INVESTIGATION OF SMALL GRAIN RESPONSE TO VARIOUS APPLICATIONS OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZERS ON SEVERAL KANSAS SOILS

by

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INTRODUCTION

Wheat is the most valuable grain crop in the world. Its total production exceeds that of any other grain and as a source of human food it ranks at the top of all agricultural products. The United States leads all other countries in wheat production and within the United States, Kansas produces more bushels of wheat over a period of years than any other state. The income to Kansas farmers from wheat exceeds that of any other agricultural commodity.

Oats is another of the cereals produced in Kansas but on a somewhat smaller scale than wheat. While this grain is used for human consumption, its chief importance is as a source of feed for livestock and poultry. With the development of improved varieties, oat production should become less hazardous in Kansas and along with the use of commercial fertilizers the total acreage as well as the yield per acre should be increased.

Practically all of the cultivated soils in Kansas, with the exception of very sandy soils as found in some of the river valleys, are suitable for the growing of wheat. The oat growing area, however, lies principally in the eastern one-third of the state.

Since the success or failure of any agricultural crop depends largely on the income received as compared to the expenses paid out, it is of great importance to obtain the optimum yield per acre. As wheat usually has a relatively higher market value than oats, a smaller increase in wheat yield will result in a greater profit than that same increase in yield of oats.

The more successful one is in obtaining maximum yield per acre depends on his ability to control those variables which prove to be the limiting factors of production. The two main variables in this case are climatic factors and an inadequate supply of available plant nutrients. Since it is impossible to control the climate, it is essential to make certain that the growing plants have a sufficient supply of available nutrients when needed.

It has been demonstrated by many investigators that wheat and oats usually will respond in some way to large amounts of plant nutrients. Many farmers in the eastern half of Kansas have been applying phosphate with their wheat for a number of years but the application of a nitrogenous fertilizer has been made only in more recent years. It is only in the last few years that commercial fertilizer has been applied to oats to any great extent.

The experiments discussed in this paper include four wheat fertility trials and three oat fertility trials, all located in the eastern half of Kansas. The objective of the experiments was first to obtain information relative to the best time, rate and method of applying nitrogenous fertilizers, and second to obtain information concerning the use of phosphorus and potassium in combination with various rates of nitrogen.

Although there are some research data available on the effects of applications of commercial fertilizer to wheat in this area of Kansas, there are very few data available relative to fertilizer response on oats. It is generally agreed, however, that the relative response of a crop to applications of nutrients depends largely on several factors which include: supply of available nutrients already present in soil, climatic conditions during crop growth, previous cropping system, and time of application of the added fertilizer.

REVIEW OF LITERATURE

Davidson was one of the first investigators to study the influence of a nitrogenous fertilizer on the yield and quality of wheat. In an experiment conducted in 1916 in Kentucky, Davidson and LeClerc (7) applied equivalent rates of 320, 160 and 106 2/3 pounds of sodium nitrate per acre to field plots. This was applied as a liquid solution to soft winter wheat at three stages of growth. Their results showed that only those plants which received nitrogen when about two inches high gave any appreciable increase in yield. Plants which received nitrogen at heading time did not increase in yield but their grain had the highest protein content and lowest percent of yellowberry. Application of sodium nitrate at the milk stage of grain had no effect on yield or protein content.

While working at College Park, Maryland, Davidson (8) made applications of sodium nitrate and calcium nitrate to field experiments of soft winter wheat. Applications were made at three different times. These results are in close agreement with his previous work. The effectiveness of nitrates in increasing yields gradually decreased as the time of application approached heading of the grain. In every case the protein content of the grain increased consistently when the applications were made nearer to heading time.

These results were substantiated by Davidson and LeClerc (9) while working with field experiments in Nebraska using a number of different fertilizer materials. Applications of nitrogen at early stages of growth produced the highest yields but the application of nitrogen at time of heading gave the best quality with respect to yellowberry and protein content.

