THE EFFECTS OF DIFFERENT RATES, TIMES, AND METHODS OF APPLICATION OF VARIOUS FERTILIZER COMBINATIONS ON THE YIELD AND QUALITY OF HARD RED WINTER WHEAT, 1949-50

by

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INTRODUCTION

The foundation of successful agriculture in Kansas is wheat production. Wheat is grown on nearly half of the cultivated acreage in Kansas. It is the most important cash crop produced here, not only from the acreage standpoint but also from the standpoint of cash value received. It follows then that anything which will affect the yield or quality of wheat in Kansas is of importance and should be studied.

Many investigations have shown that applications of various fertilizers affect the yield and quality of wheat.

With these results in mind, and also keeping in mind that the use of superphosphate at seeding time has been a long established practice here, the following experiment was established.

For this particular study, it was decided to locate experimental plots at various locations in the eastern half of the state. At each location, the objectives of the study were: (1) to determine the effect of nitrogen fertilizer, alone and in combination with phosphate and potash fertilizers, on the yield and quality of hard red winter wheat; (2) to determine the effect of type of carrier of nitrogen on wheat yield and quality; and (3) to determine the effect of time and method of application of nitrogen fertilizer on the yield and quality of wheat.

REVIEW OF LITERATURE

In early studies made by Call (7), sodium nitrate was used as a source of nitrogen. He concluded that sodium nitrate increased the yield of wheat produced on late prepared seedbeds.

Vandecaveye and Baker (37) used sodium nitrate in the Palouse area of Washington on wheat. It was concluded that the use of 100 pounds of sodium nitrate per acre increased the yield of wheat four bushels.

Davidson and LeClerc (11, 12) also used sodium nitrate in their early studies relative to fertilizer effects on wheat in Kentucky and Nebraska. In their studies, sodium nitrate was applied at one level and at three stages of plant growth. The three stages were: (1) at the time plants were about 2 inches high; (2) at time of heading; and (3) at milk stage of grain. From these studies, they concluded that: (1) yield and vegetative growth were increased by application of sodium nitrate at early stages; (2) sodium nitrate applied at time of heading increased the protein content and gave better color of grain; (3) in Kentucky, sodium nitrate applied at the milk stage had no effect on wheat; and (4) potassium chloride in Nebraska depressed the protein content of the straw and in Kentucky apparently increased the amount of yellowberry.

In two of his studies, Gericke (18, 19) used sodium nitrate to study the effect of nitrogen on the yield and protein content of wheat. From these studies he concluded that late applications of sodium nitrate increased the yield and protein content of wheat grain. He also concluded that protein content of wheat grain can be markedly altered by use of nitrogen fertilizers. This latter conclusion paved the way for a new study on fertilizer effect on wheat as influenced by variety of wheat used. After completing this study, Gericke (20) concluded that: (1) the supply of nitrogen available for the quantity of grain that any state of vegetative growth may induce determines the protein content of the wheat; (2) the amount of nitrogen available at different growth stages affects the protein content of the wheat; and (3) the variety of wheat used may markedly affect the efficiency of any fertilizer treatment.

Reitz and Myers (32) studied the effect of variety on the response of wheat to phosphate fertilizer. They found that in this study the yield of wheat was increased, the protein content of the grain was reduced, test weights were increased slightly, percentage of yellowberry was increased, and maturity was hastened by application of phosphate fertilizer. They also stated that varieties of similar adaptation tend to give equal response to applications of phosphate fertilizer.

Neidig and Snyder (30) made greenhouse and field studies on the effects of additions of nitrogen fertilizer on wheat. It was found that additions of nitrogen fertilizer gave a marked increase in the yield and percent protein of Marquis wheat in the greenhouse. In the field applications, they found that the yield was increased but the percent protein was decreased for both the Marquis and Palouse varieties of wheat.

Burke (5), and Burke and Pinckney (6) found that both wheat straw and wheat grain had a higher nitrogen content and higher yield on the fallowed plots than on continuous cropped plots. This difference was attributed to the greater amounts of nitrate nitrogen available in the fallowed plots. For the Montana wheat area, they suggest the use of either legumes or fertilizer nitrogen to offset the depletion of nitrogen in the soil by continuous cropping.

Pendleton (31) found that the use of sodium nitrate at heading time increased the yield of wheat grain on certain Iowa soils. He found that the later spring applications increased both yield and protein. The increase in yield was more significant than the increase in protein content of grain. The test weights were not affected.

Murphy (28) used superphosphate, sodium nitrate, and kainit in Oklahoma wheat studies. From this study, he concluded that: (1) nitrogen or potash did not increase yields alone or in combination; (2) phosphorus increased yields both alone and in combination with nitrogen or potash. Protein content of the wheat grain was increased by the application of nitrogen fertilizer.

In a later investigation, Murphy (29) concluded that high rates of added phosphorus, with limited or no nitrogen, may result in nitrogen deficiency in wheat. He also concluded that spring applications of nitrogen gave the greatest increase in protein content of wheat grain.

Knowles and Watkin (23) in work on assimilation and translocation of plant nutrients found that the assimilation of nutrients in the wheat plant is greatest in the early stages of growth.

Doughty, Engledow, and Sansom (13) working in Britain found that spring topdressing of wheat with nitrogen fertilizer increases the yield of wheat by increasing the head size.

Gainey and Sewell (14, 15) found that available nitrate in the field increases yield of grain and vegetative growth. They also concluded that the application of commercial nitrogenous fertilizers will increase yields and protein content of the wheat grain.

Gainey, Sewell, and Myers (16) in work on spotted wheat fields reported that the taller and darker green spots were the result of the soil supplying the wheat plants with more available nitrogen. From artificially inducing spots with fertilizers, they concluded that the time and quantity of nitrogen applied may result in no effect for light fall and summer applications and marked increases in yield and protein content of wheat for the heavy fall and spring applications.

Crofton (10) found that nitrogen fertilizers increased yield and protein content of wheat in Kansas.

Lewis and others (24) in Britain found that spring applications of nitrogen fertilizers increased yield of wheat and that the magnitude of the response depended on the previous history of the field. Watson (38), also in Britain, found similar results on yield but he also found the protein content of grain, straw, and chaff was increased by spring applications of nitrogen fertilizers.

