A STUDY OF THE ESSENTIAL NUTRIENT CONTENT OF SASKATCHEWAN FEED GRAINS

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Klaus Heinrich Hoppner

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CERTIFICATION OF THESIS WORK

We, the undersigned, certify that Klaus Heinrich Hoppner, B.S.A.

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has presented his thesis on the subject, A Study of the Essential Nutrient Content of Saskatchewan Feed Grains

that the thesis is acceptable in form and content, and that the student demonstrated a satisfactory knowledge of the field covered by this thesis in an oral examination held on

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AUTOBIOGRAPHY

The author was born at Neustettin, Province of Pommern, Germany on May 14, 1934, where he received his public school and part of his high school education. In June 1953, he immigrated to Birsay, Saskatchewan, Canada. For four years he studied Agriculture at the University of Saskatchewan and received the Bachelor of Science Degree in Agriculture (B.S.A.) in 1964. In September of 1964, an assistantship was obtained in the Department of Animal Science to study towards a M. Sc. Degree.

In 1958, the author married Karin Margot Luttger of Oberdollendorf am Rhein, Germany. They have three sons: Klaus, Kenneth and Kirk.

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1. INTRODUCTION

A fundamental principle recognized in all studies of nutritive requirements was set forth by Haecker in these words as quoted by Maynard and Loosli (40): "In order to determine the actual net nutrients required to produce a given animal product, the composition of the product should be known, as well as the composition and the available nutrients in food which is to be fed for its production, so that the nutrients in the ration might be provided in the proportions needed by the animal."

At the present time, feed grain composition data of Canadian origin is seriously lacking, and it is necessary, therefore, to rely on analytical data from elsewhere, mainly the U.S.A. There is evidence available (28, 48, 52) indicating that levels of certain nutrients in Western Canadian grains differ appreciably from those reported by the National Research Council (U.S.). There is evidence also for variations attributable to soil type and climate (28, 43, 66, 52).

According to interpretation from Grain Trade of Canada, D.B.S. statistics calculated as a percentage of domestic use in 1954/55, about 46.7% of the wheat, 90.3% of the oats, and 80.3% of the barley were utilized as livestock feed. In 1964/65 the same statistics were 31.5% for wheat, 92.7% for oats, and 83.4% for barley (24). The benefit derived in the future by Canadian livestock industry from collecting complete feed composition data across Canada on a provincial basis, showing within province variation due to soil zone, soil type and climate, therefore, could be substantial.

The study reported herein was initiated in 1964 to obtain additional data on the composition of Saskatchewan feed grains and to study effects of soil zone, soil type, climatic variation and grain variety on nutrient composition. It is intended that the project be continued for a minimum of five years in order that seasonal variations be adequately measured. Results of this study, for the proximate principles and B complex vitamins in samples obtained from the 1964 and 1965 crops, are reported in this thesis.

2. LITERATURE REVIEW

With Thaer's "Hay values" at the beginning of the 19th century evolved the concept and recognition of a chemical basis for feeding animals, as well as the field of feed analysis. Henneberg and Stohmann, working at the Weende Experiment Station in Germany, devised in 1865 a scheme for the routine description and analysis of feedstuffs. According to it, a feedstuff is partitioned into six fractions as follows: water; ash; crude protein; crude fiber; ether extract; nitrogen free extract, the latter being arrived at by difference. It is now commonly referred to as the proximate analysis and still provides the basis for the everyday chemical description of feeds and for the feeding standards of all animal species.

Similarly, as other nutrients and the vitamins were recognized one by one, these became part of the field of feed analysis also.

The nature, peculiarities and the limitations of the proximate analysis as a description of the nutritional properties of feeds have been discussed by Crampton (12, 13) and others. For the purpose of defining the relevant literature therefore, these and similar considerations in vitamin analysis will not be reviewed here. Rather, it is the intention to review those studies that concern themselves with the levels of these nutrients in feed grains, variations due to soil zone, soil type, climate and any correlations that may exist between these.

2.1 Proximate Nutrient Composition

Extensive data are available on proximate nutrient composition of grains, and a survey of it is shown in table 1. Most of this data is of U.S. origin. More pertinent in Western Canada are the data on proximate nutrient composition published annually in the Grain Research Laboratory Reports (22). A summary of maximum and minimum values for the period from 1951 to 1965 of the proximate nutrients including grades and bushel weights are listed in table 2.

Very little information is available regarding variations in composition due to soil zone, soil type and climate on any of the proximate nutrients with the exception of crude protein.

Protein content, due to its inherent importance, has received the widest attention. Anderson and Eva (2) in 1943 conducted a study on the protein content of corresponding grades of wheat drawn from the northern and southern portions of Western Canada. The data included protein contents of grades 1, 2 and 3 northern for 12 crops 1927 to 1938, drawn from the northern, northwestern, central and southern areas. The boundary between the areas was taken as that dividing zones averaging over and under 13% protein. Grades 1, 2 and 3 from the southern area averaged 14.2, 14.0 and 14.0% protein; those from the northern area averaged 12.8, 12.0 and 11.6% protein. The average difference between zones for all three grades was 2%.

The same authors (3) also made a very comprehensive study concerning the variations in the protein content of Western Canadian wheat. Based on twelve annual protein surveys, 1927 to 1938, this study presented evidence re the effects of several factors. Soil was found not to be the principal factor governing the protein content of wheat. Rainfall had a major effect on the yield and protein content. High rainfall decreases protein content and increases yield; and vice versa. There was evidence of a carry-over of moisture from one season to the next. The total effect of environmental factors other than rainfall was large, large enough in many cases to upset the normal relations between rainfall, protein content and yield. There was good evidence that the mean protein content tended to decrease with each decrease in grade from No. 1 hard to No. 3 northern.

Results of a study of the influence of soil zone on the chemical composition of cereals in Alberta by Newton (48) indicated that the wheat, barley and oats of the brown soil zone were all very high in protein content, while the wheat of the grey wooded soil zone was slightly lower in protein by comparison with the general averages. Barley and oats in this study did not follow a similar trend. However, other data showed that the protein content of barley, like that of wheat, tends to decrease from the drier to the moister zones. Average protein content of wheat, barley and oats grown in Alberta was shown not to be directly related to the nitrogen content of the soil as between the brown and

TABLE 1: Selected Values for Approximate Nutrient Composition of Wheat, Oats and Barley

Reference	Crude Protein %	Crude Fat %	Crude Fibre %	Ash %	N.F.E. %	Moisture %
Wheat						
Crampton (12)	15.0	2	4	-	-	D.M. basis
Morrison (45)	15.8	2.2	2.5	1.8	67.8	9.9
Schneider (61)	16.0	2.0	2.8	2.0	77.2	D.M. basis
U.S.-Canad. Feed Comp. (33)	14.3	1.9	3.4	1.8	78.6	D.M. basis
Oats						
Crampton (12)	12.0	5	11			
Morrison (45)	11.6	4.1	12.1	4.3	57.7	10.2
Schneider (61)	14.9	4.6	9.0	3.1	68.4	D.M. basis
U.S.-Canad. Feed Comp. (33)	12.0	5.1	12.4	3.6	66.9	D.M. basis
Barley						
Crampton (12)	13.0	2.0	6.0			
Morrison (45)	13.5	3.5	8.7	4.1	60.5	9.7
Schneider (61)	12.2	2.4	5.4	2.4	77.2	D.M. basis
U.S.-Canad. Feed Comp. (33)	13.0	2.1	5.6	2.7	76.6	D.M. basis

TABLE 2: PROXIMATE ANALYSIS OF AVERAGE SAMPLES OF LOW-GRADE WHEAT, OATS, BARLEY (GRAIN RESEARCH REPORTS, 1951 - 1965)

Grade	Bushel Weight		Chemical Composition (13.5% Moisture Basis): Crude Protein (N x 6.25)		Crude Fat		Crude Fibre		Ash		N-free Extract (by diff.)	
	lb.		%		%		%		%		%	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
Hard Red Spring Wheat												
4 Northern	58.7	62.2	13.4	15.6	1.6	2.1	1.9	3.9	1.4	1.6	64.3	67.8
No. 5	55.4	61.2	13.4	14.9	1.6	2.3	1.9	4.0	1.4	1.7	64.3	67.8
No. 6	53.7	60.2	12.3	14.9	1.6	2.0	1.8	5.0	1.5	1.7	63.2	67.8
Feed	48.5	58.2	12.3	14.5	1.6	2.3	2.1	5.1	1.5	1.8	63.3	68.3
Oats												
Extra 3 C.W.	40.8	44.0	10.4	11.9	4.2	5.9	8.6	12.8	2.7	3.2	56.0	59.5
3 C.W.	38.7	43.8	10.1	11.9	3.9	5.8	8.1	12.4	2.7	3.3	55.6	59.8
Extra 1 Feed	39.7	43.0	10.1	11.9	4.2	5.5	8.6	11.8	2.7	3.6	56.1	59.4
1 Feed	38.1	43.2	10.3	11.6	4.1	5.7	8.5	11.9	2.7	3.1	56.0	58.8
2 Feed	35.0	43.0	10.0	12.1	3.8	5.6	8.3	12.0	2.6	3.2	56.3	58.5
3 Feed	33.6	43.0	10.4	11.5	3.9	5.9	7.9	11.5	2.6	3.2	55.9	59.6
Barley												
2 C.W. six row	50.0	51.9	10.2	11.6	1.7	2.5	3.9	7.6	2.0	3.1	63.1	68.1
3 C.W. six row	47.9	51.0	10.1	11.7	1.7	2.3	4.0	7.1	2.1	2.8	64.2	67.5
2 C.W. two row	53.4	56.3	10.1	12.4	1.7	2.7	3.2	5.8	1.8	2.4	64.8	69.2
3 C.W. two row	52.1	54.6	10.9	12.6	1.8	2.5	3.4	6.9	1.9	2.6	63.7	68.1
1 Feed	48.3	51.8	10.9	11.9	1.7	2.3	3.9	6.1	2.1	2.5	64.9	67.3
2 Feed	46.4	50.8	10.9	11.9	1.7	2.3	4.1	6.7	2.0	2.6	64.3	66.8
3 Feed	39.6	50.2	10.9	12.1	1.8	2.5	4.3	6.9	2.1	2.8	63.2	66.7

black soil zones but was directly related as between the black and grey wooded.

2.2 Vitamins

2.2.1 Thiamine

A large number of values have been reported for the thiamine content of wheats. Fewer have been reported for oats and barley. A survey of the published results is summarized in table 3. Some of these were reported originally in terms other than micrograms per gram and have been recalculated to this basis.

The factors responsible for the varying amounts of thiamine in cereal grains have not been adequately defined. A varietal effect in wheat seems to be established. Connor and Straub (11) found thiamine content of wheat, obtained from the various wheat producing areas in the United States to be dependent on variety. Whiteside and Jackson (76) reported significant differences to exist between the thiamine content of different Canadian spring wheat varieties. Regent, Renown and Reward were usually higher in thiamine than Red Bobs, Thatcher, Marquis and Garnet.

Nordgren and Andrews (49), and Whiteside and Jackson (76) found environment to be a significant factor in determining the thiamine content of wheat. Wheat was grown in different localities for several seasons. Certain localities produced wheat with a higher thiamine content than others, despite varying amounts from season to season. The features of environment that may have caused this effect were not

TABLE 3: REPORTED VALUES FOR THIAMINE CONTENT OF WHEAT, OATS, AND BARLEY

Thiamine, μgr./grm.

Reference	Location	Wheat		Oats		Barley		Moisture %
		Range	Mean	Range	Mean	Range	Mean	
Davis et. al., 1943	West Canada	-	5.7	-	-	4.91-6.52	5.6	D.M. basis
Frey et al., 1950	United States	-	-	4.63- 9.69	7.17	-	-	
Hoffer et al., 1944	West Canada	2.9 -6.3	4.56	-	-	-	-	
Johannson et al., 1942	West Canada	2.2 -8.0	3.93	-	-	-	-	13.5
Jackson et al., 1943	West Canada	-	4.52	-	-	-	-	
McElroy et al., 1948	Alberta	-	4.40	-	5.58	-	4.6	13.5
Nordgren et al., 1941	Minnesota	4.4 -7.7	6.05	8.10-10.78	9.24	5.68-7.33	6.49	13.5
Robinson et al., 1950	Manitoba	3.4 -5.9	4.5	3.8 - 8.6	6.7	3.3 -5.7	4.2	13.5
Spencer et al., 1949	West Canada	3.48-6.35	-	4.75- 9.35	-	2.89-6.32	-	13.5
Spencer et al., 1949	Saskatchewan	2.73-9.57	-	-	-	2.89-6.32	-	13.5
US.-Canadian Feed Composition Tables, 1964		-	5.5	-	7.0	-	5.7	D.M. basis
Whiteside et al., 1943	West Canada	2.2 -8.0	3.93	-	-	-	-	13.5

investigated. Johannson and Rich (32) studied the variability in the thiamine content of Western Canadian wheat of the 1940 crop. Samples were taken from most of the crop districts. The means for each province were not significantly different, but Alberta showed a greater range in values. The areas producing similar levels of thiamine appeared to have a random arrangement. No relation to soil zone was observed. A similar study conducted by Hoffer et al. (28) on samples of wheat grown in the three prairie provinces in 1941 showed that Alberta samples were significantly lower and more variable than Saskatchewan or Manitoba samples.

McElroy et al. (43) found the thiamine content of wheat, oats and barley grown on the brown soil zone to be significantly higher than those of samples grown on the grey soil zone in Alberta. The black soil zone was intermediate in thiamine content. Spencer and Galgan (66) investigated the relation of thiamine content on Saskatchewan wheat to protein content, variety and soil zone. A highly significant difference was found for varieties grown in different zones for both years. The values decreased as the soil changed from brown to dark brown, to black and degraded black and finally to grey. Robinson et al. (56, 58) studied the thiamine content of Manitoba grown wheat, oats and barley of the 1946 and 1947 crop. Results showed a marked increase in the thiamine content of oats for 1947 over that for 1946. Barley and wheat showed only slight increases. Varietal effects on thiamine content in 1947 samples differed somewhat from those observed for 1946. No soil zone effect on thiamine content of any of the cereals was obtained in 1946. In 1947 rendzina and black earth soils produced wheat with higher thiamine contents. An environmental effect other than that for soil zone on thiamine content of wheat and oats was confirmed. Spencer et al. (65), reporting on a collaborative analysis of wheat, oats and barley grown in different locations of Alberta, Saskatchewan and Manitoba, showed that after taking into account intralaboratory error and the interaction between laboratories and samples, differences of 8.5% to 10.3% were necessary before samples could be considered different with respect to thiamine content.

While some attempts have been made to determine if there is any relation between vitamin contents and the content of other constituents, different investigators have reported different findings. Connor and Straub (11) reported a direct relationship between the protein content of wheat and its thiamine content. Nordgren and Andrews (49) found a significant correlation between ash and thiamine in American-grown spring wheats but not in Canadian spring wheats. A significant correlation between protein and thiamine content was noted in barley but not in wheat and oats. McElroy et al. (43), in contrast, obtained significant protein-thiamine correlations for wheat and oats only. Other significant protein-thiamine correlations for wheat are cited in (28, 58, 66, 76), and for oats and barley in (56, 58). Robinson et al. (56, 58) found significant thiamine-ash correlations in all three grains of the 1947 crop. However, for the 1946 crop they obtained a significant negative thiamine-ash correlation only in oats. There was no consistency in the correlation coefficients for the two years. Johannson and Rich (32) failed to find any relation between amounts of thiamine in wheat and either protein or ash content.

Whiteside and Jackson (76) after studying the distribution of thiamine in the wheat kernel concluded that the physical features of the kernel that are associated with high protein would also be associated with high thiamine as negative correlations were obtained between thiamine and test weight per bushel, and thiamine and weight per 1000 kernels. Dissection experiments by Jackson *et al*. (32) showed the thiamine to be largely concentrated in the scutellum portion of the wheat germ. Hoffer *et al*. (28) reported that a negative correlation between mean yield per acre and average thiamine content of Western Canadian wheat was indicated by a study of available data for three seasons. Attempts have been made to correlate thiamine content with the content of other vitamins. Robinson *et al*. (56, 58) found a correlation between thiamine and riboflavin in oats, and Frey *et al*. (19) reports a significant correlation between thiamine and niacin in oats.

2.2.2 Riboflavin

A summary of published results of riboflavin contents of wheat, oats and barley grown in Western Canada and some U.S. points are shown in table 4. Generally there are fewer data for riboflavin than for thiamine content of Canadian grains. Results of studies made in the U.S. (4, 11) showed that the riboflavin content of cereal grains is lower and less variable than is the thiamine content, and that such factors as environment, variety and protein content may be less important in relation to riboflavin than to thiamine accumulation.

McElroy et al. (43) in a study of the riboflavin content of wheat, oats, and barley grown in different soil zones in Alberta during 1944 and 1945 found that the mean riboflavin content of samples of the three cereals, grown on grey soils, was slightly lower than those grown on black or brown soils. The data indicated that the probability of significant differences in vitamin content attributable to soil zone is less for riboflavin than for thiamine. For all three soil zones the riboflavin content of the oat samples grown in 1945 was appreciably greater than for those grown in the preceding year. Robinson et al. (56, 58) in a similar study under Manitoba conditions of the 1946 and 1947 crop year, found the values for riboflavin in the three cereals to be about the same for the two years. They did not find a varietal or soil zone effect on the riboflavin content of the three cereals. Spencer et al. (65) in their collaborative analysis of wheat, oats and barley arrived at the following results. After taking into account intralaboratory error and the interaction between laboratories and samples, differences

TABLE 4: REPORTED VALUES FOR RIBOFLAVIN CONTENT OF WHEAT, OATS, AND BARLEY

Reference	Location	Riboflavin, μgr./grm. Wheat Range	Wheat Mean	Oats Range	Oats Mean	Barley Range	Barley Mean	Moisture %
Andrews et al., 1942	Minnesota	1.05-1.32	1.20	1.10-1.45	1.30	1.05-1.50	1.21	
Connor et al., 1941	U.S.	0.89-1.91	1.17	-	-	-	-	
Davis et al., 1943	West Canada	-	0.91	-	-	-	1.02	D.M. basis
Evans et al., 1945	Canada	1.0 -1.2	1.10	1.10-1.30	1.20	1.30-1.30	1.30	
Frey et al., 1950	U.S.	-	-	1.05-1.87	1.39	-	-	
Jackson et al., 1943	West Canada	-	1.24	-	-	-	-	
McElroy et al., 1948	Alberta	-	1.34	-	1.27	-	1.25	13.5
Owen et al., 1962	Alberta	-	-	-	-	.75-1.03	0.97	Air dry
Robinson et al., 1949	Manitoba	.80-1.40	1.12	.80-1.70	1.25	.90-1.9	1.28	13.5
Robinson et al., 1950	Manitoba	1.00-1.40	1.20	1.00-1.70	1.30	.90-1.6	1.30	13.5
Spencer et al., 1949	West Canada	0.94-1.47	-	0.99-1.61	-	0.96-1.61	-	13.5
U.S.-Canadian Feed Composition Tables, 1964		-	1.3	-	1.8	-	2.2	D.M. basis

of 9.4 to 12.3% were necessary before samples could be considered different with respect to riboflavin content. Dissection experiments on wheat kernels by Jackson et al. (31) indicated riboflavin to be more evenly distributed than either thiamine or niacin.

Studies on the relationship of riboflavin with other constituents have been fewer and have shown generally no indication of significance. McElroy et al. (43) obtained no positive correlation between riboflavin and protein in any of the three cereals. Frey and Watson (19) reported similar results for oats with respect to protein-riboflavin relation, but found a significant correlation between riboflavin and niacin content. Robinson et al. (56. 58) for the 1946 crop year obtained significant correlations between protein and riboflavin in wheat, and ash and riboflavin in barley. For the 1947 crop they found significant correlations between protein and riboflavin, ash and riboflavin and thiamine and riboflavin in oats. There was no consistency in the correlation coefficients for the two years.

2.2.3 Nicotinic Acid

In the case of nicotinic acid content, a marked difference seems to exist between wheat, oats and barley. Ranges and mean values which have been published in the literature are shown in table 5. Studies on varietal, soil and climatic effects have been few.

McElroy and Simonson (41) conducted a study of nicotinic acid content of wheat, oats and barley grown in

TABLE 5: REPORTED VALUES FOR NICOTINIC ACID CONTENT OF WHEAT, OATS, AND BARLEY

Reference	Location	Nicotinic Acid, µgr./grm. Wheat Range	Wheat Mean	Oats Range	Oats Mean	Barley Range	Barley Mean	Moisture %
Davis _et al._, 1943	West Canada	49.3- 66.1	58.6	-	-	69.0- 98.1	86.3	D.M. basis
Frey _et al._, 1950	U.S.	-	-	4.4-11.7	9.4	-	-	
Jackson _et al._, 1943	West Canada	-	56.5	-	-	-	-	
McElroy _et al._, 1948	Alberta	41.3- 74.0	-	7.0-17.0	-	49.3- 99.3	-	13.5
Owen _et al._, 1962	Alberta	-	-	-	-	54.1- 57.6	55.0	
Teply _et al._, 1942	West Canada	55.0-106.0	-	-	-	-	-	
Kent-Jones, 1947	-	55.0- 60.0	-	-	-	85.0-147	-	D.M. basis
U.S.-Canadian Feed Composition Tables, 1964		-	63.6	-	17.8	-	64.5	D.M. basis

different soil zones and conditions of climate in Alberta. No evidence was obtained to indicate that the soil zones on which the grains were grown had any marked effect on the accumulation of nicotinic acid. Nicotinic acid levels were highly variable in all three grains. Protein and nicotinic acid levels were found to be positively correlated in wheat and oats, while in barley, a tendency towards an inverse relation between protein and nicotinic acid was observed. The wheat and oat samples from the 1945 crop were higher in protein and in nicotinic acid content than those from the 1944 crop. The barley samples were higher in protein content in 1945 than in the preceding year, but contained essentially the same amount of nicotinic acid. Frey and Watson (19) obtained significant correlations of nicotinic acid with protein, thiamine and riboflavin levels in their chemical studies on different varieties grown under similar environmental conditions.

2.2.4 Pantothenic Acid

Data on pantothenic acid contents of Canadian grains are meager. An attempt has been made to summarize values from a few sources in table 6. Reports on studies pertaining to soil zone and climatic factors are very few. Refai and Miller (55) found significant differences in pantothenic acid content between varieties within species of wheat. Frey and Watson (19) give the values for sixteen American varieties of oats (table 6). In each case, they found the correlation coefficients of pantothenic acid with

TABLE 6: REPORTED VALUES FOR PANTOTHENIC ACID CONTENT OF WHEAT, OATS, AND BARLEY

Pantothenic Acid, μgr./grm.

Reference	Location	Wheat		Oats		Barley		Moisture %
		Range	Mean	Range	Mean	Range	Mean	
Davis et al., 1943	West Canada	-	7.9	-	-	-	4.5	D.M. basis
Frey et al., 1950	U.S.	-	-	6.3-12.7	8.9	-	-	
Owen et al., 1962	Alberta	-	-	-	-	4.6-9.59	9.28	Air dry
Refai et al., 1952		8.9-20.6	-	-	-	-	-	
Robinson, 1951		9.0-17.0	11.0	-	-	-	10.0	
Teply et al., 1942	West Canada	9.8-14.7	-	-	-	-	-	
Toepfer et al., 1954	U.S.	10.6-11.4	11.0	-	-	-	-	
U.S.-Canadian Feed Composition Tables, 1964		-	13.6	-	14.5	-	7.3	D.M. basis

protein, niacin, riboflavin and thiamine were negative but not significantly so.

