.1254	0.1322
Check	8.100	0.775	1.214	0.348	1.9906	11.3464	69.989	0.331	33.65	13.022	10.254	0.1218	0.1383
Kubanka													
Nitrogen	7.790	1.033	1.060	0.342	2.0428	11.6440	68.818	0.451	35.57	14.039	10.998	0.1684	0.2087
Phosphorus ...	7.702	1.085	1.210	0.361	1.9322	11.0138	69.226	0.519	32.00	12.778	9.985	0.1764	0.1993
Potassium	7.520	1.028	1.230	0.343	1.9841	11.3093	69.095	0.553	32.73	13.240	10.430	0.1754	0.1965
Check	7.968	0.864	1.291	0.281	2.0609	11.7470	69.605	0.457	38.97	15.156	11.111	0.1440	0.1662

OTHER FORMS OF NITROGEN—CROP 1913

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0211	0.1404	0.6815	0.9584	0.1146
Phosphorus	0.0248	0.0989	0.6538	0.8858	0.1005
Potassium	0.0315	0.1060	0.6632	0.8718	0.1139
Check	0.0319	0.1137	0.6629	0.9198	0.1180
Red Fife					
Nitrogen	0.0727	0.1308	0.6783	1.2984	0.1139
Phosphorus	0.0726	0.1235	0.6369	1.1461	0.1464
Potassium	0.0717	0.1146	0.6348	1.1556	0.1470
Check	0.0471	0.1018	0.6901	1.1537	0.1458
Kubanka					
Nitrogen	0.0433	0.1304	0.6522	1.2169	0.1507
Phosphorus	0.0431	0.1231	0.6275	1.1391	0.1495
Potassium	0.0544	0.1304	0.6532	1.1456	0.1636
Check	0.0612	0.1231	0.6631	0.2138	0.1451

MILLING RESULTS—CROP OF 1913

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in-Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.70	5.35	2.25	23.70	7.00	7.50
Phosphorus	61.30	4.95	2.15	24.75	6.85	7.75
Potassium	63.10	4.30	2.48	22.00	8.12	5.70
Check	62.35	3.90	2.90	21.60	9.25	7.40
Red Fife						
Nitrogen	58.50	3.48	3.80	26.45	2.77	6.40
Prosphorus	59.50	3.40	3.10	27.10	6.90	7.50
Potassium	56.75	5.75	5.20	27.10	5.20	5.92
Check	62.85	4.45	2.60	23.95	6.15	6.90
Kubanka						
Nitrogen	61.40	6.10	3.45	24.70	4.35	6.82
Phosphorus	58.20	7.50	4.20	22.35	7.75	6.10
Potassium	65.50	4.70	4.30	22.75	2.75	4.73
Check	58.00	6.20	4.30	25.25	6.25	8.30

BAKING TESTS*—CROP 1913

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	350	250	549	157	1580	451
Phosphorus	350	250	540	154	1480	423
Potassium	350	250	535	153	1490	426
Check	350	250	532	152	1470	420
Red Fife						
Nitrogen	350	245	540	154	1600	457
Phosphorus	350	245	546	156	1450	414
Potassium	350	245	551	157	1570	449
Check	350	245	540	154	1480	423
Kubanka						
Nitrogen	350	245	546	156	1700	486
Phosphorus	350	245	538	154	1640	469
Potassium	350	245	538	154	1500	429
Check	350	245	537	153	1510	431

*These doughs were made quite slack.

COMPOSITION OF FLOUR—CROP 1914—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phosphorus	Potassium
Defiance													
Nitrogen	8.915	0.841	1.174	0.281	1.5896	9.0609	71.550	0.455	31.75	11.697	8.275	0.1218	0.1401
Phosphorus ..	8.924	0.809	1.334	0.248	1.4312	8.1575	71.095	0.418	26.87	9.863	7.220	0.1169	0.1385
Potassium	10.032	0.791	1.269	0.260	1.4782	8.1260	71.315	0.437	26.96	10.423	7.564	0.1137	0.1316
Check	8.568	0.749	1.343	0.245	1.4983	8.[illegible]501	72.624	0.421	31.35	10.983	7.779	0.1117	0.1361
Red Fife													
Nitrogen	8.304	0.726	1.287	0.229	1.7005	9.[illegible]025	69.486	0.415	38.01	13.362	9.381	0.1062	0.1201
Phosphorus ...	8.035	0.707	1.203	0.253	1.6314	9.[illegible]985	70.991	0.371	34.48	12.311	8.837	0.1036	0.1461
Potassium	8.936	0.756	1.311	0.240	1.5426	8.[illegible]930	70.300	0.452	30.23	11.041	8.033	0.1129	0.1217
Check	7.808	0.727	1.273	0.324	1.6130	9.[illegible]940	73.173	0.377	33.20	12.334	8.677	0.1092	0.1267
Kubanka													
Nitrogen	7.334	0.958	0.911	0.297	1.7030	9.7070	69.725	0.552	25.96	10.013	8.028	0.1453	0.1768
Phosphorus ...	7.780	0.805	1.389	0.296	1.5956	9.0950	73.165	0.280	33.08	12.217	8.491	0.1195	0.1306
Potassium	6.566	0.932	1.367	0.291	1.6225	9.2480	71.041	0.372	32 31	11.733	8.701	0.1455	0.1790
Check	7.130	0.873	0.726	0.329	1.6435	9.3677	71.101	0.343	25.43	9.382	7.582	0.1484	0.1797