Garner and Sanders (17) found that light and heavy soils differ in response to ammonium sulfate. On heavy soils it is easier to obtain increases in yield than it is on light soils. Fall applications are better on heavier soils than on light soils.

Cook and Millar (8) in Michigan found no consistent increases of yield from applications of nitrogen to wheat on heavy soils. They found that other soils, medium to light texture, gave increases in yield.

Bracken (3) in his work on manure treatments found that protein content of the wheat grain was increased and the yield was increased by 16 per cent on the manured plots.

Cowie (9) of Britain has stated that nitrogen is the main requirement of wheat grown in the United Kingdom. According to his work, spring applications of nitrogen are best and there is no advantage to splitting the treatment. He also stated that phosphorus and potassium were required only as supplements in very deficient soils.

Lowrey and other (25) in Nebraska have found, in general, that winter wheat responds to nitrogen fertilizers and on certain soils to phosphorus. They also found that spring applications gave greater protein content in the wheat grain.

Smith (35), in Kansas, found that combinations of nitrogen and phosphorus, 25 pounds of each, gave significant increases in yield when placed with the seed or when the nitrogen was topdressed. Potash did not affect the yield or protein content of the grain. Test weights were reduced by extra large applications of nitrogen alone.

Simkins (34) used ammonium nitrate, superphosphate, and muriate of potash in fertilizer tests with wheat in Kansas. He found that 25 pounds of nitrogen alone and in combination with phosphorus gave the greatest increase in yields. Phosphorus alone increased the yield of wheat in southeast Kansas. Test weights were not affected by the fertilizer applications. Time of application did not affect the wheat yields or protein content significantly. He also stated that calcium cyanamid and ammonium nitrate were equally good as a nitrogen fertilizer for wheat.

Mitchell (27) and others (33, 22, 26) have found that phosphate fertilizers increase yields of wheat. This is especially true in cool moist seasons. They further state that phosphorus has no effect on test weights or protein content of the wheat grain.

METHODS OF STUDY

Location and Description of Plots

The plots for this study were laid out at four locations in the eastern one-half of Kansas. Two of the trials were in the northern half; one on the Lee Goodger farm near Belleville in Republic County, and the other on the Kansas State College Agronomy Farm near Manhattan in Riley County. The other two trials were in the southern half; one on the Bob White farm near Goddard in Sedgwick County, and one on the Clarence Ely farm near Thayer in Neosho County.

At Manhattan, the soil type was Geary silt loam. The Geary soil here is reddish brown in color. It is located on gentle sloping land. The particular field used in this study had a very gentle slope in one direction. This soil is well drained, externally and internally, and it is well suited to the production of corn and small grains. The previous cropping history of this field was soybeans 1945, oats 1946, wheat 1947, and oats 1948.

The soil type at Belleville was classed as Crete silt loam, tentative series designation. The soil at this location was dark brown in color. The drainage was not quite so good as at Manhattan. However, the field was nearly level and inasmuch as water did not stand in the field internal drainage must have been good. This soil is another upland soil best suited to corn and small grain production. The previous cropping history of this field was one of continuous wheat for the three previous years.

The Goddard soil was tentatively classified as Polo silt loam. This soil was dark brown in color and on a nearly level field with a gentle slope in one direction. The drainage of this location was sufficient to handle the year's rainfall without having water stand on the field. This soil is best suited to small grains, sorghums, and legumes such as alfalfa or sweet clover. The cropping history of this field was one of continuous wheat for the previous three years.

At Thayer, the soil was classed as Parsons silt loam. This soil was dark gray in color and the drainage was good. The field was level and apparently very uniform. The crops recommended for this soil are small grains. The cropping history of this field was one of continuous wheat for the previous two years.

Plan of the Experiment

The plan of the experimental design for the study was the same at each location. The design was a randomized complete block design after Snedecor (36). Each block consisted of 40 treatments located at random on the plots within the block. The block was replicated

Table 1. Treatments for wheat fertilizer research, 1949-50.

Treat. no.	Treatment N*	Treatment P_2O_5**	Treatment K_2O***	Method of Application		
1	100	100	100	N Broadcast	P_2O_5 At Seeding	K_2O Broadcast
2	0	100	100		"	"
3	100	0	100	"		"
4	100	100	0	"	"	
5	100	50	25	"	"	K_2O at seeding
6	50	50	25	"	"	"
7	25	50	25	"	"	"
8	100	0	0	"		
9	100	50	0	"	"	
10	100	50	25	N at seeding	"	"
11	50	50	25	"	"	"
12	25	50	25	"	"	"
13	100	0	0	"		
14	50	0	0	"		
15	25	0	0	"		
16	100	50	0	"	"	
17	50	50	0	"	"	
18	25	50	0	"	"	
19	0	50	0		"	
20	0	0	0	(No treatment)		
21	50	50	25	N topdressing Dec. 20	"	"
22	50	50	25	N " Feb. 20	"	"
23	50	50	25	N " Mar. 10	"	"
24	50	50	25	N " Mar. 30	"	"
25	50	0	0	N " Dec. 20		
26	50	0	0	N " Feb. 20		
27	50	0	0	N " Mar. 10		
28	50	0	0	N " Mar. 30		
29	50	50	0	N " Dec. 20	"	
30	50	50	0	N " Feb. 20	"	
31	50	50	0	N " Mar. 10	"	
32	50	50	0	N " Mar. 30	"	
33	25N 25N	50	25	N Half at seeding topdressing Dec. 20	"	"
34	25N 25N	50	25	N " Feb. 20	"	"
35	25N 25N	50	25	N " Mar. 10	"	"
36	25N 25N	50	25	N " Mar. 30	"	"
37	50	50	25	N ($CaCN_2$) topdressing Dec. 20	"	"
38	50	50	25	N " " Feb. 20	"	"
39	50	50	25	N " " Mar. 10	"	"
40	50	50	25	N " " Mar. 30	"	"

*N added in form of NH_4NO_3 except in treatments 37,38,39, and 40.
**P_2O_5 added in form of triple superphosphate.
***K_2O added in form of muriate of potash.

twice at Manhattan and three times at the other locations. A plan of the various treatments used is shown in Table 1.

The size of the individual plots within the block varied at the different locations. The harvested plot size was 5 and 1/3 feet by 140 feet at Manhattan, 5 and 1/3 feet by 100 feet at Belleville, 5 and 1/3 feet by 98 feet at Goddard, and 5 and 1/3 feet by 136 feet at Thayer.