Gericke (16) was another of the early investigators who studied the effects of commercial fertilizers on the yield and composition of wheat. Applications of sodium nitrate to winter wheat showed that only applications made 109 days or more after planting increased the protein content appreciably. The protein content of spring wheat showed a steady increase the nearer the applications were made to harvest time. Gericke concluded that the reason winter wheat did not respond the same as spring wheat was due to the dormancy before stooling of winter wheat.

While working in California, Gericke (15) used pot cultures of White Australian wheat to determine the reason why Pacific Coast wheat had such low protein percent. Sodium nitrate and ammonium sulfate were applied at different times at the rate of 100 pounds of nitrogen per acre. The percent protein of the grain treated 110 days after planting was 15.2 percent as compared to 8.6 percent for that treated at planting time. It was concluded that the low protein content of Pacific Coast wheat was due to an insufficient supply of available nitrogen at certain growth periods.

Gericke (17) further claimed that different properties of wheat varieties does affect the efficiency of any fertilizer treatment. The protein content of a given variety is influenced by the amount of tillering of that variety.

Neidig and Snyder (24, 25) treated Marquis wheat growing in greenhouse pots with varying amounts of nitrogen in the form of sodium nitrate, ammonium sulfate and hydrolyzed wheat extract and got a marked increase in protein content of the grain.

Other work by these investigators showed that a high moisture content in the soil containing a sufficient supply of available nitrogen resulted in a high yielding wheat with a high protein content. A low moisture content of a soil containing an excess of available nitrogen resulted in lower yields but a higher protein content of grain.

Studies of the factors influencing nitrate formation in the soil were made by Burke (5) in Montana. Results showed that plots which were alternately cropped and fallowed contained more nitrate nitrogen during the cropped year than those cropped continuously. This extra supply of available nitrogen accounted for straw and grain of a higher protein content. Because these fallow plots always produced larger yields and grain of higher protein content, it was concluded that nitrate nitrogen had a large influence and that the increases in yields could not be attributed to moisture alone.

Pendleton (27) conducted an experiment in Iowa in which sodium nitrate was applied to wheat growing on two soils. Results showed that early application of nitrogen tended to increase yields while later applications tended to increase the protein content. Increases in yield were more significant than increase in protein content and there were no significant differences in test weight.

Murphy (23) broadcast superphosphate, nitrate of soda, and kainit on wheat plots just after planting on a Kirkland sandy loam soil. His results indicated that neither nitrogen nor potassium nor any combination of the two increased the yield of wheat on this soil. Yields on these nitrogen and potassium treated plots tended to be less than untreated plots beside them. Phosphorus and potassium were found to give higher yields than phosphorus and nitrogen combinations or combinations of all three elements. Phosphorus treated plots matured earlier, had a tendency to lodge worse under adverse weather conditions during later plant development and had a repressing effect on protein content. Protein content showed an increase as the amount of nitrogen applied was increased but it required more than 75 pounds of sodium nitrate per acre to be significant.

Gainey and Sewell (12) and Gainey, Sewell and Myers (13) made investigations in Kansas to study the cause of spotted wheat fields prevalent over the state. Soil and plant material was collected from these spots and from areas adjacent to them. Plants from the spotted areas were considerably greater in length, weighed more, and contained a higher percentage of nitrogen than plants from areas adjacent to the spots. Plants grown on spotted areas removed over four times as much nitrogen from the soil as plants on adjacent areas, yet after crops were removed from the spotted areas they still contained over twice as much nitrate nitrogen as adjacent areas. The ability to accumulate nitrate nitrogen from the store of nitrogen in the soil appeared to be independent of microorganisms. When organic nitrogen was added to both soils the poorer soils were capable of transforming the added nitrogen into nitrate nitrogen just as rapidly as the spotted area soils.

