THE INFLUENCE OF PROTEIN LEVEL OF THE GRAIN ON GERMINATION, PLANT VIGOR AND GRAIN YIELD IN FOUR VARIETIES OF HARD RED WINTER WHEAT

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INTRODUCTION

In a modern concept of crop production, high yields alone should not be placed in the foreground, but rather qualitative aspects should also be considered. This concept holds true in wheat production as well.

Research workers have been trying to strike at a golden mean between quantity and quality of wheat, but so far little success has been achieved.

Quality of wheat is a relative term and depends upon its use. To the miller, making flour for bread, good quality means high test weight and low or moderate protein content; to the farmer who needs feed for his cattle it means grain that is high in digestible nutrients and has a high test weight; to the importer quality means that it should best supplement the deficiency characteristics in the home grown wheat; and to the exporter it suggests that it must be acceptable and conforming to the tastes of the importing country.

Groups of wheat factors which determine quality are---(1) Preharvest and growth or cultural, climate, classes, and varieties, soil conditions and management. Climate cannot be controlled, so the problem is to breed, select, and develop varieties best suited to the climate; (2) harvest and storage conditions; and (3) physical and chemical composition of wheat grains.

It has been established that wheat from the Great Plains is high in protein while wheat from Eastern parts of the United States is low in protein. Hastening of maturity increases protein content and lowers

yield. It is difficult to get both high yield and high quality. That is, there is a high negative correlation between yield and protein content. Grain maturity when prolonged with abundant moisture and low temperatures (as in Eastern part of the United States) will result in lower protein and increased yields.

High quality of wheat grain seems to be an inherited varietal characteristic within certain limits. In seed quality we include the summation of all those characteristics which guarantee certain definite yield potentialities of the future plant in its vegetative cycle. In the course of seed formation from the zygote - covering the period from seed setting until seed maturity, the seed value is developed.

Thus the hereditary units and the environment under which the seed is formed are the factors that determine the total composition. Seed value is therefore a product of genotype and environment.

Considerable research has been done in correlating the genetic constitution and environmental conditions affecting the wheat grain quality, but scientists being skeptic, as they ought to be, are still working to reach definite conclusions in this respect.

The chief purpose of this study is to determine to what extent the level of protein of the seed influences germination, plant vigor, and grain yield in four varieties of hard red winter wheat.

REVIEW OF LITERATURE

For many years such studies as the influence of exchange of seed, breeding new varieties, selections for nitrogen content, soil types, soil treatment, fertilizers, water and temperature relations on the percentage of nitrogen in wheat have been under investigations by various scientists. From the results of these investigations, it is held that the variation in the composition of wheat is due, chiefly, to variations in environmental conditions, such as rain, sunshine, humidity, methods of cultivation, and soil fertility.

Effect of Climate on Nitrogen Content of Wheat.

In 1884, Lawes and Gilbert (6) [1] concluded that a season favorable for long and continuous growth after heading, produced well developed kernels and larger yields; the mature grain developed under the most favorable conditions contained a high amount of starch and a low amount of nitrogen.

LeClerc (7) deduced that the differences in composition from any one locality from season to season was due to varying weather conditons. The differences in composition of wheat analyzed by him for different localities were pronounced.

Thatcher (22) in a study correlating the protein content of wheat with the rainfall in various districts from which samples were taken,

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[1] Figures in parenthesis refer to "Literature Cited", page 31.

observed that the protein content varied inversely with the total rainfall. LeClerc (8), in a comparative study of the composition of wheat growth under arid and semi-arid conditions, concluded that the nitrogen content is higher in the wheat grown on the arid and semi-arid land than it is in wheat grown on humid and irrigated land. In other words, an excessive amount of rainfall or irrigation is always accompanied by a crop containing a very low percentage of protein. Shaw (18), in studies upon influences affecting the protein content of wheat, reported that some climatic factor overshadowed, to some extent, the soil factor. Ames (1) concluded from his experiments that the variation due to season in the composition of wheat is greater than that due to the composition of the soil. Bayfield (2) concluded that rainfall has an important role in lowering the protein content of wheat when it falls just preceding or during heading time; and high temperatures during the last 2-3 weeks before harvesting tend to decrease the weight per bushel. Mangels (12) pointed out that temperatures in North Dakota in June and July are the principal factors in determining the average protein content of wheat. He also concluded that apparently no relation exists between protein content of seed and protein content of the resulting crop. Olson (14), in his study of factors affecting nitrogen content of wheat and of the changes that occur during the development of wheat, concluded that increasing the distance between the rows seemed to increase the nitrogen content of wheat grown in nursery under non-irrigated conditions, but it did not affect the nitrogen content under irrigated conditions.