The planting dates were kept as close together as the weather and work schedule would permit. The planting dates at the various locations are shown in Table 2 with the varieties of wheat planted and the dates of harvest at the various locations.

Table 2. Varieties planted, dates of planting, and dates of harvest, wheat fertility tests, 1950.

Location	Wheat variety planted	Date planted	Date harvested
Manhattan	Pawnee	October 3, 1949	June 26, 1950
Belleville	Pawnee	September 24, 1949	July 6, 1950
Goddard	Triumph	October 12, 1949	June 22, 1950
Thayer	Pawnee	October 8, 1949	June 23, 1950

Chemical Analyses of Soils

Chemical analyses were made on samples of each soil collected at random throughout the plots before treatments were added. Laboratory determinations included pH, lime requirement, available phosphorus, exchangeable potassium, and organic matter.

The pH was determined by the standard glass electrode method using the Leeds-Northrup instrument. The lime requirement was then determined by use of the Woodruff buffer solution. The buffer solution was added to each of the soils because the pH value was below pH 6.1. After allowing the suspension to stand for 30 minutes, the pH was again taken and for every tenth of a pH unit under pH 7.0, one ton of lime was recommended.

Available phosphorus was determined by the colorimetric method of Bray and Kurtz (4) as modified by Arnold and Kurtz (1).

Organic matter was run by a modification of the colorimetric method of Graham (21).

Protein Analysis

Total nitrogen was determined on the grain samples from each plot at each location by the Kjeldahl method (2). The nitrogen content was then converted to per cent protein by multiplying the percent nitrogen by the factor 5.7 (2).

Test Weight

The test weights were determined by the standard apparatus used for this purpose.

RESULTS

The results of the experiments conducted at the four locations are presented here in the following tables.

Table 3. Rainfall data for the 1949-50 wheat experiments by months for all locations.

Months	Locations			
	Manhattan	Belleville	Goddard	Thayer
August	1.98	5.11	2.35	.71
September	2.20	2.92	1.95	3.72
October	1.06	2.06	1.78	2.13
November	0.34	0.00	0.03	0.32
December	1.17	0.83	1.46	2.25
January	0.05	0.00*	0.23	0.22
February	0.53	1.63*	1.18	0.54
March	0.60	0.25*	0.47	0.77
April	2.00	0.53*	0.47	0.91
May	3.97	5.52*	0.88	4.22
June	3.56	.85	5.95	4.65
July	13.58	5.97	12.22	10.39
Total	31.02	25.67	28.97	30.83

*These measurements were taken at the Goodger Farm, others were taken at the Belleville Experimental Field.

Table 4. Soil types and chemical characteristics of soils used in 1949-50 wheat experiments.

Location	Soil type	pH	Available P lb./A	Exchangeable K lb./A	Organic matter in percent	Lime requirement lb./A
Manhattan	Geary silt loam	5.25	44.0	495	1.66	3900
Belleville	Crete silt loam*	5.45	56.5	965	1.65	2800
Goddard	Polo silt loam*	5.25	29.0	610	1.58	2800
Thayer	Parsons silt loam	5.52	11.0	189	1.54	3400

*Tentative series designation.

Table 5. The effect of method, time, and rate of application of fertilizer on the yield of hard red winter wheat in Kansas, 1949-50.

Treatment no.	Manhattan[1] bu./A	Belleville bu./A	Goddard bu./A	Thayer bu./A
1	42.9	39.5	27.8	40.3
2	33.1	33.1	27.3	29.3
3	35.5	31.7	22.5	32.3
4	40.5	39.5	28.9	41.5
5	41.6	40.3	29.6	40.1
6	39.0	36.2	25.0	32.1
7	34.3	36.4	32.6	34.0
8	32.5	33.6	22.4	33.1
9	41.2	37.6	24.5	36.8
10	46.3	35.0	28.6	36.3
11	43.7	35.7	27.7	33.3
12	40.0	34.3	27.4	33.5
13	32.1	31.8	21.4	32.3
14	35.4	34.1	21.2	29.6
15	30.8	33.2	22.5	31.8
16	45.2	37.0	26.5	36.3
17	48.2	35.8	29.2	37.8
18	38.6	33.2	28.1	27.8
19	29.2	33.4	27.6	29.8
20	27.8	28.2	23.5	33.1
21	39.8	36.5	26.1	39.1
22	42.5	36.3	26.3	38.1
23	42.9	37.3	26.0	36.5
24	44.1	36.9	27.4	39.1
25	34.9	33.5	20.4	33.6
26	38.1	33.3	22.1	39.1
27	32.0	33.3	22.2	38.3
28	33.4	33.7	22.4	35.3
29	39.0	37.3	29.0	38.1
30	40.8	34.6	25.9	35.3
31	40.2	37.7	26.3	38.0
32	44.7	36.0	27.3	34.1
33	44.0	36.4	27.2	35.8
34	40.5	36.2	25.2	34.3
35	42.1	38.2	29.5	38.5
36	42.5	36.3	30.2	37.5
37	39.0	35.2	23.9	32.8
38	38.4	36.7	26.3	31.6
39	38.0	38.0	27.6	38.8
40	40.4	35.4	26.1	34.6
LSD (.05)	6.5	3.3	5.8	
LSD (.01)	8.7	4.4	7.7	

[1]Manhattan results are means of 2 replicates, others are the means of 3 replicates.

Table 6. Statistical analyses of yield data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Thayer		
Total	119	3885.40		
Blocks	2	276.22	138.11	4.71*
Treatments	39	1320.90	33.87	1.15
Error	78	2288.28	29.34	
		Goddard		
Total	119	2621.98		
Blocks	2	668.87	334.43	26.22**
Treatments	39	953.86	24.46	1.917**
Error	78	995.26	12.76	
		Belleville		
Total	119	1081.86		
Blocks	2	90.94	45.47	11.090**
Treatments	39	671.03	17.21	4.197**
Error	78	319.89	4.10	
		Manhattan		
Total	79	2263.78		
Blocks	1	.85	.85	.0825
Treatments	39	1861.42	47.73	4.634**
Error	39	401.51	10.30	

*Significant at .05 level
**Significant at .01 level

Table 7. The effect of method, time, and rate of application of fertilizers on the protein content and protein yield of hard red winter wheat in Kansas, 1949-50.