Doneen (10) added sodium nitrate to a soil already containing a sufficient quantity of available nitrogen for large yields of wheat. The addition caused a retardation of growth during the vegetative period and did not materially increase the yield or protein content of the grain. However, when limited quantities of nitrogen were available in the soil, the addition of a nitrogenous fertilizer gave increases in yield and protein content of the grain.

This investigator also noted that applying nitrogen fertilizer after normal tillering had ceased caused the production of new tillers and greatly increased the yield of grain without materially affecting the size of kernels.

Further studies using 150, 300 and 600 pounds of sodium nitrate per acre and eight different wheat varieties showed that some varieties gave maximum yields at 150 pounds per acre while other varieties required 300 pounds.

Hopkins (19) attempted to correlate weather conditions with yield and quality of wheat in Canada, because in years of high rainfall and high yields the protein content tends to be low. He found a correlation between rainfall during the early part of the growing season and the subsequent yield of grain which he supposed to be due to stimulation of tillering and vegetative development of the plant. Because of more tillering the available nitrogen must be distributed throughout more culms and consequently there is less nitrogen in the grain.

Cook and Millar (6) applied sodium nitrate and ammonium sulfate to wheat grown on two heavy Michigan soils. Applications were applied over a period of five years at the rate of 100 pounds of sodium nitrate per acre per year. Over the five year period there were more cases of decrease or not enough increase in yields to pay for the cost of fertilizer than there were instances where yields were increased beyond payment of the fertilizer.

Garner and Sanders (14) conducted experiments of applying nitrogen fertilizer to wheat grown on light soils and on heavy soils. Ammonium sulfate tended to decrease the yield, regardless of the time of application, on light gravelly soils but gave an appreciable increase in yield on the heavier soils. It was noted that early applications on the heavier soils tended to increase the number of heads while late applications tended to increase the head size.

Watson (31), another English worker in soils, applied three rates of sodium nitrate at seven different stages of growth to pot cultures of wheat. He found no significance between time of application and the total quantity of nitrogen found in the plant but he did find significant differences in yield of dry matter produced. Although the increase in total nitrogen uptake was equal for all times of application, the ratio of nitrogen in the grain to nitrogen in the straw was greater the later the time of application.

Lewis et al. (20) applied nitrochalk in the spring to wheat experimental plots in England. Increases in yields were obtained which was due to increase in number and size of heads, the increase in size of head being due to increase in number of grains in each head. Late applications of nitrogen seemed to make the plants less susceptible to lodging and gave as large increases in yield as earlier applications.

Effectiveness of nitrogen fertilizer to wheat in New Zealand, as demonstrated by Woodcock and Allo (33), depends on the previous cropping system and weather conditions. Increases from applied nitrogen were largest in a cereal after a cereal cropping system.

If heavy rains occur during fall and winter and leach the soluble nitrates then applications of nitrogen fertilizer should give large increases in yield.

Bracken (4) studied the effects of various soil treatments on yield of winter wheat at the dry land station in central Utah. Results showed that plots plowed in late spring prior to fallow gave significantly lower yields than plots plowed in fall or early spring. There was shown to be a definite decrease in moisture percent and the amount of nitric nitrogen in the fallow land in October due to lateness of spring plowing. The major part of the available nitrogen was found to accumulate in late summer. When plots were treated with five tons of manure on alternate years there was a significant increase in protein content.

Ellis (11) investigated the effects of certain cultural and fertility practices on the protein content of wheat. Yields of wheat and straw increased significantly as the frequency of fallow increased but there was no significant increase in test weight. Four tons of barnyard manure seemed to give a greater response where fallows were less frequent, with ammonium phosphate giving a greater response where fallows were more frequent. The protein content of the grain was not decreased when manure or ammonium phosphate increased the yield.

Reitz and Myers (28) of Kansas studied the response of different wheat varieties to applications of superphosphate. All varieties having similar adaptation tended to respond in a similar manner. Variable affects were evident when the season affected the varieties differently.

