CHEMICAL AND PHYSIOLOGICAL DIFFERENCES IN THE SOFT AND HARD WHEATS

by

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INTRODUCTION

With the advent of chemurgical science the chemistry of the constituents of plants has become increasingly important. Modern world events are making necessary a search for new sources and new materials to replace those that are now scarce or cannot be obtained. An increasingly important source of new materials has been realized in the wealth of vegetation that exists in the earth.

With any plant that becomes commercially important, there arises the problem of varistal studies with the thought of improving or selecting the available varieties towards the use for which they are intended. Regardless of the plant constituent that is to be used, good agricultural practice demands that a varistal study of the constituent be made. In the case of the wheat plant, Triticum vulgare Vill., which is composed of many types of varieties, progress has been made towards improving yield and quality of grain by varietal studies. If this plant were suddenly to offer great possibilities as a source of chemical materials, a varietal study along these lines would be of great importance. It therefore seemed desirable to investigate certain chemical constituents of varieties of soft and hard wheats, especially of their dry matter developed at different periods of growth.

REVIEW OF LITERATURE

Literature pertaining directly to the problem of differences in the chemical composition and physiology of hard and soft wheats is practically nonexistent. The results of attempts to correlate and interpret differences in the two groups of wheat from literature not directly aimed at the problem were unreliable due to differences in methods of analysis, basing of results, failure to describe the varieties studied, and differences in conditions under which the studies were conducted. For these reasons a review of this nature is not included in this study.

Any attempts to investigate varietal and group differences in the chemistry and physiology of plants are greatly complicated by the fact that any series of data is true only for the conditions under which the study was conducted. Ultimately, of course, any differences must be explained genetically. This in turn refers the problem to protoplasm which merely leads to conjecture as to the real cause of differences in closely related plants. However, to rise beyond conjecture and to have a concrete basis for the explanation of differences in plants, one must begin with the science of genetics. This being beyond the scope of this work a few remarks must necessarily suffice. The geneticists and workers in other fields of plant science have conveniently catalogued differences and have grouped plants into remarkably coherent groups. One of the more satisfactory classifications for wheat was developed by Tschermak (1914). By way of illustration it is as follows:

Haploid chromosome number	Group	Stem species	Cultivated (covered)	Cultivated (naked)
7	Einkorn	T. aegilopoides	T. monococcum	Unknown
14	Emmer	T. dicoccoides	T. dicoccum	T. durum T. turgidum T. polonicum
21	Spelt	T. spelta	T. spelta	T. vulgare T. compactum

From the species vulgare many and divers varieties have been developed, all of which are certainly different. In many cases these differences are plainly revealed by merely casual observation. In other cases the differences are minute and are shown only by careful study. One of the most striking developments in the study of the differences in closely related organisms has arisen from the chemical, or more properly, the physicochemical approach to the problem. The realization of protein specificity opened a new field of study. As early as 1914 serological studies showed that quite distinct differences exist in the proteins of the wheats. The research of Nelson and Birkeland (1929) demonstrated serological differences in wheat varieties and offered a means of augmenting the selection of certain genetic characters.

Development of the Wheat Plant

The development of the wheat plant has been reviewed in considerable detail by Bailey (1925) and Miller (1939). Le Clerc and Breazeale (1911) found that at the end of 12 days of germination four percent of the potash, 17 percent of the nitrogen, and 20 percent of the phosphoric acid remained in the seed. It was found by Choate (1921) that the amount of amino nitrogen increased in the germinating seed.

Bailey (1925) showed that when the wheat seedling has absorbed most of the reserve material in the endosperm of the grain it has usually reached the stage where it is capable of an independent existence, if a suitable substratum has been provided.

According to Snyder (1893) the wheat plant during the first 50 days of its development took up 86 percent of the nitrogen, 75 percent of the potassium, 60 percent of the phosphorus, and 70 percent of the silica which it finally contained. The starch was formed mainly during the 15 days preceding heading and the following 16 days which preceded the grain milk stage. There is a substantial agreement of the work of Adorjan (1902) with that of Snyder since the former also found that the greater portion of the plant food was taken up in the earlier stages of growth. This was later drawn upon in the growth and functioning of the various plant structures. At the time of blossoming the phosphorus assimilation exceeded that of nitrogen and was at its maximum. This could possibly be expected in view of the role played by phosphorus in carbohydrate and nitrogen relations of plants. After blooming phosphorus assimilation ceased while that of nitrogen was reduced to the needs of the plant for the formation of grain.

It was found by Henry (1903) that the maximum rate of nitrogen absorption occurred at the time of the formation of the kernel. According to Wilfarth et al. (1905), the amount of starch per unit of area occurred at its maximum at the time of ripeness. The dry matter, phosphorus pentoxide, and nitrogen occurred at a maximum at the third period, and potassium and sodium at the second period (period of bloom). Waigh (1912) found that the maximum dry matter of the stalks occurred at the time of blossoming. He stated that nitrogen and mineral matter was taken up largely in the younger stages and at decreasing rates as growth proceeded.

The researches of Colin and Belval (1922) indicated that mineral matter was absorbed from the substratum by the developing wheat plant at a rapid rate in the early stages of growth. At the time of blossoming practically enough had been accumulated in the tissues of the plant to enable it to function normally during the remainder of the growth period. These mineral substances were translocated from the dying to the living parts as they were required. Nitrogen continued to be absorbed during kernel development, but at a slower rate.

According to the researches of Miller (1939) the total dry weight of the wheat plant, with a few exceptions, increased to the time of harvest. The maximal weekly increases in dry weight occurred between the period of jointing and blooming. After blooming, with a few exceptions, the dry matter decreased in the stem and leaves and increased in the heads. The increase in the amount of dry matter in the heads was found to be greater than the decrease in the stems and leaves. It was interpreted that some of the materials in the stem and leaves were withdrawn and translocated to the heads. The data indicated that the greater portion of the increase in dry matter in the heads was due to materials that were translocated to them immediately after the absorption or manufacture of the materials by the stems and leaves. The amount of nitrogen increased in amount from the seedling stage in early October until the middle of May. The maximal amount of nitrogen in the stems and leaves occurred about the time of heading, and in general it decreased thereafter. The amount of nitrogen in the heads began to increase about the time it began to decrease in the stems and leaves.

The work of Kedzie (1882, 1893) on the development of the wheat grain showed that the percentage of starch increased very rapidly for a time and later at a slower rate until the grain was ripe. The percentage of protein decreased regularly with the approach of ripeness. When the grain was allowed to become overripe the percentage of starch decreased and the protein increased somewhat, which suggested the possibility that some of the starch served as a source of energy to the plant after it had normally ripened. Teller (1898, 1912) found that the percentage of amids, ash, fat, fiber, dextrin, and pentosans decreased in the grain up to ripeness, while the starch rapidly increased. The percentage of total protein decreased until a week before maturity, and then increased. Woodman and Engledow (1924) showed that the increase in the actual amount of protein in the last eight days before harvest is due to the conversion of amino acid to protein as the amino acid content decreased slightly during that time. They considered the loss in carbohydrate in the last eight days before harvest to be due to respiration. Forty-seven days after heading the amount of ash in the grain had reached a constant quantity.

Lignin

The literature referring to lignin is voluminous, but many excellent reviews of this literature are available. The knowledge of the chemistry of lignin up to 1934 has been reviewed in considerable detail by Phillips (1934a). Other reviews have been written by Hibbert (1940), Norman (1937), and Lewis (1938).

According to Mehta (1925) lignin from wood is a brown, amorphous, faintly acidic substance with a pleasant aromatic odor, resembling vanillin in some cases. Lignin melts at 170° C. and is insoluble in water, soluble in dilute alkalies and alcohol. Its iodine value is 139 and acid value 477.

Until recently there has been no promising commercial use for lignin. At the present time there is promise that the 1,500,000 tons wasted annually from paper pulp and naval stores industries can be converted to lignin molding powders and plastics (Hill, 1940; Boehm, 1940; Marathon Paper Mills Co., 1939; Business Week, 1939).

The exact function of lignin is unknown, the function most often assigned to the substance being as a mechanical stiffening substance of supporting tissues. The role of lignin as a stiffening agent is believed to be by virtue of its association with cellulose. The association of lignin with cellulose is either physical or chemical through ester, ether, or acetal linkages. It is possible that all of these combinations may occur, depending upon the plant, its stage of growth, and conditions under which it was grown (Phillips, 1934b). Mehta (1925) believed the linkage to be glucosidal in character. The literature on the existence of a chemical bond between lignin and cellulose has been reviewed by Bailey (1940).

The manner of distribution of lignin in the cell wall is a subject of controversy. Ritter (1925) and Harlow (1932) considered that a great proportion of the lignin of wood is located in the middle lamella. According to Harlow (1928) the secondary walls of soft wood are appreciably lignified, whereas those of most hardwoods contain practically no lignin.

The chemical composition of lignin varies somewhat with the source. Phillips and Goss (1935) found that the lignin of young barley plants was different from that of the mature plants. As the plant increases in age so increases the percentage of methoxyl in the lignin.