Treat-ment no.	Manhattan[1] Per cent	lbs./A	Belleville Per cent	lbs./A	Goddard Per cent	lbs./A	Thayer Per cent	lbs./A
1	12.23	318.2	12.70	300.5	14.71	245.6	9.63	231.9
2	10.00	199.0	10.89	216.6	12.80	212.9	10.07	180.4
3	13.15	280.5	13.12	248.6	14.58	196.2	9.89	192.0
4	12.37	300.8	12.48	296.4	14.64	251.3	9.69	242.2
5	13.44	336.4	12.55	303.9	13.08	234.4	10.14	247.4
6	11.00	258.6	11.60	251.7	13.64	204.4	9.51	182.7
7	10.71	220.1	10.95	239.6	13.26	257.0	9.95	203.6
8	13.15	257.5	13.10	263.8	14.65	195.8	10.38	206.7
9	12.75	316.2	12.62	285.5	15.01	221.3	9.96	220.4
10	14.12	393.8	13.31	279.6	14.31	244.9	9.62	210.2
11	12.68	331.5	11.92	255.5	13.28	219.5	10.59	211.0
12	10.85	261.0	11.12	229.1	13.29	218.7	10.41	209.9
13	16.08	309.1	13.84	263.0	15.02	192.7	9.62	186.7
14	13.28	282.2	11.84	242.1	14.45	183.7	10.31	185.3
15	12.20	225.6	11.98	238.6	13.76	185.2	10.54	202.5
16	13.90	377.3	13.37	296.0	14.97	236.4	10.45	228.4
17	11.42	332.0	11.67	242.2	13.77	235.4	9.59	218.9
18	11.06	256.6	11.08	220.5	13.09	219.0	9.97	167.1
19	10.48	184.0	11.06	221.5	13.00	215.5	10.50	186.6
20	11.14	186.3	11.42	193.1	13.37	188.3	10.10	200.7
21	12.34	295.4	12.03	273.5	14.37	224.0	10.01	235.3
22	11.81	301.5	12.44	271.7	14.32	225.2	9.51	217.9
23	11.63	300.5	12.36	277.5	13.38	205.5	9.49	206.6
24	12.06	319.6	12.39	291.0	13.37	219.5	11.22	263.1
25	13.48	281.9	13.24	265.8	14.49	176.2	9.87	198.9
26	12.31	281.8	12.62	251.6	14.51	192.3	9.75	233.2
27	12.05	233.6	13.12	262.2	14.19	188.8	8.93	205.4
28	12.59	253.0	12.75	256.7	14.17	190.1	9.64	203.0
29	12.35	289.7	12.34	276.0	14.67	255.4	10.08	232.5
30	11.41	279.7	12.69	263.6	13.94	218.2	9.99	212.6
31	11.68	281.5	12.20	276.5	13.51	239.8	10.58	241.7
32	12.49	335.9	12.81	277.3	13.68	222.8	10.34	211.9
33	12.24	322.9	11.58	253.1	13.91	226.2	9.80	210.1
34	11.45	278.4	11.94	259.0	14.30	215.7	10.12	208.3
35	11.61	293.7	11.52	264.5	13.57	240.3	9.88	228.6
36	12.10	309.1	11.85	257.6	13.71	248.0	9.31	208.9
37	11.15	261.5	12.17	257.7	13.88	198.4	9.82	193.8
38	11.35	262.0	12.47	275.8	13.69	215.8	10.45	198.9
39	11.36	259.5	12.17	277.9	12.86	210.9	9.85	229.9
40	11.40	276.6	11.45	245.2	12.77	200.7	9.27	192.8
LSD(.05)	1.81	86.1	1.03	33.4	.78	46.9		
LSD(.01)	2.42	115.2	1.37	44.3	1.03	62.8		

[1]Manhattan results are the means of 2 replicates, others are the means of 3 replicates.

Table 8. Statistical analyses of protein data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Thayer, percent protein		
Total	119	73.41		
Blocks	2	0.71	0.355	0.5538
Treatments	39	22.72	0.583	0.9095
Error	78	49.98	0.641	
		Protein yield		
Total	119	216078.31		
Blocks	2	13722.18	6861.09	3.486*
Treatments	39	48825.08	1251.92	.636
Error	78	153530.92	1968.34	
		Goddard, percent protein		
Total	119	111.23		
Blocks	2	3.21	1.60	2.353
Treatments	39	49.63	1.27	1.868**
Error	78	52.84	.68	
		Protein yield		
Total	119	156731.34		
Blocks	2	39028.75	19514.17	24.279**
Treatments	39	55012.68	1410.58	1.755*
Error	78	62689.91	803.72	

Table 8 (concluded)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Belleville, percent protein		
Total	119	104.96		
Blocks	2	6.75	3.350	8.375**
Treatments	39	66.98	1.717	4.292**
Error	78	31.23	.400	
		Protein yield		
Total	119	102252.60		
Blocks	2	1255.39	627.69	1.493
Treatments	39	68205.35	1748.85	4.160**
Error	78	32791.86	420.41	
		Manhattan, percent protein		
Total	79	134.76		
Blocks	1	3.12	3.12	3.900
Treatments	39	100.27	2.57	3.212**
Error	39	31.37	.80	
		Protein yield		
Total	79	232186.58		
Blocks	1	942.08	942.08	.519
Treatments	39	160479.44	4114.86	2.268**
Error	39	70765.06	1814.49	

*Significant at .05 level
**Significant at .01 level

Table 9. The effect of method, time, and rate of application of fertilizers on the test weight of Hard Red Winter Wheat in Kansas, 1949-50.