Smith (30) of Kansas applied three rates of nitrogen to wheat on a Geary silt loam soil. Nitrogen was applied as plow sole applications, at seeding time, and as a topdressing. Phosphate was applied at two rates at seeding time and as plow sole applications. All combinations of nitrogen and phosphorus gave significant increases except two. There were no significant differences in test weight or in protein content of the grain. It was noted that the plow sole method of application required a much larger quantity of fertilizer to give any significant increase in yield.

Simkins (29) grew winter wheat at three locations in Kansas and obtained significant increases at all locations by the application of a commercial fertilizer. Combinations of nitrogen and phosphorus gave the greatest increases at all locations. Potassium used either alone or in combination with nitrogen and phosphorus did not show any significant increase or decrease in yield. Nitrogen, when applied alone, produced the greatest increase in protein content. No treatments showed any significant differences in test weight.

Williams (32) obtained significant increases on three out of four wheat trials in Kansas by applying nitrogenous and phosphatic fertilizers. Inclusion of potassium in the treatments showed no beneficial or detrimental effects. Heavy applications of nitrogen had a tendency to increase protein content.

Data relative to the influence of commercial fertilizers on oats are somewhat more limited than the data on wheat. One of the earlier investigators was Woods (34) of Connecticut. When he applied sodium nitrate and ammonium sulfate to oats the protein content increased in both the grain and straw in proportion somewhat to the amounts of nitrogen applied.

Bartholomew (3) of Arkansas applied 200 pounds of 20 percent superphosphate per acre before winter oats were planted in the fall. Later the plots were topdressed with three rates of ammonium nitrate and large increases were obtained. For the entire state 20 pounds of nitrogen per acre gave the largest increases per unit of nitrogen. Further investigations showed very little difference between ammonium nitrate, sodium nitrate, or ammonium sulfate for fertilizing oats.

Nelson, Lawton and Black (26) of Iowa applied nitrogen, phosphorus and potassium to oats in various combinations in 1944 and 1945. Significant results were obtained from 27 out of 29 locations by applications of a nitrogenous fertilizer. Phosphorus increased the yield significantly at 13 of the 29 locations. The average acre increase in 1944 from applying a complete fertilizer was 11.2 bushels and in 1945 was 25 bushels per acre.

Adams and Black (1) of Louisiana applied 60 pounds of nitrogen per acre as a topdressing to oats growing in a very fine sandy loam soil and obtained an average increase in yield of 27.5 bushels per acre. Other locations in the state showed that 15 pounds of nitrogen per acre at time of seeding and 15 pounds as a topdressing gave the greatest increases in oat yields.

Experiments on loessal and glacial soils in Minnesota by MacGregor (22) showed that fertilizer treatments containing 40 pounds of nitrogen per acre gave larger increases in oat yields than those treatments not containing nitrogen. There was no response from potash when used alone, but there was some increase in yield when phosphorus was applied alone.

Ammonium nitrate was applied to winter oats in Tennessee by Long (21). In most cases yields were increased with increased rates of nitrogen. Nitrogen applied to plots which followed a good legume crop had very little value. In general, spring topdressings of ammonium nitrate were more effective than applications at seeding time.

METHODS OF STUDY

Location and Description of Wheat Plots

The experimental plots for this investigation were established at four locations. Two of the plots were located in north central Kansas; one on the Duane Johnson farm north of Belleville in Republic County, and the other on the Agronomy Farm at Manhattan in Riley County. The other plots were in the southern part of Kansas; one on the Agronomy Experimental Field near Hutchinson in Reno County, and the other on the Jesse Bellah farm near Mound Valley in Labette County.

The soil type in Republic County is a Crete silty clay loam. It is a deep, dark, friable upland soil with a moderately light clay subsoil. The topography is very uniform with a gentle slope showing only slight to moderate erosion. The cropping history of this soil has been largely small grains and corn.

The soil at the Agronomy Experimental Field in Reno County is a Pratt silt loam. It is a deep, dark upland soil with moderate sandy surface soil and has a clayey subsoil. The topography is practically level and there is no erosion. The previous cropping system has been largely wheat, but it was in alfalfa for several years prior to 1949.