EXPERIMENTAL METHODS

Method of Growing Plants

Nine varieties of hard wheats and six varieties of soft wheats were sown in the field on October 2, 1940, at the rate of 1 g of grain per foot. Blackhull, Early Blackhull, Cheyenne, Kanred, Oro, Tenmarq, Turkey, Chiefkan, and Nebred were the hard wheats studied, while the soft wheats included

Fulcaster, Trumbull, Harvest Queen, and Clarkan.[1] The grain was sown in north-south rows one foot apart on a fertile loam plot maintained by the Department of Botany, Kansas Agricultural Experiment Station, Manhattan, Kansas, which had been used for wheat for a number of successive years.

Rows of soft and hard varieties were alternated; otherwise, no definite planting order was followed. Hard varieties were repeated in at least two rows and soft varieties in at least four rows. October 8, 1940, was taken as the date of emergence.

Collection of Samples

Samples for analysis which were taken at four different stages in the development of the wheat plant are designated in order as sets 1, 2, 3 and 4. All samples were arbitrarily taken as nearly as possible in the forepart of the afternoon. The samples of set 1 were collected on November 8, 1940. One hundred sixty plants were collected for each variety from two different rows of the hard wheats and from four different rows of the soft wheats. The plants were washed to remove any foreign matter adhering to the aerial parts and then superficially dried. The plants were cut into small pieces, killed in a forced-circulation oven at 100° C., dried, and weighed to the nearest 0.1 g on a Milvay double beam trip scale. The dry weights were calculated on the basis of 100 plants. The samples were then stored in Kraft paper bags until ground for analysis. Set 2 was collected on May 1,

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[1] The grain was generously supplied by the Department of Agronomy, Kansas Agricultural Experiment Station, Manhattan, Kansas.

1941, and treated in the same manner as set 1 with the exception that the dry weight was calculated on the basis of 100 culms. Set 3 was collected just after blooming when the grain had just begun to swell, and set 4 was collected two weeks later as follows: Early Blackhull, May 16 and 30; Chiefkan and Fulcaster, May 18 and June 1; Blackhull, Harvest Queen, Tenmarq, and Trumbull, May 19 and June 2; Kanred, Nebred, and Turkey, May 20 and June 3; and Cheyenne, Clarkan, and Oro, May 21 and June 4. The samples of sets 3 and 4 were divided into stem, leaf, and head samples and their dry weights recorded on the basis of 100 culms. Stem samples as referred to in this study include both the leaf sheaths and the stems. Large samples were taken in all cases to meet the recommendations of the Committee on Methods of Chemical Analysis for the American Society of Plant Physiologists (Appleman et al., 1926, 1927). As mentioned later the wheats Nittany and Gladden were almost completely winter-killed and therefore no data pertaining to them were included in this study. Trumbull was severely injured but recovered sufficiently to be sampled in sets 3 and 4.

METHODS OF ANALYSIS

Preparation of Samples for Analysis

The samples were redried at 100° C. in a forced-circulation oven. The plant material was first ground in a food chopper and then pulverized still finer with a metal mortar and pestle so that they would pass a 40-mesh sieve. The ground material was then stored in sample bottles until ready for use. Prior to analysis the samples were redried at 100°-105° C. and stored over calcium chloride in a desiccator until portions were weighed for the various determinations.

Determination of Lignin

Preliminary Extraction. A 1-g sample of dry plant material was weighed into a J. Green paper extraction thimble and extracted with 70 percent ethanol in a Bailey-Walker extractor for 12 hours.

Removal of Acid-hydrolyzable Constituents. After the alcohol extraction the sample was washed into a 250 ml Erlenmeyer flask with 150 ml of 1 + 20[2/] hydrochloric acid. The flask was covered with a 50 ml beaker and autoclaved at 15 pounds of pressure for one hour. The contents of the flask were filtered immediately through a fluted filter paper and the residue washed thoroughly with hot distilled water. A hole was punched through the filter paper and the residue washed through into a 100 ml beaker with a minimum of hot water. The sample was then dried at 90° C. in an oven.

Hydrolysis of Cellulose. When dry, the sample was allowed to cool and 2 ml of distilled water were added by means of a pipette. After the sample was moistened, it was cooled in the refrigerator (40° - 44° F.). Thirteen milliliters of 78.9 percent sulphuric acid[3/] were added and the sample stirred with a glass stirring rod. The sulphuric acid was kept at 44° F. or less at all times. After 20 hours in the refrigerator the sample was washed into a 2-l beaker containing 1100 ml of hot, but not boiling, distilled water and the sample beaker washed thoroughly and the washings

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[2/] One volume of hydrochloric acid plus 20 volumes of distilled water.

[3/] 78.9 percent H_2SO_4 made by adding 9.3 parts of acid (sp. gravity 1.84) carefully to 3.7 parts of distilled water by volume in each case.

added, making a final volume of approximately 1200 ml. The sample was boiled gently for two hours, the water of evaporation being replaced occasionally.

Crude Lignin. The boiled sample was allowed to cool and was then filtered through a fluted filter paper. After washing with cool distilled water, the crude lignin residue was washed into a 100-ml beaker and then filtered through a fired and tared Gooch crucible. The crucible was dried at 100° C., cooled, and placed over calcium chloride in a desiccator until weighed.

Determinations were made in triplicate and the determination having the weight of crude lignin nearest the average of the three was taken as the weight of crude lignin in the original sample. The ash in the crude lignin was determined from this particular triplicate and the nitrogen in the crude lignin was determined from the two remaining samples.

Ash in Crude Lignin. The Gooch crucible containing the crude lignin was placed in an electric muffle furnace and brought to red heat gradually within a period of approximately one and one-half hours. At the end of a period of 45 minutes at red heat the current was turned off and the crucible allowed to cool slowly, after which it was placed over calcium chloride in a desiccator until weighed.

Crude Protein in Lignin. Crude protein in each of the two remaining crucibles of the triplicate determination was determined after the following manner: The crude lignin and asbestos were washed from the crucible into a fluted filter paper which, with its contents, was allowed to dry and then was placed in a Kjeldahl flask. The nitrogen in this sample was

was determined after the modified Kjeldahl-Gunning-Arnold method as used by Miller (1939) and the crude protein obtained by multiplying the average of two nitrogen determinations by 6.25.

"Pure" Lignin. "Pure" lignin was determined by subtracting the weights of ash and crude protein from the weight of crude lignin. The results were expressed as percentage of the dry weight of the original sample and as grams per 100 culms. "Pure" lignin was defined as the protein and ash-free residue obtained from dry plant material by the foregoing outlined procedure. With care the procedure can be repeated to within less than five milligrams of pure lignin.

Total Nitrogen, Protein Nitrogen, and Nonprotein Nitrogen Determinations

Total nitrogen and protein nitrogen determinations were made after the methods given previously. Nonprotein nitrogen was determined by subtracting protein nitrogen from total nitrogen. The results of the determinations were expressed as percentage of the dry weight of the original sample and as grams per 100 culms.

CLIMATOLOGICAL AND SOIL MOISTURE DATA

A general summary of the climatic conditions at Manhattan, Kansas, for the winter wheat season of 1940-41 (October 1 to July 1) is given in Table 1. In Table 2 a comparison is made of the temperature and rainfall of this wheat season with the normals of these two factors. October temperatures were very mild, but were followed by a severe cold wave during the second week of November. The temperatures recorded for this cold wave

Table 1.-- Summary of climatic conditions at Manhattan, Kansas, for the wheat season of 1940-41. (Flora, 1940, 1941).

Date	Air temperature(°F.)					Precipitation
			Average			
	Max.	Min.	Max.	Min.	Mean	Inches
1940						
Oct. 1-5	90	52	79	59	69	.04
6-10	83	41	77	49	63	.12
11-15	88	33	79	48	64	.20
16-20	88	40	79	46	63	---
21-25	90	53	86	58	72	---
26-31	83	40	73	52	63	1.08
Nov. 1-5	75	37	67	44	56	T
6-10	61	28	56	38	47	.23
11-15	50	1	31	7	19	.51
16-20	69	23	57	33	45	.90
21-25	46	26	41	30	.36	.39
26-30	63	23	48	29	39	.72
Dec. 1-5	61	16	44	24	34	T
6-10	62	29	56	35	46	---
11-15	37	7	27	18	23	.82
16-20	46	4	35	18	27	.04
21-25	62	25	56	34	45	---
26-31	49	29	56	32	44	.19
1941						
Jan. 1-5	53	11	40	25	32	.04
6-10	60	19	41	26	34	.08
11-15	61	25	50	32	41	.52
16-20	44	7	38	20	29	.34
21-25	47	5	36	21	29	.89
26-31	47	12	38	23	31	.21
Feb. 1-5	61	22	48	28	38	.01
6-10	55	13	45	20	33	---
11-15	60	17	52	28	40	.03
16-20	54	16	40	24	32	.04
21-25	45	16	34	19	27	.10
26-28	42	12	36	18	27	.10
Mar. 1-5	71	18	54	27	41	.33
6-10	47	17	41	26	34	.44
11-15	47	25	43	27	35	.45
16-20	68	12	54	26	40	---
21-25	64	24	58	33	46	---
26-31	75	25	60	36	48	.01

Table 1.--(Contd.)