Shollenberger and Curtis (20) concluded from their investigations that the differences in test weight, ash, protein, sugar, and starch

between grain of the same variety grown in different environment were much larger than between grain of different varieties grown under comparable conditions. Scheck and Fetzer (19), [2] German scientists, stated that the seed value or seed quality depends both upon its genetic value and environmental value. The genetic value is being formed and constantly improved upon by the plant breeders. At the same time, this value is being acted upon and modified and changed by the environmental factors.

Effect of Moisture

Investigations pertaining to the influence of water on composition of wheat grain have been carried on over a comparatively long period. Widstoe (25) stated that large applications of water to wheat decreases its protein content in grains, especially when it is applied late. LeClerc (8) also concluded that wheat grown on arid non-irrigated land contains more protein than in wheat grown on adjoining irrigated land.

Shutt (21) states that early ripening of the wheat, such as brought about by the gradual lessening of the supply of the soil moisture tends to the production of hard glutinous wheat. Scheck and Fetzer (19) stated that seed which ripened in dry, hot climates showed a greater germination intensity, more rapid growth and higher yield than seed of the same variety grown in a moist condition.

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[2] Paper translated into English by A. M. Schlehuber.

Effect of Soil and its Composition.

Soil as a factor in influencing the composition of wheat has been studied. Shaw and Walters (17), Thatcher (22) and LeClerc (7) are of the opinion that the composition of soil has very little, if any, influence on the composition of grain. Ames (1) shows that without exception, application of nitrogen fertilizer increased the nitrogen content of wheat. Long and Ewing (10) concluded that yields can be increased by nitrogen application. When nitrogen is applied in the spring as top dressing, greater grain yields and protein are obtained. Bayfield (2) stated that the protein content will increase as the fertility of the soil increases. If soil conditions early in the season favor heavy vegetative growth and heavy yields, low protein wheat will result if the soil nitrate supply is deficient at filling time. With unfavorable growth conditions early in the season, and with a resulting small vegetative development, the protein content of the small crop harvested may be high if a plentiful supply of soil nitrates is available during the filling period. And with the right combination of nutrients available from the soil, high yield per acre can be combined with high or low protein content and with normal test weight per acre.

Mangel (12) reports that the use of proper cropping systems and legume crops as a method for increasing protein content of wheat is practical and offers most promise of success. Peterson (15), in investigations of the effect of nitrogen fertilizer on yield and protein content of wheat in Utah, concludes that the application of a commercial nitrogen fertilizer either increased the yield, the protein

content or both, and spring application proved to be more beneficial. Long and Sherbakoff (9) support Peterson (15) and state that yields as well as quality of wheat and flour are influenced by nitrogen fertilization, particularly when applied late in the development of plant.

Murphy (13) found that all fertilizers containing phosphoric acid gave higher grain yields than other fertilizer combinations, and the highest yield per acre was obtained when the fertilizer mixture consisted of three fourths super phosphate and one fourth nitrate of soda. Nitrogen fertilization increased the protein content of grain. On the other hand Bayfield (2) reported that protein increases with soil heaviness, that is, from sands to clays; with a given soil texture (silt loam) the protein content will increase as the fertility of the soil increases. Scheck and Fetzer (19) state that besides climate, soil and nutrition have numerous effects on the physiological processes of the maturing wheat plant and its grain. Further, seed which was taken from rough and poor land produced stronger and healthier plants with higher quantitative and qualitative consumptive value in the following year.

MATERIALS AND METHODS

Four varieties of hard red winter wheat grown in various experimental tests in Oklahoma in 1952 were selected for this study. The source of each lot of seed was determined by the protein content of the grain. Seed of low, medium, and high protein content was sought for each variety. The varieties, source of seed and protein percentages are given in table 1.

Table 1.--Source of seed and protein content of the wheat varieties tested.

Variety	C.I.*	Protein Level	Source of Seed	% Protein
Pawnee	11669	Low	1952 Perkins F.P.	9.29
"	"	Medium	'52 Washita County	12.03
"	"	High	'52 Blaine County (Watonga)	14.08
Wichita	11952	L	'52 Perkins F.P.	9.86
"	"	M	'52 Stillwater 1151	13.40
"	"	H	'52 Custer County	13.68
Comanche x Bkhl-Hd. Fed	12517	L	'52 Perkins F.P.	9.23
"	"	M	'52 Washita County	12.26
"	"	H	'52 Blaine County	13.45
Comanche	11673	L	'52 Perkins F.P.	9.80
"	"	M	'52 Stillwater 1509	12.71
"	"	H	'52 Blaine County	14.88

* C.I. refers to accession number of the Division of Cereal Crops and Diseases.