Treatment no.	Manhattan[1] test weight lbs./bu.	Belleville test weight lbs./bu.	Goddard test weight lbs./bu.	Thayer test weight lbs./bu.
1	60.7	56.4	62.2	61.0
2	60.0	58.1	62.5	61.8
3	60.1	55.0	62.7	61.4
4	60.9	56.3	62.6	61.0
5	59.0	56.5	62.8	61.4
6	60.8	56.7	62.4	61.3
7	60.8	56.7	62.4	61.3
8	61.2	55.3	62.4	61.6
9	61.3	56.1	62.2	61.3
10	61.2	55.7	62.2	61.3
11	61.2	57.1	62.4	61.3
12	60.6	57.9	62.4	61.7
13	60.1	54.5	62.4	61.4
14	59.9	57.3	62.4	60.8
15	58.3	56.9	62.7	61.4
16	60.9	55.5	62.2	61.2
17	60.1	57.3	62.6	61.3
18	59.9	58.1	62.6	61.0
19	60.0	57.8	62.9	61.2
20	60.3	58.2	62.9	61.4
21	60.4	56.5	62.3	61.2
22	60.7	56.5	62.0	61.5
23	61.2	53.3	62.7	61.5
24	60.8	56.1	62.5	61.0
25	60.6	52.4	62.5	61.4
26	60.3	56.0	62.7	61.3
27	59.9	52.7	62.6	61.2
28	60.4	55.8	62.9	61.5
29	60.3	56.2	62.4	61.3
30	61.5	52.5	62.5	61.4
31	60.3	56.9	62.7	61.1
32	61.2	55.7	62.6	61.2
33	61.3	56.8	62.5	61.5
34	60.3	56.9	62.2	61.6
35	60.4	57.2	62.5	61.7
36	60.0	57.0	62.5	61.3
37	60.8	57.7	62.2	61.4
38	60.9	57.5	62.6	61.3
39	60.0	57.7	62.6	61.3
40	60.5	57.7	62.6	61.4
LSD (.05)	1.1	1.2		
LSD (.01)	1.5	1.6		

[1]Manhattan results are the means of 2 replicates, others are the means of 3 replicates.

Table 10. Statistical analyses of test weight data for each location.

Source of variation	Degrees of freedom	Sum of Squares	Mean square	F
		Thayer		
Total	119	18.20		
Blocks	2	2.70	1.35	10.00**
Treatments	39	4.97	.127	.94
Error	78	10.53	.135	
		Goddard		
Total	119	10.86		
Blocks	2	1.03	.515	5.099**
Treatments	39	1.96	.050	.495
Error	78	7.87	.101	
		Belleville		
Total	119	204.16		
Blocks	2	63.39	31.69	55.50**
Treatments	39	96.20	2.47	4.33**
Error	78	44.57	.571	
		Manhattan		
Total	79	46.33		
Blocks	1	2.08	2.08	6.775*
Treatments	39	32.28	.828	2.697**
Error	39	11.97	.307	

*Significant at .05 level
**Significant at .01 level

Table 11. Wheat yields in bushels per acre as affected by the addition of phosphorus, 1950.

Location	50 lb./A[1] Available P_2O_5 added	0 lb./A[1] Available P_2O_5 added	Calculated $\bar{d}(.05)$	Calculated $\bar{d}(.01)$
Manhattan	41.68	33.25	2.05	2.74
Belleville	36.47	32.63	1.04	1.38
Goddard	26.71	22.06	1.84	2.44
Thayer	36.37	33.85	3.18	4.22

[1]n = 20 at Manhattan, 30 at other locations.

Table 12. Wheat yields in bushels per acre as affected by the addition of potash, 1950.

Location	25 lb./A[1] K_2O added	0 lb./A[1] K_2O added	Calculated $\bar{d}(.05)$	Calculated $\bar{d}(.01)$
Manhattan	42.49	41.48	2.29	3.07
Belleville	36.79	36.21	1.16	1.54
Goddard	27.10	26.40	2.05	2.72
Thayer	36.82	36.21	3.54	4.70

[1]n = 16 at Manhattan, 24 at other locations.

Table 13. Wheat yields in bushels per acre as affected by various amounts of nitrogen, 1950.

Location	25 lb./A[1] N added	50 lb./A[1] N added	100 lb./A N added	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	35.92	41.59	41.30	3.24	4.34
Belleville	34.27	35.47	36.01	2.60	3.45
Goddard	27.65	25.77	26.53	2.90	3.85
Thayer	31.77	33.20	36.25	5.02	6.66

[1] n = 8 at Manhattan, 12 at other locations .

Table 14. Wheat yields in bushels per acre as affected by type of nitrogen carrier, 1950.

Location	50 lb./A[1] N added in NH_4NO_3	50 lb./A[1] N added in $CaCN_2$	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	42.32	38.95	3.24	4.34
Belleville	36.77	36.32	2.60	3.45
Goddard	26.48	25.97	2.90	3.85
Thayer	38.20	34.45	5.02	6.66

[1] n = 8 at Manhattan, 12 at other locations.

Table 15. Wheat yields in bushels per acre as affected by different times and methods of application of 50 pounds per acre of nitrogen, 1950.

Time and method of application	Yield[1]
Broadcast before seeding	33.07
Drilled at seeding	35.10
Broadcast December 20	35.39
Broadcast February 20	35.79
Broadcast March 10	35.70
Broadcast March 30	36.88
Half drilled at seeding & half broadcast December 20	35.86
Half drilled at seeding & half broadcast February 20	34.04
Half drilled at seeding & half broadcast March 10	37.08
Half drilled at seeding & half broadcast March 30	36.61

[1]n = 11

Table 16. Percent protein of wheat as affected by the addition of phosphorus, 1950.

Location	50 lb./A[1] Available P_2O_5 added	0 lb./A[1] Available P_2O_5 added	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	12.06	12.94	.57	.77
Belleville	12.07	12.70	.33	.43
Goddard	13.62	14.32	.43	.56
Thayer	10.04	9.90	.41	.54

[1] n = 20 at Manhattan, 30 at other locations.

Table 17. Protein yield of wheat in pounds per acre as affected by addition of phosphorus, 1950.

Location	50 lb./A[1] Available P_2O_5 added	0 lb./A[1] Available P_2O_5 added	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	301.84	259.16	26.80	35.56
Belleville	267.31	248.55	10.57	14.02
Goddard	225.32	188.92	14.61	19.38
Thayer	218.78	201.45	22.86	30.32

[1] n = 20 at Manhattan, 30 at other locations.

Table 18. Percent protein of wheat as affected by the addition of potassium, 1950.

Location	25 lb./A[1] K_2O added	0 lb./A[1] K_2O added	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	12.39	12.14	.64	.86
Belleville	12.33	12.40	.36	.47
Goddard	13.72	14.12	.47	.63
Thayer	10.01	10.14	.46	.61

[1]n = 16 at Manhattan, 24 at other locations.