Date		Air temperature (°F.)					Precipitation
				Average			
		Max.	Min.	Max.	Min.	Mean	Inches
Apr.	1-5	78	38	66	43	55	.24
	6-10	76	40	65	47	56	.78
	11-15	82	46	74	57	66	.20
	16-20	82	38	71	47	59	.48
	21-25	71	35	67	40	54	---
	26-30	77	47	74	51	63	.11
May	1-5	80	55	77	58	68	.52
	6-10	80	44	74	47	61	.33
	11-15	94	46	85	58	72	---
	16-20	87	50	83	60	72	.59
	21-25	85	45	78	56	67	.92
	26-31	91	63	89	68	79	---
June	1-5	83	54	81	62	73	.19
	6-10	80	58	78	62	70	3.36
	11-15	78	53	73	55	64	.25
	16-20	90	55	86	62	74	---
	21-25	96	67	93	69	81	T
	26-30	99	65	94	72	83	T

Table 2.— Comparison of temperature and precipitation during the wheat season of 1940-41 with the normals for a 50-year period. Manhattan, Kansas (Cardwell and Flora, in press).

	Temperature			Precipitation		
Period	Mean	Normal	Departure from normal	Total	Normal	Departure from normal
1940						
October	65.2	55.9	9.3	1.44	2.14	-0.70
November	40.2	44.2	-4.0	2.75	1.83	0.92
December	35.4	31.6	3.8	1.05	0.86	0.19
1941						
January	32.2	29.3	2.9	2.08	0.69	1.39
February	33.1	22.7	0.4	0.28	1.35	-1.07
March	40.8	43.7	-3.1	1.23	2.72	-1.49
April	58.5	55.1	3.4	1.81	2.92	-1.11
May	69.6	64.5	5.1	2.36	4.43	-2.07
June	74.0	74.7	-0.7	3.80	4.69	-0.89

were the lowest ever recorded at Manhattan, Kansas, so early in the season. Some types of vegetation were severely injured and some fruit trees and smaller fruits were almost completely annihilated (Filinger, in press). The temperatures were not excessively low, but they occurred before the plants were sufficiently hardened. The soft wheats Nittany and Gladden that were to have been studied in this investigation were almost completely winter-killed as a result of such vigorous temperature changes. Trumbull was badly damaged but recovered remarkably well with the advent of milder weather. The spring months were mild and not excessively hot.

The total rainfall for the period of October 1, 1940, to July 1, 1941, was 16.80 inches, which was 4.83 inches below normal. For October the rainfall, with the exception of the last week, was comparatively small. The upper foot of soil was, as a result, very dry and it became necessary to irrigate on October 11, 1940, to prevent injury to the wheat seedlings. The period including November, December and January had a positive departure from the normal rainfall of 2.50 inches. During the period of February 1 to July 1, 1941, the rainfall departed negatively from the normal by 6.63 inches. However, an abundant reserve of soil moisture compensated in part for this negative departure.

Soil Moisture

Table 3 records the soil moisture data for the season of 1940-41. The soil samples for the determinations of moisture were taken twice in October and every week, when the weather permitted, after the growing season again started in the spring. The wilting coefficient beyond depths of one foot

Table 3.--The soil moisture content at intervals during the growing season 1940-41, expressed in percentage on a dry basis. Manhattan, Kans.

Date	Depth in feet 1	2	3	4	5	6
1940						
Oct. 14	18.9	19.8	18.3	18.4		
Oct. 21	18.5	20.8	17.5	18.5		
1941						
April 2	19.8	24.1	24.4	23.4		
April 16	20.4	24.4	23.0	23.3	22.4	22.0
April 23	14.3	21.7	21.9	22.4	22.1	21.4
May 7	17.2	22.1	23.8	23.8	23.1	22.9
May 14	17.2	22.2	23.5	22.6	22.2	22.5
May 21	16.6	20.1	22.5	22.1	22.3	21.2
May 28	23.7	20.0	22.4	21.7	21.1	21.4
June 4	13.4	18.3	18.5	18.3	19.4	20.2
Wilting coefficient	12.3	12.3	12.3	12.0		

was not dangerously approached at any time during the season after the irrigation of October 11, 1940. On April 23, 1941, the soil moisture of the upper foot approached to within two percent of the wilting coefficient and to within one percent on June 4, 1941.

EXPERIMENTAL RESULTS

A feature of a group of closely related plants is the varying of a characteristic common to all the members of the group between two extremes. Thus, in the varieties of the species Triticum vulgare one could expect to find characteristics that vary from one extreme to the other. Usually this variation is gradual, particularly in cases where a large population is represented in the group. However, this is not always true for the variations are often distinctly grouped, as seems to be the case in the varieties classed as soft wheats. In comparing the varieties of the soft wheats with those of the hard wheats, it will be noted that for any character that exhibits noticeable variation there will be an overlapping of the lesser extremes of the one group with the greater extremes of the other group. The extent to which this overlapping occurs determines to a great degree the significance of the difference between the two groups. The greater the overlapping, the less significant becomes the difference between the two groups.

It is important that the foregoing discussion be kept in mind as the data presented in this paper are discussed.

The methods used to obtain the data to be discussed have been described in detail in the section on Materials and Methods. In order to simplify the discussion, the samples taken at four different stages of growth will be referred to as sets 1, 2, 3, and 4.

Statistical data are tabulated and include the range, mean, standard error, and F-value, after the methods of Snedecor (1937). If analysis of variance showed the difference between groups to be significant at the one percent level, the difference was said to be "highly significant," whereas differences significant at the five percent level are stated as "significant."

The Dry Weight of the Wheat Plant

In order to simplify the discussion of the growth and development of plants, the convenient term "dry matter" is often used. Too often dry matter is considered as a static entity in itself, there being a failure to remember that dry matter is composed of many and diverse constituents that are dynamic and changing constantly in nature and in the proportions in which they occur in the living plant. Simply defined, dry matter is a collective term for those constituents of a living plant that are not volatile at 100° to 105° C.

The results of dry weight determinations were calculated in set 1 on the dry weight of 100 plants and in sets 2, 3, and 4 on the basis of 100 culms or on plant parts of 100 culms.

<u>The Total Dry Weight.</u> The total dry weight of the plants at the various stages of development and of the various parts is shown in Table 4. In all four sets the total dry weight of the soft wheats was greater than that of the hard wheats. In set 1 the difference was found to be signifi-

Table 4.— The dry weights in grams of 13 varieties of wheat grown at Manhattan, Kans., 1940-41.

Variety	100 plants	100 culms								
			Set 3				Set 4			
	Set 1	Set 2	Heads	Leaves	Stems	Total	Heads	Leaves	Stems	Total
SOFT										
Harvest Queen	16.3	42.0	15.8	23.5	100.4	139.7	58.9	24.6	122.5	206.0
Fulcaster	19.3	44.9	18.0	21.9	90.8	130.7	54.1	18.8	102.8	175.7
Trumbull	24.6	----	18.9	25.1	101.2	145.2	60.3	22.3	105.9	188.5
Clarkan	12.9	44.1	19.7	28.2	112.7	160.6	63.8	22.3	116.3	202.4
HARD										
Kanred	14.9	36.5	14.4	18.3	72.8	105.5	47.5	15.4	73.5	136.4
Blackhull	16.9	38.1	17.3	17.1	72.6	107.0	57.1	16.4	85.6	159.1
Turkey	12.9	32.2	16.3	19.0	73.2	108.5	49.5	16.2	77.0	142.7
Chiefkan	12.9	37.2	17.5	19.8	81.8	119.1	55.0	18.7	92.6	166.3
Tenmarq	11.4	38.4	19.9	18.7	81.6	120.2	58.1	16.2	88.0	162.3
Nebred	11.3	31.6	16.1	17.0	63.8	96.9	41.6	13.8	60.6	116.0
Cheyenne	12.8	34.6	17.1	18.9	72.7	108.7	50.9	16.5	71.0	138.4
Oro	13.2	35.2	17.6	20.6	75.8	114.0	53.2	17.8	80.9	151.9
Early Blackhull	13.7	51.3	18.6	13.6	73.3	105.5	65.0	13.3	85.6	163.9

cant and in set 2 the difference approached significance to such an extent as to warrant some question as to the insignificance of the difference. It would be expected that the initial spring growth rates of the varieties would be different. The change in significance of difference between the two groups of wheat from set 1 to set 2 would seem to indicate this. The data given in Table 4 are treated statistically in Table 5.

It may be seen from Table 5 that differences between the soft and hard wheats became greater as the season progressed and that these differences became highly significant in sets 3 and 4. The total dry weight increased from set 1 through set 4.

The Dry Weight of the Heads, Leaves, and Stems. The total dry weight of the heads was slightly more for the soft wheats in sets 3 and 4, but the differences were insignificant. During the two-week period elapsing between these sets, the dry weight of the heads increased approximately threefold.