3. EXPERIMENTAL

3.1 Objectives

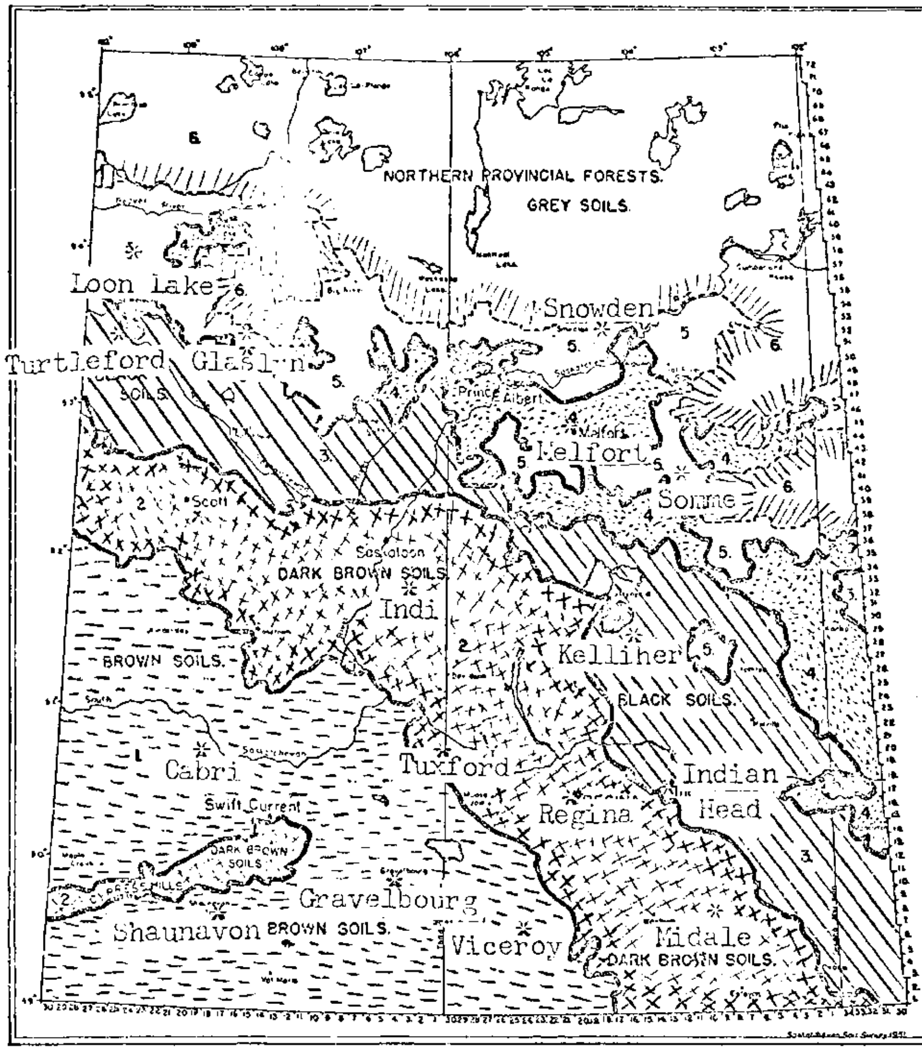
As indicated in the previous section, there are many factors that influence the essential nutrient content in feed grains. Included among these are variety, soil zone, soil type, and climatic variations between years and locations. In addition, there may be interrelationships between nutrients. Therefore, the major objectives of a project initiated in 1964 were to obtain additional data on the composition of Saskatchewan feed grains and to study effects of soil zone, soil type, variety, climatic variations, and possible relationships between constituents on nutrient composition. The study will be continued for five years in order that seasonal (i.e. climatic) variations be adequately measured. Results of the first two crop years 1964 and 1965 are reported herein.

3.2 Materials and Methods

3.2.1 Experimental Design, Data and Sample Collection

The test plots were grown at 16 locations representing the main soil zones and types of Saskatchewan as shown in figure 1. The allotment of samples from the test locations in this manner made it possible to use a 2 x 4 x 2 x (2 or 3) factorial type of design, as indicated in table 7. In each case, two test locations served as replicates for

THE SOIL ZONES OF SASKATCHEWAN



LEGEND

1. Brown Soils of the open prairie, the most arid section of the province. Wide variations in crop yields and frequent severe droughts.
2. Dark Brown Soils of the prairie, less arid than the Brown Soils. Variable crop yields but less frequent severe droughts.
3. Black Soils of the parkland. Better moisture conditions and better average yields than on the prairie. Severe droughts rarely experienced.
4. Thick Black and Greyish Black Soils of the parkland-forest belt. Good moisture conditions and high crop yields.
5. Grey Wooded Soils of the forest region. Moisture conditions good, but soils are low in organic matter and general fertility.
6. Grey Soils and Muskeg of the unsettled Northern Provincial Forest.

- - - - - - Boundary of Northern Provincial Forest Reserves.

Figure 1 - Distribution of the 16 test locations across the different Soil Zones of Saskatchewan (25).

Table 7 - EXPERIMENTAL DESIGN

Year	Soil Zone	Soil Type	Test Location	Varieties 1	Varieties 2	Varieties 3
1964	Brown	Haverhill	Shaunavon Viceroy			
		Sceptre	Cabri Gravelbourg	W.O.B.	W.O.B.	B
	Dark Brown	Weyburn	Indi Midale			
		Regina	Regina Tuxford			
	Black	Oxbow	Turtleford Kelliher			GYB
		Melfort	Indian Head Melfort			
	Grey	Waitville	Loon Lake Glaslyn			
		Arborfield	Snowden Somme			
1965	Brown	Haverhill	Shaunavon Viceroy	O.B.	O.B.	B
		Sceptre	Cabri Gravelbourg	B	B	B
	Dark Brown	Weyburn	Indi Midale	GYB	GYB	GYB
		Regina	Regina Tuxford	GYB	GYB	
	Black	Oxbow	Turtleford Kelliher	GYB	GYB	GYB B
		Melfort	Indian Head Melfort			
	Grey	Waitville	Loon Lake Glaslyn			
		Arborfield	Snowden Somme			

W = Wheat; O = Oats; B = Barley; GYB = Grade; Yield; Bu. Wt.

each soil type, light and heavy, within each soil zone. With the cooperation of members of the Crop Science Department, University of Saskatchewan, and the Research Branch, Canada Department of Agriculture, the following samples of two varieties of wheat and oats, and three varieties of barley were collected from the 1964 and the 1965 crop.

Varieties

Wheat	Oats	Barley
Canthatch	Garry	Husky
Selkirk	Rodney	Parkland
		Hannchen

The following changes in test locations from the original were made:

1964: Viceroy for Bayard
Turtleford for North Battleford
Swift Current dryland samples for Gravelbourg

1965: Shaunavon samples replaced by Swift Current clay loam samples

Samples which are incomplete or not available for analysis due to wind or hail loss, etc.

1964: Cabri samples lost entirely. All others are complete.

1965: Viceroy - only wheat samples available
Kelliher - barley variety "Hannchen" missing, others complete.
Cabri - replaced by Laverna samples except the barley varieties.

Gravelbourg - replaced completely with Kindersley samples.

Missing plots have been indicated by inserting the first letter of wheat, oats and barley in the experimental design, table 7. The samples were analyzed for the proximate principles, nicotinic acid, riboflavin, thiamine, pantothenic acid. A 1000 kernel weight was obtained from the same sample.

Data regarding yield, bushel weight and grades of the collected samples were obtained from the Crop Science Department, U. of S. However, data from some locations were not available. This created additional missing plots for these three variables, indicated by the expression GYB in the experimental design, table 7.

Originally, no provision for measuring precipitation at the test plots for this study had been made. Therefore, precipitation data for the growing seasons of both years, April to July inclusive, were obtained from the "Monthly Record" (46). Most of the stations from which the data were taken coincided with those in the experimental design. For the others, data from the stations located in the immediate vicinity were chosen. It is acknowledged that this may not give a completely valid picture regarding rainfall, since it was not measured directly on the test plots. However, it was thought that the data which were available might prove useful in the interpretation of the results obtained with respect to nutrient composition.

3.2.2 Sample Preparation and Storage

Samples as received were remixed and ground using a Christy and Norris mill through a 30 mesh screen. The ground samples were then put into appropriately marked five-pound polyethylene bags and stored at 4 to 5°C.

3.2.3 Determination of Proximate Principles

The contents of moisture, crude protein, ether extract (crude fat), crude fiber, ash and nitrogen-free extract were determined according to the standard A.O.A.C. (1960)(5) methods with the noted exceptions. The procedures for proximate principles and the B vitamins are detailed in the Appendix.

Moisture - Duplicate air dry samples were weighed into moisture dishes and dried overnight at 110°C in a forced draft oven. The loss in weight was reported as per cent moisture.

Crude Protein - The procedure used for crude protein analysis was a slight modification of the A.O.A.C. method (1960)(5) using a commercially prepared catalyst[1]. The sample weighed out on filter paper was inserted into a 500 ml Kjeldahl flask, digested with H_2SO_4 (conc.) and distilled. The receiving acid used was a 4% solution of boric acid containing 60 ml per liter of a mixed indicator, prepared

1. Kel-Pak Powder No. 1. 9.9 grms K_2SO_4; 0.41 grm HgO; 0.08 grm $CuSO_4$.
Division of Matheson Co., East Rutherford, New Jersey.

according to Sher (63), containing bromcresol green, new coccine and p-nitrophenol. Following collection of the ammonia the solution was titrated with 0.1N HCL. Crude protein was calculated based on the formula:

$$\% \text{ C.P.} = \frac{14}{100} \times \frac{\text{net titre} \times \text{normality}}{\text{Wt. of sample}} \times 6.25$$

Results were reported on an oven dry basis.

Ash - The per cent ash in dried and ground samples was determined in accordance with the A.O.A.C. (1960)(5) methods.

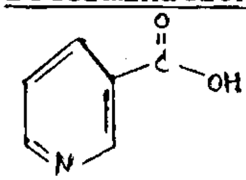
Fat - Crude fat or "ether extract" was determined by first drying the duplicate samples at 96°C and 25" Hg in a vacuum oven (A.O.A.C.)(1960)(5). The dried samples were weighed out into Whatman fat extracted single fat extraction thimbles, and extracted with diethyl ether overnight on a Goldfish extractor. After reclaiming the ether and redrying the beaker in the vacuum oven, the addition in weight to the constant recorded weight of the beaker was reported as per cent crude fat on a dry matter basis.

Crude Fiber - The Weende method, according to the A.O.A.C. method (1960)(5) was utilized for the determination of crude fiber (Appendix E). Duplicate 2 grm fat-free samples obtained from the ether extraction were boiled in 0.255N H_2SO_4. Excess acid and solubles were filtered off through "handkerchief linen". Following a hot water wash to remove the residual acid, the residues were filtered and washed off with hot water through an ignited Gooch crucible containing an acid-base washed, reignited asbestos mat.

Finally the residues were rinsed with a small volume of ethanol. When necessary, n-octyl alcohol was used to prevent excessive foaming during boiling. The weight loss of the resulting residue, following ignition was reported as per cent crude fiber on a dry matter basis.

Nitrogen-Free Extract - The usual method of determination, that of: % N.F.E. = 100 - (%H_2O + % crude protein + % Crude fat + % crude fiber + % ash) was used to determine N.F.E. and is reported herein on a dry matter basis.

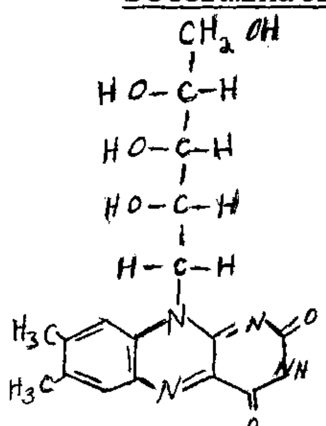
3.2.4 Determination of Nicotinic Acid



Molecular formula: $C_6H_5NO_2$

Photometric methods are usually used to assay nicotinic acid and its amide. Nearly all photometric methods are based on the Konig reaction (68) of pyridine and its derivatives with cyanogen bromide and an aromatic amine. This is also the basic reaction in the A.O.A.C. (1960) method which was employed, with modifications suggested by Campbell and Pelletier (9). In principle, in the older A.O.A.C. method nicotinic acid and nicotinamide that is present in natural products in combined form (as coenzyme I, II) are hydrolyzed by sulfuric acid. The pyridine ring of the nicotinic acid liberated by hydrolysis is opened up with cyanogen bromide. The fission product is coupled with sulfanilic acid to give a yellow polymethine dye, whose extinction is measured at 470 mμ. The modified procedure involved using calcium hydroxide as a digestant and carrying out the reaction at about 2°C to obtain a more stable color (Appendix F). The determinations were made on air dry samples and the results recalculated to a dry matter basis.

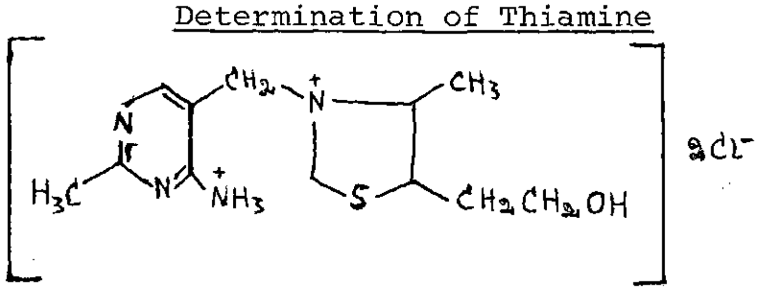
3.2.5 Determination of Riboflavin



Molecular formula: $C_{17}H_{20}N_{4}O_{6}$

Riboflavin occurs in natural products almost entirely in combined form as riboflavine-5' phosphoric acid ester (flavine mononucleotide), and linked to protein as a constituent of "yellow enzyme". A modified (18) A.O.A.C. (1960) fluorometric method for the determination of riboflavin in grains was adopted. The yellowish-green fluorescence of riboflavine in U.V. light is dependent upon the pH of the solution as well as upon the concentration. Maximum intensity of fluorescence occurs between pH 6 and 7. The fluorescence is not usually measured in this range, but rather, in the range pH 3 to 5 where the intensity-pH curve is horizontal. Within this range fluorescence intensity is constant and apart from other contaminants depends only upon the concentration of riboflavin. The sample used must be sufficiently large to bring the riboflavin concentration into the required range of measurement. After extraction with .1N H_2SO_4 at 121°C in the autoclave for 30 minutes, the mixture is cooled to room temperature and the pH adjusted to 4.5. Destruction of impurities is obtained by oxidation with permanganate, and the mixture is then decolorized with hydrogen peroxide. The fluorescence is measured after centrifuging with a fluoremeter using the appropriate filters. Using an internal standard, and by obtaining blank measurement through quenching of the riboflavin fluorescence with sodium hydrosulfite in the sample solution, the riboflavin concentration can then be calculated (Appendix G).

3.2.6 Determination of Thiamine

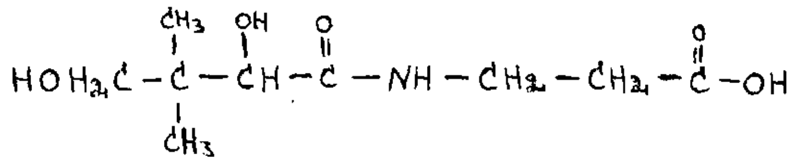


Molecular formula: $C_{12}H_{18}Cl_2N_4OS$

The most widely used method for the assay of thiamine is the so-called thiochrome reaction. The A.O.A.C. (1960) procedure was adopted for the determination of thiamine in grains. The fluorometric method (thiochrome reaction) is based on oxidation of thiamine in alkaline solution to thiochrome, which has an intense blue fluorescence. The method is mainly used for the assay of thiamine in natural products having low concentrations of thiamine and a high content of interfering substances. Before the actual thiochrome reaction can be carried out, isolation and purification of thiamine is necessary. A large amount of thiamine exists in the form of thiamine pyrophosphoric ester (cocarboxylase). These compounds are either not directly oxidizable to thiochrome or form thiochrome esters that are not extracted from alkaline solution by isobutanol.

Thiamine is extracted in acid medium since it is readily decomposed in neutral or alkaline solution. This is sufficient to hydrolyze the thiamine-protein complexes. The esters of thiamine with phosphoric acid are not broken down under these conditions. A separate enzyme hydrolysis (Takadiastase) is therefore necessary. Since the acid extract usually contains amounts of substances that produce extraneous fluorescence and reducing compounds which consume potassium ferricyanide, and therefore incomplete quantitative oxidation of thiamine to thiochrome can occur, purification is essential. For this purpose, the solution is passed over a cation exchanger. The thiamine is bound on the column together with other cations. Anions and components that do not ionize are removed when the column is washed. The thiamine is exchanged for potassium ions from hot, acidified potassium chloride solution, is eluted, and assayed by the thiochrome method. Further allowance for extraneous fluorescence is made by a blank run containing sodium hydroxide in place of the oxidizing solution. The fluorescence of the blank is subtracted from the fluorescence measured in the sample to obtain the correct value (Appendix H).

3.2.7 Determination of Pantothenic Acid



Molecular formula: $C_9H_{17}NO_5$

Pantothenic acid was determined microbiologically with Lactobacillus plantarum A.T.C.C. 8014. Bacto-Pantothenate A.O.A.C. medium[2] a complete dehydrated medium, free of pantothenate, but containing all other factors necessary for the growth of L. plantarum, was used for the assay. The addition of the sample extract prepared, containing pantothenic acid, gives a growth response which was measured turbidimetrically. The samples were hydrolyzed using a mixture of pigeon liver enzyme[3] and alkaline intestinal phosphatase[3] according to Kaplan and Lipmann (35), Novelli et al. (50), and Toepfer et al. (74) to insure that all of the pantothenic acid including that bound as coenzyme A was available to L. plantarum 8014. The pigeon liver enzyme was treated with activated Dowex 1-X8 resin, which removes bound forms of pantothenic acid (coenzyme A), according to the method by Novelli and Schmetz (51). The use of Dowex-treated liver extracts in the double-enzyme treatment, for liberation

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2. Difco Laboratories, Detroit 1, Michigan, U.S.A.
3. Mann Research Laboratories Inc., 136 Liberty Street, New York 6, New York, U.S.A.

of pantothenic acid, reduces the enzyme blank in the assay to a low correction value (Appendix I).

4. STATISTICAL ANALYSIS

Since a few of the test plots at different locations were missing for the two crop years, the original design became a factorial with some subclasses containing a reduced number of observations. Therefore, the data were subjected to Least Squares analysis (26). For this purpose, a computer program[1] specifically designed to obtain statistical analysis of data which, in general, fits a factorial design, but in which some subclasses contain a reduced number or no observations, was adopted. A complete analysis of variance, main effects, first and second order interactions, along with the correlations between nutrients, between yield, grade and bushel weight, and between nutrients, yield, grade, bushel weight and monthly as well as total growing season precipitation, was computed. Duncan's multiple range test was applied to the treatments with equal subclass numbers, and only in cases of significance and more than two levels per factor. To those treatments with unequal subclass numbers, Duncan's multiple range test was applied by utilizing Kramer's (37) extension. The difference is as follows: With equal subclass numbers, the standard error of the difference between two means is computed as $\sqrt{\frac{\text{Error Mean Square}}{n}}$, where

1. Least Squares Analysis of Data with Unequal Subclass Numbers. W.E. Lentz and G.E. Nelms, Department of Animal Science, University of Saskatchewan. 1966. (Unpublished).

n is the number of observations in a mean. With unequal subclass numbers, n is replaced by $\frac{2}{cii + cjj - 2cij}$, where the cij's refer to elements of the C-inverse matrix.

5. RESULTS AND DISCUSSION

5.1 Effects of Monthly and Total Growing Season Precipitation on Nutrient Content

Monthly rainfall data for the different soil zones and types for both years are shown in table 8. Analysis of variance results on separate months and total growing season are summarized in table 8a. From these results, it becomes evident that seasonal precipitation was significantly ($P < .01$) higher in 1965, and that May and June rains accounted for the major difference, especially the June rainfall ($P < .01$). The brown soil zone in July in these locations received about 1.5 inches more rainfall in 1965 than in 1964 ($P < .05$). The interaction between years and zones in the month of June points out the drought-like conditions which existed in the northern portion of the province, mainly in the grey and black soil zones, during 1964.

In order to find out whether precipitation influenced the levels of the nutrients and to what extent these could be correlated with each other, a correlation analysis between monthly precipitation and nutrients and total growing season precipitation and nutrients was carried out. The significant ($P < 0.01$, $P < 0.05$) partial correlations pertaining to the nutrients are summarized for each grain in table 9.

The results overall illustrated certain relationships for each grain. Other relationships, such as exists between precipitation and protein content (2, 3), particularly

TABLE 8 - MONTHLY PRECIPITATION FOR GROWING SEASON

Rainfall in Inches

Soil Zone	Soil Type	1964 April	1964 May	1964 June	1964 July	1964 Type Mean	1964 Zone Mean	1965 April	1965 May	1965 June	1965 July	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	1.32	1.62	3.15	.76	1.71		.75	3.39	3.79	2.11	2.51		
	Heavy	.64*	1.27*	5.62*	.50*	2.01	1.86	.45	1.12	3.86	1.15	1.64	2.08	1.97
Dark Brown	Light	.65	1.65	1.86	2.66	1.71		.52	4.06	4.03	2.08	2.67		
	Heavy	.32	1.64	2.49	3.99	2.11	1.91	.68	3.73	4.35	2.12	2.72	2.70	2.31
Black	Light	.67	2.49	1.16	2.81	1.78		.61	2.95	6.04	2.31	2.98		
	Heavy	.43	1.81	1.69	1.91	1.46	1.62	.71	3.66	4.26	1.79	2.61	2.80	2.21
Grey	Light	.69	1.45	.82	2.09	1.26		.27	1.72	6.37	1.80	2.54		
	Heavy	1.12	1.42	1.33	3.71	1.95	1.61	.34	2.85	4.30	3.60	2.77	2.66	2.14
Monthly Mean		0.77	1.69	2.07	2.31			0.54	2.93	4.62	2.12			
Type Mean	Light					1.62						2.68		2.15
	Heavy					1.88	1.75					2.44	2.56	2.16

* Single value

TABLE 8a - MEAN SQUARES FOR MONTHLY AND SEASON PRECIPITATION

Source	D.F.	April	May	June	July	Season
Year	1	0.544	24.12*	82.13**	0.52	156.6**
Soil Zone	3	0.160	4.03	2.55	8.13*	4.44
Soil Type	1	0.151	0.81	0.18	1.10	0.04
Year x Type	1	0.170	2.26	14.37	0.49	15.42
Year x Zone	3	0.502	1.76	15.98*	2.94	9.98
Zone x Type	3	0.320	2.12	3.14	5.09	9.45
Year x Zone x Type	3	0.148	2.07	1.23	0.60	3.07
Missing Plots	(1)					
Error	15	0.29	4.26	4.55	1.97	8.92

* P<.05

** P<.01

TABLE 9 - SIGNIFICANT PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, MONTHLY AND GROWING SEASON PRECIPITATION

Source	Wheat	Oats	Barley
Season	Moisture, 0.315*	Crude Fiber, -0.319* N.F.E., 0.356*	Ash, 0.332**
April	Ash, 0.331*	N.F.E., 0.471**	
May		Crude Fiber, -0.364* N.F.E., 0.580** Nicotinic Acid, -0.332* Pantothenic Acid, -0.326*	Ash, 0.480** Riboflavin, -0.305**
June	Thiamine, 0.408**		Ash, -0.273*
July	Ash, 0.318* Riboflavin, 0.313*	Crude Fiber, -0.338* N.F.E., 0.356*	Ash, 0.381**

* $P < 0.05$
** $P < 0.01$

in the case of wheat, did not appear as such in any of the grains in this study.

In wheat, moisture content seems to be closely related to growing season precipitation and the ash content to April and July precipitation. June and July precipitation were positively correlated with thiamine and riboflavin content respectively.

In oats, the inverse relationship of crude fiber and the positive relationship of the N.F.E. fraction to precipitation is quite evident throughout the growing season, indicating that increased precipitation reduces crude fiber content and increases the N.F.E. fraction. Nicotinic acid and pantothenic acid appear to be adversely affected by increased precipitation during the month of May.

Ash content in barley appears to be quite strongly influenced by precipitation and over the growing season period appears to be increased with increase in precipitation. Riboflavin content tends to be adversely affected by increased precipitation during May. Riboflavin and thiamine were found to be significantly correlated with protein content in each grain, and it is quite conceivable that variation in protein content may cause corresponding variations in these two vitamins. Niacin and pantothenic acid, however, were not correlated in this way.

It should be pointed out that the above relationships do not, in fact, represent effects of seasonal precipitation alone. Other unrecorded factors, such as soil moisture reserves, evaporation rates, etc., undoubtedly play an important role. Precipitation data per se are unreliable as an indicator of moisture effects.

Unless one has proper experimental control of all of these factors, which was not the case (including the precipitation data) in this study, trying to relate these statistically is both difficult and risky.

5.2 The Effects of Years, Soil Zone, Soil Type and Variety on the Proximate Principles in Wheat

Mean values are shown in tables 10 to 15, and the results of the factorial analysis in table 16.

Moisture

Moisture contents ranged from 8.02 to 11.95%. Soil zones had a significant effect ($P < .01$) on the moisture content. The dark brown and grey soil zones showed higher moisture contents than either the brown or black zones. Significant interactions between year and zones ($P < .01$) and zones and types ($P < .05$) resulted due to the black and grey zones showing lower moisture content in 1964 than 1965, with the heavier type in the brown zone, contrary to the other zones, having the lower moisture contents. The significant ($P < .05$) year x zone x type interaction reflected the fact that in 1964 samples from the heavy types in the dark brown and black soil zones were lower in moisture content than those from the light types, while in 1965 this occurred only in the brown soil zone.