OTHER FORMS OF NITROGEN—CROP 1914

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0146	0.1161	0.7115	0.7464	0.0796
Phosphorus	0.0146	0.1025	0.6254	0.6857	0.0864
Potassium	0.0109	0.0937	0.6744	0.6993	0.0821
Check	0.0153	0.1223	0.7190	0.7187	0.0814
Red Fife					
Nitrogen	0.0224	0.1165	0.7066	0.8555	0.0887
Phosphorus	0.0221	0.1030	0.7086	0.8357	0.0827
Potassium	0.0217	0.1301	0.5905	0.8004	0.0796
Check	0.0258	0.1031	0.6227	0.8614	0.0820
Kubanka					
Nitrogen	0.0260	0.0888	0.7644	0.8242	0.3234
Phosphorus	0.0221	0.1100	0.6008	0.8627	0.0907
Potassium	0.0261	0.1042	0.6293	0.8618	0.1121
Check	0.0374	0.0749	0.6766	0.8546	0.1831

MILLING RESULTS—CROP OF 1914

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.35	4.95	2.75	28.40	2.45	6.34
Phosphorus	55.35	6.35	3.95	27.45	6.90	7.37
Potassium	58.85	6.50	3.10	26.60	4.95	8.40
Check	57.85	4.20	2.60	28.80	6.55	7.67
Red Fife						
Nitrogen	63.50	4.70	2.40	23.75	5.65	6.62
Phosphorus	60.60	6.10	2.70	23.75	6.85	6.91
Potassium	60.85	4.85	3.60	27.35	3.35	7.66
Check	61.31	6.10	4.90	25.85	1.80	6.89
Kubanka						
Nitrogen	56.95	8.85	5.30	25.80	3.10	5.12
Phosphorus	53.50	8.60	5.75	25.45	6.70	7.85
Potassium	54.35	7.65	5.40	25.35	7.25	6.30
Check	57.70	7.55	4.10	24.60	6.05	5.00

BAKING TESTS—CROP 1914

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf	Volume per 100 grms. of flour
Defiance						
Nitrogen	350	240	526	150	1600	459
Phosphorus	350	240	519	148	1420	406
Potassium	350	240	538	154	1420	406
Check	350	240	523	150	1420	406
Red Fife						
Nitrogen	350	220	513	147	1590	454
Phosphorus	350	220	537	153	1590	454
Potassium	350	220	508	145	1720	491
Check	350	220	518	148	1520	434
Kubanka						
Nitrogen	350	230	533	148	1640	469
Phosphorus	350	220	509	145	1590	454
Potassium	350	225	509	145	1460	417
Check	350	225	522	149	1520	454

COMPOSITION OF FLOURS—CROP OF 1915—AIR-DRIED

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos-phorus	Potas-sium
Defiance													
Nitrogen	10.435	0.897	1.443	0.380	1.9810	11.292	67.716	0.541	34.00	12.466	7.842	0.1466	0.1942
Phosphorus ..	10.448	0.696	1.126	0.355	1.4351	8.180	69.827	0.341	27.00	9.774	7.232	0.1067	0.1259
Potassium ...	10.767	0.787	1.121	0.414	1.4572	8.300	68.676	0.329	28.13	10.505	7.537	0.0962	0.1409
Check	8.908	0.773	1.226	0.370	1.4770	8.419	71.161	0.347	26.07	9.984	7.458	0.1284	0.1321
Red Fife													
Nitrogen	8.817	0.715	1.197	0.282	1.5211	8.670	71.128	0.212	30.60	11.225	8.020	0.1297	0.1174
Phosphorus ..	8.643	0.718	1.179	0.243	1.3775	7.852	72.653	0.241	26.17	9.479	6.643	0.1022	0.1169
Potassium ...	8.302	0.766	1.236	0.287	1.4324	8.166	69.240	0.243	24.90	9.461	7.177	0.1104	0.1453
Check	8.170	0.830	1.298	0.296	1.4315	8.160	73.616	0.280	24.17	9.236	7.046	0.1160	0.1408
Kubanka													
Nitrogen	9.714	1.008	1.350	0.293	1.7288	9.832	68.179	0.364	33.97	12.679	9.203	0.1480	0.1826
Phosphorus ..	7.826	1.031	1.417	0.276	1.4100	8.037	69.979	0.323	35.40	12.992	9.462	0.1510	0.1992
Potassium ...	8.124	0.988	1.605	0.273	1.6412	9.355	70.993	0.382	32.63	12.087	8.633	0.1372	0.1721
Check	7.766	1.142	1.406	0.282	1.6407	9.388	70.688	0.383	32.50	12.334	9.461	0.1521	0.1880

OTHER FORMS OF NITROGEN—CROP 1915

	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.0042	0.1400	0.9030	0.8960	0.0907
Phosphorus	0.0179	0.1074	0.6192	0.6819	0.0907
Potassium	0.0215	0.1071	0.6173	0.6789	0.1402
Check	0.0183	0.1094	0.7063	0.6795	0.1206
Red Fife					
Nitrogen	0.0218	0.1014	0.6932	0.7483	0.1152
Phosphorus	0.0147	0.1098	0.5837	0.7018	0.0851
Potassium	0.0148	0.0886	0.6995	0.6592	0.1108
Check	0.0220	0.0952	0.6399	0.7186	0.0913
Kubanka					
Nitrogen	0.0323	0.1148	0.6935	0.9487	0.3204
Phosphorus	0.0260	0.1263	0.7022	0.9730	0.3780
Potassium	0.0294	0.1248	0.6782	0.8676	0.1488
Check	0.0294	0.1028	0.6811	0.9977	0.3645