The total dry weight of the leaves of the soft wheats was greater than that of the hard wheats in both sets. The differences were found to be highly significant. The total dry weight of the leaves of both groups decreased slightly in set 4.

The difference between the total dry weight of the stems of the soft and hard wheats was striking in both sets. The differences were found to be highly significant. The total dry weight of the stems of both groups increased slightly in set 4.

Percentages of the Total Dry Weight Contributed by the Various Parts. The data relative to this topic are in Table 6, and their statistical treatment in Table 7. The percentage of the total dry weight contributed by the heads was higher in the hard wheats than in the soft varieties.

Table 5.— Statistical comparison of the dry weights of soft and hard wheats grown at Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
1	Hard	11.3	16.9	5.6	13.3	± 0.6	7.62*
	Soft	12.9	24.6	11.7	18.3	± 2.5	
2	Hard	31.6	51.3	19.7	37.5	± 1.9	3.16/
	Soft	42.0	44.9	2.9	43.7	± 0.9	
3	HEADS						
	Hard	14.4	19.9	5.5	17.4	± 0.5	4.40/
	Soft	15.8	19.7	3.9	18.1	± 1.7	
	LEAVES						
	Hard	13.8	20.8	7.0	18.2	± 0.7	23.78**
	Soft	21.9	28.2	6.3	24.7	± 1.4	
	STEMS						
	Hard	63.8	81.8	18.0	74.2	± 1.8	47.48**
	Soft	90.8	112.7	21.9	101.3	± 4.5	
	TOTAL DRY WT.						
	Hard	96.9	120.2	23.3	109.5	± 2.4	40.56**
	Soft	130.7	160.6	29.9	144.1	± 8.6	
4	HEADS						
	Hard	41.6	65.0	23.4	53.1	± 2.3	2.79/
	Soft	54.1	63.8	9.7	59.3	± 2.2	
	LEAVES						
	Hard	13.8	18.7	4.9	16.0	± 0.6	26.65**
	Soft	18.8	24.6	5.8	22.0	± 1.2	
	STEMS						
	Hard	60.6	92.6	32.0	79.4	± 3.3	30.78**
	Soft	102.8	122.5	19.7	111.9	± 4.6	
	TOTAL DRY WT.						
	Hard	116.0	166.3	50.3	148.6	± 5.5	21.76**
	Soft	175.7	206.0	30.3	193.2	± 6.9	

*Significant at 5 percent level.
/Nonsignificant.
**Highly significant at 1 percent level.

Table 6.— The percentage of the total dry weight in grams contained in the heads, leaves and stems of 13 varieties of wheat grown at Manhattan, Kans., 1940-41.

Variety	Set 3			Set 4		
	Heads	Leaves	Stems	Heads	Leaves	Stems
SOFT						
Harvest Queen	11.31	16.82	71.87	28.59	11.94	59.47
Fulcaster	13.77	16.76	69.47	30.79	10.70	58.51
Trumbull	13.02	17.29	69.69	31.99	11.83	56.18
Clarkan	12.27	17.56	70.17	31.52	11.02	57.46
HARD						
Kanred	13.66	17.35	69.00	34.82	11.29	53.89
Blackhull	16.17	15.98	67.85	35.89	10.31	53.80
Turkey	15.02	17.51	67.47	34.69	11.35	53.96
Chiefkan	14.69	16.63	68.68	33.08	11.24	55.68
Tenmarq	16.55	15.56	67.89	35.80	9.98	54.22
Nebred	16.62	17.54	65.84	35.86	11.90	52.24
Cheyenne	15.73	17.39	66.88	36.78	11.92	51.30
Oro	15.44	18.25	66.31	35.02	11.72	53.26
Early Blackhull	17.75	13.03	69.22	39.66	8.11	52.23

Table 7.— Statistical comparison of soft and hard wheats in relation to percentage of total dry weight contained in heads, stems, and leaves. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
3	HEADS						
	Hard	13.65	17.75	4.10	15.74	± 0.40	19.98**
	Soft	11.31	13.77	2.46	12.59	± 0.53	
	LEAVES						
	Hard	13.03	18.25	5.22	16.58	± 0.52	2.40†
	Soft	16.76	17.56	0.80	17.11	± 0.18	
	STEMS						
	Hard	65.84	69.22	3.38	67.68	± 0.39	14.22**
	Soft	69.47	71.87	2.40	70.30	± 0.54	
4	HEADS						
	Hard	33.07	39.66	6.59	35.74	± 0.60	23.32**
	Soft	28.59	31.99	3.40	30.72	± 0.76	
	LEAVES						
	Hard	8.11	11.92	3.81	10.87	± 0.41	1.72†
	Soft	10.70	11.94	1.24	11.37	± 0.30	
	STEMS						
	Hard	51.30	55.68	4.38	53.39	± 0.61	33.06**
	Soft	56.18	59.47	3.29	57.91	± 0.97	

**Highly significant at 1 percent level.

† Nonsignificant.

This difference between the two groups was found to be highly significant.

The leaves contributed the smallest portion to the total dry weight in both sets, and the differences in this regard between the hard and soft wheats were small and nonsignificant. The percentage of the total dry weight contained in the leaves decreased in set 4.

The stems occupied the greatest portion of the total dry weight in both sets. The percentage was higher for the soft wheats and this difference was highly significant. The percentage decreased in both groups in set 4.

<u>The Relation of the Dry Weights of the Leaves and Stems to the Dry Weight of the Heads.</u> The ratios of the weight of leaves to heads, stems to heads, and leaves and stems to heads were determined and recorded in Table 8. The data are treated statistically in Table 9 and show that the values of the ratios were always higher for the soft group than the hard group and these differences were highly significant in all cases with the exception of the ratio of leaves to heads in set 4. In this case the difference was significant at the five percent level, but closely approached the one percent level. All the ratios determined decreased in value in set 4. The ratios were significantly lower in the case of the hard wheats largely because the contribution of the leaves and stems to the total dry weight was so much greater in the soft wheats. Actually there was no significant difference between the two groups in relation to the total dry weight of the heads.

Table 8.--Ratio of the weight of the various parts of the wheat plant to the weight of the heads of 13 varieties grown at Manhattan, Kans., 1940-41.

	Set 3			Set 4		
Variety	Leaves to heads	Stems to heads	Stems and leaves to heads	Leaves to heads	Stems to heads	Stems and leaves to heads
SOFT						
Harvest Queen	1.49	6.35	7.84	0.42	2.08	2.50
Fulcaster	1.22	5.04	6.26	0.35	1.90	2.25
Trumbull	1.33	5.35	6.68	0.37	1.76	2.13
Clarkan	1.43	5.72	7.15	0.35	1.82	2.17
HARD						
Kanred	1.27	5.06	6.33	0.32	1.55	1.87
Blackhull	0.99	4.20	5.18	0.29	1.50	1.79
Turkey	1.17	4.49	5.66	0.33	1.56	1.89
Chiefkan	1.13	4.67	5.81	0.34	1.68	2.02
Tenmarq	0.94	4.10	5.04	0.28	1.51	1.79
Nebred	1.06	3.96	5.02	0.33	1.46	1.79
Cheyenne	1.11	4.25	5.36	0.32	1.39	1.71
Oro	1.18	4.30	5.48	0.33	1.52	1.85
Early Blackhull	0.73	3.90	4.63	0.20	1.32	1.54

Table 9.--Statistical comparison of soft and hard wheats in relation to the ratio of various parts to the head. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
3	LEAVES/HEADS						
	Hard	0.73	1.27	0.54	1.06	± 0.05	11.31**
	Soft	1.22	1.49	0.27	1.37	± 0.08	
	STEMS/HEADS						
	Hard	3.90	5.06	1.16	4.33	± 0.12	25.01**
	Soft	5.04	6.35	1.31	5.62	± 0.27	
	STEMS + LEAVES/HEADS						
	Hard	5.02	6.33	1.31	5.39	± 0.17	22.72**
	Soft	6.26	7.84	1.58	6.98	± 0.34	
4	LEAVES/HEADS						
	Hard	0.20	0.34	0.14	0.30	± 0.01	7.53*
	Soft	0.35	0.42	0.07	0.37	± 0.02	
	STEMS/HEADS						
	Hard	1.32	1.68	0.36	1.50	± 0.04	32.58**
	Soft	1.76	2.08	0.32	1.89	± 0.03	
	STEMS + LEAVES/HEADS						
	Hard	1.54	2.02	0.48	1.81	± 0.05	28.62**
	Soft	2.13	2.50	0.37	2.26	± 0.09	

*Significant at 5 percent level.
**Highly significant at 1 percent level.