Crude Protein

The crude protein content (N x 6.25) of the wheat

TABLE 10 - MOISTURE CONTENT OF WHEAT

Soil Zone	Soil Type	Moisture, % 1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	10.35	10.43	10.39		9.68	9.40	9.54		
	Heavy	10.60*	10.59*	10.60	10.50	8.15	8.43	8.29	8.92	9.70[b]
Dark Brown	Light	11.57	11.05	11.31		10.01	10.19	10.10		
	Heavy	10.98	10.80	10.89	11.10	11.12	10.89	11.01	10.56	10.82[a]
Black	Light	10.57	10.27	10.42		10.64	10.30	10.47		
	Heavy	9.73	9.88	9.81	10.12	10.90	10.67	10.79	10.63	10.37[a,b]
Grey	Light	10.33	9.78	10.06		10.91	10.88	10.90		
	Heavy	11.00	11.89	11.45	10.76	11.60	11.56	11.58	11.24	10.99[a]
Variety Mean	Canthatch	10.64				10.38				10.50
	Selkirk		10.59				10.29			10.44
Type Mean	Light			10.54				10.25		10.39
	Heavy			10.69	10.61			10.42	10.33	10.55

* Single value

a,b Zone means with the same superscript are not significantly different (P 0.01)

TABLE 11 - CRUDE PROTEIN CONTENT OF WHEAT

Soil Zone	Soil Type	Crude Protein, % ** Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type	Zone	Overall Zone Mean
Brown	Light	20.20	18.48	19.34		17.66	18.07	17.86		
	Heavy	21.31*	19.11*	20.21	19.78	18.41	17.97	18.19	18.02	18.90
Dark Brown	Light	18.78	17.96	18.37		18.32	18.29	18.30		
	Heavy	18.92	18.65	18.78	18.58	16.06	16.44	16.25	17.28	17.92
Black	Light	19.88	19.36	19.62		18.74	18.58	18.66		
	Heavy	18.99	17.87	18.43	19.02	16.03	16.04	16.04	17.35	18.18
Grey	Light	20.17	20.08	20.12		16.78	16.97	16.88		
	Heavy	19.19	19.30	19.24	19.68	17.54	17.83	17.68	17.28	18.48
Variety Mean	Canthatch	19.68				17.44				18.56
	Selkirk		18.85				17.52			18.18
Type Mean	Light			19.36				17.92		18.64
	Heavy			19.17	19.26			17.04	17.48	18.10

* Single value
** Data are reported on a moisture-free basis

TABLE 12 - CRUDE FAT CONTENT OF WHEAT

		Crude Fat, % **								
		1964				1965				
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	2.16	2.01	2.08		2.16]	1.94	2.06		
	Heavy	2.02*	1.98*	2.00	2.04	2.13	1.84	1.99	2.03	2.03
Dark Brown	Light	1.99	2.09	2.04		2.01	2.08	2.05		
	Heavy	2.04	1.98	2.01	2.03	2.09	1.78	1.94	2.00	2.01
Black	Light	2.06	1.87	1.97		2.03	1.95	1.99		
	Heavy	2.03	1.90	1.97	1.97	2.11	1.90	2.01	2.00	1.98
Grey	Light	2.13	1.80	1.97		2.14	1.88	2.01		
	Heavy	1.97	2.00	1.99	1.98	1.90	1.78	1.84	1.93	1.95
Variety Mean	Canthatch	2.05				2.07				2.06
	Selkirk		1.95				1.89			1.92
Type Mean	Light			2.01				2.03		2.02
	Heavy			1.99	2.00			1.94	1.98	1.96

* Single value
** Data are expressed on a moisture-free basis

TABLE 13 - CRUDE FIBRE CONTENT OF WHEAT

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Fibre, % **								
Brown	Light	3.22	3.06	3.14		3.18	3.11	3.15		
	Heavy	3.26*	3.29*	3.28	3.21	3.14	2.98	3.06	3.11	3.16[a]
Dark Brown	Light	2.91	2.93	2.92		3.23	3.05	3.14		
	Heavy	2.90	2.85	2.88	2.90	3.12	2.93	3.03	3.09	2.99[a]
Black	Light	2.80	2.73	2.77		3.15	3.09	3.12		
	Heavy	2.84	2.92	2.88	2.83	3.06	2.89	2.98	3.05	2.94[b]
Grey	Light	3.17	2.90	3.04		3.25	3.49	3.37		
	Heavy	2.69	2.93	2.81	2.93	3.13	3.04	3.09	3.23	3.08[a]
Variety Mean	Canthatch	2.97				3.16				3.07
	Selkirk		2.95				3.07			3.01
Type Mean	Light			2.97				3.19		3.08
	Heavy			2.96				3.04	3.12	3.00

* Single value
** Data are reported on a moisture-free basis
a,b Zone means with the same superscript are not significantly different (P 0.05)

TABLE 14 - NITROGEN FREE EXTRACT CONTENT OF WHEAT

		Nitrogen Free Extract, %**								
		1964				1965				
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	72.66	74.62	73.64		75.03	75.09	75.06		
	Heavy	71.72*	74.64*	73.19	73.42	74.55	72.98	73.77	74.42	73.91
Dark Brown	Light	74.55	75.22	74.89		74.71	74.85	74.78		
	Heavy	74.36	74.85	74.61	74.75	75.87	77.15	76.52	75.66	75.19
Black	Light	73.32	74.02	73.67		74.37	74.45	74.41		
	Heavy	74.51	75.75	75.14	74.41	77.23	77.57	77.41	75.91	75.16
Grey	Light	72.47	73.14	72.81		76.17	76.09	76.14		
	Heavy	73.99	73.91	73.96	73.39	75.43	75.48	75.46	75.80	74.58
Variety Mean	Canthatch	73.45				75.42				74.45
	Selkirk		74.52				75.46			74.97
Type Mean	Light			73.75				75.09		74.42
	Heavy			74.23	73.98			75.79	75.44	75.00

* Single value
** Data are expressed on a moisture-free basis

TABLE 15 - ASH CONTENT OF WHEAT

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Ash, %								
Brown	Light	1.77	1.83	1.80		1.98	1.79	1.89	1.89	
	Heavy	1.69*	1.73*	1.71	1.76	1.78	1.79	1.79	1.84	1.80^{b}
Dark Brown	Light	1.78	1.81	1.80		1.69	1.74	1.72		
	Heavy	1.84	1.68	1.76	1.78	1.86	1.71	1.79	1.76	1.77^{b}
Black	Light	1.95	2.03	1.99		1.72	1.93	1.83		
	Heavy	1.64	1.58	1.61	1.80	1.58	1.61	1.60	1.72	1.76^{b}
Grey	Light	2.07	2.09	2.08		1.68	1.59	1.64		
	Heavy	2.17	2.15	2.16	2.12	2.02	1.88	1.95	1.80	1.96^{a}
Variety Mean	Canthatch	1.86				1.79				1.83
	Selkirk		1.86				1.76			1.81
Type Mean	Light			1.92				1.77		1.84
	Heavy			1.81	1.86			1.78	1.78	1.80

* Single value
a,b Zone means with the same superscript are not significantly different (P 0.05)

TABLE 16 - MEAN SQUARES FOR PROXIMATE PRINCIPLES IN WHEAT

Source	D.F.	Moisture	Crude Protein	Crude Fat	Crude Fiber	N.F.E.	Ash
Year	1	1.189	47.85**	0.005	0.348**	36.05**	0.118
Soil Zone	3	4.655**	2.502	0.019	0.136*	6.103	0.139*
Soil Type	1	0.346	4.415	0.048	0.101	2.773	0.036
Variety	1	0.047	2.180	0.295**	0.041	3.334	0.002
Year x Variety	1	0.013	3.239	0.030	0.016	2.957	0.008
Year x Type	1	0.002	1.799	0.014	0.088	1.003	0.058
Year x Zone	3	3.491**	0.844	0.005	0.109	2.123	0.115*
Zone x Type	3	1.656*	4.305	0.007	0.057	3.653	0.175**
Zone x Variety	3	0.084	0.831	0.011	0.014	0.251	0.013
Type x Variety	1	0.414	0.021	0.00004	0.003	0.018	0.016
Year x Zone x Type	3	1.596*	3.122	0.009	0.010	2.683	0.008
Year x Zone x Variety	3	0.065	0.492	0.008	0.013	1.598	0.014
Year x Type x Variety	1	0.267	0.004	0.034	0.107	1.527	0.0003
Zone x Type x Variety	3	0.097	0.236	0.042	0.003	0.343	0.015
Missing Plots	(2)						
Error	33	0.463	3.065	0.017	0.043	3.884	0.038

* P<.05
** P<.01

samples ranged from 13.78 to 21.31%. A significant ($P<.01$) difference was noted between years. Samples of the 1964 crop were about 1.8% higher in crude protein content. There were no soil zone, type or variety differences.

Crude Fat

The crude fat content of wheat ranged between 1.67 and 2.29%. The significant variety difference ($P<.01$) showed Canthatch wheat to be higher by about 0.14% in crude fat content than Selkirk wheat. This difference was evident in both crop years. Although statistically not significant, the trend was for the crude fat to decrease somewhat from the brown to the grey soil zone.

Crude Fiber

Crude fiber content in wheat ranged between 2.72 and 3.45%. The crude fiber content varied significantly between years ($P<.01$), with the higher fiber content resulting in 1965. In both years the black soil zone produced wheat with significantly ($P<.05$) lower crude fiber content. There were no soil type or variety differences.

Nitrogen Free Extract

The N.F.E. content of wheat ranged between 70.84 and 79.69. In 1965 the N.F.E. content was significantly ($P<.01$) higher than in 1964. No other effects were noted.

Ash

Ash contents of the wheat samples varied from 1.43 to 2.34%. The grey soil zone gave rise to significantly higher ($P<.05$) ash contents. With the exception of the brown soil zone, all zones showed higher ash content in 1964 than in 1965 ($P < .05$). Samples from the heavier soil type within the black soil zone were consistently lower in ash content. The light type in the grey soil zone in 1965 produced a much lower ash content in the samples than in 1964.

The values for the proximate principles in wheat compare favourably with those shown in table 2 (Grain Research Reports, 1951-1965). Protein values are somewhat higher, because the protein content of the 1964 samples was high and generally the samples in this study were of a higher grade.

5.3 The Effects of Years, Soil Zone, Soil Type and Variety on the B-vitamin content of Wheat

Mean values of the B-vitamin content of wheat are shown in tables 17 to 20, and the results of the factorial analysis in table 21.

Nicotinic Acid

Nicotinic acid values for the wheat samples ranged between 49.0 to 91.8 mg/kg. The Canthatch wheat was found to contain about 14.5 mg/kg more nicotinic acid than Selkirk wheat, significant at ($P < 0.01$). This difference was evident in both years. The lower contents of nicotinic acid in the brown soil zone in 1965 and the black soil zone in 1964 gave rise to the year x zone interaction ($P < .05$). No overall soil zone, year and type differences were found. Selkirk wheat nicotinic acid content compares with those reported in the literature and summarized in table 5; however, the mean

TABLE 17 - NICOTINIC ACID CONTENT OF WHEAT

Soil Zone	Soil Zone	Nicotinic acid, mg./Kg. ** 1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	72.55	60.70	66.62		73.85	58.35	66.10		
	Heavy	87.70*	64.70*	76.20	71.41	68.50	54.95	61.72	63.91	67.66
Dark Brown	Light	74.95	61.40	68.18		79.05	67.05	73.05		
	Heavy	75.20	60.00	67.60	67.89	82.45	59.25	70.85	71.95	69.92
Black	Light	65.55	55.10	60.32		87.85	66.30	77.07		
	Heavy	72.85	60.90	66.88	63.60	74.85	61.35	68.10	72.58	68.08
Grey	Light	74.85	54.10	64.48		67.35	55.45	61.40		
	Heavy	69.85	62.00	65.92	65.20	73.80	64.65	69.22	65.31	65.26
Variety Mean	Canthatch	74.18				75.96				74.99
	Selkirk		59.86				60.92			60.48
Type Mean	Light			64.90				69.40		67.15
	Heavy			69.15	67.02			67.47	68.44	68.31

* Single value
** Data are reported on a moisture-free basis

TABLE 18 - RIBOFLAVIN CONTENT OF WHEAT

		Riboflavin, mg./Kg. **								
		1964				1965				
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	1.88	1.92	1.90		1.44	1.30	1.37		
	Heavy	2.11*	1.93*	2.02	1.96	1.53	1.36	1.45	1.41	1.69
Dark Brown	Light	1.81	1.81	1.81		1.43	1.51	1.47		
	Heavy	1.83	2.30	2.07	1.94	1.44	1.37	1.41	1.44	1.68
Black	Light	1.80	1.87	1.84		1.57	1.49	1.53		
	Heavy	1.66	1.80	1.73	1.79	1.31	1.40	1.36	1.45	1.61
Grey	Light	2.08	2.02	2.05		1.56	1.64	1.60		
	Heavy	1.87	1.90	1.89	1.97	1.53	1.59	1.56	1.58	1.77
Variety Mean	Canthatch	1.88				1.48				1.68
	Selkirk		1.94				1.46			1.69
Type Mean	Light			1.90				1.49		1.69
	Heavy			1.93	1.91			1.44	1.47	1.69

* Single value
** Data are reported on a moisture-free basis

TABLE 19 - THIAMINE CONTENT OF WHEAT

		Thiamine, mg./Kg. **								
		1964				1965				Overall
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Zone Mean
Brown	Light	5.26	4.79	5.03		5.15	4.97	5.06		
	Heavy	5.00*	5.17*	5.09	5.06	4.96	4.85	4.91	4.99	5.02[a]
Dark Brown	Light	4.79	4.58	4.69		5.05	5.05	5.05		
	Heavy	4.75	4.55	4.65	4.67	4.79	4.55	4.67	4.86	4.76[b]
Black	Light	4.92	4.98	4.95		5.24	5.00	5.12		
	Heavy	4.74	4.65	4.70	4.83	4.79	4.56	4.68	4.90	4.85[b]
Grey	Light	4.97	4.64	4.81		4.36	4.30	4.33		
	Heavy	4.55	4.53	4.54	4.68	4.78	4.57	4.68	4.51	4.58[b]
Variety Mean	Canthatch	4.86				4.89				4.87
	Selkirk		4.71				4.73			4.72
Type Mean	Light			4.87				4.89		4.87
	Heavy			4.74	4.80			4.73	4.81	4.73

* Single value
** Data are reported on a moisture-free basis
a,b Zone means with the same superscript are not significantly different (P 0.05)

TABLE 20 - PANTOTHENIC ACID CONTENT OF WHEAT

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkir	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Pantothenic Acid, mg./Kg. **								
Brown	Light	14.14	12.72	13.43		9.78	10.52	10.15		
	Heavy	15.08*	16.11	15.60	14.52	10.28	12.35	11.32	10.74	12.62[b]
Dark Brown	Light	14.62	17.15	15.89		9.44	10.09	9.77		
	Heavy	13.62	16.14	14.88	15.39	9.21	10.53	9.87	9.82	12.60[b]
Black	Light	14.40	16.82	15.61		10.32	9.81	10.07		
	Heavy	12.90	13.23	13.07	14.34	9.44	9.82	9.63	9.85	12.09[b]
Grey	Light	16.57	26.43	21.50		12.92	10.73	11.83		
	Heavy	17.52	19.44	18.48	19.99	12.79	10.06	11.43	11.63	15.82[a]
Variety Mean	Canthatch	14.86				10.52				12.71
	Selkirk		17.26				10.49			13.85
Type Mean	Light			16.61				10.45		13.53
	Heavy			15.51	16.06			10.56	10.50	13.03

* Single value
** Data are reported on a moisture-free basis
a,b Zone means with the same superscript are not significantly different (P 0.01)

TABLE 21 - MEAN SQUARES FOR B VITAMINS OF WHEAT

Source	D.F.	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid
Year	1	30.47	2.968**	0.0005	465.96**
Soil Zone	3	59.02	0.068	0.474*	46.47**
Soil Type	1	20.04]	0.002	0.293	3.78
Variety	1	3205.07**	0.010	0.345	19.65
Year x Variety	1	4.25	0.031	0.001	20.77
Year x Type	1	143.26	0.022	0.005	5.60
Year x Zone	3	172.20*	0.037	0.102	15.56
Zone x Type	3	34.62	0.063	0.115	8.26
Zone x Variety	3	9.54	0.030	0.001	1.84
Type x Variety	1	0.485	0.013	0.010	2.19
Year x Zone x Type	3	104.13	0.033	0.189	2.25
Year x Zone x Variety	3	20.70	0.017	0.018	17.72
Year x Type x Variety	1	0.003	0.014	0.068	6.92
Zone x Type x Variety	3	40.50	0.011	0.034	6.01
Missing Plots	(2)				
Error	33	44.77	0.044	0.126	8.62

* $P < .05$
** $P < .01$

content of Canthatch wheat was found to be considerably greater. Findings with respect to soil zones are similar to those of McElroy and Simonson (41).

Riboflavin

The riboflavin content of the wheat ranged between 1.18 and 2.87 mg/kg. Difference in riboflavin content of the wheat samples for the two years amounted to about 0.5 mg/kg, with 1965 having the significantly ($P < 0.05$) lower content. There were no other significant effects. The mean riboflavin content of the wheat was generally higher by about 0.4 mg/kg than those reported in table 4. Soil zone findings agree with those found by Robinson et al. (56, 58) and McElroy et al. (43).

Thiamine

Thiamine content of the wheat ranged from 4.16 to 5.73 mg/kg. The thiamine content of samples from the brown soil zone were found to be significantly ($P < 0.05$) higher than those from the other soil zones. The lowest value appeared in the grey soil zone, 5.02 mg/kg as compared to 4.58 mg/kg. There were no year, type or variety differences.

The values for thiamine content agree with those reported and summarized for wheat in table 3. Soil zone differences are similar to those reported by McElroy et al. (43) and others (66, 56, 58).

Pantothenic Acid

Pantothenic acid levels were highly variable ranging from 7.93 to 27.57 mg/kg. In 1965 the pantothenic acid content of wheat was significantly lower than in 1964.

($P < 0.01$). The difference between the two years amounted to about 5.5 mg/kg. The grey soil zone showed a significantly higher ($P < 0.01$) pantothenic acid content. This was particularly evident in 1964. The difference compared to the other zones is about 3.0 mg/kg. Since there is a positive relation between ash and pantothenic acid content, and since sulfur is a constituent of coenzyme A, it might be speculated that difference in availability with change in moisture conditions in the sometimes sulfur deficient grey soil zone bears some relationship to the difference accounted for between zones and years in wheat.

Available literature reports (table 6) indicate a considerable range; however, the range and the mean values obtained in this study are somewhat higher. The overall mean of 13.28 mg/kg for both years does compare with the mean of 13.6 mg/kg cited in the Joint U.S.-Canadian Feed Composition Tables, but as evident in this study the variation between years and zones can give rise to considerable differences in content.

5.4 Correlations between Nutrients, Agronomic Characteristics and Precipitation for Wheat

The results of the correlation analysis for wheat are shown in table 22 and 23. The data and factorial analysis for the agronomic characters can be found in the appendix L to L_4. Thiamine and riboflavin were significantly and positively ($P < 0.05$) correlated with ash and significantly ($P < 0.01$) and negatively with N.F.E., yield and 1000 kernel weight.

TABLE 22 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, AGRONOMIC CHARACTERS AND PRECIPITATION - WHEAT

	Moisture	Crude Protein	Crude Fat	Crude Fiber	N.F.E.	Ash	1000 Kernel Weight
Moisture	———						
Crude Protein	0.546**	———					
Crude Fat	0.114	-0.180	———				
Crude Fiber	0.103	0.158	-0.037	———			
N.F.E.	-0.506**	-0.916**	0.099	-0.252	———		
Ash	0.225	0.349	-0.099	0.262	-0.388*	———	
1000 Kernel Weight	-0.420**	-0.473**	-0.015	-0.404	0.476**	-0.145	———
Yield	-0.299	-0.547**	0.243	-0.233	0.524**	-0.325	0.349*
Bushel Weight	-0.161	-0.313	0.235	-0.365*	0.307	-0.133	0.536**
Nicotinic Acid	0.265	0.299	-0.164	0.133	-0.255	0.258	-0.230
Riboflavin	0.327*	0.401*	-0.223	0.214	-0.430*	0.241	-0.210
Thiamine	0.551**	0.692**	-0.002	0.251	-0.644**	0.285	-0.757**
Pantothenic Acid	-0.061	0.270	0.049	0.196	-0.285	0.327*	-0.120
Grade	-0.062	-0.304	-0.103	-0.063	-0.253	-0.031	+0.180
April	0.269	-0.144	-0.077	0.040	0.043	0.331*	0.015
May	0.169	-0.259	-0.081	-0.074	0.267	-0.207	0.074
June	0.246	0.277	-0.055	-0.147	-0.155	-0.228	-0.202
July	-0.054	-0.073	-0.097	-0.042	-0.001	0.318	0.186
Season	0.315*	-0.042	-0.154	-0.168	-0.087	-0.096	-0.003

* $P < .05$
** $P < .01$

TABLE 23 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENT, AGRONOMIC CHARACTERS AND PRECIPITATION - WHEAT

	Yield	Bushel Weight	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid	Grade
Moisture							
Crude Protein							
Crude Fat							
Crude Fiber							
N.F.E.							
Ash							
1000 Kernel Weight							
Yield	———						
Bushel Weight	-0.010	———					
Nicotinic Acid	0.065	-0.374*	———				
Riboflavin	-0.195	-0.243	0.333*	———			
Thiamine	-0.348*	-0.459**	0.318	0.181	———		
Pantothenic Acid	-0.219	-0.411*	0.261	0.126	0.127	———	
Grade	-0.220	+0.435*	-0.206	-0.269	-0.308	-0.220	———
April	0.149	-0.093	-0.006	-0.036	-0.078	-0.235	+0.143
May	0.076	-0.103	0.051	0.054	-0.138	-0.099	+0.290*
June	-0.135	0.045	0.067	-0.044	-0.408**	-0.139	-0.222
July	-0.091	0.169	0.040	0.313*	-0.225	0.061	-0.236
Season	-0.052	0.019	0.101	0.146	0.076	-0.182	-0.028

* $P < .05$
** $P < .01$

Pantothenic acid was significantly ($P<0.05$) and positively correlated with ash. Nicotinic acid and pantothenic acid were not significantly correlated with protein which is contrary to the findings of McElroy and Simonson (41) and Frey and Watson (19). The significant ($P<0.01$ and $P<0.05$) negative correlations between thiamine, 1000 kernel weight and bushel weight are in agreement with those reported by Whiteside and Jackson (76). Hoffer et al. (28) reported a negative and significant correlation between yield and thiamine which also was evident ($P<0.05$) in this study. Among the B-vitamins, riboflavin and nicotinic acid were found significantly and positively correlated ($P<0.05$). Similar results were found by Frey and Watson (19).

5.5 Summary

Yearly differences among the proximate principles in wheat occurred in crude protein, crude fiber and N.F.E. content. The crude protein content was higher in 1964 by about 1.8%. Crude fiber and N.F.E. were higher in 1965. Among the B-vitamins, riboflavin and pantothenic acid showed yearly differences. The riboflavin content was about 0.5 mg/kg lower in 1965. For pantothenic acid, the difference amounted to a substantial 5.5 mg/kg.

Varieties, as shown in the case of nicotinic acid and crude fat content, are important in the consideration of nutrient composition and quality as a feed grain. Canthatch, on the average, contained about 14.5 mg/kg more nicotinic acid than Selkirk and about 0.14% more crude fat.

Soil zones had an effect on moisture, crude fiber, ash, thiamine and pantothenic acid content. Moisture content was highest in the brown and grey soil zone; crude fiber content was lowest in the black zone; ash content highest in the grey zone; thiamine content was highest in the brown zone; and pantothenic acid content was higher by about 3.0 mg/kg in the grey soil zone as compared to the other soil zones.

There were no overall soil type differences for any of the nutrients in wheat.

6. THE EFFECTS OF YEARS, SOIL ZONES, SOIL TYPE AND VARIETY ON THE PROXIMATE PRINCIPLES IN OATS

Mean values are shown in tables 24 to 29, and the results of the factorial analysis in table 30.