Germination studies were made with these lots of seed in; (1) a standard germinator, (2) in wooden flats, and (3) in the field.

Germination Percentage in the Germinator

One hundred seeds of each variety and each protein level were selected and placed in the germinator on germination pads on October 1, 1952 in two replications. Room temperature was maintained at 66°F to 68°F. Germination counts were made at the end of 4 and at 7 days.

Germination in Flats

The same varieties together with a check (Ponca, C.I.12128), were seeded on November 1 and 2, 1952 in 36 wooden flats measuring 20" x 14" x 3½". Each flat was then divided into quarters by means of cardboards and filled with pure coarse sand. After irrigating the flats, 24 holes were made in each quarter by means of a seeder frame. The holes were spaced one inch apart and planting was done at the rate of one seed per hole. All the flats were seeded in the same manner. For this study, 3 sets of 3 replications of each were seeded. The final germination data were taken on November 19, 1952.

Hoogland's [3] nutrient solution was applied as needed, till the plants were harvested in turn for the determination of forage weights.

Germination in the Field

The same varieties were seeded in the field with a hand drill in 4-10 foot rows in 4 replications on November 14, 1952. The seedbed was prepared in the usual manner and was seeded at the rate of three-fourths of a gram for each foot of row. At the time of seeding the moisture

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[3] Suggested by Prof. O. C. Schultz.

content of the soil was somewhat low and therefore germination was irregular until it rained at a later date.

In this experiment the germination observations were taken on 7 different dates, viz: December 7, 8, 9, 11, 15, 18 and 29.

Forage Weights

The wheat plants in each set of flats used in the germination test were clipped on 3 different dates for the determination of forage yields. In the first set, the whole plants were taken from each quarter of the flat on December 24, 1952, their roots washed with water and the whole plants spread on paper in a room for drying. When dried, the tops (stems and leaves) were weighed.

On February 14 and March 14, 1953, the second and third sets were clipped, their green weights were taken and then spread in the room separately for drying. Finally the dry weights also were determined.

Yield and Other Agronomic Determinations

In addition to observing the germination capacity of these wheats in the field trial, other data including heading and ripening dates, tillering, height, weights per bushel, and yield were taken in the usual manner.

EXPERIMENTAL RESULTS

Germination

The details of the germination of 4 varieties of wheat with variable protein contents are given in table 2. 100 seeds for each of 2 replications were placed into the germinator on October 4, 1952 and the germination counts were taken 4 days and again 7 days after seeding.

There was very little difference between the germination percentages after 4 and 7 days because the environment for germination was optimum. The germination capacity of the low protein, medium protein and high protein wheat varied in a regular order; that is, it was lower in the low protein, intermediate in the medium protein and higher in the high protein wheat.

Table 2.--The percent of germination of the 4 varieties of wheat of variable protein contents. Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	After 4 days Replications I	II	Av.%	After 7 days Replications I	II	Average %		
Pawnee	Low	81	86	83.5	89	91	90.0		
	Medium	84	85	84.5	90	91		90.5	
	High	94	89	91.5	98	92			95.0
Wichita	L	85	81	83.0	92	91	91.5		
	M	90	86	88.0	93	90		91.5	
	H	92	94	92.0	94	95			94.5
C.I.12517	L	78	80	79.0	90	88	89.0		
	M	85	87	86.0	89	94		91.5	
	H	92	92	92.0	95	96			95.5
Comanche	L	83	82	82.5	89	90	89.5		
	M	85	88	86.5	91	93		92.0	
	H	90	90	90.0	93	95			93.5
Grand average percentage							90.0	91.4	94.6

A summary of the germination percentage of wheat varieties with varying protein contents grown in flats is given in table 3. In each quarter of the flat, there were 24 seeds and these quarters were replicated 3 times.

In this case also the germination capacity of wheat of different protein levels varied. There was a good relationship between the different levels of protein in seeds and their germination capacity. That is, the higher the protein content, the greater the germination intensity or vice versa.