Translocation to the Head. The gain or loss in the dry weight of the leaves, stems, and heads and the amount of dry matter absorbed or manufactured and translocated to the head was determined for a two-week period. These data are presented in Table 10. In all varieties but one there was a loss in dry weight of the leaves, but there was little difference between the soft and hard wheats in this regard. In all varieties except two there was an increase in the dry weight of the stems, the increase being twice as great in the case of the soft wheats. Four of the 13 varieties showed a definite decrease in the total dry weight of the leaves and stems. As a group, the soft wheats' increase in the total dry weight of the stems and leaves was about two and one-half times that of the hard wheat group. The dry weight of the heads increased greatly in all varieties, the soft wheat increase being almost 1.2 times the hard wheat increase. There were only four varieties that showed increase in dry weight of the heads to come in part from materials already present in the stems and leaves. The greatest portion of the increase in head weight was due to the translocation of materials that were absorbed and manufactured within the two-week period. There was considerable variation among the varieties studied indicating that they were physiologically different or reacted differently to the environment in the season of 1940-41.

The Lignin of the Wheat Plant

The amounts of lignin in the seedling samples of sets 1 and 2 and the stems of sets 3 and 4 were determined by a method described in detail in the section on Materials and Methods.

Table 10.--Gain or loss in dry weight in grams of leaves, stems, and heads in the two-week period from stage 3 to stage 4. Manhattan, Kans., 1940-41.

Variety	Gain or loss in dry weight of				Dry matter absorbed or manufactured
	Leaves	Stems	Stems + Leaves	Heads	
SOFT					
Harvest Queen	1.1	22.1	23.2	43.1	66.3
Fulcaster	-3.1	12.0	8.9	36.1	45.0
Trumbull	-2.8	4.7	1.9	41.4	43.3
Clarkan	-5.9	3.6	-2.3	44.1	41.8
Mean	-2.7	10.6	7.9	41.2	49.1
HARD					
Kanred	-2.9	0.7	-2.2	33.1	30.9
Blackhull	-0.7	13.0	12.3	39.8	52.1
Turkey	-2.8	3.8	1.0	33.2	34.2
Chiefkan	-1.1	10.8	9.7	37.5	47.2
Tenmarq	-2.5	6.4	3.9	38.2	42.1
Nebred	-3.2	-3.2	-6.4	25.5	19.1
Cheyenne	-2.4	-1.7	-4.1	33.8	29.7
Oro	-3.0	5.3	2.3	35.6	37.9
Early Blackhull	-0.5	12.3	11.8	46.2	58.0
Mean	-2.1	5.2	3.1	35.9	39.0

Percentage of Lignin. These data are recorded in Table 11. The percentage of lignin in the wheat plant increased as the season progressed. In the seedlings the amount of lignin was approximately three to four percent of the dry weight for set 1 and approximately five to seven percent for set 2. Shortly after blooming the stems contained eight to 10 percent lignin based on the dry weight of the stems and two weeks later lignin made up approximately 10 to 11 percent of the dry weight of the stems. The differences between the soft and hard wheats were very small in all sets and were definitely insignificant (Table 12).

Grams of Lignin in 100 Culms. The amount of lignin increased throughout the season as shown in Table 11. No significant differences were observed between the soft and hard wheats during the seedling stages. The lignin content of the soft wheat stems in sets 3 and 4 was higher than that of the hard wheats.

The Nitrogen of the Wheat Plant

The total nitrogen, protein nitrogen, and nonprotein nitrogen were determined for the seedlings of set 1, whole plants of set 2, and for the heads, leaves, and stems of sets 3 and 4. The results were expressed as percentage of dry weight and as grams per 100 plants or per 100 culms.

Percentage of Total Nitrogen. These data are presented in Table 13 and treated statistically in Table 14. Total nitrogen expressed as percentage of dry weight was highest in the seedlings of set 1 and as the season progressed, the percentage decreased. The variation in the varieties studied was not great and only one instance of a significant difference

Table 11.— The percentage on a dry basis and actual amount in grams of lignin in 13 varieties of wheat at four different stages of growth. Manhattan, Kans., 1940-41.

	Whole plants				100 stems			
	Set 1		Set 2		Set 3		Set 4	
Variety	Percent dry wt.	Grams	Percent dry wt.	Grams	Percent dry wt.	Grams	Percent dry wt.	Grams
SOFT								
Harvest Queen	4.49	0.73	7.18	3.02	8.79	8.83	10.67	13.07
Fulcaster	3.66	0.70	5.98	2.69	8.28	7.52	10.08	10.34
Trumbull	4.40	1.08	----	----	8.18	8.28	10.30	10.91
Clarkan	3.88	0.50	5.83	2.57	10.53	11.87	10.97	12.76
HARD								
Kanred	4.12	0.61	8.24	2.40	9.13	6.65	10.32	7.59
Blackhull	3.77	0.64	5.54	2.11	9.03	6.56	11.08	9.48
Turkey	4.30	0.55	5.41	1.74	8.14	5.96	10.46	8.05
Chiefkan	3.34	0.43	7.13	2.65	9.06	7.41	11.19	10.36
Tenmarq	3.38	0.39	5.68	2.18	8.82	7.20	10.31	9.07
Nebred	4.47	0.51	7.59	2.40	9.16	5.86	11.07	6.70
Cheyenne	3.85	0.49	7.23	2.50	9.34	6.79	11.10	7.88
Oro	4.00	0.53	5.64	1.99	6.86	6.70	11.14	9.01
Early Blackhull	3.91	0.54	5.99	3.07	9.28	6.80	10.63	9.10

Table 12.--Statistical comparison of lignin in soft and hard wheats. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
			Percentage on a Dry Basis				
1	Hard	3.34	4.47	1.13	3.68	± 0.26	1.00†
	Soft	3.66	4.49	0.83	4.11	± 0.20	
2	Hard	5.41	7.59	2.18	6.27	± 0.24	87.93†
	Soft	5.83	7.18	1.35	6.30	± 0.37	
3	STEMS						
	Hard	8.14	9.34	1.20	8.98	± 0.12	110.05†
	Soft	8.18	10.53	2.35	8.95	± 0.54	
4	STEMS						
	Hard	10.31	11.19	0.88	10.81	± 0.13	6.26†
	Soft	10.06	10.97	0.93	10.50	± 0.20	
			Actual Amount in Grams				
1	Hard	0.39	0.64	0.25	0.52	± 0.03	1.14†
	Soft	0.50	1.08	0.58	0.75	± 0.33	
2	Hard	1.74	3.07	1.33	2.34	± 0.13	3.01†
	Soft	2.57	3.02	0.45	2.07	± 0.12	
3	STEMS						
	Hard	5.86	7.41	1.55	6.66	± 0.17	14.31**
	Soft	7.52	11.87	4.35	9.13	± 0.95	
4	STEMS						
	Hard	6.70	10.36	3.66	8.58	± 0.37	20.08**
	Soft	10.34	13.07	2.73	11.77	± 0.67	

† Nonsignificant.
**Highly significant at 1 percent level.

Table 13.--The percentage of total nitrogen of 13 varieties of wheat at four different stages of growth. Manhattan, Kans., 1940-41.

Variety	Set 1	Set 2	Set 3			Set 4		
			Heads	Leaves	Stems	Heads	Leaves	Stems
SOFT								
Harvest Queen	4.05	2.38	1.59	2.04	0.56	1.54	1.26	0.43
Fulcaster	4.42	2.38	1.72	2.35	0.64	1.62	1.19	0.42
Trumbull	4.21	----	1.69	2.18	0.58	1.55	1.27	0.43
Clarkan	4.12	2.51	1.84	2.46	0.67	1.59	1.15	0.43
HARD								
Kanred	4.09	1.85	1.74	1.80	0.56	1.48	1.02	0.43
Blackhull	4.26	2.00	1.70	2.00	0.66	1.53	1.13	0141
Turkey	4.13	2.29	1.76	1.92	0.57	1.59	1.25	0.50
Chiefkan	4.15	2.60	1.75	2.28	0.72	1.59	1.44	0.60
Tenmarq	4.12	2.25	1.64	1.98	0.62	1.45	1.05	0.41
Nebred	4.04	2.49	1.77	2.28	0.65	1.48	1.42	0.42
Cheyenne	4.07	2.34	1.83	1.89	0.60	1.52	1.13	0.41
Oro	4.04	2.36	1.78	1.87	0.63	1.55	1.05	0.43
Early Blackhull	4.15	1.89	1.66	1.86	0.71	1.52	1.00	0.46

Table 14.–Statistical comparison of the percentage of total nitrogen in soft and hard wheats. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
1	Hard	4.04	4.26	0.22	4.12	± 0.02	1.84†
	Soft	4.05	4.42	0.37	4.20	± 0.06	
2	Hard	1.85	2.60	0.75	2.23	± 0.09	1.49†
	Soft	2.38	2.51	0.13	1.82	± 0.05	
3	HEADS						
	Hard	1.64	1.83	0.19	1.74	± 0.02	4.66†
	Soft	1.59	1.72	0.13	1.66	± 0.03	
	LEAVES						
	Hard	1.80	2.28	0.48	1.99	± 0.06	6.33*
	Soft	2.04	2.46	0.42	2.26	± 0.09	
	STEMS						
	Hard	0.56	0.72	0.16	0.64	± 0.02	2.00†
	Soft	0.58	0.67	0.09	0.61	± 0.03	
4	HEADS						
	Hard	1.45	1.59	0.14	1.52	± 0.01	3.52†
	Soft	1.54	1.62	0.08	1.58	± 0.02	
	LEAVES						
	Hard	1.00	1.44	0.44	1.17	± 0.06	2.89†
	Soft	1.15	1.27	0.12	1.22	± 0.03	
	STEMS						
	Hard	0.41	0.60	0.19	0.45	± 0.02	1.75†
	Soft	0.42	0.43	0.01	0.43	± 0.01	

† Nonsignificant.
* Significant at 5 percent level.

between the soft and hard wheats was noted. The mean of the leaves of the soft wheats in set 3 was 2.26 as compared to the hard wheat mean of 1.99, a difference that was significant. In set 4 the difference in the leaves of the two groups became nonsignificant.