Table 19. Protein yield of wheat in pounds per acre as affected by the addition of potassium, 1950.

Location	25 lb./A[1] K_2O added	0 lb./A[1] K_2O added	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan	317.16	299.84	30.44	40.72
Belleville	275.55	263.78	11.76	15.60
Goddard	222.18	227.19	16.26	21.57
Thayer	221.80	220.89	80.44	106.71

[1]n = 16 at Manhattan, 24 at other locations.

Table 20. Percent protein of wheat as affected by the addition of different rates of nitrogen, 1950.

Location	25 lb./A N added	50 lb./A N added	100 lb./A N added	Calculated $\bar{d}(.05)$	Calculated $\bar{d}(.01)$
Manhattan[1]	11.20	12.09	14.38	.90	1.21
Belleville	11.28	11.76	13.27	.51	.68
Goddard	13.35	13.78	14.34	.67	.89
Thayer	10.22	10.00	9.96	.65	.86

[1]n = 8 at Manhattan, 12 at other locations.

Table 21. Protein yield of wheat in pounds per acre as affected by the addition of different rates of nitrogen, 1950.

Location	25 lb./A N added	50 lb./A N added	100 lb./A N added	Calculated $\bar{d}(.05)$	Calculated $\bar{d}(.01)$
Manhattan[1]	240.83	301.08	354.14	43.05	57.60
Belleville	231.95	247.87	285.64	16.68	22.12
Goddard	220.01	210.73	227.08	23.24	30.84
Thayer	195.78	199.48	218.18	36.08	47.86

[1]n = 8 at Manhattan, 12 at other locations.

Table 22. Percent protein wheat as affected by nitrogen carrier, 1950.

Location	50 lb./A N added in NH_4NO_3	50 lb./A N added in $CaCN_2$	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan[1]	11.96	11.31	.90	1.21
Belleville	12.30	12.06	.51	.68
Goddard	13.86	13.30	.67	.89
Thayer	10.06	9.85	.65	.86

[1] n = 8 at Manhattan, 12 at other locations

Table 23. Protein yield of wheat in pounds per acre as affected by nitrogen carrier, 1950.

Location	50 lb./A N added in NH_4NO_3	50 lb./A N added in $CaCN_2$	Calculated $\bar{d}(.05)$	$\bar{d}(.01)$
Manhattan[1]	304.25	264.93	43.05	57.60
Belleville	278.43	264.18	16.68	22.12
Goddard	218.55	206.45	23.24	30.84
Thayer	230.76	203.86	36.08	47.86

Table 24. Percent protein of wheat, for all locations, as affected by method and time of application of 50 pounds per acre nitrogen as NH_4NO_3, 1950.

Method and time of application	Percent protein
Broadcast before seeding	11.44
Drilled at seeding	12.12
Broadcast December 20	12.19
Broadcast February 20	12.02
Broadcast March 10	11.71
Broadcast March 30	12.26
Half drilled at seeding & half broadcast December 20	11.88
Half drilled at seeding & half broadcast February 20	11.95
Half drilled at seeding & half broadcast March 10	11.64
Half drilled at seeding & half broadcast March 30	11.74

Table 25. Protein yield of wheat in pounds per acre as affected by method and time of application of 50 pounds per acre nitrogen as NH_4NO_3, for all locations, 1950.

Method and time of application	lb./A protein
Broadcast before seeding	224.34
Drilled at seeding	254.40
Broadcast December 20	257.06
Broadcast February 20	254.06
Broadcast March 10	247.54
Broadcast March 30	273.32
Half drilled at seeding and half broadcast December 20	253.06
Half drilled at seeding and half broadcast February 20	240.34
Half drilled at seeding and half broadcast March 10	256.78
Half drilled at seeding and half broadcast March 30	255.89

DISCUSSION

Manhattan

Rainfall data for the growing season, Table 3, showed an overall distribution of rainfall lower than usual. There was, however, sufficient moisture to obtain a good stand in the fall and to maintain the growth. As a consequence, moisture probably was not a limiting factor at Manhattan.

The soil at Manhattan, Table 4, was well supplied with exchangeable potassium but only medium in available phosphorus and organic matter. This suggested that a response could not be expected from potash fertilizer.

The statistical analysis of yield data, Table 6, showed that there were significant differences between treatments as they affected yield, Table 5. Treatments 10, 16, 17, and 32 gave the highest yields. Treatments 16, 17, and 32 were applications of 50 and 100 pounds of nitrogen in combination with phosphorus, and for treatment 10 the combination also included potassium. The phosphorus and potassium combination without nitrogen gave a yield which was not significantly different from no treatment. Nitrogen alone did not increase the yield of wheat significantly except at the 50 pound per acre level.

That protein content of the grain affected significantly by treatments is shown by analysis of variance, Table 8. Treatments 10, 13, and 16, in Table 7, all of which were treatments containing 100 pounds of nitrogen, gave significant increases in percent protein at the 1 percent level. Treatments

3, 5, 14, and 25 gave significant increases in percent protein at the 5 percent level. None of the treatments gave a significant decrease in percent protein. The data for protein removed in the grain in pounds per acre were analyzed statistically and it was found that the treatments affected significantly the amount of protein in the grain. There were more treatments which showed significant differences in yield of protein per acre than in percent protein. This would be expected since pounds of protein per acre is a product of both yield and percent protein and the yield effect was significant for all but 8 of the treatments used. The increases in protein content were from the 100 and 50 pound rates of nitrogen. The 25 pound rate of nitrogen did not affect the protein content significantly, percentage wise or in pounds per acre.

The statistical analysis of the test weight data, Table 10, showed that test weights were affected significantly by treatments. The effect was a decrease in test weights for treatments 5, 15, and 30, Table 9. Treatment 5 was the 100 pound rate of nitrogen; treatment 15 was a 25 pound application of nitrogen alone; and treatment 30 was a 50 pound rate of nitrogen.

Belleville

Total rainfall at Belleville, Table 3, was less than an inch below the annual average. However, the distribution was not that of an average year but it was conducive to a good stand in the fall. There was enough subsurface moisture to continue normal growth. This indicates that moisture supply was not a limiting factor at this location.