Table 3.—Number of seedlings and germination percentage of the 4 varieties of wheat with low, medium, and high protein levels grown in flats. Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	No. of seedlings set I	set II	set III	Av.	Average % germination		
		(Av. of 3 reps.)						
Pawnee	Low	20.0	20.3	21.0	20.4	85.0		
	Medium	20.7	21.3	21.3	21.4		89.2	
	High	22.0	22.0	23.3	22.4			93.3
Wichita	L	19.7	19.3	19.7	19.6	81.6		
	M	20.7	19.0	18.0	19.8		82.5	
	H	21.7	21.7	22.0	21.8			90.8
C.I.12517	L	19.0	19.3	20.7	19.7	82.1		
	M	20.3	20.3	21.0	20.7		86.2	
	H	20.7	23.0	23.0	22.2			92.5
Comanche	L	20.0	21.7	20.7	20.8	86.6		
	M	20.7	20.7	21.7	21.0		87.5	
	H	23.3	22.3	22.3	22.7			94.5
Grand average percentage						83.8	86.3	92.7

The estimated percent of emergence of the 4 varieties of wheat grown in the field is presented in table 4. The observations for the estimated germination were taken on 7 different dates -- December 7,

8, 9, 11, 15, 18 and 29. Here the variation in the emergence is greater than it was in the germinator or in the flats. This variability probably was caused by the differences in moisture content at different locations of the field and by other physical, chemical and biological characteristics of the soil. As pointed out already, there was insufficient moisture in the soil at the time of seeding this experiment.

There was not much difference in the seedling vigor of plants from the low and from the medium protein wheat seed. In the case of Pawnee, the low protein level was greater in germinating power than both the medium and high protein plots during the first observations. At the later dates, however, when the moisture content of the soil was more uniform, the high protein wheat surpassed the low and medium protein wheats.

It should be pointed out that these figures are estimates and no exact counts of the seedlings were made.

Table 4.--Estimated percentage of emergence on each of 7 dates of 4 varieties of hard red winter wheat seeded in field on November 14, 1952, Stillwater, Oklahoma.

Variety	Date	Low Protein					Medium Protein					High Protein				
		*I	II	III	IV	Av.	*I	II	III	IV	Av.	*I	II	III	IV	Av.
Pawnee	12/7	0	10	40	80	32.5	0	30	0	60	22.5	0	40	0	70	27.5
	8	5	20	50	80	38.8	5	50	10	70	33.8	5	50	50	90	48.8
	9	15	25	60	85	46.3	10	55	25	80	42.5	20	80	70	95	61.3
	11	20	30	60	85	48.8	15	65	30	85	48.8	30	90	80	95	73.8
	15	30	40	65	90	56.3	20	70	45	90	56.3	60	95	90	98	85.7
	18	60	50	70	90	67.5	30	75	60	90	63.8	80	95	90	98	90.8
	29	70	80	85	90	81.3	70	90	85	90	83.8	95	95	95	98	95.8
Wichita	12/7	0	25	10	40	18.5	0	0	0	20	5.0	0	20	5	60	21.2
	8	0	30	15	70	28.5	0	0	0	50	12.5	15	50	15	80	40.0
	9	5	35	20	70	32.5	10	40	30	70	37.5	40	70	50	90	62.5
	11	10	40	30	75	38.5	20	45	40	75	45.0	50	85	60	95	72.5
	15	20	50	40	80	47.5	25	50	45	80	50.0	55	90	70	98	78.2
	18	30	55	60	85	57.5	35	55	50	85	56.2	80	95	75	98	87.0
	29	70	80	80	90	80.0	75	80	80	90	81.2	95	95	90	98	94.5
C.I. 12517	12/7	10	5	5	20	10.0	0	0	0	50	12.5	0	0	50	70	30.3
	8	20	10	15	50	23.5	40	0	0	80	30.0	0	0	70	80	37.5
	9	30	15	20	70	33.7	50	15	30	85	45.0	60	25	80	90	63.7
	11	35	20	30	75	40.0	60	20	40	85	51.2	60	50	85	95	72.5
	15	40	30	35	80	46.2	65	25	45	85	55.0	65	60	90	95	77.5
	18	50	50	45	85	57.5	80	60	55	90	71.2	70	70	95	98	83.2
	29	80	85	85	90	85.0	90	85	85	90	87.5	90	85	98	98	92.7
Comanche	12/7	5	0	0	15	5.0	0	0	0	25	6.2	0	0	5	50	13.7
	8	10	5	10	50	18.7	0	0	5	60	16.2	0	20	20	70	27.5
	9	10	10	15	50	21.2	15	15	25	60	28.7	15	60	60	90	56.2
	11	20	15	20	55	35.0	20	20	35	65	35.0	30	65	65	95	63.7
	15	30	20	25	60	35.7	35	30	40	70	43.7	35	70	70	98	68.2
	18	50	50	35	70	51.2	50	60	50	75	58.5	75	85	85	98	85.7
	29	80	80	80	85	81.2	80	85	90	95	87.5	95	90	90	98	93.2
Av. of the 4 varieties						81.9					85.0					94.0

* I II III IV Replications

Forage Weights

The green weights of the two sets of flats clipped on February 14, and March 14, 1953 are given in table 5. It was evident that there was some correlation between different protein levels of the wheat seed and the growth and vigor of the seedlings. With exceptions of Wichita on February 14 and Comanche on March 14, there was a regular increase in the green weights of tops of the seedlings on both dates. The weights were higher in the high protein levels, intermediate in the medium and lower in the low protein wheat, even though sometimes there was only a slight difference between these weights.