Grams of Total Nitrogen in 100 Plants or 100 Culms (Tables 15 and 16). The total amount of nitrogen in the plant as a whole was higher in the soft wheats than in the hard wheats. The differences between the two groups of wheat in this respect were highly significant in all sets except set 1, the difference there being significant at the five percent level. The total amount of nitrogen in the plant increased in amount from set 1 through set 4.

There was no difference in the two groups of wheat in set 3 in so far as the total nitrogen of the heads was concerned. However, in set 4 the soft wheat heads were higher in total nitrogen than the hard wheats. The significance of the difference was very near the five percent level. This change was due to greater translocation of nitrogen to the heads in the case of the soft wheats (Table 23). The total nitrogen of the soft wheat heads increased 3.1 times in set 4 over the amount present in set 3. The increase was 2.7 times in the hard wheats.

In set 3 the difference between the stems of the hard wheats and soft wheats in total nitrogen content was highly significant. However, in set 4 the difference was only significant. The nitrogen content of the stems of both groups was less in set 4 than in set 3.

Table 15.--The actual amount of total nitrogen in grams in 13 varieties of wheat at four different stages of growth. Manhattan, Kans., 1940-41.

Variety	100 plants		100 culms							
			Set 3				Set 4			
	Set 1	Set 2	Heads	Leaves	Stems	Total	Heads	Leaves	Stems	Total
SOFT										
Harvest Queen	0.66	1.00	0.25	0.48	0.56	1.29	0.91	0.31	0.53	1.75
Fulcaster	0.85	1.07	0.31	0.51	0.58	1.40	0.88	0.22	0.43	1.53
Trumbull	1.04	----	0.32	0.55	0.59	1.46	0.93	0.28	0.46	1.67
Clarkan	0.53	1.11	0.32	0.69	0.76	1.77	1.01	0.26	0.50	1.77
HARD										
Kanred	0.61	0.71	0.25	0.33	0.41	0.99	0.70	0.16	0.32	1.18
Blackhull	0.72	0.76	0.29	0.34	0.48	1.11	0.87	0.19	0.35	1.41
Turkey	0.53	0.74	0.29	0.36	0.42	1.07	0.79	0.20	0.39	1.36
Chiefkan	0.54	0.97	0.31	0.45	0.59	1.35	0.87	0.27	0.56	1.70
Tenmarq	0.47	0.86	0.33	0.37	0.51	1.21	0.84	0.17	0.36	1.37
Nebred	0.46	0.79	0.28	0.39	0.41	1.08	0.62	0.20	0.25	1.07
Cheyenne	0.52	0.81	0.31	0.36	0.44	1.11	0.77	0.19	0.29	1.25
Oro	0.53	0.83	0.31	0.39	0.48	1.18	0.82	0.19	0.35	1.36
Early Blackhull	0.57	0.97	0.31	0.26	0.52	1.09	0.99	0.13	0.39	1.51

Table 16.--Statistical comparison of the actual amount of total nitrogen in soft and hard wheats. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
1	Hard	0.47	0.72	0.25	0.55	± 0.03	7.45*
	Soft	0.53	1.04	0.51	0.77	± 0.11	
2	Hard	0.71	0.97	0.26	0.83	± 0.03	16.33**
	Soft	1.00	1.11	0.11	1.06	± 0.03	
3	HEADS						
	Hard	0.25	0.31	0.06	0.30	± 0.01	----
	Soft	0.25	0.32	0.07	0.30	± 0.02	
	LEAVES						
	Hard	0.26	0.45	0.19	0.36	± 0.02	24.84**
	Soft	0.48	0.69	0.21	0.56	± 0.05	
	STEMS						
	Hard	0.41	0.59	0.18	0.47	± 0.02	12.32**
	Soft	0.56	0.76	0.20	0.62	± 0.05	
	TOTAL						
	Hard	0.99	1.35	0.36	1.13	± 0.03	18.20**
	Soft	1.29	1.77	0.48	1.48	± 0.10	
4	HEADS						
	Hard	0.62	0.99	0.37	0.81	± 0.04	4.73†
	Soft	0.88	1.01	0.13	0.93	± 0.03	
	LEAVES						
	Hard	0.13	0.27	0.14	0.19	± 0.01	12.21**
	Soft	0.22	0.31	0.09	0.27	± 0.02	
	STEMS						
	Hard	0.25	0.56	0.31	0.38	± 0.03	6.40*
	Soft	0.43	0.53	0.10	0.48	± 0.02	
	TOTAL						
	Hard	1.07	1.70	0.67	1.36	± 0.06	10.27**
	Soft	1.53	1.77	0.24	1.68	± 0.05	

* Significant at 5 percent level.
**Highly significant at 1 percent level.
† Nonsignificant.

Percentage of Protein Nitrogen. In Table 17 is shown the percentage of protein nitrogen in the plants at four different stages of development. These results are treated statistically in Table 18. In the plants of the various types of wheat from 75 to 80 percent of the total nitrogen was found in protein. The percentage of protein nitrogen decreased throughout the season. There was very little variation in the percentage of protein nitrogen among the varieties studied and with the exception of the heads and leaves of set 3 there were no significant differences between the soft and hard wheats. In set 3 the heads of the hard wheats contained a greater percentage of protein nitrogen than did the heads of the soft wheats and this difference was highly significant. The fact that larger amounts of protein nitrogen were translocated into the soft wheat heads than the hard wheat heads accounts for the insignificance of the difference between the groups in set 4. There was a significant difference between the leaves of the two groups in set 3. The soft wheat leaves contained a larger percentage of protein nitrogen. The difference between the two kinds of wheat became insignificant in set 4.

Grams of Protein Nitrogen. The grams of protein nitrogen in 100 plants or in 100 culms are shown in Table 19, and the statistical analyses of these data are shown in Table 20. The total amount of protein nitrogen in the plant increased in all varieties as the season progressed, being always higher in the soft wheats. The difference between the soft and hard wheats in this respect was highly significant in all sets except set 1 where it very closely approached the one percent level.

Table 17.— The percentage of protein nitrogen of 13 varieties of wheat at four different stages of growth. Manhattan, Kans., 1940-41.

Variety	Set 1	Set 2	Set 3			Set 4		
			Heads	Leaves	Stems	Heads	Leaves	Stems
SOFT								
Harvest Queen	3.30	1.83	1.21	1.70	0.41	1.19	0.98	0.33
Fulcaster	3.49	1.86	1.33	1.90	0.50	1.28	0.92	0.33
Trumbull	3.31	----	1.23	1.80	0.44	1.19	1.02	0.32
Clarkan	3.36	1.98	1.18	2.01	0.54	1.25	0.86	0.31
HARD								
Kanred	3.22	1.35	1.39	1.43	0.43	1.17	0.78	0.31
Blackhull	3.43	1.54	1.34	1.63	0.52	1.22	0.92	0.30
Turkey	3.31	1.76	1.39	1.53	0.45	1.26	0.97	0.39
Chiefkan	3.33	2.04	1.32	1.86	0.67	1.20	1.16	0.46
Tenmarq	3.31	1.74	1.33	1.58	0.44	1.13	0.82	0.31
Nebred	3.22	2.01	1.39	1.85	0.46	1.14	1.16	0.33
Cheyenne	3.26	1.84	1.41	1.53	0.45	1.19	0.87	0.31
Oro	3.23	1.85	1.37	1.46	0.47	1.19	0.82	0.31
Early Blackhull	3.30	1.57	1.34	1.56	0.55	1.19	0.81	0.36

Table 18.--Statistical comparison of the percentage of protein nitrogen in soft and hard wheats. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
1	Hard	3.22	3.43	0.21	3.29	± 0.02	2.89†
	Soft	3.30	3.49	0.19	3.37	± 0.05	
2	Hard	1.35	2.04	0.69	1.74	± 0.07	1.14†
	Soft	1.83	1.98	0.15	1.89	± 0.06	
3	HEADS						
	Hard	1.32	1.41	0.09	1.36	± 0.01	23.53**
	Soft	1.18	1.33	0.15	1.24	± 0.03	
	LEAVES						
	Hard	1.43	1.86	0.43	1.60	± 0.05	7.74*
	Soft	1.70	2.01	0.31	1.85	± 0.09	
	STEMS						
	Hard	0.43	0.67	0.24	0.49	± 0.03	4.33†
	Soft	0.41	0.54	0.13	0.47	± 0.03	
4	HEADS						
	Hard	1.13	1.26	0.13	1.19	± 0.01	2.53†
	Soft	1.19	1.28	0.09	1.23	± 0.02	
	LEAVES						
	Hard	0.78	1.16	0.38	0.92	± 0.05	13.06†
	Soft	0.86	1.02	0.16	0.95	± 0.04	
	STEMS						
	Hard	0.30	0.46	0.16	0.34	± 0.02	1.91†
	Soft	0.31	0.33	0.02	0.32	± 0.01	

† Nonsignificant.
* Significant at 5 percent level.
**Highly significant at 1 percent level.