Moisture

Moisture contents for oats ranged from 6.78 to 9.98%. Zones had a significant effect ($P<0.01$) on the moisture content. The brown soil zone was significantly ($P<0.01$) lower in moisture content than the dark brown and grey soil zones. The difference amounted to about 1% in moisture content. The year x type interaction, significant at ($P<0.05$), was due to the lighter types in 1964 and the heavier types in 1965 having the higher moisture content. The lighter type in the brown zone showed consistently higher moisture content which was reflected in a significant ($P<0.05$) zone x type interaction.

TABLE 24 - MOISTURE CONTENT OF OATS

Moisture, %

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	8.23	8.54	8.38		7.51*	8.28*	7.90		
	Heavy	7.24*	7.21*	7.22	7.80	7.10	7.06	7.08	7.49	7.64[b]
Dark Brown	Light	8.11	8.63	8.37		8.10	8.39	8.24		
	Heavy	8.55	9.00	8.78	8.58	9.04	9.09	9.06	8.65	8.61[a]
Black	Light	8.22	8.28	8.25		7.50	8.04	7.77		
	Heavy	8.14	8.26	8.20	8.22	8.29	9.09	8.69	8.23	8.23[ab]
Grey	Light	8.10	8.93	8.52		8.33	8.33	8.33		
	Heavy	8.63	7.93	8.28	8.40	8.90	9.76	9.33	8.83	8.62[a]
Variety Mean	Garry	8.15				8.10				8.13
	Rodney		8.35				8.50			8.43
Type Mean	Light			8.38				8.06		8.21
	Heavy			8.12	8.25			8.54	8.30	8.33

* Single value

a,b Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 25 - CRUDE PROTEIN CONTENT OF OATS

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Protein, %**								
Brown	Light	15.78	15.62	15.70		12.37*	12.22*	12.30		
	Heavy	14.87*	15.67*	15.27	15.48	15.36	15.42	15.39	13.84	14.66
Dark Brown	Light	15.70	14.56	15.13		14.95	14.86	14.90		
	Heavy	15.62	15.12	15.37	15.25	14.27	14.12	14.20	14.55	14.90
Black	Light	16.00	15.01	15.50		14.83	14.20	14.52		
	Heavy	15.23	14.69	14.96	15.23	12.88	12.83	12.86	13.69	14.46
Grey	Light	13.02	13.16	13.09		14.00	13.38	13.69		
	Heavy	14.46	14.44	14.45	13.77	15.06	14.56	14.81	14.25	14.01
Variety Mean	Garry	15.09				14.22				14.65
	Rodney		14.78				13.95			14.37
Type Mean	Light			14.85				13.85		14.35
	Heavy			15.01	14.93			14.31	14.08	14.66

* Single value
** Data are reported on a moisture-free basis

TABLE 26 - CRUDE FAT CONTENT OF OATS

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Fat, %**								
Brown	Light	4.39	5.05	4.72		4.48*	5.35*	4.92		
	Heavy	4.34*	5.50*	4.92	4.82	4.11	5.15	4.63	4.78	4.79[b]
Dark Brown	Light	4.85	5.67	5.26		4.51	5.09	4.80		
	Heavy	4.62	5.82	5.22	5.24	4.83	5.51	5.17	4.99	5.11[ab]
Black	Light	5.03	6.18	5.61		4.45	5.47	4.96		
	Heavy	4.86	5.64	5.25	5.43	5.07	6.16	5.62	5.29	5.35[a]
Grey	Light	5.08	6.34	5.71		4.94	5.69	5.32		
	Heavy	4.76	6.48	5.62	5.67	5.00	6.20	5.60	5.46	5.56[a]
Variety Mean	Garry	4.74				4.67				4.70
	Rodney		5.84				5.58			5.70
Type Mean	Light			5.32				5.00		5.15
	Heavy			5.25	5.28			5.25	5.12	5.25

* Single value

** Data are reported on a moisture-free basis

a,b Zone means with the same superscript are not significantly different (P>0.01)

TABLE 27 - CRUDE FIBER CONTENT OF OATS

		Crude Fiber, %**								
		1964				1965				Overall
Soil Zone	Soil Type	Garry	Rodney	Type Mean	Zone Mean	Garry	Rodney	Type Mean	Zone Mean	Zone Mean
Brown	Light	14.44	13.15	13.80		15.52*	13.31*	14.42		
	Heavy	14.99*	12.53*	13.76	13.78	15.36	13.42	14.39	14.41	14.10
Dark Brown	Light	12.76	12.02	12.39		15.07	13.85	14.46		
	Heavy	13.32	10.74	12.03	12.21	13.30	12.25	12.78	13.62	12.91
Black	Light	11.78	10.14	10.96		15.87	13.93	14.90		
	Heavy	12.98	11.76	12.37	11.67	14.08	12.08	13.08	13.99	12.83
Grey	Light	15.77	13.42	14.60		14.69	13.04	13.87		
	Heavy	14.81	11.92	13.37	13.99	12.58	11.04	11.81	12.84	13.41
Variety Mean	Garry	13.86				14.36				14.20
	Rodney		11.96				12.87			12.42
Type Mean	Light			12.94				14.41		13.67
	Heavy			12.88	12.91			13.01	13.71	12.95

* Single value
** Data are reported on a moisture-free basis

TABLE 28 - NITROGEN FREE EXTRACT CONTENT OF OATS

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Nitrogen Free Extract, %**								
Brown	Light	61.65	62.53	62.09		64.26	65.77	65.02		
	Heavy	62.52*	63.06*	62.79	62.44	61.23	62.37	61.80	63.41	62.92
Dark Brown	Light	63.48	64.60	64.04		61.85	61.90	61.87		
	Heavy	62.44	64.62	64.54	63.80	63.84	64.36	64.10	62.99	63.38
Black	Light	63.72	65.33	64.53		61.78	63.47	62.63		
	Heavy	63.20	64.41	63.81	64.17	64.61	65.69	65.15	63.89	64.03
Grey	Light	62.07	63.30	62.69		63.29	65.10	64.20		
	Heavy	62.39	63.71	63.05	62.87	64.00	64.90	64.45	64.33	63.60
Variety Mean	Garry	62.68				63.11				62.89
	Rodney		63.95				64.19			64.09
Type Mean	Light			63.34				63.43		63.37
	Heavy			63.30	63.32			63.87	63.65	63.59

* Single value
** Data are reported on a moisture-free basis

TABLE 29 - ASH CONTENT OF OATS

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	3.74	3.67	3.71		3.37*	3.35*	3.36		
	Heavy	3.28*	3.24*	3.26	3.49	3.94	3.65	3.80	3.58	3.53[ab]
Dark Brown	Light	3.23	3.16	3.20		3.62	4.30	3.96		
	Heavy	4.01	3.72	3.87	3.54	3.77	3.78	3.78	3.87	3.70[a]
Black	Light	3.48	3.34	3.41		3.08	2.93	3.01		
	Heavy	3.74	3.50	3.62	3.52	3.37	3.25	3.31	3.16	3.34[b]
Grey	Light	4.07	3.94	4.01		3.09	2.80	2.95		
	Heavy	3.58	3.46	3.52	3.77	3.37	3.30	3.34	3.15	3.43[b]
Variety Mean	Garry	3.64				3.45				3.55
	Rodney		3.50				3.42			3.45
Type Mean	Light			3.58				3.32		3.44
	Heavy			3.57	3.57			3.56	3.44	3.56

Ash, %

* Single value
a,b Zone means with the same superscript are not significantly different ($P > 0.05$)

Crude Protein

The crude protein content of the oat samples ranged between 11.2 and 16.31%. Protein contents in the two years were significantly ($P<0.05$) different, with the mean protein content of 1964 being higher by about 0.85%. The significant ($P<0.05$) zone x type interaction occurred because in both years the heavier type in the grey soil zone produced consistently the higher protein content, while in the brown zone this was only true in 1965. There were no significant overall soil zone, type or variety differences.

Crude Fat

Crude fat content of the oat samples ranged between 4.10 and 6.56%. The significant ($P<0.01$) variety differences shows that Rodney oats contain about 1% more crude fat than Garry oats. This difference in crude fat was consistent in both years. Soil zone differences in crude fat content in oats are in contrast to those obtained for wheat. A significant ($P<0.01$) zone effect was obtained, with the brown soil zone being lower in crude fat content than either the grey and black soil zones.

Crude Fiber

In the oats samples, the crude fiber content varied between 10.60 and 18.01%. The significant ($P<0.05$) year differences amounted to about 0.8%, with the 1964 samples being lower in crude fiber content. Garry oats had a significantly ($P<0.01$) higher crude fiber content than Rodney. The difference of about 1.8% is quite consistent throughout both years. Soil type differences significant at ($P<0.05$) may be largely attributed to the difference in response of Garry oats to the light soil type in 1965 when the crude fiber content in these locations was considerably increased. All soil zones except the grey zone showed much higher crude fiber content in 1965 than in 1964 resulting in the significant ($P<0.01$) year x zone interaction.

Nitrogen Free Extract

N.F.E. contents for the oat samples ranged between 58.94 and 67.24%. A highly significant ($P<0.01$) variety difference reflected the fact that Rodney oats is higher in N.F.E. content than Garry.

Ash

Ash content for the oat samples ranged from 2.47 to 5.21%. The dark brown soil zone produced a significantly ($P<0.05$) greater ash content than either the black or grey soil zone. The year x zone interaction was also significant ($P<0.01$). Both the black and grey soil zones were higher in ash content in 1964 than in 1965 while brown and dark brown zones were higher in 1965.

The values for the proximate principles of oats in this study when compared to the values for oats reported and summarized in table 2 (Grain Research Report, 1951-1965) appear to be higher in crude protein, crude fiber and ash content and lower in the N.F.E. fraction. The reported values, however, come from all over Western Canada and reflect a much larger sample number. The results of this study may also be an indication of the difference of oats grown under Saskatchewan conditions.

6.1 The Effects of Years, Soil Zones, Soil Type and Variety on the B-Vitamin Content of Oats

Mean values of the B-vitamin content of oats are shown in tables 31 to 34, and the results of the factorial analysis in table 35.

Nicotinic Acid

Nicotinic acid content of the oat samples ranged between 10.60 and 21.10 mg/kg. Year differences in nicotinic acid content were significant at ($P<0.01$) with 1964 producing the higher content (2.8 mg/kg). In 1964 Garry oats and in 1965 Rodney contained more nicotinic acid, and this is reflected in the significant ($P<0.05$) year x variety interaction. It perhaps points out the difference in response to environmental conditions between the two varieties. There were no overall soil zone, type or variety differences.

The mean values for nicotinic acid content obtained in this study were higher than those reported by McElroy and Simonson (41) and Frey and Watson (19) by about 4.0 to 5.0 mg/kg, but compare with the mean of 17.8 cited in the Joint U.S.-Canadian Feed Composition Tables. Soil zone and year findings are in agreement with those reported by McElroy and Simonson (41).

Riboflavin

The riboflavin content of the oat samples ranged

TABLE 31 - NICOTINIC ACID CONTENT OF OATS

		Nicotinic Acid, mg./kg.**								
		1964				1965				Overall
Soil Zone	Soil Type	Garry	Rodney	Type Mean	Zone Mean	Garry	Rodney	Type Mean	Zone Mean	Zone Mean
Brown	Light	19.75	16.60	18.18		10.60*	13.10*	11.85		
	Heavy	16.60*	18.60*	17.60	17.89	17.20	17.65	17.42	14.64	16.26
Dark Brown	Light	19.30	18.45	18.88		16.05	16.55	16.30		
	Heavy	19.65	18.95	19.30	19.09	12.75	16.35	14.55	15.42	17.25
Black	Light	19.00	16.05	17.52		14.05	14.70	14.38		
	Heavy	17.20	16.90	17.05	17.28	13.95	13.80	13.88	14.13	15.71
Grey	Light	16.25	16.40	16.32		16.50	15.95	16.22		
	Heavy	16.80	15.20	16.00	16.16	11.90	15.95	13.92	15.07	15.62
Variety Mean	Garry	18.07				14.12				16.17
	Rodney		17.14				15.38			16.25
Type Mean	Light			17.72				14.69		16.21
	Heavy			17.49	17.61			14.94	14.81	16.21

* Single value
** Data are reported on a moisture-free basis

TABLE 32 - RIBOFLAVIN CONTENT OF OATS

		Riboflavin, mg/kg**								
		1964				1965				
Soil Zone	Soil Type	Garry	Rodney	Type Mean	Zone Mean	Garry	Rodney	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	2.05	2.44	2.25		1.54*	1.76*	1.65		
	Heavy	2.37*	1.78*	2.08	2.17	1.74	1.93	1.84	1.75	1.95[ab]
Dark Brown	Light	1.77	1.83	1.80		1.58	1.88	1.73		
	Heavy	1.78	1.68	1.73	1.77	1.71	1.61	1.66	1.70	1.73[b]
Black	Light	1.88	1.78	1.83		1.65	1.65	1.65		
	Heavy	2.02	1.83	1.93	1.88	1.58	1.35	1.47	1.56	1.71[b]
Grey	Light	2.49	2.59	2.54		1.62	1.73	1.68		
	Heavy	1.74	2.12	1.93	2.24	1.66	1.87	1.77	1.73	1.97[a]
Variety Mean	Garry	2.01				1.64				1.81
	Rodney		2.01				1.72			1.87
Type Mean	Light			2.10				1.68		1.89
	Heavy			1.92	2.01			1.68	1.67	1.79

* Single value

** Data are reported on a moisture-free basis

a,b Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 33 - THIAMINE CONTENT OF OATS

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Thiamine, mg/kg**								
Brown	Light	8.68	7.05	7.87		6.87*	6.17*	6.52		
	Heavy	9.14*	7.58*	8.36	8.12	8.58	6.50	7.54	7.03	7.57[a]
Dark Brown	Light	7.85	6.30	7.08		8.12	6.86	7.49		
	Heavy	7.87	6.40	7.14	7.11	7.61	6.15	6.88	7.19	7.14[a]
Black	Light	7.96	6.14	7.05		8.10	6.78	7.44		
	Heavy	8.05	6.40	7.23	7.14	7.50	6.34	6.92	7.18	7.16[a]
Grey	Light	5.72	4.58	5.15		7.00	6.11	6.56		
	Heavy	6.51	5.29	5.90	5.53	8.39	6.71	7.55	7.06	6.29[b]
Variety Mean	Garry	7.72				7.77				7.76
	Rodney		6.23				6.45			6.32
Type Mean	Light			6.79				7.01		6.90
	Heavy			7.16	6.97			7.22	7.11	7.19

* Single value
** Data are reported on a moisture-free basis
a,b Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 34 - PANTOTHENIC ACID CONTENT OF OATS

Pantothenic Acid, mg/kg**

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	6.86	7.75	7.31		7.64*	10.98*	9.31		
	Heavy	7.88*	9.03*	8.46	7.89	6.09	8.75	7.42	8.37	8.12
Dark Brown	Light	10.15	6.37	8.26		9.16	9.00	9.08		
	Heavy	6.50	6.87	6.69	7.48	7.74	6.98	7.36	8.22	7.84
Black	Light	6.68	6.34	6.51		8.58	8.69	8.64		
	Heavy	8.06	6.12	7.09	6.80	6.54	5.81	6.18	7.41	7.1
Grey	Light	8.40	8.38	8.39		4.82	8.34	6.58		
	Heavy	7.26	7.37	7.32	7.86	9.09	7.90	8.50	7.54	7.69
Variety Mean	Garry	7.72				7.46				7.57
	Rodney		7.28				8.31			7.81
Type Mean	Light			7.62				8.40		8.01
	Heavy			7.39	7.50			7.36	7.88	7.37

* Single value
** Data are reported on a moisture-free basis

TABLE 35 - MEAN SQUARES FOR B-VITAMINS OF OATS

Source	D.F.	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid
Year	1	110.86**	1.562**	0.293	2.052
Soil Zone	3	9.074	0.290**	4.127**	2.611
Soil Type	1	0.001	0.122	1.252*	5.734
Variety	1	0.076	0.052	30.02**	0.830
Year x Variety	1	18.91*	0.033	0.124	5.946
Year x Type	1	0.867	0.133	0.083	2.322
Year x Zone	3	5.245	0.142	0.386**	0.897
Zone x Type	3	8.524	0.050	1.345*	3.024
Zone x Variety	3	1.512	0.079	0.056	7.219*
Type x Variety	1	6.783	0.127	0.212	0.847
Year x Zone x Type	3	11.28	0.178	0.337	7.661*
Year x Zone x Variety	3	0.175	0.020	0.060	0.182
Year x Type x Variety	1	0.075	0.0001	0.262	6.082
Zone x Type x Variety	3	0.096	0.072	0.117	2.987
Missing Plots	(4)				
Error	31	4.151	0.050	0.311	2.323

* $P < .05$
** $P < .01$

between 1.33 and 2.92 mg/kg. Difference in riboflavin for the two years amounted to about 0.35 mg/kg, with 1964 having the significantly ($P<0.01$) lower content. Zone differences amounted to 0.25 mg/kg with the grey soil zone being significantly ($P<0.01$) higher than the dark brown or black soil zones. The year x zone x type interaction, significant at ($P<0.05$), resulted because in 1964 the heavy soil type had the higher value in the black soil zone only, while in 1965 this trend was reversed and the heavier type gave rise to the lowest value obtained for the two years. No significant overall type or variety differences were found. The mean values and range obtained for riboflavin content in oats are higher than those reported in table 4, but compare with the mean of 1.8 mg/kg cited in the Joint U.S.-Canadian Feed Composition Tables. Soil zone effects obtained do not agree with those reported by Robinson *et al*. (56, 58) and are in direct contrast with those reported by McElroy *et al*. (43) in Alberta.

Thiamine

Thiamine content of the oat samples ranged from 4.54 to 9.17 mg/kg. The grey soil zone had a significantly ($P<0.01$) lower thiamine content (1 mg/kg). The significant year x zone interaction points out that this was mainly due to the grey zone producing a very low value in 1964. The lighter types produced a significantly ($P<0.05$) lower thiamine content and this was more evident in 1964. Throughout both years Garry oats showed a significantly

($P<0.01$) higher (1.4 mg/kg) thiamine content. Significant ($P<0.05$) zone x type interaction resulted because in the dark brown and black zones in 1965 the lighter soil types produced the higher thiamine content.

The mean values and range of thiamine content for oats in this study are in agreement with those reported and summarized in table 3. Soil zone results are similar to those reported in (43, 56, 58) and follow those obtained for wheat in this study.

Pantothenic Acid

The pantothenic acid content of the oat samples ranged between 4.22 to 11.95 mg/kg. No significant main effects were obtained. The significant ($P<0.05$) interaction between zones and variety resulted because Garry oats in 1964 and 1965 was higher in pantothenic acid content in the dark brown and black soil zones and Rodney oats in both years higher in the brown soil zone and the grey zone only in 1965. The fact that the lighter soil type in 1965 produced a higher pantothenic acid content in all zones except the grey soil zone, and that in 1964 this trend is followed by the dark brown and grey zones, resulted in the significant ($P<0.05$) year x zone x type interaction.

The mean values and range of pantothenic acid content compare with those reported by Frey and Watson (19), but are only about one-half the value of the mean cited in the Joint U.S.-Canadian Feed Composition Tables.

6.2 Correlations between Nutrients, Agronomic Characteristics and Precipitation for Oats

Correlation analysis results for oats are shown in table 36 and 37. The data and factorial analysis of the agronomic characters can be found in the appendix M to M_4. Crude protein was significantly ($P<0.01$) and negatively correlated with N.F.E., and yield and significantly and positively correlated with thiamine and moisture ($P<0.01$). Protein-thiamine, riboflavin correlations were also reported by Robinson et al. (56, 58).

6.3 Summary

Among the proximate principles of oats significant yearly differences occurred in crude protein and crude fiber content. In 1964 the oat samples contained 0.85% more crude protein than in 1965 and about 0.8% less in crude fiber. Year differences for the B-vitamins occurred in nicotinic acid and riboflavin. Nicotinic acid content was increased by 2.8 mg/kg in 1964 and riboflavin was higher in 1965 by about 0.35 mg/kg.

Variety differences were significant with respect to crude fat, crude fiber and thiamine. Garry oats was higher in crude fiber by about 1.8% and lower in crude fat by approximately 1% than Rodney oats. However, Garry oats

TABLE 36 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, AGRONOMIC CHARACTERS AND PRECIPITATION - OATS

	Moisture	Crude Protein	Crude Fat	Crude Fiber	N.F.E.	Ash	1000 Kernel Weight
Moisture	———						
Crude Protein	0.628**	———					
Crude Fat	-0.106	-0.446*	———				
Crude Fiber	-0.245	-0.099	-0.363*	———			
N.F.E.	-0.523**	-0.693**	0.322	-0.490*	———		
Ash	0.015	-0.038	-0.373*	0.214	0.101	———	
1000 Kernel Weight	0.127	-0.078	0.180	-0.644**	0.433*	-0.030	———
Yield	-0.527**	-0.608**	0.254	0.012	0.569	0.043	0.222
Bushel Weight	0.091	-0.007	0.322	-0.666**	0.455*	-0.142	0.694**
Nicotinic Acid	0.285	0.301	-0.060	0.269	-0.483*	0.072	-0.270
Riboflavin	0.143	0.191	0.054	0.190	-0.345*	-0.030	-0.081
Thiamine	0.028	0.458**	-0.189	0.102	-0.282	-0.138	-0.029
Pantothenic Acid	0.065	0.161	-0.045	0.134	-0.188	0.206	-0.210
Grade	-0.066	+0.078	-0.089	-0.309	-0.229	-0.108	+0.332
April	-0.224	-0.265	0.195	-0.286	0.559**	-0.144	0.241
May	-0.090	-0.275	0.089	-0.364*	0.340	-0.267	0.544**
June	0.273	0.027	-0.137	0.180	0.118	0.121	0.054
July	0.230	0.044	0.264	-0.338*	-0.007	-0.210	0.275
Season	0.202	-0.190	0.118	-0.319*	0.345	-0.213	0.576**

* $P < .05$
** $P < .01$

TABLE 37 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, AGRONOMIC CHARACTERS AND PRECIPITATION - OATS

	Yield	Bushel Weight	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid	Grade
Moisture							
Crude Protein							
Crude Fat							
Crude Fiber							
N.F.E.							
Ash							
1000 Kernel Weight							
Yield	———						
Bushel Weight	0.226	———					
Nicotinic Acid	-0.510**	-0.324	———				
Riboflavin	-0.133	-0.002	-0.008	———			
Thiamine	0.198	-0.009	-0.017	0.025	———		
Pantothenic Acid	-0.280	-0.055	0.232	0.115	-0.067	———	
Grade	-0.234	+0.494**	-0.156	+0.022	-0.171	+0.093	———
April	0.143	0.371*	-0.131	-0.236	-0.094	-0.041	+0.453**
May	0.358*	0.052	-0.332*	-0.025	-0.070	-0.326*	+0.298
June	0.149	0.199	0.010	0.060	0.001	0.198	+0.091
July	0.009	0.391*	-0.084	0.029	-0.083	-0.139	-0.258
Season	0.305	0.423**	-0.275	-0.003	-0.101	-0.145	+0.167

* $P < .05$
** $P < .01$

was higher in thiamine content than Rodney, the difference being about 1.4 mg/kg.

Significant soil zone effects were observed for moisture, crude fat, ash, riboflavin and thiamine. The moisture content was lowest in the brown soil zone and varied from the dark brown and grey zone by about 1%. Crude fat was lower in the brown zone than in either the black or grey soil zone. This is completely opposite to the trend indicated for wheat. Ash content for oats was highest in the dark brown soil zone when compared to the black or grey soil zone. Riboflavin values were higher in the grey soil zone by about 0.25 mg/kg than either the dark brown or black soil zones. The thiamine content was significantly lower in the grey soil zone (1 mg/kg).

Significant soil type effects were observed for crude fiber and thiamine. The lighter soil type produced higher crude fiber and lower thiamine contents in oats.

7. THE EFFECTS OF YEARS, SOIL ZONES, SOIL TYPE AND VARIETY ON THE PROXIMATE PRINCIPLES IN BARLEY

Mean values are shown in tables 38 to 43, and the results of the factorial analysis in table 44.