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in-Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	56.25	4.00	2.15	31.60	6.00	7.30
Phosphorus	53.50	5.50	2.05	33.25	5.70	8.40
Potassium	58.00	3.50	1.60	30.35	6.55	7.30
Check	54.45	4.70	2.20	33.35	5.30	6.30
Red Fife						
Nitrogen	58.00	2.55	5.25	29.25	4.95	4.70
Phosphorus	58.20	3.90	2.60	31.50	3.80	6.30
Potassium	58.50	3.45	2.75	31.10	4.20	5.30
Check	59.95	2.95	3.05	28.40	5.65	6.30
Kubanka						
Nitrogen	49.75	7.85	5.85	31.25	5.30	4.80
Phosphorus	55.25	8.75	4.20	27.50	4.30	6.70
Potassium	60.20	6.70	2.70	24.60	5.80	5.20
Check	56.50	8.25	4.95	23.35	6.95	7.00

BAKING TESTS—CROP 1915

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	350	220	534	148	1480	465
Phosphorus	350	220	504	144	1260	389
Potassium	350	220	511	146	1640	469
Check	350	220	505	144	1420	406
Red Fife						
Nitrogen	350	220	504	144	1580	451
Phosphorus	350	220	511	146	1360	389
Potassium	350	220	517	148	1520	438
Check	350	220	513	146	1340	383
Kubanka						
Nitrogen	350	225	519	158	1500	429
Phosphorus	350	220	529	151	1120	320
Potassium	350	220	515	147	1220	349
Check	350	220	525	150	1200	343

COMPOSITION OF WHEAT—CROP OF 1917

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phosphorus	Potassium
Defiance													
Nitrogen, 80 lbs.....	12.943	1.317	1.708	2.608	2.293	13.070	57.454	1.427	34.733	14.166	7.181	0.314	0.408
Phosphorus, 40 lbs..	13.098	1.569	1.913	2.810	1.728	9.849	62.568	1.267	22.933	9.633	6.346	0.356	0.400
Potassium, 150 lbs..	12.483	1.430	1.828	2.765	1.724	9.827	61.200	1.295	25.266	10.466	6.662	0.353	0.399
Check, none	12.383	1.488	1.953	2.890	1.692	9.644	60.660	1.210	24.600	9.866	6.559	0.342	0.382
Red Fife													
Nitrogen, 80 lbs.....	12.220	1.346	1.872	2.753	2.276	12.973	59.932	1.485	38.000	15.133	7.715	0.350	0.320
Phosphorus, 40 lbs..	12.335	1.553	1.840	2.878	1.793	10.220	60.966	1.592	26.966	11.166	7.077	0.394	0.376
Potassium, 150 lbs..	12.400	1.371	1.808	2.760	2.048	11.673	60.534	1.583	31.000	12.433	7.390	0.404	0.382
Check, none	12.475	1.590	1.825	2.770	1.870	10.659	59.724	1.504	30.566	12.200	7.433	0.397	0.381
Kubanka													
Nitrogen, 80 lbs.....	12.493	1.220	2.005	2.740	2.259	12.876	58.140	1.794	38.300	14.833	7.204	0.329	0.365
Phosphorus, 40 lbs..	11.713	1.281	2.263	2.750	1.814	10.340	61.140	1.721	26.200	10.866	7.022	0.382	0.397
Potassium, 150 lbs..	11.700	1.583	2.060	2.698	1.946	11.092	60.570	1.697	31.666	12.566	7.191	0.378	0.427
Check, none	11.675	1.633	2.190	2.800	1.891	10.778	60.768	1.663	29.666	11.733	6.946	0.388	0.393

FORMS OF NITROGEN AS AFFECTED BY FERTILIZERS (Wheat)

Variety and Fertilizer	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen
Defiance				
Nitrogen, 80 pounds	0.098	0.210	0.728	1.257
Phosphorus, 40 pounds	0.077	0.182	0.518	0.951
Potassium, 150 pounds	0.056	0.196	0.518	0.954
Check, None	0.070	0.182	0.518	0.922
Red Fife				
Nitrogen, 80 pounds	0.049	0.238	0.714	1.275
Phosphorus, 40 pounds	0.084	0.196	0.511	1.002
Potassium, 150 pounds	0.091	0.210	0.539	1.208
Check, None	0.098	0.238	0.569	1.065
Kubanka				
Nitrogen, 80 pounds	0.077	0.210	0.679	1.293
Phosphorus, 40 pounds........	0.070	0.224	0.455	1.065
Potassium, 150 pounds	0.077	0.224	0.511	1.134
Check, None	0.084	0.224	0.441	1.142