Table 5.--Green weights in grams of 4 varieties of hard red winter wheat grown in flats, Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	Date Harvested	Replications I	II	III	Average	
Pawnee	Low	2/14	30.6	42.0	37.2	39.96	
		3/14	72.4	82.3	109.0		87.90
	Medium	2/14	33.3	45.5	42.0	40.27	
		3/14	102.2	118.1	104.5		108.30
	High	2/14	56.2	45.5	41.5	47.73	
		3/14	116.6	128.0	122.9		122.50
						*42.65	106.57
Wichita	Low	2/14	54.8	52.0	57.0	54.60	
		3/14	102.1	121.1	98.2		107.10
	Medium	2/14	48.3	56.1	49.1	51.16	
		3/14	110.4	128.6	102.0		113.70
	High	2/14	75.0	68.5	87.8	77.10	
		3/14	129.2	168.1	118.8		138.70
						*60.95	119.83
C.I.12517	Low	2/14	35.5	45.9	42.0	41.13	
		3/14	115.0	79.5	88.3		94.30
	Medium	2/14	67.0	46.7	65.5	59.73	
		3/14	112.3	108.7	87.0		106.00
	High	2/14	77.5	62.5	52.0	64.00	
		3/14	124.1	117.1	103.1		114.80
						*54.95	105.03
Comanche	Low	2/14	38.0	58.5	40.5	45.66	
		3/14	106.2	75.7	86.1		93.30
	Medium	2/14	53.2	44.8	48.6	48.86	
		3/14	90.4	84.1	88.8		87.70
	High	2/14	53.0	64.5	47.8	55.10	
		3/14	120.7	95.3	96.8		104.30
						*49.87	95.10
Grand average weight of the 4 varieties						52.52	106.55

* Average of the variety

The air dry weights of the plants from the flats clipped on December 24, 1952, February 14, and March 14, 1953 are given in Table 6.

Again with two exceptions, i.e. Wichita on February 14 and Comanche on March 14, there was a similar relationship between the dry weights and the protein levels. On the whole, Wichita had the highest weights -- being the earliest variety.

Table 6.--Air dry weights in grams of 4 varieties grown in flats, Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	Date Harvested	Replications I	II	III	Averages		
		12/24	1.00	1.34	1.27	1.63		
Pawnee	Low	2/14	5.00	7.84	7.35		6.73	
		3/14	9.50	13.00	15.80			14.76
		12/24	1.10	1.64	1.46	1.30		
	Med.	2/14	6.30	8.42	7.92		7.55	
		3/14	14.10	18.10	15.20			15.80
		12/24	1.40	1.71	1.52	1.54		
	High	2/14	9.63	8.50	8.13		8.75	
		3/14	16.80	19.30	18.05			18.05
						*1.49	7.68	16.20
		12/24	1.23	1.09	0.95	1.09		
Wichita	Low	2/14	9.15	8.55	9.40		9.03	
		3/14	14.92	21.65	12.80			16.46
		12/24	1.05	1.15	1.52	1.21		
	Med.	2/14	8.25	9.65	8.79		8.89	
		3/14	16.65	23.25	14.50			18.13
		12/24	1.41	1.48	1.66	1.52		
	High	2/14	9.95	11.45	14.27		11.89	
		3/14	21.10	29.10	12.45			23.22
						*1.27	9.94	19.27
		12/24	1.25	0.88	1.25	1.13		
C.I.12517	Low	2/14	6.92	8.28	7.80		7.66	
		3/14	18.90	11.15	13.00			14.35
		12/24	1.32	1.36	1.24	1.31		
	Med.	2/14	11.90	8.70	9.50		10.03	
		3/14	19.20	15.30	12.45			15.65
		12/24	1.61	1.42	1.50	1.18		
	High	2/14	13.75	12.00	9.75		11.83	
		3/14	20.90	18.65	16.55			18.70
						*1.21	9.84	16.23
		12/24	1.19	0.95	1.10	1.08		
Comanche	Low	2/14	7.10	9.65	7.75		8.16	
		3/14	17.00	11.20	12.25			13.48
		12/24	1.18	1.10	1.12	1.13		
	Med.	2/14	8.98	7.85	8.55		8.46	
		3/14	13.35	12.65	12.20			12.73
		12/24	1.43	1.15	1.36	1.31		
	High	2/14	8.70	10.43	8.40		9.17	
		3/14	19.20	13.70	13.42			15.44
						*1.17	8.59	13.88
Grand average						1.28	9.01	16.39

* Average of the variety.