Table 19.--The amount of protein nitrogen in grams in 13 varieties of wheat at four different stages of growth. Manhattan, Kans., 1940-41.

Variety	100 plants	100 culms								
	Set 1	Set 2	Set 3				Set 4			
			Heads	Leaves	Stems	Total	Heads	Leaves	Stems	Total
SOFT										
Harvest Queen	0.54	0.77	0.19	0.40	0.41	1.00	0.70	0.24	0.40	1.34
Fulcaster	0.67	0.84	0.24	0.42	0.45	1.11	0.69	0.17	0.34	1.20
Trumbull	0.81	----	0.23	0.45	0.45	1.13	0.72	0.23	0.34	1.29
Clarkan	0.43	0.87	0.23	0.57	0.61	1.41	0.80	0.19	0.36	1.35
HARD										
Kanred	0.46	0.52	0.20	0.26	0.31	0.77	0.56	0.12	0.23	0.91
Blackhull	0.58	0.59	0.23	0.28	0.38	0.89	0.70	0.15	0.26	1.11
Turkey	0.43	0.67	0.23	0.29	0.33	0.85	0.62	0.16	0.30	1.08
Chiefkan	0.43	0.76	0.23	0.37	0.55	1.15	0.66	0.22	0.43	1.31
Tenmarq	0.38	0.67	0.26	0.30	0.36	0.92	0.66	0.13	0.27	1.06
Nebred	0.36	0.64	0.22	0.31	0.29	0.82	0.47	0.16	0.20	0.83
Cheyenne	0.42	0.64	0.24	0.29	0.33	0.86	0.61	0.14	0.22	0.97
Oro	0.43	0.65	0.24	0.30	0.36	0.90	0.63	0.15	0.25	1.03
Early Blackhull	0.45	0.81	0.25	0.22	0.40	0.87	0.77	0.11	0.31	1.19

Table 20.—Statistical comparison of the amount of protein nitrogen in soft and hard wheats. Manhattan, Kans., 1940-41.

Set	Group	Low	High	Range	Mean	Standard error	F-value
1	Hard	0.36	0.58	0.22	0.44	± 0.02	8.08*
	Soft	0.43	0.81	0.38	0.61	± 0.08	
2	Hard	0.52	0.81	0.29	0.65	± 0.03	10.03**
	Soft	0.77	0.87	0.10	0.83	± 0.03	
3	HEADS						
	Hard	0.20	0.26	0.06	0.23	± 0.003	1.33†
	Soft	0.19	0.24	0.05	0.22	± 0.01	
	LEAVES						
	Hard	0.22	0.37	0.15	0.29	± 0.01	28.21**
	Soft	0.40	0.57	0.17	0.46	± 0.04	
	STEMS						
	Hard	0.29	0.55	0.26	0.37	± 0.03	5.45*
	Soft	0.41	0.61	0.20	0.48	± 0.05	
	TOTAL						
	Hard	0.77	1.15	0.38	0.89	± 0.04	12.25**
	Soft	1.00	1.41	0.41	1.16	± 0.08	
4	HEADS						
	Hard	0.47	0.77	0.30	0.63	± 0.03	4.36†
	Soft	0.69	0.80	0.11	0.73	± 0.03	
	LEAVES						
	Hard	0.11	0.22	0.11	0.15	± 0.01	9.50*
	Soft	0.17	0.24	0.07	0.21	± 0.02	
	STEMS						
	Hard	0.20	0.43	0.23	0.27	± 0.02	5.61*
	Soft	0.34	0.40	0.06	0.38	± 0.02	
	TOTAL						
	Hard	0.83	1.31	0.48	1.05	± 0.05	9.77**
	Soft	1.20	1.35	0.15	1.30	± 0.03	

* Significant at 5 percent level.
**Highly significant at 1 percent level.
† Nonsignificant.

The amount of protein nitrogen in the heads increased greatly in the two-week period represented by sets 3 and 4, increasing approximately 2.8 times in the case of the hard wheats and approximately 3.3 times in the soft wheats. There was practically no difference in the amounts present in the soft and hard wheat heads of set 3, but because of a greater increase of protein nitrogen in the heads of the soft wheats, the difference between the two groups approached the five percent level in set 4.

The protein nitrogen content of the soft wheat leaves in set 3 was approximately 1.6 times that of the hard wheat leaves, a highly significant difference. In set 4 the difference, though not marked, was significant. The amount of protein nitrogen in the soft wheat leaves in set 4 was 1.4 times that of the hard wheat leaves. There was a decrease in the amount of protein nitrogen in set 4 over set 3 in both groups of wheat.

The stems of the soft wheats contained more protein nitrogen than the hard wheats in both sets and the difference was significant in each set. The amount of protein nitrogen decreased in both groups during the two-week period, the soft wheats decreasing slightly more than the hard wheats.

Percentage of Nonprotein Nitrogen. The percentage of nonprotein nitrogen in the plant as a whole fluctuated from set to set. There was a decrease in set 2 over set 1 and then a rise in set 3, followed by a decrease in set 4. There were no significant differences in the percentage of nonprotein nitrogen in the soft and hard wheats in any respect.

Grams of Nonprotein Nitrogen in 100 Plants or 100 Culms. The nonprotein nitrogen content of the entire plant increased during the season, the soft wheats having a higher content at each stage than the hard wheats.

The difference between the two groups of wheat was significant in set 1 and highly significant in the other three sets.

The heads of the soft wheats contained more nonprotein nitrogen than the heads of the hard wheats in both sets 3 and 4. The difference was significant in set 3, but only approached significance in set 4. There was approximately a threefold increase in the nonprotein nitrogen of the heads of both groups during the two-week period represented by sets 3 and 4.

Between the nonprotein nitrogen content of the leaves of both groups of wheat for sets 3 and 4, there was a highly significant difference, but the content was higher in the soft wheats. There was a decrease in the amount present for both groups in set 4.

The greater content of nonprotein nitrogen in the stems of the soft wheats of both sets was significant. There was a very slight decrease in the nonprotein nitrogen of the stems in set 4.

Translocation of Nitrogen. The gain or loss in grams of total nitrogen, protein nitrogen, and nonprotein nitrogen in the various parts of the wheat plant was determined for a two-week period. There was a decrease in the amount of protein nitrogen in both leaves and stems of all varieties studied (Table 21). The amount of protein nitrogen in the heads increased for all varieties and this increase was greater than the decrease in the leaves and stems except in the variety Clarkan. The decrease in the leaves and stems represents materials translocated to other portions of the plant. With the exception of Clarkan the translocation was to the heads. Since the increase in the heads was usually greater than the dedrease in the stems and leaves, it is logical to assume that this excess had its origin

Table 21.--Gain or loss in grams of protein nitrogen in leaves, stems and heads in a two-week period and the amount absorbed from the roots or soil during that time. Manhattan, Kans., 1940-41.

Variety	Gain or loss in protein nitrogen of Leaves	Stems	Stems + Leaves	Heads	Amount absorbed from the roots or from the soil
SOFT					
Harvest Queen	-0.16	-0.01	-0.17	0.51	0.34
Fulcaster	-0.25	-0.11	-0.36	0.45	0.09
Trumbull	-0.22	-0.11	-0.33	0.49	0.16
Clarkan	-0.38	-0.25	-0.63	0.57	-0.06
HARD					
Kanred	-0.14	-0.08	-0.22	0.36	0.14
Blackhull	-0.13	-0.12	-0.25	0.47	0.22
Turkey	-0.13	-0.03	-0.16	0.39	0.23
Chiefkan	-0.15	-0.12	-0.27	0.43	0.16
Tenmarq	-0.17	-0.09	-0.26	0.40	0.14
Nebred	-0.15	-0.09	-0.24	0.25	0.01
Cheyenne	-0.15	-0.11	-0.26	0.37	0.11
Oro	-0.15	-0.11	-0.26	0.39	0.13
Early Blackhull	-0.11	-0.09	-0.20	0.45	0.25

in the roots, being translocated from the roots or absorbed from the soil and subsequently translocated. In the case of Clarkan the decrease in the leaves and stems exceeded the head increase by 0.06 of a gram. This can be explained by assuming that 0.06 of a gram was translocated to the roots. It could also be explained by the occurrence of defoliation in set 4, or by the presence of an error which defies location. The protein nitrogen of the soft wheat leaves decreased much more than that of the hard wheat leaves and it was found that this difference was highly significant (Table 24). The protein nitrogen of the soft wheat stems decreased more than that of the hard wheat stems but not significantly so. It was found that the protein nitrogen increase of the soft wheat heads was more than that of the hard wheat heads and the difference was highly significant. There was only a slight and nonsignificant difference in the amount of nitrogen absorbed and converted to protein in the heads of the two groups of wheat.