The location of the plots at the Agronomy Farm at Manhattan was on a Geary silty clay loam. This soil is characterized by being a deep, very dark upland soil, having moderately friable to clayey subsoils. The surface is moderately sloping and shows only moderate erosion. Previous cropping has been largely small grains.

The experimental plots at Mound Valley were located on a Cherokee silt loam soil which is a deep to moderately deep, light colored upland soil having a claypan or semi-claypay subsoil. The topography was gently sloping with very little evidence of erosion. Previous cropping consisted largely of small grains and corn.

Location and Description of Oat Plots

Locations for the three oat experimental plots were: the Agronomy Farm at Manhattan in Riley County; the Agronomy Experimental Field near Thayer in Neosho County, and the Emory Johnson farm near Belleville in Republic County.

Soil descriptions for the Manhattan and Belleville plots are similar to the description of the wheat plots at these locations, in that the soil type at Manhattan is a Geary silty clay loam and at Belleville a Crete silty clay loam.

The plots near Thayer were located on a Parsons silt loam, which is a moderately deep to deep, light colored upland soil having a claypan or semi-claypan subsoil. The surface was gently sloping and there was little evidence of erosion.

Chemical Analyses of Soils

Soil analyses for the wheat and oat plots are presented in Table 1. The pH determinations were made on a Leeds and Northrup glass electrode meter using a 1:1 soil and water paste. Total available phosphorus was determined by Brays colorimetric method. Exchangeable potassium determinations were made on the Perkins and

Elmer model 52A flame photometer. Organic matter was determined by the wet oxidation method as given by Graham (18). Lime requirements were determined by using the Woodruff buffer method.

Two of the most noticable features of the soil analyses table are that all locations are quite low in available phosphorus and all locations, except Mound Valley and Thayer, are quite high in exchangeable potassium.

Table 1. Chemical characteristics of soils used in 1950-51 wheat and oat experiments.

Location	pH	Available P lbs/acre	Exchangeable K lbs/acre	Organic matter percent	Lime requirement lbs/acre
Wheat experiments					
Manhattan	5.4	30	415	1.7	3,000
Belleville	5.6	55	550	2.0	2,000
Hutchinson	5.6	37	445	2.4	1,000
Mound Valley	5.7	50	41	1.5	2,000
Oat experiments					
Manhattan	5.5	85	497	2.4	4,000
Belleville	6.0	33	540	1.8	1,000
Thayer	6.2	27	99	1.4	1,250

Plan of Experiment

The experimental design was the same for all locations. Each wheat experiment consisted of twenty-five different treatments making up a randomized block. Each treatment was replicated four times, making a total of four blocks containing twenty-five plots each.

The treatments were designed on the factorial system in which several different amounts of the three fertilizer elements (nitrogen, phosphorus and potassium) were included in all possible combinations.

Additional treatments holding potassium and phosphorus constant were used to note what effects time of application of nitrogenous fertilizer had on the response of wheat. All wheat locations were randomized individually.

The size of each individual plot as planted was 5 feet 3 inches or one drill width wide with the length varying slightly between locations but in all cases it was over 100 feet long. A space of 9 inches was left between plots within a block. Yields of harvested grain were determined on the particular fraction of an acre harvested.

Plots for the three oat experiments were designed the same for all locations. Each location consisted of twenty different treatments in a randomized block with each block being replicated four times. The factorial design was again employed and all locations had the same randomization. Each plot was 5 feet 3 inches in width with the planted and harvested length varying some between locations.

Experimental Procedure

The usual wheat and oat seed bed preparations were made. Planting and harvesting dates as well as varieties planted are listed in Table 2.

Planting was done with a small 9 hole 7 inch grain drill and harvesting was done by combine. During harvest the combine was allowed to clean out for several minutes on completion of each plot. Then the bags of grain were weighed and recorded and a sample was taken for protein analysis.