COMPOSITION OF THE FLOUR—CROP 1917

Variety and Fertilizer	Moisture	Ash	Fat	Fibre	Nitrogen	Protein	Starch	Sucrose	Wet Gluten	Dry Gluten	True Gluten	Phos-Phorus-	Potas-sium
Defiance													
Nitrogen	9.775	0.515	1.198	0.328	2.289	13.047	66.564	0.740	47.833	16.500	7.425	0.1398	0.1748
Phosphorus	9.805	0.619	1.295	0.270	1.701	9.696	72.072	0.745	31.132	10.833	7.555	0.1431	0.1655
Potassium	9.743	0.564	1.208	0.263	1.708	9.736	70.884	0.747	34.600	11.566	7.086	0.1314	0.1646
Check	10.245	0.595	1.398	0.225	1.701	9.696	70.273	0.786	31.633	10.300	7.606	0.1472	0.1597
Red Fife													
Nitrogen	9.575	0.525	1.330	0.203	2.366	13.468	67.485	0.821	49.900	16.733	6.905	0.1212	0.1344
Phosphorus	9.801	0.488	1.305	0.183	1.834	10.454	69.998	0.854	40.333	12.633	6.980	0.1358	0.1359
Potassium	9.673	0.487	1.395	0.263	2.044	11.651	69.434	0.785	43.000	15.800	6.748	0.1614	0.1418
Check	9.500	0.479	1.513	0.345	2.023	11.531	68.364	0.833	41.200	14.600	7.065	0.1540	0.1296
Kubanka													
Nitrogen	9.570	0.791	1.693	0.283	2.384	13.589	64.530	0.952	48.666	16.966	7.447	0.1782	0.2055
Phosphorus	9.185	0.732	1.643	0.343	1.785	10.175	69.264	0.953	32.633	12.200	7.403	0.1910	0.1982
Potassium	9.135	0.566	1.558	0.270	1.834	10.454	69.372	0.921	36.166	12.900	7.274	0.1864	0.2118
Check	8.263	0.551	1.503	0.305	1.799	10.254	70.452	0.998	35.333	13.033	7.651	0.1690	0.1828

OTHER FORMS OF NITROGEN—CROP OF 1917 (Flour)

Variety and Fertilizer	Amid Nitrogen	Albumin Nitrogen	Gliadin Nitrogen	Glutenin Nitrogen	Acidity of Flour
Defiance					
Nitrogen	0.042	0.168	0.910	1.169	0.1201
Phosphorus	0.042	0.112	0.651	0.896	0.0723
Potassium	0.042	0.266	0.525	0.882	0.0698
Check	0.056	0.154	0.609	1.309	0.0772
Red Fife					
Nitrogen	0.077	0.182	0.798	1.001	0.0883
Phosphorus	0.049	0.154	0.630	1.134	0.0760
Potassium	0.077	0.154	0.679	1.106	0.0919
Check	0.056	0.154	0.707	1.376	0.0858
Kubanka					
Nitrogen	0.056	0.238	0.714	0.966	0.0833
Phosphorus	0.061	0.168	0.590	1.071	0.0895
Potassium	0.042	0.168	0.553	0.994	0.0858
Check	0.035	0.168	0.602	0.896	0.0772

MILLING RESULTS—CROP OF 1917

Variety and Fertilizer	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Defiance						
Nitrogen	61.5	4.6	4.1	23.9	6.3	6.1
Phosphorus	60.1	3.3	3.6	24.0	8.2	5.2
Potassium	60.7	4.2	2.8	25.2	7.1	4.9
Check	62.5	3.7	2.3	24.6	6.9	4.2
Red Fife						
Nitrogen	64.9	1.7	1.5	25.1	6.8	5.0
Phosphorus	63.5	2.1	1.7	28.2	6.0	5.0
Potassium	64.7	2.2	1.6	26.5	5.0	5.3
Check	64.4	3.4	2.1	26.5	5.4	4.8
Kubanka						
Nitrogen	66.9	2.1	1.9	23.9	5.2	5.8
Phosphorus	65.2	3.8	3.2	26.1	2.9	4.5
Potassium	62.7	3.4	1.4	27.6	4.9	5.4
Check	63.7	3.0	1.5	30.3	3.7	4.0

BAKING TESTS CROP 1917

Variety and Fertilizer	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Defiance						
Nitrogen	400	235	572	143	1980	495
Phosphorus	400	250	583	146	1660	415
Potassium	400	242	577	144	1760	440
Check	400	234	567	142	1680	420
Red Fife						
Nitrogen	400	240	590	148	2040	508
Phosphorus	400	236	589	147	1880	470
Potassium	400	241	577	144	1900	475
Check	400	235	572	143	1740	435
Kubanka						
Nitrogen	400	250	571	143	1860	465
Phosphorus	400	250	573	144	1720	430
Potassium	400	250	587	147	1780	445
Check	400	240	567	142	1740	435

Variety	First Grade Flour	Second Grade Flour	Shorts	Bran	Loss of Mill Products in Air-drying	Loss of Flour in Air-drying
Kanred	62.7	3.1	1.4	27.6	3.1	4.0
Beardless Turkey (light)	68.4	1.4	1.6	26.1	4.8	3.8
Beardless Turkey (dark)	67.9	1.9	2.1	24.8	3.4	5.4
Marquis	65.3	1.6	1.5	28.9	2.8	4.7
Fultz Mediterranian	65.7	1.7	1.4	28.6	2.6	3.5
Defiance	62.7	2.4	1.7	30.5	2.7	4.9
Red Russian	62.5	2.1	1.6	30.1	3.9	5.8
Turkey Red (Dry land)	63.1	1.6	1.1	29.4	5.0	5.3
Preston	67.4	1.6	1.1	25.7	4.1	4.1

BAKING TESTS—CROP OF 1917*

Variety	Flour Taken Grams	Water Taken c.c.	Weight of Loaf	Bread per 100 of Flour	Volume of loaf c.c.	Vol. per 100 grms. of flour
Kanred**	400	240	576	144	1800	450
Beardless Turkey (Light grains)	400	228	575	144	1700	425
Beardless Turkey (dark grains)	400	235	574	144	2000	500
Marquis	400	270	619	155	1790	448
Fultz Mediterranean	400	250	598	150	1800	450
Defiance	400	240	580	145	1930	483
Red Russian	400	233	579	145	1960	490
Turkey Red Dry land	400	260	601	150	1880	470
Preston	400	250	597	149	1940	485

*These samples were milled in the laboratory and represent straight flours.