Moisture

The moisture content of the barley samples ranged from 7.5 to 11.04%. The brown soil zone had a significantly ($P<0.01$) lower moisture content than either the dark brown, black or grey soil zone. Soil type differences were

TABLE 38 - MOISTURE CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Moisture, %										
Brown	Light	9.70	9.66	9.63	9.66		8.90*	8.78*	9.14*	8.94		
	Heavy	8.93*	9.09*	10.19*	9.40	9.53	7.66*	7.74*	7.50*	7.63	8.29	8.91^a
Dark Brown	Light	9.77	9.67	8.44	9.29		9.64	9.44	9.46	9.51		
	Heavy	9.72	10.06	9.96	9.91	9.60	9.71	9.92	9.81	9.81	9.66	9.63^b
Black	Light	9.47	9.52	9.39	9.46		9.28	9.58	9.00*	9.29		
	Heavy	9.80	9.57	9.66	9.68	9.57	9.87	10.05	9.62	9.85	9.57	9.57^b
Grey	Light	8.66	8.50	8.28	8.48		9.49	9.70	9.64	9.61		
	Heavy	10.68	10.28	10.83	10.60	9.54	9.86	9.89	10.09	9.95	9.78	9.66^b
Variety Mean	Husky	9.58					9.30					9.44
	Parkland		9.54					9.39				9.46
	Hannchen			9.55					9.28			9.41
Type Mean	Light				9.22					9.34		9.28
	Heavy				9.90	9.56				9.31	9.32	9.60

* Single value

a,b Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 39 - CRUDE PROTEIN CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Protein, %**										
Brown	Light	14.80	14.80	15.50	15.03		11.88*	12.56*	12.52*	12.32	12.32	
	Heavy	17.12*	15.80*	13.64*	15.52	15.28	14.86*	15.08*	16.23*	15.39	13.86	14.57
Dark Brown	Light	14.60	14.25	14.69	14.51		14.86	15.21	17.66	15.91		
	Heavy	13.72	14.38	14.95	14.35	14.43	13.47	14.01	15.32	14.27	15.09	14.76
Black	Light	15.50	15.72	16.64	15.95		15.87	15.65	19.50*	17.01		
	Heavy	14.96	15.28	16.42	15.55	15.75	12.91	13.50	15.16	13.86	15.44	15.60
Grey	Light	14.94	15.10	15.98	15.34		14.36	14.40	15.14	14.63		
	Heavy	15.66	14.93	17.06	15.88	15.61	15.68	16.34	18.60	16.87	15.75	15.68
Variety Mean	Husky	15.16					14.24					14.70[a]
	Parkland		15.03					14.59				14.81[ab]
	Hannchen			15.61					16.27			15.94[b]
Type Mean	Light				15.21					14.97		15.09
	Heavy				15.33	15.27				15.10	15.04	15.22

* Single value
** Data are reported on a moisture-free basis
a,b Variety means with the same superscript are not significantly different (P > 0.01)

TABLE 40 - CRUDE FAT CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Fat, %**										
Brown	Light	2.06	2.09	2.19	2.11		2.01*	2.22*	2.46*	2.23		
	Heavy	2.28*	2.14*	2.32*	2.25	2.18	2.30*	2.24*	2.41*	2.32	2.28	2.23[a]
Dark Brown	Light	1.95	2.05	2.11	2.04		2.05	1.99	2.10	2.05		
	Heavy	2.13	2.15	2.29	2.19	2.12	2.01	2.11	2.27	2.13	2.09	2.11[b]
Black	Light	1.98	2.15	2.25	2.13		2.09	2.11	2.16*	2.12		
	Heavy	1.81	2.11	2.26	2.06	2.10	1.95	2.11	2.25	2.10	2.11	2.11[b]
Grey	Light	2.06	1.97	2.16	2.06		2.15	2.18	2.38	2.24		
	Heavy	1.86	1.90	2.16	1.97	2.02	1.96	1.84	2.13	1.98	2.11	2.07[b]
Variety Mean	Husky	2.02					2.07					2.05[a]
	Parkland		2.07					2.10				2.09[a]
	Hannchen			2.22					2.37			2.30[b]
Type Mean	Light				2.09					2.16		2.13
	Heavy				2.12	2.11				2.13	2.15	2.13

* Single value

** Data are reported on a moisture-free basis

a,b Variety and Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 41 - CRUDE FIBER CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Crude Fiber, %**										
Brown	Light	6.02	5.78	4.94	5.58		6.19*	5.93*	4.93*	5.68		
	Heavy	6.31*	5.91*	5.12*	5.78	5.68	5.94*	5.64*	4.86*	5.48	5.58	5.63
Dark Brown	Light	6.08	6.37	5.14	5.86		6.30	6.10	5.40	5.93		
	Heavy	5.85	5.78	4.74	5.46	5.66	5.67	5.45	4.63	5.25	5.59	5.63
Black	Light	5.65	5.40	4.68	5.24		6.30	5.81	6.06*	6.06		
	Heavy	5.96	5.51	5.17	5.55	5.40	5.81	5.57	5.16	5.51	5.79	5.60
Grey	Light	5.51	5.08	4.81	5.13		5.91	5.62	4.62	5.38		
	Heavy	5.95	6.09	4.93	5.66	5.40	6.04	5.88	5.30	5.74	5.56	5.48
	Husky	5.92					6.02					5.97^{a}
	Parkland		5.74					5.75				5.75^{a}
	Hannchen			4.94					5.12			5.03^{b}
Type Mean	Light				5.45					5.76		5.61
	Heavy				5.61					5.50	5.63	5.56

* Single value
** Data are reported on a moisture-free basis
a,b Variety means with the same superscript are not significantly different ($P > 0.01$)

TABLE 42 - NITROGEN FREE EXTRACT CONTENT OF BARLEY

		Nitrogen Free Extract, %**										
		1964					1965					Overall
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Zone Mean
Brown	Light	74.48	74.99	75.06	74.84		77.15*	76.82*	77.82*	77.26		
	Heavy	71.86*	73.86*	76.68*	74.13	74.49	74.16*	74.46*	74.17*	74.26	75.77	75.13
Dark Brown	Light	74.63	74.68	75.46	74.92		74.28	73.87	72.02	73.39		
	Heavy	75.55	74.98	75.41	75.31	75.12	76.05	75.87	75.13	75.68	74.54	74.83
Black	Light	73.85	73.95	73.74	73.85		73.19	73.92	69.93*	72.35		
	Heavy	74.33	73.82	73.47	73.88	73.87	76.82	76.34	74.81	75.99	74.17	74.02
Grey	Light	74.71	74.41	74.37	74.50		75.32	75.31	75.76	75.46		
	Heavy	73.68	74.41	73.24	73.78	74.14	73.57	73.21	71.17	72.65	74.06	74.10
Variety Mean	Husky	74.13					75.07					74.60
	Parkland		74.38					74.98				74.68
	Hannchen			74.68					73.85			74.26
Type Mean	Light				74.53					74.62		74.58
	Heavy				74.28	74.41				74.65	74.63	74.46

* Single value
** Data are reported on a moisture-free basis

TABLE 43 - ASH CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Ash, %										
Brown	Light	2.65	2.35	2.32	2.44		2.77*	2.47*	2.27*	2.50		
	Heavy	2.43*	2.29*	2.24*	2.32	2.38	2.74*	2.58*	2.33*	2.55	2.53	2.46[a]
Dark Brown	Light	2.74	2.66	2.61	2.67		2.53	2.85	2.83]	2.74		
	Heavy	2.76	2.73	2.61	2.70	2.69	2.80	2.56	2.67	2.68	2.71	2.70[b]
Black	Light	3.03	2.79	2.71	2.84		2.56	2.52	2.35*	2.48		
	Heavy	2.95	2.78	2.69	2.81	2.83	2.51	2.49	2.63	2.54	2.51	2.67[b]
Grey	Light	2.80	2.73	2.68	2.74		2.27	2.50	2.11	2.29		
	Heavy	2.85	2.68	2.62	2.72	2.73	2.77	2.74	2.81	2.77	2.53	2.63[b]
Variety Mean	Husky	2.78					2.62					2.70[a]
	Parkland		2.63					2.59				2.61[ab]
	Hannchen			2.56					2.50			2.53[b]
Type Mean	Light				2.68					2.50		2.59
	Heavy				2.64	2.66				2.64	2.57	2.64

* Single value

a,b Variety and Zone means with the same superscript are not significantly different ($P > 0.05$)

TABLE 44 - MEAN SQUARES FOR PROXIMATE PRINCIPLES OF BARLEY

	D.F.	Moisture	Crude Protein	Crude Fat	Crude Fiber	N.F.E.	Ash
Year	1	1.070	1.234	0.038	0.035	3.661	0.139
Soil Zone	3	1.969**	6.264	0.084**	0.045	3.504	0.186*
Soil Type	1	2.020*	0.373	0.00004	0.079	2.160	0.048
Variety	2	0.018	12.758**	0.297**	6.753**	0.072	0.181*
Year x Variety	2	0.032	3.660	0.001	0.176	1.413	0.026
Year x Type	1	2.529*	0.006	0.018	0.778*	0.189	0.142
Year x Zone	3	1.805**	3.391	0.018	0.165	4.097	0.200*
Zone x Type	3	2.957**	14.662**	0.109**	0.761**	12.423**	0.084
Zone x Variety	6	0.161	1.256	0.018	0.126	1.268	0.032
Type x Variety	2	0.345	0.166	0.005	0.0007	0.390	0.017
Year x Zone x Type	3	1.160*	7.625*	0.012	0.279	5.769	0.091
Year x Zone x Variety	6	0.142	0.328	0.009	0.047	0.323	0.017
Year x Type x Variety	2	0.366	0.128	0.001	0.017	1.121	0.037
Zone x Type x Variety	6	0.095	0.962	0.012	0.032	1.139	0.022
Missing Plots	(10)						
Error	44	0.370	2.329	0.016	0.168	2.728	0.053

* $P < .05$
** $P < .01$

significant ($P<0.05$), with the heavy type showing the greater moisture content. A significant ($P<0.01$) interaction between years and zones resulted because the brown soil zone in 1965 was significantly lower in moisture content than in 1964. Similarly the significant interaction ($P<0.05$) between year and type occurred due to the lighter type in 1965 being basically identical in moisture content to the heavier type. The zone x type interaction was significant ($P<0.01$) because in the brown zone during both years the lighter type showed the higher mean moisture content.

Crude Protein

Crude protein of the barley samples ranged between 10.46 and 19.50%. The two-row variety Hannchen had a significantly ($P<0.01$) higher crude protein content than either Husky or Parkland. The difference amounted to about 1% and were evident in both years. In both years in the black and dark brown soil zones the lighter soil types produced the higher protein content which gave rise to the zone x type interaction. The lowest crude protein content was produced on the lighter soil type in the brown soil zone in 1965. No overall significant year, zone or type effects were evident.

Crude Fat

Crude fat content of the barley samples ranged between 1.57 and 2.46%. A significantly ($P<0.01$) higher crude fat content occurred in the brown soil zone. Hannchen barley contained significantly ($P<0.01$) more crude fat than either of the other two varieties. The significant ($P<0.01$)

zone x type interaction resulted because the lighter soil types in the black and grey zones produced the higher crude fat content, whereas in the brown and dark brown zones this effect was reversed. There were no overall significant year and type differences.

Crude Fiber

The crude fiber content of barley ranged between 4.46 and 6.96%. Hannchen barley contained significantly ($P<0.01$) less crude fiber than either Husky or Parkland barley. During 1964 the heavy soil type produced higher crude fiber content and in 1965 this difference was reversed, giving rise to the significant ($P<0.05$) year x type interaction. In 1964 the heavier type in the black and grey zone and in 1965 in the grey zone only produced higher crude fiber content, resulting in the significant ($P<0.01$) zone x type interaction. There were no overall significant year, zone or type differences.

Nitrogen Free Extract

N.F.E. content of the barley ranged from 70.61 to 79.55%. The significant ($P<0.01$) zone x type interaction reflected the high N.F.E. values in light type brown soils in 1965. No overall significant year, soil zone, soil type or variety effects were found.

Ash

Ash content of the barley samples ranged between 2.02 and 3.22%. The brown soil zone produced barley with significantly ($P<0.05$) lower ash content than either the dark brown, black or grey zones. Hannchen barley also contained significantly ($P<0.05$) less ash than Husky barley. The brown soil zone in 1965 produced the lowest ash content among the zones for both years, and this resulted in the significant ($P<0.05$) year x zone interaction. There were no significant overall year or type differences.

Except for protein and N.F.E., the values of the proximate principles in barley compare with those reported and summarized in table 2 (Grain Research Reports 1951-1965). The mean crude protein content of the barley samples in this study is about 1.5% higher and the N.F.E., consequently, somewhat lower in content.

7.1 The Effect of Years, Soil Zones, Soil Type and Variety on the B-Vitamin Content of Barley

Mean values of the B-vitamin content of barley are shown in tables 45 to 48, and the results of the factorial analysis in table 49.

Nicotinic Acid

Nicotinic acid content of the barley samples ranged between 81.70 and 119.3 mg/kg. The black and grey soil zones produced significantly ($P<0.01$) higher nicotinic acid contents in barley than the brown and dark brown soil zones. This

TABLE 45 - NICOTINIC ACID CONTENT OF BARLEY

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		Nicotinic Acid, mg/kg**										
Brown	Light	87.30	92.25	87.30	89.0		116.40*	106.90*	96.10*	106.5		
	Heavy	93.80*	95.20*	94.90*	94.6	91.9	82.10*	95.90*	79.50*	85.8	96.2	94.0^{a}
Dark Brown	Light	95.90	100.75	96.60	97.8		102.00	101.85	109.25	104.4		
	Heavy	90.45	98.10	96.70	95.1	96.4	84.45	94.60	93.65	90.9	97.6	97.0^{a}
Black	Light	97.80	102.25	99.90	100.0		102.75	101.85	101.20*	101.9		
	Heavy	107.40	103.85	104.35	105.2	102.6	106.10	109.15	114.25	109.8	105.9	104.2^{b}
Grey	Light	111.50	107.50	106.10	108.4		89.25	99.20	88.90	92.5		
	Heavy	107.55	106.20	105.25	106.3	107.4	108.10	104.80	112.95	108.6	100.5	104.0^{b}
Variety Mean	Husky	98.96					98.89					98.9
	Parkland		100.76					101.78				101.3
	Hannchen			98.89					99.48			99.2
Type Mean	Light				98.8					101.3		100.0
	Heavy				100.3	99.6				98.8	100.0	99.6

* Single value
** Data are expressed on a moisture-free basis
a,b Zone means with the same superscript are not significantly different ($P>0.01$)

TABLE 46 - RIBOFLAVIN CONTENT OF BARLEY

		Riboflavin, mg/kg**										
		1964					1965					
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	1.88	1.93	2.05	1.95		1.54*	1.43*	1.73*	1.57		
	Heavy	2.12*	2.35*	1.93*	2.13	2.04	1.68*	1.48*	1.49*	1.55	1.56	1.80[a]
Dark Brown	Light	1.83	2.04	1.91	1.93		1.52	2.04	1.94	1.83		
	Heavy	1.85	1.91	2.03	1.93	1.93	1.46	1.49	1.97	1.64	1.74	1.84[a]
Black	Light	2.24	2.56	2.57	2.46		1.61	1.84	2.11*	1.84		
	Heavy	1.92	2.00	2.16	2.03	2.25	1.54	1.49	1.55	1.53	1.69	1.97[ab]
Grey	Light	2.51	2.49	2.68	2.56		1.78	1.61	1.84	1.74		
	Heavy	2.42	2.33	2.45	2.40	2.48	1.81	1.80	2.19	1.93	1.84	2.16[b]
Variety Mean	Husky	2.10					1.62					1.86
	Parkland		2.20					1.65				1.93
	Hannchen			2.22					1.85			2.04
Type Mean	Light				2.23					1.75		1.99
	Heavy				2.13	2.18				1.66	1.71	1.90

* Single value
** Data are expressed on a moisture-free basis
a,b Zone means with the same superscript are not significantly different ($P > 0.01$)

TABLE 47 - THIAMINE CONTENT OF BARLEY

Thiamine, mg/kg**

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	4.87	4.88	4.42	4.72		4.35*	4.89*	4.62*	4.62		
	Heavy	5.28*	5.93*	5.05*	5.42	5.07	4.27*	4.60*	5.13*	4.67	4.65	4.86
Dark Brown	Light	5.03	5.47	4.75	5.08		5.22	5.22	5.86	5.43		
	Heavy	4.13	4.71	4.12	4.32	4.70	4.35	4.56	4.84	4.58	5.01	4.86
Black	Light	4.55	4.69	4.33	4.52		5.03	4.92	6.25*	5.40		
	Heavy	4.58	5.43	4.98	5.00	4.76	4.94	4.99	5.26	5.06	5.23	5.00
Grey	Light	3.81	4.16	4.13	4.03		4.67	4.87	4.40	4.65		
	Heavy	4.28	4.24	4.57	4.36	4.20	5.12	5.54	5.92	5.53	5.09	4.65
Variety Mean	Husky	4.58					4.74					4.66
	Parkland		4.94					4.95				4.95
	Hannchen			4.54					5.29			4.92
Type Mean	Light				4.59					5.03		4.81
	Heavy				4.78	4.68				4.96	5.00	4.87

* Single value
** Data are expressed on a moisture-free basis

TABLE 48 - PANTOTHENIC ACID CONTENT OF BARLEY

		Pantothenic Acid, mg/kg**										
		1964					1965					
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	8.73	8.95	9.04	8.91		9.90*	10.38*	9.46*	9.91		
	Heavy	9.17*	7.81*	10.46*	9.15	9.03	12.14*	9.16*	10.45*	10.58	10.58	9.64[a]
Dark Brown	Light	8.54	10.65	9.84	9.68		12.87	13.22	11.01	12.37		
	Heavy	9.27	9.04	9.42	9.24	9.46	12.94	9.77	12.04	11.58	11.98	10.72[ab]
Black	Light	10.22	9.97	9.83	10.01		9.75	9.79	15.62*	11.72		
	Heavy	10.41	9.35	9.80	9.85	9.93	11.74	9.10	12.93	11.26	11.49	10.71[ab]
Grey	Light	11.11	13.07	9.91	11.36		7.62	11.64	9.72	9.66		
	Heavy	10.42	12.24	12.49	11.72	11.54	12.92	9.66	16.80	13.13	11.40	11.47[b]
Variety Mean	Husky	9.73					11.24					10.48
	Parkland		10.14					10.34				10.24
	Hannchen			10.10					12.25			11.17
Type Mean	Light				9.99					10.92		10.46
	Heavy				9.99	9.99				11.64	11.28	10.82

* Single value

** Data are expressed on a moisture-free basis

a,b Zone means with the same superscript are not significantly different ($P > 0.05$)

TABLE 49 - MEAN SQUARES FOR B VITAMINS OF BARLEY

	D.F.	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid
Year	1	5.898	4.382**	1.804**	29.87**
Soil Zone	3	494.11**	0.560**	0.442	9.89*
Soil Type	1	5.197	0.164	0.080	3.597
Variety	2	50.30	0.207	0.628	5.815
Year x Variety	2	0.937	0.050	0.869*	6.281
Year x Type	1	84.52	0.002	0.262	3.560
Year x Zone	3	139.36*	0.231*	1.253**	6.380
Zone x Type	3	370.58**	0.199	2.175**	6.691
Zone x Variety	6	45.92	0.049	0.044	3.600
Type x Variety	2	35.45	0.031	0.108	18.06**
Year x Zone x Type	3	420.43**	0.096	0.515	3.432
Year x Zone x Variety	6	32.89	0.019	0.208	4.325
Year x Type x Variety	2	19.64	0.006	0.011	5.284
Zone x Type x Variety	6	23.12	0.057	0.105	3.802
Missing Plots	(10)				
Error	44	47.89	0.071	0.212	3.493

* $P < .05$
** $P < .01$

was quite evident in both years and the difference was approximately 8 mg/kg. The brown soil zone in 1964 produced significantly ($P<0.05$) lower nicotinic acid content when compared to the other zones. Zone x type interaction were significant ($P<0.01$) because barleys grown in the heavier soil type in the brown and dark brown zone and the light type in the grey soil had considerably less nicotinic acid in the barley in 1964 than in 1965. Since this effect was reversed in the brown soil zone in 1964, a significant ($P<0.01$) year x zone x type interaction resulted. No overall year, type or variety differences were obtained.

Mean values for nicotinic acid content of the barley samples in this study were in comparison with different values reported in table 5 anywhere from 20 to 40 mg/kg higher. The soil zone differences found are in contrast to those reported for barley by McElroy and Simonson (41), who did not find any soil zone effects on nicotinic acid content.

Riboflavin

The riboflavin content of the barley samples ranged from 1.29 to 2.84 mg/kg. Year differences ($P<0.01$) amounted to 0.4 mg/kg, 1964 being higher in content. The grey soil zone showed significantly ($P<0.01$) higher in riboflavin content than the brown or dark brown zone (0.3 mg/kg). In 1965 the brown soil zone and in 1964 the dark brown zone had the lowest riboflavin values, giving rise to the significant ($P<0.05$) year x zone interaction.

The mean and range of the riboflavin content of the barley samples in this study were higher on the average by about 0.8 mg/kg than those reported in table 4, but compared favourably with the mean reported in the Joint U.S.-Canadian Feed Composition Tables. Soil zone findings are not in agreement with those of Robinson et al. (56, 58) for Manitoba and are contrary to the results obtained by McElroy et al. (43), who found a lower riboflavin content in the grey soil zone.

Thiamine

The thiamine content for the barley samples ranged between 3.91 and 6.45 mg/kg. Thiamine content for the two years were significantly different ($P<0.01$), with 1965 showing the higher content. That Hannchen barley contained more thiamine in 1965 than in 1964 was reflected in a significant ($P<0.05$) year x variety interaction. In 1964 the lowest thiamine content of the samples originated in the grey soil zone, while in 1965 this occurred in the brown soil zone, giving rise to the significant ($P<0.01$) year x zone interaction. The significant ($P<0.01$) zone x type interaction occurred because in 1964 the light type in only the dark brown soil zone produced the higher riboflavin content, while in 1965 this occurred in both the dark brown and black soil zone. No significant overall differences due to soil zones, types or varieties were found.

Thiamine values obtained for the barley samples in this study are in agreement with those reported in table 3. McElroy et al. (43) did find soil zone differences in thiamine content for barley in their study. However, Robinson et al. (56, 58) found no soil zone differences for the 1946 crop year but did for the 1947 crop year. The latter situation is similar to the findings in this study since for both years soil zone differences were completely reversed.

Pantothenic Acid

Pantothenic acid values in the barley samples ranged between 7.26 and 17.96 mg/kg. Overall significant ($P<0.01$) year differences amounted to 1.28 mg/kg with 1965 samples having the higher content. The grey soil zone showed a significantly ($P<0.05$) higher pantothenic acid content than the brown soil zone, with the other zones being intermediate. The difference between the two zones was approximately 1.8 mg/kg. Parkland barley consistently in both years gave a greater response when grown on the lighter soil type in all of the soil zones, which becomes evident from the significant ($P<0.01$) type x variety interaction. There were no overall significant soil type or variety differences.

The pantothenic acid values for barley obtained in this study, mean values and range, were higher than those reported by other workers. As summarized in table 6, the mean value is about 3.3 mg/kg higher than the mean of 7.3 mg/kg reported in the Joint U.S.-Canadian Feed Composition Tables. It should be noted that the double enzyme extraction procedure used in the present study has been shown (47) to yield higher values, at least in wheat, than do other methods.

7.2 Correlations between Nutrients, Agronomic Characteristics and Precipitation for Barley

Correlation analysis results for barley are shown in tables 50 and 51. The data and factorial analysis of the agronomic characters for barley can be found in the appendix N to N_4.

Both riboflavin and thiamine were found significantly ($P<0.05$ and $P<0.01$) and positively correlated with protein. Thiamine was also found significantly ($P<0.01$) and positively correlated with crude fiber and significantly ($P<0.01$) and negatively with 1000 kernel weight. Riboflavin was found to be significantly ($P<0.01$) and negatively correlated with yield and significantly ($P<0.05$) and positively with bushel weight. Crude protein correlations were significant ($P<0.01$) and negative with crude fat and N.F.E., significant ($P<0.05$) and negative with 1000 kernel weight and significant ($P<0.01$) and positive with bushel weight. The nicotinic acid content in barley was found to be significantly ($P<0.05$) and positively correlated with crude fiber and ash, and significantly ($P<0.05$) and negatively with bushel weight. Pantothenic acid in barley was significantly ($P<0.05$) and positively correlated with grade. There were no significant correlations between B-vitamins. Robinson et al. (56, 58) reports a protein-thiamine correlation in barley, but none was obtained by Robinson et al. (56, 58) and McElroy et al. (43) between riboflavin and protein in barley.