The total average dry weights in grams, their means and standard deviations for the Ponca check are 11.22, 88.61, 155.60; 1.020, 7.384, 12.966; 0.174, 1.504, and 1.688 for December 24, 1952, February 14, and March 14, 1953 respectively.

The germination of the Ponca variety was very low compared with the other varieties because the seed was not selected. Therefore these figures are given separately.

These results indicated that the standard deviations were normal and the variations in dry weight of the forage between the different flats were no greater than would be expected assuming a homogeneous population.

Yield and Other Agronomic Determinations.

Tillering Capacity

The average number of tillers with fertile heads in the border rows of the field plots are given in table 7. There was an increase in the number of tillers from low to high protein in case of Pawnee and C.I.12517, but in Wichita, the medium protein wheat had the lowest number of tillers, and in Comanche, the low protein wheat seed had the highest number of tillers.

This irregularity may have been due to the heterogeneity of the field. The general trend was for more tillers from high protein seed and less from low protein seed. The average of all the low, medium and high protein seed indicated that the highest number of tillers emerged from the high protein seed and approximately equal number of tillers arose from low and medium protein seed.

Table 7.--Number of tillers with fertile heads in border rows of the 4 varieties of hard red winter wheat. Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	Average number of tillers of 2 border rows. Replications I	II	III	IV	Average		
Pawnee	Low	231.5	244.0	247.5	223.0	236.0		
	Med.	242.5	249.0	258.0	223.5		243.0	
	High	250.0	286.0	284.0	229.0			262.4
Wichita	L	214.5	229.5	203.0	172.5	229.8		
	M	192.0	169.5	184.5	207.0		188.2	
	H	226.5	263.5	253.0	232.0			243.7
C.I.12517	L	215.5	224.0	223.5	203.5	216.6		
	M	263.0	245.0	241.0	264.5		253.3	
	H	291.5	251.0	305.0	266.5			278.4
Comanche	L	257.0	266.0	225.0	222.0	242.5		
	M	236.5	226.5	235.0	199.5		224.3	
	H	261.5	261.0	229.5	196.5			237.1
Grand average of the 4 varieties						231.2	227.2	255.4

Heights of Plants in Inches

The heights in inches of the 4 varieties of wheat each with 3 different protein levels are shown in table 8. It indicated that throughout the first replication except a few cases as in Wichita and C.I. 12517, the height of each variety was less than in the 3 other replications. The reason for this might be the lower fertility of the soil on this location.

In general, the plants from high protein seed were shorter than those from medium or low protein seed, though the differences were negligible.

Table 8.--Heights of plants in inches of 4 varieties of wheat in the 4 replications with 3 protein levels. Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	Height in inches Replications I	II	III	IV	Average		
Pawnee	Low	30	37	36	34	34.2		
	Med.	30	36	35	34		33.7	
	High	32	35	34	34			33.7
Wichita	L	28	27	32	32	29.7		
	M	24	30	33	35		30.5	
	H	24	31	30	33			29.5
C.I.12517	L	25	35	34	35	32.2		
	M	35	31	36	36		34.5	
	H	26	31	36	34			31.7
Comanche	L	37	38	36	35	36.5		
	M	33	33	35	38		34.7	
	H	26	38	35	38			34.2
Grand average of the 4 varieties						32.6	33.3	32.5

Heading and Ripening Dates

The heading and ripening dates of the 4 different varieties are given in table 9. All the heading and ripening of the wheats took place during May and June, respectively. The first replication headed and ripened before the others. This also was probably due to the low soil fertility or lack of moisture.

It also was observed that generally the high protein level wheats were the earliest to head and ripen as compared to medium and low protein wheats.

Table 9.—Heading and ripening dates of 4 varieties of wheat with low, medium and high protein levels.