**This sample was grown in Kansas.

BAKING TESTS OF FLOUR FROM SOME COLORADO MILLS *1917.

Brand and Where Milled	Flour used Grams	Water Added c.c.	Weight of Loaf	Bread per 100 flour	Volume of Loaf	Volume per 100 Gms. flour	Remarks
Defiance							
Lindell Mills, Fort Collins	400	230	568	142	1960	490	
Lindell Mills, Fort Collins	400	229	574	144	1880	470	
Lindell Mills, Fort Collins	400	230	579	145	1820	455	
Lindell Mills, Fort Collins	400	230	567	142	1825	456	Defiance 50 Idaho 50
Lindell Mills, Fort Collins	400	230	566	142	1990	498	
Lindell Mills, Fort Collins	400	240	579	145	2020	505	
Hoffman's Best							
Fort Collins	400	260	594	149	1960	490	
Fort Collins	400	255	593	148	1860	465	
Fort Collins	400	273	611	153	2044	511	
Fort Collins	400	288			2065	516	
Fort Collins	400	250	592	148	1970	492	
Fort Collins	400	245	576	144	1900	475	
Fort Collins	400	212	555	139	1920	480	Defiance & Winter Wheat
Major C							
Pueblo	400	230	563	141	2000	500	Hard Wheat
Pueblo	400	230	586	146	1900	475	Straight Flour Intentionally Underproved
Nonpariel							
Longmont	400	240	582	146	1800	450	
Pride of the Rockies							
Longmont	400	250	599	150	1930	495	
Longmont	400	266	615	154	1900	475	
Longmont	400	270	601	150	1990	498	
Longmont	400	266	617	154	1980	495	
Bread King, Boulder	400	250	590	148	1900	475	
Golden Seal, Golden	400	250	585	146	1960	490	Spring 50 Winter 50, a 70 percent patent
Silver Bell, Alamosa	400	240	577	144	1960	490	Soft wheat
White Loaf, Denver	400	235	577	144	2005	501	
Golden Seal, Golden	400	250	585	146	1960	490	
Pure Gold, Denver	400	225	569	142	1860	465	
La Junta	400	235	580	145	2000	500	
Loveland	400	235	575	144	1745	436	
Velvet, Berthoud	400	250	585	146	1840	460	Turkey Red Straight
Snow Flake, Greeley	400	235	584	146	1900	475	(53 percent white 35 percent red 30 percent Marquis)

*I am indebted to the Colorado Milling and Elevator Company for many of these samples which they kindly provided for me.

MOISTURE, NITROGEN AND PROTEIN IN SOME FLOURS FROM DIFFERENT PARTS OF THE STATE

Brand	Where milled	Percent Moisture	Percent Nitrogen	Percent Protein
Major C	Pueblo	11.32	2.156	12.2892
Nonpareil	Longmont	11.05	1.708	9.7356
Golden Seal	Golden	12.01	1.827	10.1439
Silver Bell	Alamosa	11.28	1.407	8.0199
White Loaf	Denver	10.71	1.869	10.6533
Pure Gold	Denver	11.31	1.785	10.1745
———	La Junta	11.47	1.883	10.7331
———	Loveland	11.90	1.701	9.6957
Velvet	Berthoud	11.22	1.652	9.4164
Snow Flake	Greeley	11.06	1.771	10.0947

BAKING TESTS WITH CHECK FLOURS*

Brand	Made by	Flour Taken	Water Used	Weight of Loaf grms	Bread per 100 of flour	Volume of loaf	Volume per 100 grams of flour
Gold Medal	Washburn Crosby & Co.	400	257	603	151	2000	500
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	574	144	2055	514
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	572	143	1980	495
Gold Medal	Washburn Crosby & Co. 2d. sample	400	230	574	144	2000	500
Cream	Plainville, Kansas	400	250	588	147	1900	475
Cream	Plainville, Kansas 2d sample	400	250	602	151	2020	505
Cream	Plainville, Kansas 3d sample	400	247	594	149	1970	493
Cream	Plainville, Kansas 4th sample	400	267	593	148	1910	478
Jersey Cream	Kansas	400	230	574	144	2165	541
Prize Winner	Hays City, Kansas	400	255	600	150	2005	501
Prize Winner	Hays City, Kansas	400	255	576	144	1980	495

*These samples represent high grade, patent flours and are air-dried under our conditions.

DIFFERENCES PERSIST IN PROPERTIES OF FLOURS

The object in view in this part of our study has been to show by results obtained experimentally that the differences observed in the composition of the wheats grown with the different fertilizers persist in the properties of the corresponding flours. These may seem to be self evident facts. I was inclined to consider them such to so great an extent that I seriously considered the omission of all milling and baking experiments in connection with this work, but I was advised that it would be better to present these features in detail and not to assume a complete parallelism between the composition of the wheat and flour and a perfect correspondence between the composition and the baking qualities of the flours.

There were two considerations which inclined me to act on this advice in addition to my confidence in the advice itself. These were: First, that I am persuaded that there are other factors than the composition of a flour entering into its properties. Second, because no study of Colorado flours has been made previous to this time. Whatever the millers may know has not been made public. This feature is, it is true, only incidental to my main purpose but it seemed that it would be better to present it in connection with our work than to make it the object of a special investigation. This reason appealed more forcefully when we considered that, aside from the study of the definite question proposed, this station has no definite policy which would call for an extended study of the cereals. The principal reason for any hesitancy has been in the question in regard to the extent of the experiments, i.e., whether it represents a sufficient number of samples from the different sections of the State and has been extended over a sufficient lenght of time.