The soil analyses, Table 4, indicated that this location was well supplied with exchangeable potassium and medium in supplies of available phosphorus and of organic matter. From these results, it would be expected that the soil would respond to nitrogenous and phosphatic fertilizers but not to potash fertilizers.

The analysis of variance on the yield data, Table 6, showed that the treatments affected the yield significantly. All treatments gave significantly greater yields than the no treatment. The greatest increases were from treatments supplying 100 pounds and 50 pounds of nitrogen per acre. The 25 pound rate of nitrogen gave about the same increase as the phosphorus and potassium combination or phosphorus alone. Potassium did not affect the yield significantly.

Statistical analyses of the protein data, Table 8, showed that treatments affected significantly the protein content of grain. The 100 pound and 50 pound rates of nitrogen were responsible for the increase in percent protein in the grain. The greatest increase was a result of the 100 pound rate of nitrogen. The 25 pound rate of nitrogen did not affect the percent protein in the wheat grain. None of the treatments gave a significant decrease in percent protein in the wheat grain. All treatments gave a significant increase in the pounds of protein per acre except treatment 18, the 25 pound rate of nitrogen, Table 7.

Statistical analysis of the test weight data, Table 10, showed that treatments affected the test weight significantly. The 100 pound and 50 pound rates of nitrogen decreased test weights significantly. The reduction in test weight was greatest for the 50 pound rate of nitrogen when applied alone, Table 9.

Goddard

Rainfall at Goddard, Table 3, was low throughout the early growing season and high at the end of the season, resulting in total rainfall only 1.40 inches below the annual average. The low rainfall throughout the early growing season did not appear to affect the stand or the vegetative growth to an appreciable extent. It is indicated by the results of the experiment that response to fertilizer treatments was affected by the low rainfall during the formative period of the grain.

The soil at this location was shown by the soil analysis, Table 4, to be high in exchangeable potassium, low in available phosphorus, and medium in organic matter. These results indicated that a response could be expected from applications of nitrogenous and phosphatic fertilizer, but no response should be expected from addition of potash fertilizer.

The analysis of variance on the yield data, Table 6, showed that treatments significantly affected the yield of wheat. Only four treatments showed a significant increase in yield, they were treatments 5, 7, 35, and 36, Table 5. The greatest increase was from treatment 7, 25 pound rate of nitrogen. This increase was significant at the 1 percent level. Differences in yield caused by treatments 5, 100 pound rate of nitrogen, and 35 and 36, 50 pound rate of nitrogen, were statistically significant at the 5 percent level.

The percent protein in the wheat grain was affected significantly by treatments at the 1 percent level; the yield of protein per acre was also affected significantly by treatments but only at the 5 percent level, Table 8. This latter was to be expected since pounds of protein per acre is a product of the percent protein in the wheat grain and the yield of wheat grain, for which only 4 treatments were significantly different. The 100 pound rate of nitrogen was responsible for the greatest increase in percent protein in the grain, Table 7. The 50 pound rate of nitrogen was responsible for the remaining significant differences of percent protein in the grain. The 25 pound rate of nitrogen gave no significant increase of percent protein in the grain.

The yield of protein per acre was affected to the greatest extent by treatment 7, 25 pound rate of nitrogen, Table 7, followed by treatments 29, 50 pound rate of nitrogen, and 3, 100 pound rate of nitrogen. The great significance of the 25 pound rate of nitrogen is apparently explained by the effect of this treatment on yield as stated previously.

The test weight data, Table 9, when subjected to analysis of variance, Table 10, showed no effect of treatment.

Thayer

From the soil analyses, Table 4, it is noted that available phosphorus was low and organic matter was medium. The exchangeable potassium was the lowest of all the locations but could still be classed as satisfactory for wheat production. These tests indicated that wheat grown on this soil could be expected to respond to nitrogenous and phosphatic fertilizers but should not be expected to respond to potash fertilizer.

Even though the soil tests indicated that response could be expected from fertilizer applications, the analyses of variance in Tables 6, 8, and 10 showed that there were no significant differences between treatments for yield, protein, or test weight. However, if Tables 5, 7, and 9 are inspected, it will be noted that the general trends for yield, protein, and test weight follow the trends at the other locations. Since this trend is evident, there must be some reason for there not being statistically significant differences.

Inspection of the rainfall data, Table 3, shows that with the exceptions of the months December and July the rainfall at this location was below average. Total rainfall was about 8.6 inches below average. Therefore it is suggested that the effect of low rainfall throughout the growing season might have been partially responsible for there being no statically significant differences at this location.

Supplemental Comparisons

Comparisons of various treatment effects on yield and protein were made and a t-test, after Snedecor (36), was computed for significant variation. These data with the results of the t-test are reported in Tables 11 to 25.

The effect on yield of treatments containing 50 pounds of phosphorus per acre was compared with treatments containing no phosphorus in Table 11. The yields were increased significantly to the 1 percent level at all locations except Thayer by the inclusion of phosphorus in the fertilizer treatment. At Thayer, there was no significant difference between the treatments containing no phosphorus and those containing 50 pounds of phosphorus per acre.

In Table 12, it is seen that there was no significant effect, beneficial or detrimental, on the yield of wheat from the inclusion of potash in the fertilizer mixture.

The effect of various rates of nitrogen on yield is shown in Table 13. At Manhattan, both the 50 pound rate and the 100 pound rate of nitrogen increased the yield significantly to the 1 percent level over the 25 pound rate of nitrogen. There was, however, no significant difference between the 50 pound rate and the 100 pound rate of nitrogen at Manhattan. It is also to be noted for the other locations that there was no significant difference between the three rates.

The effect on yield of type of nitrogen carrier was compared in Table 14. This comparison showed a significant increase in yield at the 5 percent level for ammonium nitrate over calcium cyanamide at Manhattan. There were no significant differences between the effects of carriers at the other locations.

In Table 15, the effects of time and method of application of 50 pounds of nitrogen per acre were compared. No t-test was made for significance as this table shows a composite comparison including all locations. It is noted that there was a tendency for nitrogen broadcast before seeding and the split applications applied half at seeding and half on February 20 to be slightly lower in yield than the other treatments.