Variety	Protein Level	Heading or Ripening	Replications I	II	III	IV	Average	
Pawnee	Low	Hd/1	16	17	16	17	16.5	
		Rp/2	10	13	11	12		11.7
	Med.	Hd	16	17	17	16	16.5	
		Rp	11	12	11	12		11.5
	High	Hd	16	17	16	16	16.3	
		Rp	10	11	11	11		10.7
							*16.4	11.3
Wichita	Low	Hd	6	7	7	8	7.0	
		Rp	8	9	10	10		9.2
	Med.	Hd	6	7	9	8	7.5	
		Rp	7	9	9	9		8.5
	High	Hd	6	7	7	8	7.0	
		Rp	6	8	8	8		7.5
							* 7.2	8.4
C.I.12517	Low	Hd	9	13	17	17	16.5	
		Rp	10	12	13	13		12.0
	Med.	Hd	15	12	16	16	14.7	
		Rp	11	10	12	12		11.2
	High	Hd	17	14	14	17	15.5	
		Rp	10	10	11	11		10.5
							*15.6	11.2
Comanche	Low	Hd	12	13	17	17	14.7	
		Rp	11	13	12	13		12.2
	Med.	Hd	16	13	16	14	14.7	
		Rp	11	11	12	9		13.2
	High	Hd	10	16	16	18	15.0	
		Rp	9	9	11	12		10.2
							*14.8	11.8
Grand average							13.28	9.86

/1 Hd - Heading in May
/2 Rp - Ripening in June
* Average of the heading and ripening dates.

Test Weights

Test weights for the 4 varieties of wheat with 3 different levels of protein are given in table 10. Pounds per bushel of Wichita was the highest, then came C.I. 12517 and the remaining two - Comanche and Pawnee were exactly equal.

The overall averages of low, medium and high protein indicated that the low protein levels had the highest test weights, and there was very little difference between medium and high protein levels.

Table 10.—Pounds per bushel of the 4 varieties of wheat with 3 different levels of protein. Stillwater, Oklahoma, 1952-53.

Protein Level	Pawnee	Wichita	C.I.12517	Comanche	Average
Low	56.4	59.5	56.7	56.1	57.2
Med.	55.1	59.6	56.8	55.1	56.6
High	55.5	59.2	57.3	55.6	56.9
Average	55.6	59.4	56.9	55.6	

Grain Yields

Details of grain yields in bushel per acre are presented in table 11. Wichita ranked first, C.I. 12517, Comanche and Pawnee followed in order, each one decreased in yield in order from Wichita by nearly 2 bushels per acre. There seemed to be no definite relationship between the yields of low, medium and high protein content wheats. But when the overall average yield was found out, there was a slight relationship, that is, the grain yield was higher in low, intermediate in medium and lower in the high protein level wheats. Although this difference was very slight and negligible.

Table 11.—Yield of grains in bushels per acre of the 4 varieties of wheat with low, medium and high protein levels. Stillwater, Oklahoma, 1952-53.

Variety	Protein Level	Replications I	II	III	IV	Average		
Pawnee	Low	26.1	23.3	25.4	22.8	24.4		
	Med.	21.3	22.5	23.2	20.6		21.9	
	High	25.5	22.4	22.8	24.5			23.8
								*23.37
Wichita	L	29.8	32.6	28.7	26.3	29.3		
	M	25.8	30.6	24.4	32.6		28.3	
	H	28.4	30.1	29.8	29.6			29.4
								*29.06
C.I.12517	L	29.7	27.1	25.6	23.4	26.4		
	M	35.3	28.4	26.2	30.1		30.0	
	H	27.0	25.3	31.3	21.9			26.3
								*27.61
Comanche	L	27.5	27.1	25.9	23.9	26.1		
	M	20.0	27.7	25.0	25.8		24.6	
	H	26.2	25.0	25.6	21.8			24.6
								*25.12
Grand average of the 4 varieties						26.5	26.2	26.0

* Varietal average.

Analysis of variance of grain yields of the field experiment with respect to the 4 varieties of wheat each with 3 levels of protein are given in table 12. This analysis indicated that the varietal results were highly significant while the protein levels and replications were nonsignificant.

Table 12.—Analysis of variance of grain yields of 4 varieties of wheat each with 3 levels of protein.

Item	S.S.	D.F.	Variance	F. Value
Total	564.55	47		highly
Varieties	231.60	3	77.20	9.72 significant
Protein levels	2.12	2	1.06	0.13 nonsignificant
Replications	20.67	3	6.89	0.87 nonsignificant
Error	310.16	39	7.94	

DISCUSSION

In this study of the influence of protein levels of the grain on germination, plant vigor, other agronomic characteristics and yield, some very good relationships were found. These relations were more variable from the field data than those obtained from the germinator and from the flats. For example, in case of the germination studies, there seemed to be a definite relationship between the germination vigor of high, medium and low protein seed. It was highest in the high protein content seed, intermediate in the medium and lowest in the low protein seed. This apparent relationship was somewhat less definite in case of the flats and was practically non-existent in case of the field experiment.