It would undoubtedly have been better from this standpoint if the number of general samples had been increased. On the other hand, the data presented in other portions of this account of our work show clearly that labor spent on a general sample when we know nothing of the conditions under which it has been produced is largely in vain because this knowledge is absolutely necessary to a correct interpretation of the results obtained, and it is very probable that the data obtained by the study of our own samples are of more value than those which we might have obtained from the study of any number of general samples collected over a period twice as long as we have continued this study.

Another question arises in this connection, i.e., Should not a greater number of varieties have been studied in considerable detail before the data presented and the inferences drawn from them should be accepted as of general applicability? The answer to this is that observation in the field and analyses of the wheat produced show that the general inferences drawn are justified and that a study of more varieties, and especially of general samples, would have a cumulative value only and in many cases would have no value at all due to the fact that it would be practically impossible, as we have unfortunately found to be the case, to obtain reliable information about the conditions under which the samples were produced, without which the results would have no value for our purpose, in fact would simply be results with no possible rational interpretation.

While we willingly admit the possible advisability of a more extended investigation of the features of our study which apply to those subjects which are incidentally applicable to the general questions pertaining to the properties of Colorado wheat, we are inclined to believe that the results presented would be supported even in detail by a more extended series of experiments.

The primary purpose of this study is to ascertain whether our wheats are soft, and if so to ascertain the causes. These questions have been answered in so far as they pertain to the plants and grain in the parts of this study previously published. In this part we have continued the study, extending it to the milling qualities of the wheat, also to the composition and baking qualities of the flour.

We found that the prevalent notion that irrigation influenced the composition and character of the wheat, causing softness or starchiness in the grain is not justified by the facts in the case, but that we can grow very hard, flinty wheat, applying at the same time an ample supply of water. On this subject we have confined ourselves to the grain produced and have not undertaken to find out whether there are any differences in the milling and baking qualities of irrigated wheat which can be attributed to this cause. We have assumed, and believe ourselves justified in doing so, that the effect of irrigating the plants will express itself upon these properties in the same sense and to a corresponding degree that it affcets the composition of the wheat.

This is not so much an assumption as a conclusion based on the results obtained, which show a very close relation between the composition of the wheat and the properties of the flour produced.

ONLY DIFFERENCE BETWEEN DRY-LAND AND IRRIGATED WHEAT IS IN BRAN YIELDED

We have analyzed dry-land wheat, milled it and baked bread from the flour. The only difference that we have been able to detect between it and wheat of the same grade grown under irrigation is in the amount of bran that it yields. Turkey Red, for instance, grown with irrigation yields around 25 percent of bran. Grown under dry-land conditions it yields 4 to 5 percent more. So far as the composition of the wheat or the baking qualities of the flour produced is concerned, we failed to observe any difference. The one is as good as the other provided they are of the same grade. These statements will of course not apply if a strongly yellow-berried or starchy wheat grown on dry land be compared with a flinty wheat grown under irrigation or vise versa. The flinty wheat would in each case be the better wheat or flour. Dry-land wheat is frequently grown after fallow cultivation. Sometimes, however, it is not. In this case the kernels will be small in size with probably a large percentage of mealy ones, in the former case they will be medium to small in size with but few or no mealy ones. We interpret the small size of the kernels and their high yield of bran in milling as characteristic effects of the dry-land conditions in which there is simply a lack of sufficient water to complete the proper or normal activities of the plant in filling out the grain. Otherwise they do not differ from wheat grown under irrigation.

APPLICATION OF NITRATES PRODUCES BETTER FLOUR

We present in the tables given in this bulletin the composition of the flour yielded by the crops of 1913. 1914, 1915 and 1917. The composition of the crops of 1913, 1914 and 1915 may be found in Bulletin No. 219, Colorado Experiment Station, while that of the crop of 1917 is given in this bulletin. These tables, giving the composition of the crops grown, show that under our soil conditions nitrate, in this case sodic nitrate, produces hard wheat rich in nitrogen. This is true in every case without regard to the variety used in the experiment. This is not to be understood as stating that one can convert a soft variety of wheat into a hard one by applying sodic nitrate to the soil. We cannot change the variety characteristics, but we can grow flinty berries of this variety which are richer in nitrogen than berries grown without it and to this extent we modify the wheat produced, and the flour obtained from this flinty wheat is better flour than such as is prepared from mealy berries of the same variety. This fact appears in every one of the tables giving the composition and baking qualities of the products from the wheats grown on our experimental plots.

MILLING AND BAKING TESTS MUST BE COMPARABLE

In this connection the manner of milling must be considered and the grades of flour compared must be as nearly alike as is possible to prepare, also the process of baking must be as nearly alike as is feasible to apply or the results will not be comparable. These facts are evident, especially to persons who have done any of this kind of work, but the necessity of keeping the conditions as nearly uniform as possible in order to obtain comparable results may be shown rather forcefully by the two following baking experiments:

The two flours were made from the same lot of wheat. One hundred grams of one sample ground in our routine way gave 147 grams of bread measuring 470 c. c. The same sample ground with a little change in the manner of milling gave for 100 grams of flour 154 grams of bread having a volume of 562 c.c. In this case we obtain a much larger yield by volume and 7.0 percent more by weight, or 13 one-pound loaves per barrel. We have made a straight flour throughout. The second-grade flour separated was small in quantity and was poor in quality. Our results do not represent the best flour that could be made from the wheats used, but we have aimed to make the results comparable with one another. The baking tests, however, compare fairly well the results obtained with well known brands of commercial flours which we used as standards for comparison. These best commercial brands represent the highest skill in blending the wheats and milling them, besides, their color is improved by bleaching. Only a few of our loaves were decidedly poor in color, the reason for which was not always clear.