Nonprotein nitrogen decreased in the leaves of all varieties (Table 22) but increased in the stems of all except Turkey and Chiefkan. Nonprotein nitrogen increased in the heads of all varieties, and with one exception this increase was greater than the decrease in the corresponding materials of the leaves and stems. Some nonprotein nitrogen was translocated from the roots to the heads in the case of all varieties except Nebred. There were no significant differences between the soft and hard wheats in relation to loss or gain or translocation of nonprotein nitrogen in any of the various parts of the wheat plant (Table 24).

Table 22.—Gain or loss in grams of nonprotein nitrogen in leaves, stems, and heads in a two-week period and the amount absorbed from the roots or soil in that time. Manhattan, Kans., 1940-41.

Variety	Gain or loss in nonprotein nitrogen of				Amount absorbed from the roots or from the soil
	Leaves	Stems	Stems + Leaves	Heads	
SOFT					
Harvest Queen	-0.01	-0.02	-0.03	0.15	0.12
Fulcaster	-0.04	-0.04	-0.08	0.12	0.04
Trumbull	-0.05	-0.02	-0.07	0.12	0.05
Clarkan	-0.05	-0.01	-0.06	0.12	0.06
HARD					
Kanred	-0.03	-0.01	-0.04	0.09	0.05
Blackhull	-0.02	-0.01	-0.03	0.11	0.08
Turkey	-0.03	0.00	-0.03	0.11	0.08
Chiefkan	-0.03	0.09	0.06	0.13	0.19
Tenmarq	-0.03	-0.06	-0.09	0.11	0.02
Nebred	-0.04	-0.07	-0.11	0.09	-0.02
Cheyenne	-0.02	-0.04	-0.06	0.09	0.03
Oro	-0.05	-0.02	-0.07	0.12	0.05
Early Blackhull	-0.02	-0.04	-0.06	0.16	0.10

Table 23.--Gain or loss in grams of total nitrogen in leaves, stems, and heads in a two-week period and amount absorbed from the roots or soil during that period. Manhattan, Kans., 1940-41.

Variety	Gain or loss in nonprotein nitrogen of Leaves	Stems	Stems + Leaves	Heads	Amount absorbed from the roots or from the soil
SOFT					
Harvest Queen	-0.17	-0.03	-0.20	0.66	0.46
Fulcaster	-0.29	-0.15	-0.44	0.57	0.13
Trumbull	-0.27	-0.13	-0.40	0.61	0.21
Clarkan	-0.43	-0.26	-0.69	0.69	0.00
HARD					
Kanred	-0.17	-0.09	-0.26	0.45	0.19
Blackhull	-0.15	-0.13	-0.28	0.58	0.30
Turkey	-0.16	-0.03	-0.19	0.50	0.31
Chiefkan	-0.18	-0.03	-0.21	0.56	0.35
Tenmarq	-0.20	-0.15	-0.35	0.51	0.16
Nebred	-0.19	-0.16	-0.35	0.34	-0.01
Cheyenne	-0.17	-0.15	-0.32	0.46	0.14
Oro	-0.20	-0.13	-0.33	0.51	0.18
Early Blackhull	-0.13	-0.13	-0.26	0.68	0.42

Table 24.—Statistical comparison of soft and hard wheats in relation to gain or loss of nitrogen in leaves, stems, and heads during a two-week period and amount absorbed from the roots or soil during that time. Manhattan, Kans., 1940-41.

Group	Mean	Standard error	F-value
	Total Nitrogen		
LEAVES			
Hard	-0.17	± 0.01	10.97**
Soft	-0.29	± 0.05	
STEMS			
Hard	-0.11	± 0.02	1.59†
Soft	-0.14	± 0.05	
STEMS + LEAVES			
Hard	-0.28	± 0.02	4.55†
Soft	-0.43	± 0.10	
HEADS			
Hard	0.51	± 0.03	5.70*
Soft	0.63	± 0.03	
AMOUNT ABSORBED FROM THE ROOTS OR SOIL			
Hard	0.23	± 0.06	5.61†
Soft	0.20	± 0.10	
	Protein Nitrogen		
LEAVES			
Hard	-0.14	± 0.01	12.92**
Soft	-0.25	± 0.05	
STEMS			
Hard	-0.09	± 0.01	1.60†
Soft	-0.12	± 0.05	
STEMS + LEAVES			
Hard	-0.24	± 0.01	4.76†
Soft	-0.38	± 0.09	
HEADS			
Hard	0.39	± 0.02	10.16**
Soft	0.51	± 0.03	

Table 24.--(Contd.)

Group	Mean	Standard error	F-value
AMOUNT ABSORBED FROM THE ROOTS OR SOIL			
Hard	0.15	± 0.02	1.77†
Soft	0.13	± 0.08	
	Nonprotein Nitrogen		
LEAVES			
Hard	-0.03	± 0.003	2.00†
Soft	-0.04	± 0.01	
STEMS			
Hard	-0.02	± 0.02	----
Soft	-0.02	± 0.01	
STEMS + LEAVES			
Hard	-0.05	± 0.02	4.50†
Soft	-0.03	± 0.01	
HEADS			
Hard	0.11	± 0.01	1.50†
Soft	0.13	± 0.01	
AMOUNT ABSORBED FROM THE ROOTS OR SOIL			
Hard	0.05	± 0.02	----
Soft	0.07	± 0.02	

*Significant at 5 percent level.
**Highly significant at 1 percent level.
† Nonsignificant.

SUMMARY

1. Nine varieties of hard wheats and four varieties of soft wheats were grown in random rows during the season of 1940-41 for the purpose of determining, if possible, the difference between hard and soft wheats.

2. Four sets of samples were collected throughout the growing season. One set of samples was collected in the fall, one in the early spring, one at blooming time, and the last set two weeks after blooming. The last two sets were divided into stems, leaves, and heads.

3. The plants were killed with dry heat and ground to minus 40-mesh fineness. All samples were dried at 100°-105° C. prior to analysis.

4. The dry weight, total nitrogen, protein nitrogen, and nonprotein nitrogen were determined for all samples. Lignin was determined for the seedling samples of sets 1 and 2 and for the stem samples of sets 3 and 4. The dry weight data were expressed as grams per 100 plants in set 1 and as grams per 100 culms or parts thereof for the other three sets. Analytical results were expressed as percentage of dry weight and as grams per 100 plants, or 100 culms or parts thereof.

5. The soft wheats as a group have a more rapid growth rate and contain significantly more dry matter at all stages of growth than do the hard wheats. This difference is manifest mostly in the leaves and stems of the soft wheats, there being no significant difference in the total dry matter of the heads of the two groups. The most striking difference observed between the two groups of wheat is the larger total dry weight of the stems of the soft wheats.

6. The ratios of the weight of leaves to heads, stems to heads, and leaves and stems to heads were always significantly higher for the soft wheats than the hard wheats. Because of the heavier weight of the stems and leaves of the soft wheats, the percentage of total dry weight contributed by the heads was significantly higher in the hard wheats.

7. There was considerable variation in the varieties as to the amount of dry matter translocated to the heads during a two-week period, indicating distinct physiological differences between the varieties studied.

8. The varieties of soft and hard wheats studied showed little variation in the percentage of lignin in the dry matter. The actual amount of lignin present in the soft wheat stems thus was significantly greater than that present in the hard wheat stems because of the greater amount of dry matter present in the soft wheats.

9. The variation in the percentage of nitrogen present in the dry matter of the varieties studied was not marked, but the total amount of nitrogen in the plant as a whole was significantly higher in the soft wheats than in the hard wheats.

10. Seventy-five to 85 percent of the total nitrogen of the wheat plant was protein nitrogen. Although there was little variation in the percentage of protein nitrogen among the varieties studied, the total amount was significantly greater in the soft wheats than in the hard wheats.

11. No significant differences were observed in the percentages of nonprotein nitrogen in the varieties studied; however, because of the higher dry matter in the soft wheats, the actual amount of nonprotein nitrogen was significantly larger than in the hard wheats.

12. The soft wheats translocated more protein nitrogen from the leaves to the heads than did the hard wheats, but there was no significant difference relative to the amount of nitrogen absorbed and converted to protein by the heads of the two groups.

13. In general there was little difference in the varieties studied as to their percentage composition. However, due to much larger content of dry matter in the soft wheats, the actual amount of the constituents studied was significantly more than in the hard wheats.

14. The two groups of wheat studied differed physiologically as shown by their difference in growth rate and the amount of material they were capable of absorbing and translocating to the heads.

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