TABLE 50 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, AGRONOMIC CHARACTERS AND PRECIPITATION - BARLEY

	Moisture	Crude Protein	Crude Fat	Crude Fiber	N.F.E.	Ash	1000 Kernel Weight
Moisture	—						
Crude Protein	0.127	—					
Crude Fat	0.077	-0.430**	—				
Crude Fiber	0.286	0.118	0.042	—			
N.F.E.	-0.237	-0.951**	0.359*	-0.312*	—		
Ash	-0.052	-0.086	-0.042	0.004	-0.164	—	
1000 Kernel Weight	-0.269	-0.334*	0.069	-0.627**	0.485**	-0.070	—
Yield	-0.312	-0.298	0.163	0.086	0.288	-0.248	0.189
Bushel Weight	-0.038	0.414**	-0.159	-0.484**	-0.242	0.293*	0.249
Nicotinic Acid	0.207	-0.215	0.280	0.366*	0.102	0.351*	-0.147
Riboflavin	0.238	0.320*	-0.198	-0.009	-0.265	0.043	-0.232
Thiamine	0.087	0.398**	-0.160	0.603**	-0.312*	0.054	-0.449**
Pantothenic Acid	-0.045	0.033	0.317	-0.097	-0.011	0.080	-0.015
Grade	-0.180	+0.289	+0.123	-0.175	0.238	-0.103	-0.082
April	0.119	-0.003	0.078	0.022	-0.092	0.207	-0.169
May	-0.121	-0.189	-0.115	-0.113	0.191	0.480**	0.200
June	-0.115	0.223	0.006	0.065	-0.166	-0.273*	-0.163
July	0.086	0.058	-0.171	-0.065	-0.223	0.381**	0.032
Season	-0.010	0.059	-0.135	-0.053	-0.122	0.332**	0.001

* $P < .05$
** $P < .01$

TABLE 51 - PARTIAL CORRELATION COEFFICIENTS BETWEEN NUTRIENTS, AGRONOMIC CHARACTERS AND PRECIPITATION - BARLEY

	Yield	Bushel Weight	Nicotinic Acid	Riboflavin	Thiamine	Pantothenic Acid	Grade
Moisture							
Crude Protein							
Crude Fat							
Crude Fiber							
N.F.E.							
Ash							
1000 Kernel Weight							
Yield							
Bushel Weight	0.038						
Nicotinic Acid	0.219	-0.393*					
Riboflavin	-0.436*	0.346*	-0.188				
Thiamine	0.218	-0.111	0.134	-0.097			
Pantothenic Acid	0.078	0.212	-0.099	-0.109	0.057		
Grade	+0.048	+0.253*	-0.096	-0.110	+0.142	+0.286*	
April	-0.117	-0.223	0.073	0.024	0.013	-0.022	-0.453**
May	-0.289*	0.103	0.189	-0.305**	0.086	-0.018	-0.298*
June	-0.081	-0.005	-0.084	0.004	0.157	-0.044	-0.091
July	0.003	0.109	-0.010	0.212	-0.108	0.007	0.258*
Season	-0.213	0.054	0.073	-0.096	0.120	-0.044	-0.167

* P < .05
** P < .01

7.3 Summary

Yearly differences in barley occurred among the B-vitamins. Riboflavin content was higher in 1964 by 0.4 mg/kg, thiamine content increased in 1965 by 0.32 mg/kg, and pantothenic acid was increased in 1965 by about 1.28 mg/kg.

Variety differences were significant for crude protein, crude fat and crude fiber. In each case the two-row variety was significantly different from the other six-row variety, Husky and Parkland. Hannchen was higher in crude protein by 1%, in crude fat by 0.21%, lower in crude fiber by about 0.8% than Husky or Parkland, but was only lower in ash content than Husky by about 0.17%.

Significant soil zone effects in barley were observed for moisture, crude fat, ash, nicotinic acid, riboflavin and pantothenic acid. The brown soil zone gave rise to lower moisture content, higher fat content, and lower ash content. The grey and black soil zones produced about 8 mg/kg more nicotinic acid. The grey soil zone produced 0.3 mg/kg more riboflavin than the brown and dark brown soil zones, and the grey zone also produced more pantothenic acid (1.8 mg/kg) than the brown soil zone.

The only soil type effect was observed for moisture content, with the heavier type showing the higher moisture content. Although there was only one main type effect, zone x type interactions were prominent among the proximate nutrients for barley, possibly reflecting the influence of reserve soil moisture.

8. CONCLUSIONS

The results of this study of the essential nutrient content of Saskatchewan feed grains indicate that there are three main factors which can give rise to difference in composition.

1. Year effect can account for substantial differences in nutrient content. This was found to play less of a role for barley than for wheat and oats for the proximate principles, but was equally important with respect to the B-vitamins. It may be assumed that the year effect is attributable to the combined influence of climate and soil environment.
2. Varieties, in the case of every grain, were an important factor in the consideration of nutrient content and quality as a feed grain. The variety factor points out the need for expansion of research in breeding better varieties for feed grains.
3. Soil zones accounted for the greatest number of significant differences in nutrient content. In magnitude, however, soil zone differences were generally lower than those attributable to years or varieties. The response of the zones was not identical from year to year, and a dependency on climatic conditions was probably the cause. Recognition of these differences is of importance.

This study should prove useful in forming a background of information for the anticipated "Feed Testing facilities", so that useful and more extensive recommendations can be made to the livestock producer in Saskatchewan. Certainly, after completion of the five-year study, a more conclusive picture will be obtained.

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APPENDIX A

Determination of Moisture

Reference (5)

Procedure

Weigh out duplicate samples into moisture dishes and dry overnight at 110°C in a forced draft oven with lids off. Place dishes in desiccator, cool, replace lids and reweigh. Report loss after drying as per cent moisture.

APPENDIX B

Determination of Ash

Reference (5)

Procedure

Weigh 2 grms of sample in duplicate into porcelain crucible, place in muffle furnace. Heat furnace to 600°C and ash at this temperature for two hours. Transfer crucibles directly to desiccator, cool, and weigh immediately, reporting residue as per cent ash.

APPENDIX C

Macro Kjeldahl Determination of Nitrogen

Reference (5, 63)

Reagents

1. Concentrated Sulfuric Acid: Fisher Reagent Grade (92 - 98% H_2SO_4).
2. Preparation of sodium hydroxide solution.
   Dissolve 2000 grms NaOH and 160 grms $Na_2S_2O_3 \cdot 5H_2O$ in 2000 mls of distilled water.
3. Receiving acid.
   Dissolve 80.0 grms H_3BO_3 in 2000 ml distilled water by heating and vigorous stirring. Add 60 ml of mixed indicator.
4. Mixed indicator (according to Sher, 1955)(63).
   Mix 2.8 grms bromcresol green in 80 ml 95% EtOH, 80.0 ml of 0.5N NaOH plus 1500 ml distilled water. Add 176.8 ml of aqueous 1% new coccine and 6.00 grms of p-nitrophenol dissolved in 95% EtOH. Dilute to 2000 ml volume and test for neutral grey color at pH 4.6 in a 50 ml sample using an acetate or phthalate buffer. If the grey color is not shown, add small amounts of either the 1% new coccine solution or the bromcresol green solution and retest. Correct the bulk of the indicator by a proportionate amount.

Procedure

1. Accurately weigh approximately one gram samples on filter paper and place in 500 ml Kjeldahl flasks.
2. Duplicate blanks using only filter paper are run with every set.

3. Add one package of the commercially prepared catalyst Kel Pak.
4. Add 25 ml conc. H_2SO_4 while rotating the flask to wash adhering particles down the sides.
5. Digest for approximately one half hour using medium heat. Rotate flasks periodically to digest material not immersed in the acid.
6. Cool and add carefully 250 ml distilled water.
7. Add zinc granules or boiling chips.
8. Place 500 ml Erlenmeyer flasks containing 50 ml receiving acid under the still outlets at an angle so that the tips are immersed in the acid.
9. Turn on water supply to the still.
10. Add 100 ml of 50% NaOH to the Kjeldahl flasks while holding the flask at a 45 degree angle to form a NaOH layer at the bottom. Immediately attach the flask to the distillation trap and swirl once vigorously before placing on the burner.
11. Switch on burners and distill until approximately 200 ml distillate has been collected.
12. Lower the Erlenmeyer flasks to the lower shelf before turning off the burners and allow to drain for a few minutes.
13. Titrate to a neutral grey with standardized to approximately 0.1N HCL. The color changes from green to blue to grey; yellow color appears if excess HCL is added.
14. Calculation: % Protein = Normality of HCL x 14 x $\frac{1000}{100}$ x

$$\frac{1}{\text{Sample wt.}} \times \text{net titre} \times 6.25.$$

APPENDIX D

Determination of Crude Fat (Ether extracts)

Reference (5)

Reagents

Anhydrous diethyl ether

Procedure

1. Weigh out 2.000 gram samples, previously dried in vacuum oven at 96°C and 25 inches Hg, into single extraction thimbles (22 x 80 mm).
2. Obtain constant weight of clean dry Goldfish beaker. Add 50 ml of ether and place thimble contained in sample tube and beaker on Goldfish extractor. Extract overnight with heater switch on high and hotplate lowered about 1/8 inch.
3. Lower hotplates, place hot plate guard over heater, remove beaker, substitute sample tube with solvent reclaiming tube. Reassemble and reflux ether until beaker almost dry. Shut off heaters, remove beakers plus extract and dry 30 minutes as above in vacuum oven, place in desiccator, cool and weigh. Addition in weight is ether extract, reported as per cent ether extract or crude fat. Extracted samples are dried to remove ether and stored for crude fiber analysis.

APPENDIX E

Determination of Crude Fiber

Reference (5)

Reagents

1. 0.255N H_2SO_4.
2. 0.313N NaOH.
3. Acid and base washed asbestos, Gooch grade, medium fiber.

Procedure

1. Turn on hotplates on acid and base reflux unit and fiber digestion rack, and also turn on water for reflux condensers on both units.
2. Transfer previously fat extracted samples together with ca. 0.5 grms of acid-base washed and reignited asbestos into 600 ccm digestion beakers.
3. After the 0.255N acid and 0.313 base have come to constant boiling, add 200 ml of the acid to the digestion beaker rinsing down the sides, plus 2 - 3 drops of n-octyl alcohol to prevent foaming, and place on digestion rack. Contents of flask must come to boiling within one minute and boiling must continue briskly exactly 30 minutes. Take care to keep material from remaining on sides of beakers out of contact with solution.
4. After 30 minutes, remove beaker, immediately filter through "Handkerchief linen" in funnel, and wash with boiling H_2O until washings are no longer acid.
5. Fold filter cloth over inside back of beaker and wash down with boiling base. Remove linen, wash down sides and make

up volume to 200 ml. Replace on digestion rack and digest, boiling for 30 minutes.

6. Prepare Gooch crucible with asbestos mat. After 30 minutes have elapsed, remove beaker from digestion rack and filter through Gooch crucible with suction. Wash down walls of crucible until free of base with boiling water. Rinse with a small volume of ethanol.

7. Dry crucible and contents at 110°C to constant weight. Cool in desiccator and weigh.

8. Ignite contents of crucible in muffle furnace at 600°C for 30 minutes. Cool in desiccator and reweigh. Report loss in weight as crude fiber. Calculation based on sample weight taken for crude fat determination.

APPENDIX F

Determination of Nicotinic Acid

References (9, 5, 68)

Reagents

1. Nicotinic acid stock solution.

   Dissolve 50 mgrms U.S.P. Nicotinic acid Reference Standard, previously dried and stored in dark desiccator over P_2O_5, in 25% ethyl alcohol to make 500 ml. Store in refrigerator. Concentration, 1 ml = μgrms nicotinic acid.

2. Nicotinic acid standard solution.

   Dilute 10 ml of the stock solution to 100 ml with H_2O. Prepare fresh for each set of determinations. Concentration 1 ml = 10 μgrms nicotinic acid.

3. Phosphate buffer solution.

   Dissolve 60 grms of $Na_2HPO_4 \cdot 7H_2O$ and 10 grms KH_2PO_4 in warm H_2O and dilute to 200 ml.

4. Cyanogen bromide solution - 10%.

   Prepare under fume hood. Warm 370 ml H_2O to 40°C in large flask and add 40 grms CNBr. Shake unit dissolved, cool, and dilute to 400 ml. Do not let CNBr solution come in contact with skin. Store in coldroom.

5. 55% Sulfanilic acid solution.

   Add 27 ml H_2O and 27 ml conc. NH_4OH to 55 grms sulfanilic acid and shake until dissolved, warming if necessary. Adjust to pH 7.0 with few drops NH_4OH or 5N HCL and dilute to 100 ml. Store in dark.

Procedure

1. Preparation of standards and samples.

(a) Standards - Run one reagent blank and 5 levels of nicotinic acid standard solution with samples throughout determination. Place 1.5 grm $Ca(OH)_2$ into each of six 100 ml volumetric flasks. Add 0, 5, 10, 15, 20, 25 mls of standard solution, make up to 70 ml with H_2O, mix, and autoclave two hours at 15 pounds pressure (121°C). Mix thoroughly while still hot. Cool and dilute to volume and mix. Store overnight with samples in coldroom.

(b) Samples - Use the following convenient sample weights:

Barley	2 grms
Wheat	3 grms
Oats	4 grms

Weigh in duplicate into 125 ml Erlenmeyer flasks containing 1.5 grms $Ca(OH)_2$ each. To all flasks add 80 ml H_2O, mix, and autoclave two hours at 15 pounds pressure. Mix while hot, and dilute to 100 ml with water in a 100 graduate cylinder and return to flask. Store in coldroom overnight.

2. Transfer ca. 40 mls of standard and sample extract into 50 ml centrifuge tubes and centrifuge. Pipet 20 mls of supernatant into separate centrifuge tubes containing 8 grms $(NH_4)_2SO_4$ and 2 ml phosphate buffer solution. Shake to dissolve and warm to 57°C (55 - 60°C) in water bath. Filter through Whatman 2 (No. 12) paper, refiltering if necessary to obtain clear solution, or centrifuge.

3. Color development.

Conduct one additional tube as standard blank for each set of determinations, but do not add CNBr. In each duplicate tube place 5 ml standard or sample solution, add 10 ml H_2O to standard and sample blanks, and let all tubes stand 30 minutes in ice bath in coldroom. Add to samples, standards and reagent blank consecutively 10 ml CNBr, followed in 30 seconds by 1 ml sulfanilic acid solution. Mix contents of tubes immediately after each reagent is added. Stopper tubes and replace in ice bath. To the standard blank add 1 ml sulfanilic acid.

4. Color measurement.

Set Spectronic 20, Wavelength = 470 mμ to 100% transmittance with standard blank and read standards. For sample solutions use sample blank to adjust to 100% transmission and read sample solutions. Read Reagent blank. Determine transmittance 12 - 15 minutes after addition of sulfanilic acid. Tubes must be cooled uniformly, and each time cuvette must be wiped dry just before reading. If cuvettes fog up, dip momentarily in hot H_2O and wipe before reading. Plot standard curve of %T of standards less that of reagent blank against nicotinic acid concentration in μgrms/100 ml on semi-log graph paper, and draw straight line of best fit. From this line read concentration, C, corresponding to transmittance of sample corrected for sample blank and reagent blank.

$$\text{mgrms/kg nicotinic acid} = \frac{C}{\text{Sample wt.}} \times \frac{1000}{1000}$$

APPENDIX G

Determination of Riboflavin

Reference (18, 5, 68)

Reagents

1. Sulfuric acid 0.1N

2. Sodium acetate 2.5M

3. Potassium permanganate, 4% - Prepare fresh daily.

4. Hydrogen peroxide, 3%. Dilute 30% H_2O_2 1:10 with H_2O. (Hydrogen peroxide of 30% concentration is stable at freezer temperature up to two years).

5. Riboflavin stock solution.

   Dissolve 50 mgrm U.S.P. Riboflavin Reference Standard previously dried and stored in the dark in a desiccator, over P_2O_5, in 0.02N HOAc (acetic acid) to make 500 ml. Store in dark under toluene in refrigerator.

   1 ml - 100 μgrms Riboflavin.

6. Riboflavin working standard.

   Dilute 1 ml riboflavin stock solution with water to 100 ml. Prepare fresh daily. Protect from light.

   1 ml = 1 μgrm Riboflavin.

Procedure

1. Sample size.

   Accurately weigh in duplicate air dry, well mixed sample into 100 ml V-flask in the following amounts.

For Samples Containing	Weigh
0 - 0.8 mg/lb.	5 grms
0.8 - 2.0 mg/lb.	4 grms
2.0 - 4.0 mg/lb.	2 grms

For the three classes of grain samples it was found convenient to use a 4 grm sample weight throughout.

2. Extraction.

Add 75 ml 0.1N sulfuric acid, mix, and autoclave at 15 pounds for 30 minutes. Cool to room temperature.

3. Adjustment of pH.

Add 5 ml of 2.5M sodium acetate solution and mix well. The samples then are left standing overnight at room temperature (or at least one hour). The solution is now approximately pH 4.5 - 4.6. Make up to volume with water, mix, and filter through medium fast paper such as Whatman No. 4, discarding first 10 - 15 mls.

4. Oxidation of impurities.

In two centrifuge tubes, marked A and B, carry out oxidation in duplicate as follows.

	Low Blank Material		High Blank Material	
	Tube A	Tube B	Tube A	Tube B
Sample solution	10 ml	10 ml	10 ml	10 ml
Standard solution	1 ml		1 ml	
Water	1 ml	2 ml		1 ml
4% Potassium Permanganate	0.5 ml	0.5 ml	1 ml	1 ml
Time lapse	2 min.	2 min.	4 min.	4 min.
3% H_2O_2	0.5 ml	0.5 ml	1.0 ml	1 ml

If the blank reading is 20% or more of the sample reading by the low-blank procedure, the high-blank procedure should be used. For the grain samples analyzed, the high-blank procedure was used throughout.

Mix samples after each addition of permanganate. Shake after adding peroxide until foaming is negligible. This prevents formation of gas bubbles in cuvettes. Centrifuge to clarify and if not clear, oxidize second aliquot and filter both discarding the first 5 ml of filtrate. Transfer aliquot of solution to cuvette and measure fluorescence.

5. Turner 110 fluoremeter setting and measurement.

The following filters are installed:

Primary: #110 - 816 (2A) plus #110 - 813 (47B)

Secondary: #110 - 818 (2A - 12)

Range: 10X

N.D. Filter: 50%

Make readings with no more than 10 seconds exposure in fluoremeter. Determine fluorescence of solutions A and B. Then, to solution B in cuvette, add 20 mg sodium hydrosulfide, stir, and immediately determine the blank fluorescence, C. Do not use readings, C, after colloidal sulfur begins to form.

6. Calculations.

$$\text{Riboflavin mg/lb} = \frac{B - C}{A - B} \times \frac{R}{S} \times \frac{V}{V_1} \times .454$$

$$\text{mg/kg} = \frac{B - C}{A - B} \times \frac{R}{S} \times \frac{V}{V_1} \times 1$$

A = Fluoremeter reading of sample plus riboflavin standard.

B = Fluoremeter reading of sample plus water.

C = Fluoremeter reading after addition of sodium hydrosulfite.

R = Standard riboflavin added μgrms/V_1 ml sample solution.

V = Original volume of sample solution, mls.

V_1 = Volume of sample solution taken for measurement, mls.

S = Sample weight, grams.

APPENDIX H

Determination of Thiamine

Reference (5, 68)

Reagents

1. Double normal sodium acetate.

   Dissolve 275 grms $NaOAC \cdot 3H_2O$ in enough H_2O to make 1 litre of solution.

2. 0.1N HCL.

3. Neutral potassium chloride solution.

   Dissolve 250 grms KCL in H_2O to make 1 litre of solution.

4. Acid KCL solution.

   Add 8.5 ml HCL to 1 liter of the neutral KCL solution.

5. Sodium hydroxide solution 15%.

6. Potassium ferricyanide solution 1%.

   Dissolve 1 grm $K_3Fe(CN)_6$ in H_2O to make 100 ml. Prepare solution on the day it is used.

7. Oxidizing reagent.

   Mix 4.0 ml of the 1% $K_3Fe(CN)_6$ solution with the 15% NaOH solution to make 100 ml. Use within 4 hours.

8. Isobutyl alcohol.

   If blank reads too high fluorescence (greater than 10% of the fluorescence of the standard solution), redistill in all-glass apparatus.

9. Thiamine hydrochloride stock solution I.

   Weigh accurately 50 mg U. S. P. Thiamine Hydrochloride Reference Standard that has been dried to constant weight over P_2O_5 in desiccator. Since reference standard is hygroscopic, take precautions to avoid absorption of moisture. Dissolve in 20% alcohol adjusted to pH 3.5 - 4.3 with HCL, and dilute to 500 ml with the acidified alcohol. Store in glass light-resistant flask in refrigerator. Concentration, 1 ml = 100 μgrms.

10. Thiamine hydrochloride stock solution II.

Dilute 50 ml stock solution I to 500 ml with 20% acidified alcohol (pH 3.5 - 4.3). Concentration, 1 ml = 10 μgrms.

11. Base exchange silicate.

Purified base exchange silicate may be purchased from Fisher Scientific Company Ltd. as "Special Decalso for Thiochrome determination", 50 - 80 mesh size. Purify artificially prepared silicate of base exchange type as follows: Place a convenient quantity in a suitable beaker, add enough hot 3% HOAC to cover material and boil 10 - 15 minutes, stirring continuously. Let mixture settle and decant supernatant. Repeat washing three times, then wash similarly three times with hot KCL solution (1 part by weight KCL to 4 volumes of water) and finally wash with boiling distilled water until last washing gives no reaction for chloride. Dry material at 100°C and store i in well closed container.

12. Enzyme solution.

Prepare on day on which it is to be used. A 10% aqueous solution of Takadiastase[1] of 100% potency, potent in

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1. Takadiastase was generously supplied by Parke, Davis and Company.

diastatic and phosphorolytic activity was prepared.

13. Chromatographic tubes.

    Glass chromatographic tubes were made according to A.O.A.C. specifications. Flow rate, approximately 1 ml/minute.

Procedure

1. Sample extraction and enzyme hydrolysis.

   Duplicate 3 grm air dry samples for all three classes of grains were used throughout and weighed directly into 100 ml volumetric flasks. Add 60 ml of 0.1N HCL, and autoclave for 30 minutes at 121° - 123°C. Cool, add another 5 ml 0.1N HCL, mix, and adjust to pH 4.0 - 4.5 with 5 ml of the 2N NaOAc. Add 5 ml of enzyme solution, mix, and include in waterbath overnight at 47°C (45°C - 50°C). Cool, dilute to 100 ml with 0.1N HCL and filter through Whatman No. 541 ashless filter paper. Use 10 mls of Stock solution II, and treat standard same as sample.

2. Purification.

   Pass through prepared chromatographic tubes a 5 ml aliquot of the filtered standard solution, and a 25 ml aliquot of the filtered sample solution. Wash columns with three 5 ml portions of almost boiling H_2O, taking care to keep the surface of the base exchange silicate covered. Elute thiamine from column by passing through five 4.0 - 4.5 ml portions of almost boiling acidified KCL solution, taking care to prevent liquid level from falling below silicate surface until final portion of acidified KCL solution has been added. Collect eluate in 25 ml V-flask, cool, and dilute to volume with acid-KCL solution. Designate this as assay solution.

3. Oxidation of thiamine to thiochrome.

Weigh 1.5 grms of NaCl into 40 ml centrifuge tubes and add a 5 ml aliquot of either sample or standard assay solution. Protect solutions from light. Add 3 ml oxidizing reagent from an automatic filling 10 ml syringe that delivers in one to two seconds, and hold tube so that stream of solution does not hit the side of the tube. Swirl tube gently on Vortex mixer for 30 seconds. After 13 ml of isobutyl alcohol has been added, immediately thereafter, stopper, again mix on Vortex mixer for 30 seconds. A final mixing is done after the isobutyl alcohol has been added to all the tubes.

To the assay and standard blanks, add 3 ml of the 15% NaOH solution instead of oxidizing reagent. If necessary, centrifuge at low speed until clear supernatant extract can be obtained from each tube. Pipet or decant aliquot of the isobutyl alcohol extract (upper layer) from each tube into cell for measurement of thiochrome fluorescence.

4. Turner 110 Fluoremeter setting:

The recommended filters are:

Primary: #110 - 811 (7 - 60)

Secondary: #110 - 813 (47B) plus #110 - 816 (2A)

Range extension filter: #110 - 823, 10% - place over (2A)

Range: 10X

5. Thiochrome fluorescence measurement.

   Measure fluorescence of isobutyl alcohol extract from oxidized assay solution and call this reading "A". Next measure fluorescence of the extract from assay solution which has been treated with 3 ml 15% NaOH and call this reading (assay blank) "b". Then measure fluorescence of the oxidized standard solution and call this reading "S". Again measure fluorescence of the extract from standard solution treated with 3 ml 15% NaOH and call this reading (standard blank) "d".