NITRATES PRODUCE HIGHER GLUTEN CONTENT

An examination of the tables presented shows clearly that there are no great or consistent differences in the composition of the flours produced from the check, potash or phosphorus wheats. These are in every group nearly the same, but there is regularly a difference in favor of the nitrate wheat in gluten content which may be taken as the determinative feature. This advantage in favor of the nitrate wheat persists throughout all of our tests and finally appears in the volume of the baked loaf.

The figures of the table express only those differences which are shown by the balance, or the measuring cylinder, but there are other differences. The gluten is softer and darker, the texture of the loaf is better but I cannot say that I could detect any difference in the flavor of the loaves.

The flour made from the flinty samples of the respective varieties of wheat, the ones grown with the application of the nitrate, were really the best flours.

RESULTS ARE INDEPENDENT OF WEATHER

No one denies that the climate may have an influence upon the wheat produced in different countries or in the same locality in different years but the cause of hardness and softness is the supply of nitrate available to the plants or rather its ratio to the potassium. This has been insisted on in previous bulletins, particularly in Bulletin No.

219 of this station and we here have it expressing itself in the baking qualities of the flour.

These results are independent of the weather conditions. In 1914 we had an abundant crop of low quality of wheat, the cause of which was probably a spell of wet weather late in July which induced an abundant development of rust. I say probably because I cannot definitely assert that this was the cause. But all other conditions were so favorable throughout the season that the low quality of the wheat and, as we now see, of the flour too, is a matter of surprise. This wet spell, followed by the rusting of the plants, is the only untoward condition that we have to offer in explanation. In 1915 we can state with full confidence that much rainy weather and a very severe attack of rust practically ruined some of our plots and injured all of them. These are climatic effects that are evident but they are fortunate events instead of regrettable ones from the standpoint of our study, for while they injured our crops, this injury was concurrent with the development of the rust, as is shown in Bulletin No. 217, in which we discuss the development of the crop for 1915. They scarcely obscured the specific effects of the soil factors, i.e., those of the nitrate and potassium in any degree. The flintiness produced by the nitrate was characteristic in the one case and the mealiness in the other though some of the nitrate wheat was badly shrunken and most of the samples in a less degree. The flours made from these crops also show quite as pronouncedly as the better crops of 1913 and 1917 the effects of the nitrate upon the baking quality of the flour. This statement relative to the flour is true even in the case of the Defiance wheat grown with the application of nitrates, which was so shrunken that I could not sell it for milling purposes, but only as chicken feed.

SHRUNKEN GRAIN YIELDED AS MUCH FLOUR AS OTHER SAMPLES

Our experience with this excessively shrunken grain was a surprise to us in that it yielded as much flour as the other samples of the same variety per 100 pounds. In the second place, this flour showed the characteristic effects of the nitrate as markedly as other samples of nitrate flour and this was also true of its baking qualities. This flour gave a better loaf than that prepared from the check plot or from the one dressed with phosphorus but inferior to the one prepared from the plot receiving potassium. This is the only instance in which the nitrate flour did not yield the best loaf in every respect, but even in this worst case the climatic conditions, including the rust, did not conceal and scarcely modified in any degree the effects of the nitrate applied to the soil.

SERIES OF FACTS ESTABLISHED

We have established a series of facts pertaining to the effects of the soil conditions upon the composition of the plants and upon the grain produced, further we have shown that irrigation produces no effect upon the composition of the grain; further that when the plants are kept continuously wet the percentage of nitrogen in the plant is depressed, but we were not able to follow this effect upon the composition of the grain because of the development of rust, which apparently stops the transference of the material for the filling of the grain and causes shrinkage. In this connection we have shown that ripe grain is susceptible to the leaching action of water, giving up both nitrogen and potassium. We have not determined whether the composition and baking properties of the flour are affected by such washing or leaching or whether this effect is confined to the outer portions of the berry, or the bran. We have not considered any other portion of the berry than the flour produced and we find that the soil conditions produce distinctive characteristics of composition and properties in the flour similar to those produced in the grain, which express themselves in the baking qualities of the flour and the characteristics of the loaf.

MUCH DEPENDS ON THE MILLING OF WHEAT

While our climate is undoubtedly favorable to the production of good wheat, as has been repeatedly pointed out by writers on this subject, the quality of our wheat is after all determined by our soil conditions, especially by the relative supply of nitric nitrogen and potassium. The reputation of our flour has probably been earned by the general use of an inferior bread-making variety and the practice, especially in the past, of planting wheat after wheat till the crop was all yellow or mealy. This reputation is no longer deserved. With our climate and proper soil conditions we can produce first quality wheat as well as big crops. The question of producing good flour from such wheat is one of milling and it is difficult to lay too much stress on this process.