Under controlled conditions as in a germinator and in flats, this relationship conformed to the findings of Scheck and Fetzer (19). The lack of such relationship probably can be attributed to the complexity of the climate, soil and its nature, moisture and temperature conditions (1, 7, 18, and 22).

In comparing the green and dry forage weights obtained from flat experiment, a rather good relationship was found between the 3 protein levels of wheat, and the results obtained were similar to those obtained by Scheck and Fetzer (19).

The tillering data indicated that there was no definite relationship between the number of tillers and the various protein levels of wheat except in Pawnee and C.I. 12517. But the overall averages of low, medium and high protein content wheat gave an indication towards more tillers in high protein levels, less in medium and intermediate in

the low protein content wheat. This variation may probably be explained by the investigations of LeClerc (7) who stated that weather conditions and climate had the greatest influence upon the growth, yield and quality of the wheat crop, and partly by the researches of Scheck and Fetzer (19), who concluded that high protein seeds have more vigorous growth than the lower protein seeds.

The heights of plants measured in inches gave no clear indication to the behavior of the different protein level wheats which is in conformity with the findings of so many research workers - Mangels (12) who stated that apparently no relationship exists between protein content of seed and growth and protein content of the resulting crop; and Bayfield (2) who stated that the proper combination of soil nutrients are necessary for proper growth of the wheat crop. This irregularity in heights may be due to the heterogeneity of the soil, moisture conditions and other climatic factors. The data for height of plant indicated that the plants were slightly shorter in case of the high protein content seed.

The heading and ripening data indicated that plants, on seemingly poor spots of soil headed and ripened first and more-over, the high protein content wheats which were shorter in heights, also headed first and ripened first, and these findings coincided with the findings of Lawes and Gilbert (6), LeClerc and Yoder (8) and Shutt (21).

Wichita, an early maturing variety headed and ripened first, and all along its growth, it had shown vigor in germination, growth, heading, ripening, bushel weights and yield. This characteristic of the variety is in line with the findings of Gericke (4).

The test weights of the wheat varieties indicated that there is a slight relationship between the test weights of low protein seeds and medium and high protein seeds. It is higher from the low protein grain than from the highest protein grains. Wichita had the highest test weight, followed by C.I. 12517 and Pawnee and Comanche had equal test weights.

Wichita, being the earliest maturing variety and therefore, had more capacity to absorb nutrients from the soil in a comparatively shorter time than the other somewhat later varieties surpassed the other varieties in every phase of growth and yield. The other varieties, due to the extreme hot days during the last week of the ripening stage, did not get sufficient time to mature properly and consequently they were low in test weights and yields.

Reviewing the whole of this study on the influence of different levels of protein on the germination, plant vigor, other agronomic characteristics and yields, etc., it can be concluded that under controlled conditions of climate, soil, nutrients, moisture and temperature, there is a positive influence of the high protein, medium protein and low protein content seeds on the plant growth—vigorous in high protein seed and low in low protein seed (19). However, due to uncontrollable factors in the field, this relationship was practically nonexistent.

It should be recognized that not only has the climate a great influence on the yield and quality of wheat but also soil, fertilizers, moisture and temperature play an important role in the success of the wheat crop (1, 2, 9, 10, 12, 13, 14, 15, 20, 23, 24, and 25). Further,

the seed quality is not only influenced by the environmental factors alone, but also by the genetic constitution of the seed (3, 4, 11, 16, 17, and 19).

SUMMARY

1. High protein content seed had the highest germination, medium protein had intermediate germination and low protein seed had the lowest germination in all three tests - in the germinator, in the flats and in the field. It was less pronounced in the field than in the germinator and in the flats.
2. Similarly forage weights - green as well as dry, varied. It was highest in the high protein levels and followed in order by medium and low protein content seed.
3. Tillering capacity in the various protein content seeds indicated no relationship, probably due to the uncontrollable complexities of climate, soil and the plant nutrients, etc. However there was a slight increase in tillering in high protein wheat.
4. The earliest maturing wheat (Wichita) had the shortest straw but the highest grain yield and test weight. It also showed promising growth in its early stages of development. In others, there was not much difference in heights of the plants, though there was a slight tendency towards shortness in the high protein wheat.
5. The high protein wheats usually headed and ripened first. Wichita was the earliest.
6. Wichita had the highest test weight, followed by C.I. 12517. Pawnee and Comanche had equal test weights. High protein wheat had a tendency to give lower test weights in the over-all averages.
7. There was very little difference in the yields from the 3 different protein levels of wheat, though there was a slight but nonsignificant decrease in the yields of the high protein wheat.

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