6. Calculations.

   μgrms thiamine hydrochloride in 5 ml assay solution = $\frac{A-b}{S-d}$

   $$\text{mg/kg} = \frac{A-b}{S-d} \times \frac{V}{V_1} \times \frac{1}{S} \times \frac{1000}{1000}$$

   V = Original volume of sample solution, ml.

   V_1 = Volume of sample solution taken.

   S = Sample weight, grams.

APPENDIX I

Microbiological determination of Pantothenic Acid using

Lactobacillus plantarum A.T.C.C. 8014

Reference (15, 51, 50, 68, 64, 74, 7, 10, 35)

Reagents

1. Pigeon liver acetone powder - 10% solution.
2. Alkaline phosphatase (intestinal) - 2% solution (1 Bodansky unit/mgrm).
3. Bacto-Pantothenate A.O.A.C. medium (Difco)
4. Bacto-Lactobacilli Agar A.O.A.C. (Difco)
5. Bacto-Lacobacilli Broth A.O.A.C. (Difco)
6. Dowex 1-X8, 200 - 400 mesh.
7. Tris Buffer (Tham) - 1M; pH = 8.3.
8. Potassium bicarbonate - 0.02N.
9. Sodium acetate - 0.2N.
10. Acetic acid - 0.2N.
11. HCL - 0.1N.
12. Pantothenic acid Standard Solution.

    Dissolve 50 mgrms dried calcium pantothenate in about 500 ml distilled water, 10 ml 0.2N acetic acid and 100 ml 0.2N sodium acetate. Dilute with additional water to make calcium pantothenate concentration exactly 43.47 μgrms per ml or 40 μgrms pantothenic acid per ml. This solution is diluted further by adding 25 ml to 500 ml distilled water, 10 ml 0.2N acetic acid and 100 ml 0.2N sodium acetate and diluted to one liter with distilled water. This stock solution contains 1.0 μgrm pantothenic acid per ml. The working standard is made by diluting 20 ml of the stock solution to 1000 ml with distilled water, or 0.020 μgrms pantothenic acid per ml. Use 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 mls for standard curve.

Procedure

1. Activation of Dowex 1-X8.

   100 grms of Dowex 1 are washed twice with 1 volume of 1N HCL stirring for 10 minutes each time and filtered with vacuum. The acid treated resin is then washed 8 - 10 times with distilled water until the pH is approximately 5.

2. Extraction of pigeon liver powder.

   Using the freezing compartment of a refrigerator or the deep freeze, chill and rechill thoroughly all equipment between steps. Centrifugation is carried out at 6000 rpm, and temperature just below 0°C.

   Ten grams of the pigeon liver powder is extracted with 100 ml of 0.02N potassium bicarbonate (cold) by rubbing it in a mortar held in an ice-salt bath. The solids are then removed by centrifuging.

3. Purification of liver enzyme extract.

   One half (50 grms) of the activated Dowex is mixed with the potassium bicarbonate extract of the pigeon liver powder and centrifuged; the supernatant liquid is decanted and mixed with the remaining half of the Dowex 1, and centrifuged again. Mix each time by stirring for about two minutes. The purified liver enzyme preparations are then dispensed into convenient volumes in sterile stoppered tubes and stored in a deep freeze.

4. Preparation of alkaline phosphatase.

A two per cent solution is prepared in distilled water prior to use.

5. Preparation of stock cultures.

Stock cultures of L. plantarum are prepared by stab inoculation of Bacto-Lactobacilli Agar A.O.A.C. prepared according to Difco recommendation, dispensed in 10 ml volumes to 10 tubes, sterilized for 10 minutes, inoculated and incubated at 37°C for 18 hours. The cultures are stored in the refrigerator and prepared once a week. Cultures are not used for preparing the inoculum if more than a week old.

6. Preparation of inoculum.

Inoculum for assay is prepared by subculturing from a stock culture on Bacto-Lactobacilli Broth A.O.A.C. prepared according to Difco recommendations, dispensed in 10 ml volumes to 4 tubes, sterilized for 10 minutes, inoculated and incubated for 18 hours at 37°C. After incubation, the cells are centrifuged under aseptic conditions, and the supernatant is drawn off. The cells are then washed twice in 10 ml 0.85% sterile NaCl and resuspended in 10 ml of the sterile NaCl. One drop of this suspension is used to inoculate each assay tube.

7. Preparation and enzymatic hydrolysis of the samples.

Weigh out duplicate 0.5 grms of sample, fat extracted sample for oats, into 25 ml Erlenmeyer flask, add 2.5 ml

H_2O, 0.4 ml Tris buffer (pH 8.3), 0.4 ml just thawed pigeon liver enzyme, 0.4 ml of 2% alkaline phosphatase, and incubate at 37°C for 4 hours or overnight. After incubation the extracts are made up to a volume of 100 ml and mixed; about 10 ml aliquots are centrifuged at 12,000 rpm. The supernatants are added directly to the medium in the assay tubes.

8. Preparation of Bacto-Pantothenate A.O.A.C. assay medium. To rehydrate the basal medium, dissolve 7.3 grms in 100 ml of distilled water and heat to boiling for two to three minutes. The slight precipitate which forms should be evenly distributed by shaking. Dispense in 5 ml quantities using automatic pipettes into assay tubes. Final reaction pH 6.8 at 25°C.

9. Assay procedure.

   To duplicate assay tubes containing 5 ml of basal medium are added increasing amounts of:

   Standard - 7 levels - 0, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0 ml.
   Oats - Sample - 3 levels - 0, 0.8, 1.0, 1.2 ml.
   Barley - Sample - 3 levels - 0, 0.8, 1.0, 1.2 ml.
   Wheat - Sample - 3 levels - 0, 0.6, 0.8, 1.0 ml.
   Blanks - uninoculated,

   and sufficient distilled water to give a total of 10 ml per tube. The tubes are then autoclaved for 10 minutes at 15 pounds (121°C). Prolonged heating of the medium will give unsatisfactory results. Cool and inoculate each tube aseptically, using a syringe, with one drop of the inoculum prepared as described. The tubes are then incubated at 37°C for 18 hours.

10. Measurement of turbidity.

After incubation, the turbidity of the standards, blanks and samples is measured on the Spectronic 20 spectrophotometer at 546 mμ. The instrument is set to 100% transmission with the inoculated incubated blanks. The turbidities of the standard solutions are plotted against concentration of pantothenic acid in nanograms on semi-log graph paper. The turbidities of the sample solutions are converted into the corresponding concentrations using the standard curve over its linear portion. Multiplication by the dilution factors, etc. gives the amount of pantothenic acid in the sample.

APPENDIX J

Composition of Saskatchewan feed grains - Means and Ranges

		Wheat		Oats		Barley	
		Mean	Range	Mean	Range	Mean	Range
Moisture	%	10.47	8.02-11.95	8.32	6.78- 9.98	9.53	7.50- 11.04
Crude Protein	%	18.31	13.78-21.31	14.56	11.28- 16.31	15.18	10.46- 19.50
Crude Fat	%	1.99	1.67- 2.29	5.22	4.10- 6.56	2.11	1.57- 2.46
Crude Fiber	%	3.03	2.72- 3.45	13.26	10.60- 18.01	5.60	4.46- 6.96
N.F.E.	%	74.77	70.84-79.69	63.36	58.94- 67.24	74.65	70.61- 79.55
Ash	%	1.82	1.43- 2.34	3.51	2.47- 5.21	2.63	2.02- 3.22
Nicotinic Acid	gr/grm.	67.46	49.00-91.80	16.31	10.60- 21.10	100.20	81.70-119.30
Riboflavin	gr/grm.	1.68	1.18- 2.87	1.84	1.33- 2.92	1.96	1.29- 2.84
Thiamine	gr/grm.	4.80	4.16- 5.73	7.01	4.54- 9.17	4.82	3.91- 6.45
Pantothenic Acid	gr/grm.	13.28	7.93-27.57	7.61	4.22- 11.95	10.63	7.26- 17.96
1000 Kernel Wt.	grams	29.02	18.80-39.80	29.47	21.95-35.35	32.98	23.85- 42.00
Yield	bu/acre	28.6	6.0 -55.0	70.2	8.0 -127.0	43.7	7.0 - 91.0
Bushel Weight	lb.	60.	54.0 -65.0	37.9	28.0 - 44.0	49.9	44.0 - 55.0
Grade		-	1N - 5	-	1CW - 3 fd.	-	1CW - 2 fd.

APPENDIX K

Precipitation Data on Test Locations (46)

Soil Zone	Soil Type	Station	1964 April	1964 May	1964 June	1964 July	Station Change	1965 April	1965 May	1965 June	1965 July
Brown	Light	Shaunavon	2.03	1.45	4.26	.59		.78	2.15	3.85	2.66
		Readlyn	.61	1.79	2.03	.92		.72	4.63	3.73	1.55
	Heavy	Shackleton CDA	1.36	1.66	2.07	.58	Loverna CDA	.49	1.49	3.62	1.40
		Swift Current CDA	.64	1.27	5.62	.50	Kindersley CDA	.41	.74	4.09	.89
Dark Brown	Light	Dundurn	.62	1.90	0.40	2.21		.49	1.23	4.85	1.39
		Midale	.68	1.40	3.32	3.10		.54	6.88	3.20	2.76
	Heavy	Regina CDA	.25	1.23	3.61	6.02		.66	4.07	4.18	2.29
		Moose Jaw A	.39	2.04	1.36	1.96		.69	3.38	4.51	1.94
Black	Light	Turtleford	1.06	1.77	.39	3.26		,16	2.05	7.83	1.37
		Kelliher CDA	.28	3.21	1.92	2.36		1.06	3.85	4.25	3.25
	Heavy	Indian Head	.48	2.70	2.43	2.02		.90	4.86	3.82	1.50
		Melfort CDA	.38	.91	.94	1.80		.52	2.46	4.69	2.08
Grey	Light	Loon Lake	.69	1.01	1.08	2.61		.22	1.62	8.80	1.05
		Glaslyn CDA	.69	1.89	.55	1.57		.32	1.82	3.92	2.54
	Heavy	Snowden CDA	.69	0.45	1.55	3.48		.23	1.74	3.23	3.92
		Somme	1.54	2.39	1.51	3.94		.44	3.94	5.36	3.27

Rainfall, inches

APPENDIX L

Agronomic Characters of Wheat - 1000 Kernel Weight

Grams per 1000 Kernels

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	27.08	29.73	28.41		22.90	28.28	25.59		
	Heavy	27.60*	25.40*	26.50	27.46	22.48	28.18	25.33	25.46	26.45
Dark Brown	Light	26.90	33.08	29.99		20.63	27.13	23.88		
	Heavy	29.40	34.23	31.82	30.91	22.53	31.88	27.21	25.55	28.22
Black	Light	34.68	36.35	35.52		22.48	28.35	25.42		
	Heavy	28.05	32.85	30.45	32.99	26.18	31.78	28.98	27.20	30.09
Grey	Light	30.08	32.80	31.44		25.20	31.23	28.22		
	Heavy	32.98	36.65	34.82	33.13	24.30	34.85	29.58	28.90	31.01
Variety Mean	Canthatch	29.60				23.34				26.44
	Selkirk		32.64				30.21			31.44
Type Mean	Light			31.34				25.78		
	Heavy			30.90	31.11			27.80	26.77	29.33

* Single value

APPENDIX L_1

Agronomic Characters of Wheat - Bushel Weight

Pounds per Bushel

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	61.0	59.0	60.0		60.5	58.5	59.5		
	Heavy	60.0*	56.0*	58.0	59.0	60.5	60.0	60.3	59.9	59.5
Dark Brown	Light	63.0	61.0	62.0		58.0	56.0	57.0		
	Heavy	63.5	62.0	62.8	62.4	60.5	61.0	60.8	58.9	60.6
Black	Light	64.0	62.0	63.0		58.0*	58.0*	58.0		
	Heavy	63.0	60.5	61.8	62.4	63.5	63.5	63.5	60.8	62.1
Grey	Light	60.0	59.5	59.8		59.5	60.0	59.8		
	Heavy	62.5	59.5	61.0	60.4	61.0	61.0	61.0	60.4	60.4
Variety Mean	Canthatch	62.0				60.2				61.1
	Selkirk		59.9				59.8			59.9
Type Mean	Light			61.2				58.6		59.9
	Heavy			60.9	61.0			61.4	60.0	61.1

* Single value

APPENDIX L_2

Agronomic Characters of Wheat - Yield per Acre

Bushels per Acre

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	22.0	18.5	20.3		26.5	30.0	28.3		
	Heavy	16.0*	14.0*	15.0	17.6	28.0	26.5	27.3	27.8	22.7
Dark Brown	Light	29.0	25.0	27.0		25.0	29.5	27.3		
	Heavy	31.0	30.0	30.5	28.8	26.0	25.0	25.5	26.4	27.6
Black	Light	26.5	25.5	26.0		36.0*	42.0*	39.0		
	Heavy	37.0	32.5	34.8	30.4	48.5	50.5	49.5	44.3	37.3
Grey	Light	11.0	8.0	9.5		23.5	30.0	26.8		
	Heavy	35.0	30.0	32.5	21.0	35.0	39.0	37.0	31.9	26.4
Variety Mean	Canthatch	25.9				31.1				28.5
	Selkirk		22.9				34.1			28.5
Type Mean	Light			20.7				30.35		25.5
	Heavy			28.2	24.44			34.82	32.56	31.5

* Single value

APPENDIX L_3

Agronomic Characters of Wheat - Grade

		Grades			
		1964		1965	
Soil Zone	Soil Type	Canthatch	Selkirk	Canthatch	Selkirk
Brown	Light	2N	3N	2N	2N
		3N	3N	3N	5
	Heavy	2N	4N	2N	2N
				2N	2N
Dark Brown	Light	2N	2N	5	5
		3N	3N	2N	2N
	Heavy	4N	4N	2N	2N
		1N	1N	3N	2N
Black	Light	2N	2N	5	5
		3N	3N		
	Heavy	2N	2N	1N	2N
		3N	3N	1N	2N
Grey	Light	3N	3N	3N	3N
		3N	3N	4N	4N
	Heavy	3N	4N	2N	2N
		4N	4N	3N	2N

APPENDIX L_4

Mean Squares for Agronomic Characters of Wheat

Source	D.F.	1000 Kernel† Weight	Bushel Weight	Yield	Grade
Year	1	284.37**	16.07*	939.8**	0.056
Soil Zone	3	58.79**	9.80*	502.5*	0.661
Soil Type	1	9.13	22.24**	512.5*	8.01**
Variety	1	379.23**	24.83**	0.003	0.901
Year x Variety	1	53.66**	10.20	137.5	0.096
Year x Type	1	22.37*	34.72**	32.0	14.22**
Year x Zone	3	9.99	13.74**	195.7	1.26
Zone x Type	3	14.43	5.89	287.9*	1.57
Zone x Variety	3	9.25	1.04	2.53	0.592
Type x Variety	1	2.06	90.91	20.95	0.005
Year x Zone x Type	3	19.82*	6.76	52.88	0.935
Year x Zone x Variety	3	2.14	0.24	5.92	0.278
Year x Type x Variety	1	4.77	3.60	14.80	0.506
Zone x Type x Variety	3	3.49	1.50	1.29	0.051
Missing Plots	(4)	(2)			
Error †(33)	31	5.19	2.87	68.22	0.976

* P<.05
** P<.01

APPENDIX M

Agronomic Characters of Oats - 1000 Kernel Weight

Grams per 1000 Kernel

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	31.25	32.13	31.69		28.10*	26.05	27.08		
	Heavy	28.05*	28.50*	28.28	29.99	27.38	27.23	27.31	27.20	28.58
Dark Brown	Light	29.23	30.30	29.77		25.93	25.60	25.77		
	Heavy	26.30	29.83	28.07	28.92	26.45	27.65	27.05	26.41	27.64
Black	Light	36.88	36.55	36.72		25.65	26.55	26.10		
	Heavy	28.20	31.38	29.79	33.26	27.95	28.73	28.34	27.22	30.23
Grey	Light	29.38	30.73	30.06		30.80	30.73	30.77		
	Heavy	30.38	30.50	30.44	30.25	31.98	33.40	32.69	31.73	29.52
Variety Mean	Garry	29.96				28.03				28.96
	Rodney		31.24				28.24			29.76
Type Mean	Light			32.06				27.43		29.74
	Heavy			29.14	30.59			28.85		28.99

* Single value

APPENDIX M_1

Agronomic Characters of Oats - Bushel Weight

Pounds per Bushel

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	36.0	37.5	36.8		37.0*	39.0*	38.0		
	Heavy	34.0*	36.0*	35.0	35.9	38.5	38.0	38.3	38.1	37.0
Dark Brown	Light	37.0	39.0	38.0		36.0*	37.0*	36.5		
	Heavy	38.0	40.0	39.0	38.5	38.0*	37.0*	37.5	37.0	37.8
Black	Light	42.0	41.5	41.8		37.0*	39.0*	38.0		
	Heavy	37.5	40.0	38.8	40.3	39.0	39.5	39.3	38.6	39.4
Grey	Light	36.0	37.5	36.8		40.0	39.0	39.5		
	Heavy	32.5	35.5	34.0	35.4	36.5	38.0	37.3	38.4	36.9
Variety Mean	Garry	36.6				37.8				37.2
	Rodney		38.4				38.3			38.3
Type Mean	Light			38.3				38.0		38.2
	Heavy			36.7	37.5			38.1	38.0	37.4

* Single value

APPENDIX M_2

Agronomic Characters of Oats - Yield per Acre

Bushels per Acre

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	60.5	49.5	55.0		72.0*	69.0*	70.5		
	Heavy	30.0*	25.0*	27.5	41.3	52.5	51.5	52.0	61.3	51.3
Dark Brown	Light	61.0	59.5	60.3		125.0*	114.0*	119.5		
	Heavy	69.5	66.5	68.0	64.1	96.0*	73.0*	84.5	102.0	83.1
Black	Light	38.5	45.0	41.7		121.0*	117.0*	119.0		
	Heavy	68.5	68.5	68.5	55.1	113.5	109.5	111.5	115.3	85.2
Grey	Light	24.0	28.5	26.3		67.0	71.0	69.0		
	Heavy	77.0	87.0	82.0	54.1	103.5	102.5	103.0	86.0	70.1
Variety Mean	Garry	53.6				93.8				73.6
	Rodney		53.7				88.4			71.1
Type Mean	Light			45.8				94.5		70.2
	Heavy			61.5	53.7			87.7	91.1	74.6

* Single value

APPENDIX M_3

Agronomic Characters of Oats - Grade

		Grades			
		1964		1965	
Soil Zone	Soil Type	Garry	Rodney	Garry	Rodney
Brown	Light	1 fd 1 fd	1 fd 1 fd	2 CW	1 CW
	Heavy	2 fd	1 fd	2 CW 2 CW	X3 CW X3 CW
Dark Brown	Light	1 fd 3 CW	1 fd 3 CW	3 CW	1 fd
	Heavy	X1 fd 2 CW	X1 fd 2 CW	1 CW	1 CW
Black	Light	2 CW 1 fd	2 CW 1 fd	1 fd	X1 fd
	Heavy	2 CW X1 fd	2 CW 3 CW	3 CW X3 CW	3 CW 3 CW
Grey	Light	3 CW 2 CW	3 CW 2 CW	X3 CW 3 CW	X3 CW 3 CW
	Heavy	2 fd 3 CW	2 fd 3 CW	3 fd 1 fd	3 fd 1 fd

APPENDIX M_4

Mean Squares for Agronomic Characters of Oats

Source	D.F.	1000 Kernel† Weight	Bushel Weight	Yield	Grade
Year	1	85.88**	3.45	17135.9**	9.35
Soil Zone	3	35.91*	18.25*	2720.2*	2.84
Soil Type	1	7.808	7.45	243.8	0.05
Variety	1	9.455	15.15	78.1	0.05
Year x Variety	1	4.157	4.81	81.6	0.51
Year x Type	1	66.317*	8.68	1534.3	0.76
Year x Zone	3	37.810*	19.26*	860.1	18.36**
Zone x Type	3	9.259	6.62	3081.7*	20.70**
Zone x Variety	3	1.268	0.05	119.4	0.26
Type x Variety	1	4.500	0.21	6.8	0.02
Year x Zone x Type	3	11.133	2.88	348.5	1.91
Year x Zone x Variety	3	0.756	0.75	48.5	0.15
Year x Type x Variety	1	0.002	0.28	17.9	0.41
Zone x Type x Variety	3	0.682	1.86	14.4	0.16
Missing Plots	(10)				
Error †(31)	25	9.788	5.37	746.7	2.26

* $P < .05$
** $P < .01$

APPENDIX N

1000 Kernel Weight of Barley

Grams per 1000 Kernels

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	28.58	29.10	34.60	30.76		26.80*	31.10*	32.00*	29.97		
	Heavy	28.00*	26.50*	28.00*	27.50	29.13	27.85	36.55	29.15	31.18	30.58	29.86
Dark Brown	Light	35.73	30.93	34.65	33.77		29.40	31.35	27.25	29.33		
	Heavy	34.48	35.90	37.38	35.92	34.85	33.95	36.63	36.00	35.53	32.43	33.64
Black	Light	37.48	38.13	39.03	38.21		29.35	33.48	26.45*	29.76		
	Heavy	30.65	32.80	33.65	32.37	35.29	32.35	33.65	31.50	32.50	31.13	33.21
Grey	Light	36.30	30.30	34.55	33.72		32.83	34.53	35.63	34.33		
	Heavy	35.05	32.98	36.53	34.85	34.29	32.38	37.50	33.90	34.59	34.46	34.38
Variety Mean	Husky	33.28					30.61					31.95
	Parkland		32.08					34.35				33.22
	Hannchen			34.80					31.49			33.15
Type Mean	Light				34.12					30.85		32.49
	Heavy				32.66	33.39				33.45	32.15	33.06

* Single value

APPENDIX N_1

Bushel Weight of Barley

		1964					1965					
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Overall Zone Mean
		Pounds per Bushel										
Brown	Light	48.0	50.0	52.0	50.0		51.0*	54.0*	55.0*	53.3		
	Heavy	48.0*	48.0*	52.0*	49.3	49.7	49.0*	52.0*	51.0*	50.7	52.0	50.9
Dark Brown	Light	46.5	47.0	50.0	47.8		47.0*	49.0*	46.0*	47.3		
	Heavy	47.0	49.0	51.5	49.2	48.5	51.5	53.5	53.0	52.7	50.1	49.3
Black	Light	49.5	50.5	52.0*	50.7		51.0*	51.0*	†	51.0		
	Heavy	45.5	47.0	50.0	47.5	49.1	50.5	52.5	50.0	51.0	51.0	50.1
Grey	Light	47.5	48.5	50.0	48.7		51.5	51.5	54.5	52.5		
	Heavy	48.0	47.5	50.0	48.5	48.6	48.5	51.5	50.0	50.0	51.3	50.0
Variety Mean	Husky	47.5					50.0					48.8
	Parkland		48.4					51.9				50.2
	Hannchen			50.9					44.9			47.9
Type Mean	Light				49.3					51.0		50.2
	Heavy				48.6	49.0				51.1	51.1	49.9

* Single value
† All values missing

APPENDIX N_2

Yield per Acre of Barley

Bushels per Acre

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	40.5	49.5	42.5	44.2		46.0*	50.0*	43.0*	46.3		
	Heavy	18.0*	20.0*	21.0*	19.7	31.9	40.0*	48.0*	52.0*	46.7	46.5	39.2
Dark Brown	Light	21.5	20.0	31.0	24.2		60.0*	58.0*	39.0*	52.3		
	Heavy	39.0	29.0	45.0	37.7	30.9	54.0	48.5	56.0	52.8	52.6	41.8
Black	Light	33.0	33.0	17.0*	27.7		71.0*	78.0*	†	74.5		
	Heavy	46.5	45.0	44.5	45.3	36.5	74.5	81.5	67.5	74.5	74.5	55.5
Grey	Light	15.5	13.0	17.0	15.2		43.5	44.0	53.5	47.0		
	Heavy	43.5	44.0	50.0	45.8	30.5	64.5	62.5	52.5	59.8	53.4	42.0
Variety Mean	Husky	32.2					56.7					44.5
	Parkland		31.7					58.8				45.3
	Hannchen			33.5					51.9			42.7
Type Mean	Light				27.8					55.2		41.5
	Heavy				37.1	32.4				58.5	56.8	47.8

* Single value
† All values missing

APPENDIX N_3

Agronomic Characters of Barley - Grade

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1965 Husky	1965 Parkland	1965 Hannchen
Brown	Light	1 fd	2 CW 6R	1 CW 2 R	1 fd	1 CW	1 CW
		1 fd	1 fd	1 CW			
	Heavy	1 fd	2 CW	1 CW	1 fd	2 CW	2 CW
Dark Brown	Light	2 fd	3 CW	1 fd	1 fd	3 CW	2 CW
		1 fd	3 CW	Rej. 2 CW			
	Heavy	1 fd	2 fd	1 CW	1 fd	1 CW	1 CW
		1 fd	2 CW	1 CW	1 fd	1 CW	1 CW
Black	Light	2 fd	2 CW	2 CW	1 fd	1 fd	
		1 fd	1 fd				
	Heavy	2 fd	2 fd	2 CW	1 fd	2 CW	1 fd
		1 fd	1 fd	2 CW	1 fd	2CW	2 CW
Grey	Light	2 fd	3 CW	3 CW	2 fd	2 CW	2 CW
		2 fd	2 CW	2 CW	2 fd	2 CW	2 CW
	Heavy	1 fd	1 fd	1 fd	1fd	1 fd	1 fd
		1 fd	3 CW	3 CW	1 fd	1 fd	2 fd

APPENDIX N_4

Mean Squares for Agronomic Characters of Barley

Source	D.F.	1000 Kernel† Weight	Bushel Weight	Yield	Grade
Year	1	15.25	64.69**	8799.3**	0.518
Soil Zone	3	53.76**	6.69	467.1	4.511**
Soil Type	1	16.88	0.81	931.9*	0.011
Variety	2	29.04*	26.02*	16.5	23.452**
Year x Variety	2	52.15**	13.41	135.6	2.20*
Year x Type	1	55.28*	2.97	81.7	0.003
Year x Zone	3	34.40*	1.52	162.8	0.558
Zone x Type	3	45.54**	25.81**	774.8**	2.291*
Zone x Variety	6	4.64	1.04	87.0	0.780
Type x Variety	2	3.18	0.43	47.3	0.438
Year x Zone x Type	3	30.09*	13.32*	306.0	1.097
Year x Zone x Variety	6	2.79	1.81	23.5	0.386
Year x Type x Variety	2	1.20	1.96	0.5	0.843
Zone x Type x Variety	6	6.24	1.04	57.1	1.514
Missing Plots	(17)				
Error †(44)	37	8.44	4.54	168.5	0.589

* P<.05
** P<.01

APPENDIX O

Estimation of TDN and DCP for cattle and swine from the proximate principles of the three classes of grain according to Schneider *et al*.