Through the courtesy of the Colorado Milling and Elevator Company and especially of Mr. G. B. Irwin, the manager of its mill at this place, we are able to present the baking results obtained with flours produced by different mills which we may take as representative of our wheats and the flours produced from them. These results are presented in the table under the caption of "Baking Tests of Flours from Some Colorado Mills". Some of these are straight flours, others are various grades of patent flours from 50 to 70 percent and grading into straight flours. The results of such tests can be considered as the basis of just comparisons only when they have been made under the same conditions throughout. It would be wholly inadmissible to compare baking results obtained by myself with those obtained by a skilful baker even though he used the same brand of flour. This principle is still more imperative when it concerns milling products as an expert miller might use my appliances and make an excellent flour but he certainly would be able to produce a much better flour in his own plant. For such reasons I have presented a separate table entitled "Baking Tests with Check Flours" which represents the best brands on our market in order to compare the results obtained with our Colorado flours. These check flours are, of course, high-grade patent flours, while the samples from the mills of this State are of various grades made from a variety of different wheats in some cases blended by chance mixing in the bins, in others with a definite purpose and wisely, and in others not blended at all. These facts should all be borne in mind in making any comparisons of the results.

An examination of these tables shows that with the check flour the lowest yield of bread from 100 grams or flour was 143 grams and that two other trials with this flour gave 144 grams. The smallest volume yielded by 100 grams of any of these samples was 475 c.c., other samples of the same brand yielded 478,493 and 505 c.c., showing fairly uniform results in this respect. The largest yield of bread from 100 grams of flour was 151 grams, and the largest volume was 541 c.c. All of these samples are supposed to have been made from hard wheats. We know that this is not the case with the samples from the Colorado mills. In a few instances we know of what wheats the flours were made. For instance, flour No. 4 was made from a mixture of Defiance wheat* and a soft Idaho wheat, probably Dicklow Spring wheat, also, No. 13 was made from a mixture which was very rich in Defiance, again, No. 23 "Silver Bell" brand was a 70-percent patent made from soft wheat. We find that the flour from the Defiance wheat requires the least water and yields the smallest weight of bread, and is always deficient in volume. Sample No. 13, which required only 53 percent of water to make a dough was flour from Defiance wheat. We see that the water required by these samples varies from 57 to 72 percent. The maximum that I have found required by a sample of Colorado flour was one of Mr. Hoffman's which required 88 percent. This sample is not given in the tables. The range in the water required by these samples is mostly from 57 to 62 percent, which is fully an average water requirement. The water content of these flours themselves, as we have shown in a separate table, is mostly a little less than 12.0 percent and the crude protein about 10.0 percent, except for flour made from distinctly soft wheats, in which it may fall materially below 10.0 percent.

The yield of bread per 100 lbs. of flour is from 144 to 154 lbs. or from 282 to 305 one-pound loaves per barrel of 196 pounds, except

*Defiance wheat is not to be confused with "Defiance" flour which is ground from blended wheats.

for the soft wheat flours, which fall below this yield. The minimum yield that we have found is 272 loaves. This result is in harmony with the statements often made relative to our flours, but it no longer represents the facts. The check flours that we used as criteria of excellence yielded from 280 to 296 loaves per barrel.

In volume, our flours yielded from 100 grams of flour, from 455 to 511 c.c. mostly, however, from 470 to 500 c.c. The samples prepared from soft wheats show their deficiency in this as well as in other respects. Our check samples ranged from 475 to 514 c.c. for each 100 grams of flour used. It is evident that our flours compare favorably with the best on the market and can be produced of uniform quality if the desire to do so is strong enough. This might be different in the case of small mills receiving all kinds of wheat, varying from good, hard wheat, either spring or winter wheat, to very soft, indifferent wheat.

We have given the results on such samples as we could obtain. They represent different localities, the products of different mills and the skill of different millers. These results are in harmony with the conclusions that we have elsewhere drawn based wholly upon analytical results, i.e., that our wheats are not inferior in composition or in bread-making qualities to the same varieties grown elsewhere, but that on the contrary our conditions produce excellent wheats when the soil is properly cultivated and advisedly fertilized.

SUMMARY

The character of the grain produced depends upon the relative supply of the respective plant foods.

The important factor in our conditions is the ratio of the nitric nitrogen to the available potassium.

Organic nitrogen, as in farmyard manure, is not nitrified rapidly enough to affect the composition and physical properties of wheat.

Phosphorus does not produce in our soils the effects usually ascribed to it.

Potassium in excessive ratio to nitric nitrogen produces meally wheat.

Excessive irrigation does not produce meally or soft wheat.

Frequent rainfall, accompanied by heavy dews, reduces the ash and nitrogen content of the plant.

Rainfall and dews sufficient to keep the plants wet, together with poor ventilation, are accompanied by a development of rust which seriously interferes with the maturation of the plant.

Fallowing the land has the effect of increasing the nitrates, and under normal conditions will produce hard wheat.

There is a close relation between the physical quantities of the wheat and its composition.

The milling qualities of the wheat are closely related to the physical and chemical qualities.

The baking qualities of the flour are related to the hardness or softness of the wheat.

The process of milling is of very great importance in determining the quality of the flour produced.

Colorado wheat is mostly hard enough to produce good bread-making flour.

Flour produced in Colorado from Colorado wheat is usually good flour.

Some of the better grades of Colorado flours compare favorably with the best commercial flours.

Flour made from dry-land wheat is identical in quality with flour made from the same kind and quality of wheat grown with irrigation.

Dry-land wheat yields more bran than irrigated wheat.

Shrunken wheat yields more bran than plump wheat.

Flour made from shrunken wheat is not poorer in quality than that made from plump wheat. The quality of such flour depends upon the cause of the shrunkenness; if it be caused by the presence of nitrates the quality will be high, it may be higher than that of flour made from plump grain of the same variety.