In Table 16, the average percent protein in the wheat grain is compared between treatments containing 50 pounds of phosphorus per acre and treatments containing no phosphorus. Phosphorus included in the treatment reduced the percent protein in the wheat grain significantly beyond the 1 percent level for all locations except Thayer. At Thayer, there was no significant difference between the effect of treatments containing phosphorus and those containing no phosphorus.

The yield of protein, however, was increased significantly above the 1 percent level by the inclusion of phosphorus in the fertilizer treatments, Table 17. This was true at all locations except Thayer, where treatments containing no phosphorus were no different than treatments containing phosphorus. This apparent reversal in effect of phosphorus on yield of protein when compared to its effect on percent protein is to be expected when one considers that the yield of protein reflects the influence of yield of grain which was increased significantly by the inclusion of phosphorus in the fertilizer mixture.

A comparison was made of the effects of treatments containing 25 pounds per acre potassium and those containing no potassium on percent protein in the grain, Table 18, and on yield of protein, Table 19. Potassium had no effect on either except at Belleville. At Belleville, there was an increase in yield of protein which was barely significant at the 5 percent level.

The effects of rates of nitrogen on percent protein and on yield of protein were compared in Tables 20 and 21 respectively.

At Manhattan, the 100 pound rate of nitrogen increased the percent protein in the grain over the 50 pound rate and the 25 pound rate of nitrogen. The increase was significant to the 1 percent level for both comparisons. The 50 pound rate increased the percent protein in the grain significantly to the 5 percent level over the 25 pound rate of nitrogen. For yield of protein, the 100 pound rate of nitrogen gave an increase over the 25 pound rate of nitrogen which was significant at the 1 percent level and was significant to the 5 percent level over the 50 pound rate of nitrogen. The 50 pound rate of nitrogen gave an increase in yield of protein which was significant to the 1 percent level over the 25 pound rate of nitrogen.

The 100 pound rate of nitrogen increased both percent protein in the grain and yield of protein over the 25 pound rate and the 50 pound rate of nitrogen at Belleville. The increase was significant to the 1 percent level. There was no significant difference between the effects of the 25 pound rate and the 50 pound rate of nitrogen on protein, percent or yield, at this location.

At Goddard and Thayer there were no significant differences between rates of nitrogen in their effect on protein, percent or yield.

The effects of nitrogen carrier on percent protein in the grain and yield of protein were compared in Tables 22 and 23, respectively. There were no significant differences between the effects of types of nitrogen carrier on either percent protein in the grain or yield of protein.

Comparisons, including all locations, were made of the effect of time and method of application of 50 pounds of nitrogen per acre on the percent protein in the grain, Table 24, and on the yield of protein, Table 25. Nitrogen broadcast before seeding produced grain that was some lower in percent protein than the other treatments. There was a tendency for the spring applications to give slightly greater values for percent protein than the winter applications. Also the application of the entire amount of nitrogen at the various times tended to give slightly higher values than did the split treatments applied at the same dates. The trends for yield of protein, Table 25, were very similar to those described above for percent protein in the grain.

SUMMARY AND CONCLUSIONS

1. Nitrogen fertilizer increased the yield of wheat at all locations, however, the increase at Thayer was not significant.

2. Increasing the amount of nitrogen fertilizer applied increased the yield of wheat most consistently at Manhattan.

3. Inclusion of phosphatic fertilizer in the treatment increased the yield of wheat at all locations, however, the increase at Thayer was not significant.

4. The inclusion of potash fertilizer in the treatment had no effect, beneficial or detrimental, at any location on yield. At only one location, Belleville, did there occur a significant increase in protein yield from the inclusion of potash. For all other locations the protein, percent or yield, was not affected by the inclusion of potash in the fertilizer treatment.

5. Time of application of nitrogen fertilizer affected somewhat the yield of wheat. The nitrogen broadcast before seeding did not give the increases in yield that were obtained from the later applications.

6. Type of carrier gave no significant difference in effect upon yield of grain or upon protein, percent and yield, at any location except for Manhattan. At Manhattan, NH_4NO_3 was superior to $CaCN_2$ in increasing the yield of grain.

7. Test weights were affected by several treatments at Manhattan and Belleville but not at Goddard and Thayer. The

effect at Belleville was a reduction of test weight of the treated plot yield below that of the untreated plot yield, and at Manhattan the effect in general was reversed from that at Belleville.

8. Protein was increased by several treatments as a result of the use of nitrogen fertilizer, either alone or in combination with phosphorus and potash fertilizers. This tendency was most pronounced for the heavier applications of nitrogen.

9. Percent protein was decreased significantly while yield of protein was increased significantly by the inclusion of phosphorus in the fertilizer mixture at all locations except Thayer, where no difference was found between the phosphorus treated and those not getting additional phosphorus. This apparent reversal in effect is caused most probably by the influence of phosphorus on the yield of grain which is reflected in the yield of protein.

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THE EFFECTS OF DIFFERENT RATES, TIMES, AND METHODS OF APPLICATION OF VARIOUS FERTILIZER COMBINATIONS ON THE YIELD AND QUALITY OF HARD RED WINTER WHEAT, 1949-50

by

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An experiment was established at four different locations in the eastern half of Kansas for the purpose of:

(1) determining the effect of nitrogen fertilizer, alone and in combination with phosphate and potash fertilizers, on the yield and quality of wheat;

(2) determining the effect of type of carrier of nitrogen on wheat yield and quality; and

(3) determining the effect of time and method of application of nitrogen fertilizer on the yield and quality of wheat.

In order to furnish answers for the above questions, the experiment was laid out at each location following a randomized complete block design. Chemical analyses were made on the soils from each location, and the results used to help interpret data collected from the locations. Protein analysis and test weight determinations were made on a sample from each plot for all locations. A statistical analysis was made on the data from each location.

The results of the experiment showed:

(1) that nitrogen increased the yield of wheat and also increased the protein, percent and yield per acre;

(2) that the inclusion of phosphorus in the fertilizer mixture increased the yield, decreased the percent protein, and increased the yield of protein per acre;

(3) that the inclusion of potash in the fertilizer

treatment had no effect on yield or protein, percent in grain or yield per acre;

(4) that type of carrier of nitrogen makes little to no difference in most instances;

(5) that time and method of application of nitrogen do not differ very much in their effect on yield and quality of wheat; and

(6) that test weights were affected to a limited degree by several treatments but in general there was no effect of treatment on test weight, either beneficial or detrimental.