Reference (61, 62)

Procedure

The general equation used:

$$Y = \bar{y} + b_1(X_1 - \bar{X}_1) + b_2(X_2 - \bar{X}_2) + b_3(X_3 - \bar{X}_3) + b_4(X_4 - \bar{X}_4),$$

where Y = digestion coefficient for a given nutrient (or content of TDN),

X_1 = % crude protein, X_2 = % crude fiber,

X_3 = % N.F.E., X_4 = % fat,

$\bar{y}$ = average digestion coefficient (or content of TDN) for the particular class of feed involved.

Source of the equation constants required was Schneider's "Feeds of the World", (61). Per cent H_2O in average Barley reported – Cattle – 14.2% Swine – 13.6%
Cattle – 12.7% Swine – 10.1%
(Sheep) – 11.3% Swine – 11.6%

For Cattle:

Symbol	Feed Character	For TDN Wheat	Oats	Barley	For DCP Wheat	Oats	Barley
$\bar{y}$		77.8	65.5	70.7	77.0	75.0	75.0
$\bar{X}_1$	% crude protein	12.9	11.9	11.7			
$\bar{X}_2$	% crude fiber	3.0	10.5	4.9			
$\bar{X}_3$	% N.F.E.	68.9	58.0	65.3			
$\bar{X}_4$	% Fat	1.9	3.5	1.5			
	For Swine:						
$\bar{y}$		81.0	65.4	69.9	92.0	84.0	77.0
$\bar{X}_1$	% crude protein	14.1	13.4	10.7			
$\bar{X}_2$	% crude fiber	2.5	8.1	4.6			
$\bar{X}_3$	% N.F.E.	68.2	61.6	66.6			
$\bar{X}_4$	% Fat	1.8	4.1	1.9			

APPENDIX O_1

Formulas used to Calculate TDN and DCP.

A. Estimation of % TDN for cattle.

1. Wheat $Y = 77.8 + .238(X_1 - 12.9) + .395(X_3 - 68.9) + 1.095(X_4 - 1.9)$.

2. Barley $Y = 70.9 + .238(X_1 - 11.7) + .395(X_3 - 65.3) + 1.095(X_4 - 1.5)$.

3. Oats $Y = 65.5 + .238(X_1 - 11.9) + .395(X_3 - 58.0) + 1.095(X_4 - 3.5)$.

B. Estimation of % digestibility of protein for cattle.

1. Wheat $Y = 77.0 + .187(X_1 - 12.9) - .077(X_2 - 3.0) - .798(X_3 - 68.9)$.

2. Barley $Y = 75.0 + .187(X_1 - 11.7) - .077(X_2 - 4.9) - .798(X_3 - 65.3)$.

3. Oats $Y = 75.0 + .187(X_1 - 11.9) - .077(X_2 - 10.5) - .798(X_3 - 58.0)$.

4. Multiply % digestibility x % protein to obtain % DCP in D.M. of each sample.

C. Estimation of % TDN for swine.

1. Wheat $Y = 81.0 - .318(X_1 - 14.1) + .687(X_2 - 2.5) + 1.162(X_3 - 68.2)$.

2. Barley $Y = 69.9 - .318(X_1 - 10.7) + .687(X_2 - 4.6) + 1.162(X_3 - 66.6)$.

3. Oats $Y = 65.4 - .318(X_1 - 13.4) + .687(X_2 - 8.1) + 1.162(X_3 - 61.6)$.

D. Estimation of % digestibility of protein for swine.

1. Wheat $Y = 92.0 - 1.359(X_1 - 14.1) + .241(X_2 - 2.5) -$

$.035(X_3 - 68.2)$.

2. Barley $Y = 77.0 - 1.359(X_1 - 10.7) + .241(X_2 - 4.6) - .035(X_3 - 66.6)$.

3. Oats $Y = 84.0 - 1.359(X_1 - 13.4) + .241(X_2 - 8.1) - .035(X_3 - 61.6)$.

4. Calculate % DCP.

APPENDIX O_2

T.D.N. Content of Wheat for Cattle

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		T.D.N., %**								
Brown	Light	81.30	81.50	81.40		81.64	81.51	81.58		
	Heavy	81.05*	81.63*	81.34	81.37	81.59	80.54	81.06	81.32	81.34
Dark Brown	Light	81.52	81.70	81.61		81.56	81.62	81.59		
	Heavy	81.54	81.60	81.57	81.59	81.51	81.76	81.64	81.62	81.60
Black	Light	81.38	81.32	81.35		81.48	81.40	81.44		
	Heavy	81.60	81.68	81.64	81.50	82.06	81.97	82.02	81.73	81.62
Grey	Light	81.19	81.07	81.13		81.85	81.58	81.72		
	Heavy	81.38	81.40	81.39	81.26	81.48	81.44	81.46	81.59	81.42
Variety Mean	Canthatch	81.37				81.65				81.51
	Selkirk		81.49				81.48			81.48
Type Mean	Light			81.37				81.58		81.48
	Heavy			81.48	81.42			81.54	81.56	81.51

* Single value
** Data are expressed on a moisture-free basis

APPENDIX O_3

DCP Content of Wheat for Cattle

		DCP, %**								
		1964				1965				
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	15.24	13.58	14.41		12.94	13.28	13.11		
	Heavy	16.26*	14.06*	15.16	14.78	13.54	13.42	13.48	13.30	14.04
Dark Brown	Light	13.86	13.16	13.51		13.47	13.40	13.44		
	Heavy	13.96	13.68	13.82	13.66	11.57	11.69	11.63	12.54	13.10
Black	Light	14.88	14.36	14.62		13.83	13.68	13.76		
	Heavy	14.00	12.95	13.48	14.05	11.42	11.38	11.40	12.58	13.32
Grey	Light	15.24	15.05	15.14		12.07	12.22	12.14		
	Heavy	14.24	14.34	14.29	14.72	12.76	12.96	12.86	12.50	13.61
Variety Mean	Canthatch	14.71				12.70				13.70
	Selkirk		13.90				12.75			13.32
Type Mean	Light			14.42				13.11		13.76
	Heavy			14.19	14.30			12.34	12.72	13.26

* Single value
** Data are expressed on a moisture-free basis

APPENDIX O_4

TDN Content of Wheat for Swine

		TDN, %**								
		1964				1965				Overall
Soil Zone	Soil Type	Canthatch	Selkirk	Type Mean	Zone Mean	Canthatch	Selkirk	Type Mean	Zone Mean	Zone Mean
Brown	Light	84.73	87.45	86.09		88.26	88.16	88.21		
	Heavy	83.32*	87.43*	85.38	85.74	87.44	85.65	86.54	87.38	86.56
Dark Brown	Light	87.16	88.22	87.69		87.72	87.77	87.74		
	Heavy	86.90	87.51	87.20	87.44	89.71	90.94	90.32	89.03	88.24
Black	Light	85.31	86.24	85.78		87.14	87.24	87.19		
	Heavy	87.00	88.84	87.92	86.85	91.26	91.54	91.40	89.30	88.08
Grey	Light	84.49	85.11	84.80		89.90	89.92	89.91		
	Heavy	86.24	86.28	86.26	85.53	88.73	88.64	88.68	89.30	87.42
Variety Mean	Canthatch	85.64				88.77				87.20
	Selkirk		87.14				88.73			87.94
Type Mean	Light			86.09				88.26		87.18
	Heavy			86.69	86.39			89.24	88.75	87.96

* Single value
** Data are expressed on a moisture-free basis

APPENDIX O_5

DCP Content of Wheat for Swine

D.C.P., %**

Soil Zone	Soil Type	1964 Canthatch	1964 Selkirk	1964 Type Mean	1964 Zone Mean	1965 Canthatch	1965 Selkirk	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	16.90	15.88	16.39		15.30	15.52	15.41		
	Heavy	17.53*	16.27*	16.90	16.64	15.84	15.57	15.70	15.56	16.10
Dark Brown	Light	16.01	15.47	15.74		15.75	15.76	15.76		
	Heavy	16.14	15.98	16.06	15.90	14.32	14.56	14.44	15.10	15.50
Black	Light	16.70	16.39	16.54		16.02	15.94	15.97		
	Heavy	16.16	15.49	15.82	16.18	14.24	14.22	14.23	15.10	15.64
Grey	Light	16.88	16.82	16.85		14.80	14.94	14.87		
	Heavy	16.28	16.35	16.32	16.58	15.27	15.48	15.38	15.12	15.85
Variety Mean	Canthatch	16.58				15.19				15.88
	Selkirk		16.08				15.25			15.66
Type Mean	Light			16.38				15.50		15.94
	Heavy			16.28	16.33			14.94	15.22	15.61

* Single value
** Data are expressed on a moisture-free basis

APPENDIX O_6

Mean Squares for TDN and DCP Content of Wheat

Source	D.F.	Cattle TDN	Cattle DCP	Swine TDN	Swine DCP
Year	1	0.316	40.36**	92.30**	19.72**
Soil Zone	3	0.279	2.82	9.92	1.17
Soil Type	1	0.005	2.19	5.14	1.02
Variety	1	0.023	1.59	5.62	0.52
Year x Variety	1	0.257	3.27	9.11	1.37
Year x Type	1	0.114	0.366	0.208	0.361
Year x Zone	3	0.131	0.885	4.51	0.343
Zone x Type	3	0.225	2.19	7.62	1.12
Zone x Variety	3	0.062	0.584	0.563	0.286
Type x Variety	1	0.001	0.077	0.093	0.029
Year x Zone x Type	3	0.110	2.26	5.89	1.20
Year x Zone x Variety	3	0.142	0.551	2.80	0.148
Year x Type x Variety	1	0.034	0.013	0.003	0.012
Zone x Type x Variety	3	0.054	0.182	0.427	0.109
Missing Plots	(2)				
Error	31	0.203	2.59	7.76	1.25

* $P < .05$
** $P < .01$

APPENDIX P

TDN Content of Oats for Cattle

TDN, %**

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	68.84	69.86	69.35		69.16*	70.67*	69.92		
	Heavy	68.91*	70.59*	69.75	69.55	68.26	69.87	69.06	69.49	69.52
Dark Brown	Light	70.04	71.11	70.58		68.85	69.48	69.16		
	Heavy	69.36	71.42	70.39	70.48	69.82	70.74	70.28	69.72	70.10
Black	Light	70.40	72.07	71.24		68.72	70.36	69.54		
	Heavy	69.83	71.03	70.43	70.84	70.06	71.67	70.86	70.20	70.52
Grey	Light	69.10	71.00	70.05		69.66	71.06	70.36		
	Heavy	69.22	71.62	70.42	70.24	70.26	71.81	71.04	70.70	70.47
Variety Mean	Garry	69.46				69.35				69.40
	Rodney		71.09				70.71			70.90
Type Mean	Light			70.30				69.74		70.02
	Heavy			70.25	70.28			70.31	70.02	70.28

* Single value
** Data are expressed on a moisture-free basis

APPENDIX P_1

D.C.P. Content of Oats for Cattle

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		D.C.P., %**								
Brown	Light	11.44	11.24	11.34		8.62*	8.39*	8.50		
	Heavy	10.65*	11.21*	10.93	11.14	11.17	11.10	11.14	9.82	10.48
Dark Brown	Light	11.17	10.22	10.70		10.80	10.74	10.77		
	Heavy	11.24	10.64	10.94	10.82	10.07	9.91	9.99	10.38	10.60
Black	Light	11.38	10.47	10.92		10.70	10.06	10.38		
	Heavy	10.86	10.33	10.60	10.76	8.74	8.86	8.80	9.59	10.18
Grey	Light	9.33	9.33	9.33		9.93	9.30	9.62		
	Heavy	10.36	10.26	10.31	9.82	10.64	10.20	10.42	10.02	9.92
Variety Mean	Garry	10.80				10.08				10.44
	Rodney		10.46				9.82			10.14
Type Mean	Light			10.57				9.82		10.20
	Heavy			10.70	10.64			10.09	9.96	10.40

* Single value
** Data are expressed on a moisture-free basis

APPENDIX P_2

TDN Content of Oats for Swine

TDN, %**

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	69.05	69.24	69.14		73.92*	74.20*	74.06		
	Heavy	70.74*	69.42*	70.08	69.61	69.34	69.30	69.32	71.69	70.65
Dark Brown	Light	70.05	71.20	70.62		69.98	69.22	69.60		
	Heavy	69.24	70.16	69.70	70.16	71.30	71.23	71.26	70.43	70.30
Black	Light	69.55	70.62	70.08		70.49	71.32	70.90		
	Heavy	70.03	70.78	70.40	70.24	73.17	73.06	73.12	72.01	71.12
Grey	Light	71.34	71.10	71.22		71.69	72.86	72.28		
	Heavy	70.59	70.14	70.36	70.79	70.74	70.88	70.81	71.54	71.16
Variety Mean	Garry	70.07				71.33				70.70
	Rodney		70.33				71.51			70.92
Type Mean	Light			70.26				71.71		70.98
	Heavy			70.14	70.20			71.13	71.42	70.64

* Single value
** Data are expressed on a moisture-free basis

APPENDIX P_3

DCP Content of Oats for Swine

Soil Zone	Soil Type	1964 Garry	1964 Rodney	1964 Type Mean	1964 Zone Mean	1965 Garry	1965 Rodney	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
		DCP, %**								
Brown	Light	12.99	12.83	12.91		10.77*	10.60*	10.68		
	Heavy	12.44*	12.84*	12.64	12.78	12.75	12.72	12.74	11.71	12.24
Dark Brown	Light	12.84	12.10	12.47		12.49	12.40	12.44		
	Heavy	12.84	12.43	12.64	12.56	11.98	11.84	11.91	12.18	12.37
Black	Light	13.00	12.34	12.67		12.44	11.96	12.20		
	Heavy	12.58	12.20	12.39	12.53	11.05	10.95	11.00	11.60	12.06
Grey	Light	11.20	11.22	11.21		11.85	11.39	11.62		
	Heavy	12.16	12.02	12.09	11.65	12.45	12.07	12.26	11.94	11.80
Variety Mean	Garry	12.51				11.97				12.24
	Rodney		12.25				11.74			12.00
Type Mean	Light			12.32				11.74		12.03
	Heavy			12.44	12.38			11.98	11.86	12.21

* Single value
** Data are expressed on a moisture-free basis

APPENDIX P_4

Mean Squares for TDN and DCP Content of Oats

Source	D.F.	Cattle TDN	Cattle DCP	Swine TDN	Swine DCP
Year	1	1.427	4.53	11.74*	2.942
Soil Zone	3	4.119**	1.785	5.50	1.06
Soil Type	1	0.700	0.328	0.528	0.293
Variety	1	26.16**	1.12	0.308	0.683
Year x Variety	1	0.339	0.039	0.174	0.016
Year x Type	1	1.07	0.025	0.072	0.011
Year x Zone	3	2.26*	1.95	5.08	1.47
Zone x Type	3	0.790	2.91	7.16	1.92
Zone x Variety	3	0.309	0.136	0.267	0.078
Type x Variety	1	0.446	0.299	0.613	0.179
Year x Zone x Type	3	1.36	2.86	11.72*	1.63
Year x Zone x Variety	3	0.274	0.320	1.40	0.154
Year x Type x Variety	1	0.001	0.001	0.002	0.000
Zone x Type x Variety	3	0.202	0.033	0.168	0.031
Missing Plots	(4)				
Error	25	0.395	1.10	2.51	0.726

* $P < .05$
** $P < .01$

APPENDIX Q

TDN Content of Barley for Cattle

TDN, %**

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	75.68	75.91	76.21	75.93		75.98*	76.24*	76.89*	76.37		
	Heavy	75.44*	75.76*	76.55*	75.92	75.92	75.83*	75.93*	76.28*	76.01	76.19	76.06
Dark Brown	Light	75.57	75.60	76.09	75.75		75.60	75.48	75.42	75.49		
	Heavy	75.92	75.86	76.33	76.04	75.90	75.92	76.09	76.28	76.10	75.80	75.85
Black	Light	75.51	75.78	76.02	75.77		75.45	75.71	75.11*	75.42		
	Heavy	75.38	75.58	75.88	75.61	75.69	76.02	76.16	76.09	76.09	75.76	75.72
Grey	Light	75.80	75.62	76.02	75.81		76.00	76.04	76.61	76.22		
	Heavy	75.44	75.50	75.83	75.59	75.70	75.41	75.29	75.34	75.35	75.78	75.68
Variety Mean	Husky	75.59					75.78					75.68
	Parkland		75.70					75.86				75.78
	Hannchen			76.12					76.00			76.06
Type Mean	Light				75.82					75.88		75.85
	Heavy				75.79	75.80				75.89	75.88	75.84

* Single value
** Data are expressed on a moisture-free basis

APPENDIX Q_1

DCP Content of Barley for Cattle

DCP, %**

Soil Zone	Soil Type	1964 Husky	1964 Parkland	1964 Hannchen	1964 Type Mean	1964 Zone Mean	1965 Husky	1965 Parkland	1965 Hannchen	1965 Type Mean	1965 Zone Mean	Overall Zone Mean
Brown	Light	10.10	10.04	10.54	10.23		7.78*	8.28*	8.16*	8.07		
	Heavy	12.10*	10.88*	9.04*	10.66	10.44	10.17*	10.29*	11.16*	10.54	9.30	9.87
Dark Brown	Light	9.93	9.68	9.92	9.84		10.16	10.46	12.49	11.04		
	Heavy	9.21	9.73	10.10	9.68	9.76	8.98	9.38	10.40	9.59	10.32	10.04
Black	Light	10.66	10.82	11.52	11.00		11.02	10.77	14.17*	11.99		
	Heavy	10.24	10.52	11.40	10.72	10.86	8.58	9.02	10.48	9.36	10.68	10.77
Grey	Light	10.17	10.32	10.96	10.48		9.68	9.72	10.20	9.87		
	Heavy	10.81	10.19	11.88	10.96	10.72	10.83	11.35	13.32	11.83	10.85	10.78
Variety Mean	Husky	10.40					9.65					10.02
	Parkland		10.27					9.91				10.09
	Hannchen			10.67					11.29			10.98
Type Mean	Light				10.39					10.24		10.32
	Heavy				10.50	10.44				10.33	10.28	10.42

* Single value

** Data are expressed on a moisture-free basis

APPENDIX Q_2

TDN Content of Barley for Swine

		TDN, %**										
		1964					1965					
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Overall Mean Zone
Brown	Light	78.73	79.15	78.44	78.77		82.88*	82.10*	82.59*	82.52		
	Heavy	75.15*	77.61*	81.04*	77.93	78.35	78.28*	78.35*	77.12*	77.92	80.22	79.28
Dark Brown	Light	79.02	79.38	79.29	79.23		78.66	77.94	74.53	77.04		
	Heavy	80.20	79.28	78.88	79.45	79.34	80.73	80.20	78.36	79.76	78.40	78.87
Black	Light	77.52	77.39	76.35	77.09		77.08	77.66	71.97*	75.57		
	Heavy	78.46	77.80	76.45	77.57	77.33	81.91	80.99	78.40	80.43	78.00	77.66
Grey	Light	78.60	78.39	77.39	78.13		79.77	79.54	79.14	79.48		
	Heavy	77.48	78.64	75.82	77.31	77.72	77.39	76.66	73.17	75.74	77.61	77.66
Variety Mean	Husky	78.14					79.59					78.86
	Parkland		78.46					79.18				78.82
	Hannchen			77.96					76.91			77.44
Type Mean	Light				78.30					78.65		78.48
	Heavy				78.06	78.18				78.46	78.56	78.26

* Single value
** Data are expressed on a moisture-free basis

APPENDIX Q_3

DCP Content of Barley for Swine

		DCP, %**										
		1964					1965					
Soil Zone	Soil Type	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Husky	Parkland	Hannchen	Type Mean	Zone Mean	Overall Zone Mean
Brown	Light	10.56	10.56	10.88	10.67		8.96*	9.35*	9.29*	9.20		
	Heavy	11.73*	11.08*	9.93*	10.91	10.79	10.61*	10.71*	11.24*	10.85	10.02	10.40
Dark Brown	Light	10.46	10.30	10.46	10.41		10.62	10.79	11.93	11.11		
	Heavy	9.99	10.35	10.60	10.31	10.36	9.86	10.14	10.78	10.26	10.68	10.52
Black	Light	10.92	11.01	11.42	11.12		11.13	11.00	12.73*	11.62		
	Heavy	10.62	10.81	11.32	10.92	11.02	9.47	9.80	10.51	9.93	10.78	10.90
Grey	Light	10.62	10.71	11.12	10.82		10.34	10.34	10.69	10.46		
	Heavy	11.02	10.65	11.64	11.10	10.96	11.03	11.34	12.32	11.56	11.01	10.98
Variety Mean	Husky	10.74					10.25					10.50
	Parkland		10.68					10.43				10.56
	Hannchen			10.92					11.19			11.06
Type Mean	Light				10.76					10.60		10.68
	Heavy				10.81	10.78				10.65	10.62	10.73

* Single value
** Data are expressed on a moisture-free basis

APPENDIX Q4

Mean Squares for TDN and DCP Content of Barley

Source	D.F.	Cattle TDN	Cattle DCP	Swine TDN	Swine DCP
Year	1	0.372	1.59	6.95	0.872
Soil Zone	3	0.307	2.95	9.00	1.16
Soil Type	1	0.120	1.27	4.37	0.354
Variety	2	1.06**	2.59	5.65	0.896
Year x Variety	2	0.029	0.913	3.10	0.280
Year x Type	1	0.035	0.299	1.11	0.087
Year x Zone	3	0.116	2.93	8.55	1.24
Zone x Type	3	0.852**	6.24*	21.13*	2.42*
Zone x Variety	6	0.057	0.616	2.33	0.189
Type x Variety	2	0.022	0.155	0.541	0.039
Year x Zone x Type	3	0.239	3.21	11.39	1.32
Year x Zone x Variety	6	0.003	0.203	0.701	0.084
Year x Type x Variety	2	0.084	0.531	1.73	0.163
Zone x Type x Variety	6	0.016	0.689	2.34	0.231
Missing Plots	(10)				
Error	37	0.140	1.76	5.56	0.71

* $P < .05$
** $P < .01$