Table 2. Date of planting and harvesting and varieties used for wheat and oat fertility tests, 1950-51.

Location	Date planted	Date harvested	Variety
Wheat			
Hutchinson	Oct. 9	July 6	Ponca
Manhattan	Oct. 5	July 16-17	Ponca
Belleville	Sept. 26	July 20	Pawnee
Mound Valley	Oct. 5	July 25	Pawnee
Oats			
Manhattan	Mar. 21	July 21	Cherokee
Belleville	Apr. 2	July 24	Clinton
Thayer	Mar. 17	July 25	Cherokee

The fertilizers used in these experiments were ammonium nitrate (33.5 percent N), triple superphosphate (45 percent P_2O_5) and muriate of potash (60 percent K_2O). All fertilizer, except that topdressed as spring and winter applications, was applied at planting time with the fertilizer attachment on the grain drill. Topdressings of ammonium nitrate were made by using the fertilizer attachment on the drill on dates indicated in the tables.

Protein Analyses of the Grain

Protein analyses were made on grain samples of both wheat and oats from each plot at each location. Total nitrogen was determined by the Kjeldahl method (2) and the percent protein was obtained by multiplying the nitrogen content by 5.7 (2).

Test Weight

Test weights were determined by the standard apparatus for this procedure. Grain samples containing an excessive amount of weeds were cleaned before test weight determinations were made.

RESULTS

Results of the experiment are presented in the following tables and drawings. In general, the wheat data are treated first followed by the oat data.

Table 3. Precipitation for the 1950-51 wheat and oat experiments by months for each location.

Month	Location				
	Hutchinson	Manhattan	Belleville	Mound Valley	Thayer
August	5.36	3.72	8.60	2.22	4.11
September	1.77	.30	4.85	2.73	1.60
October	1.61	1.63	2.32	.51	.10
November	.15	.43	.49	.10	.06
December	.15	1.02	.31	T	.04
January	.84	.47	1.55	1.65	.12
February	1.33	1.42	1.77	3.35	2.17
March	2.16	2.62	1.63	1.07	.97
April	3.04	3.45	4.99	2.53	3.63
May	8.86	8.62	3.63	3.27	4.35
June	9.73	10.28	9.68	13.73	13.76
July	2.09	13.59	7.50	4.69	11.12
Total	37.09	47.55	47.32	35.85	42.03

Table 4. The effect of method, time and rate of application of fertilizer on the yield of hard red winter wheat at Hutchinson, 1950-51.

	Treatment			Yield	Test Wt	Protein	
No	N	P_2O_5	K_2O	bu/acre	lbs/bu	percent	lbs/acre
1.	0	0	0	27.1	59.8	14.0	251.5
2.	50	0	0	38.6	58.8	14.6	338.4
3.	0	50	0	39.5	61.5	13.7	322.6
4.	50	50	0	54.2	61.0	14.7	479.8
5.	0	0	25	31.9	59.3	14.2	270.0
6.	50	0	25	41.4	58.6	14.6	365.2
7.	0	50	25	50.4	61.4	13.4	407.5
8.	50	50	25	49.4	61.7	13.9	415.0
9.	25	0	0	39.3	58.8	13.8	326.4
10.	25	50	0	43.8	61.5	14.2	368.2
11.	25	0	25	38.4	59.1	14.2	323.6
12.	25	50	25	47.4	61.6	14.1	404.7
13.	100	0	0	35.7	59.4	15.2	326.5
14.	100	50	0	49.7	61.0	14.9	439.0
15.	100	0	25	34.7	59.2	14.8	308.3
16.	100	50	25	45.2	61.3	14.7	396.7
17.	50	50	25(N-Dec. 20)	49.0	61.6	14.6	433.3
18.	50	50	25(N-Feb. 20)	49.5	61.2	14.8	439.1
19.	50	50	25(N-Mar. 10)	51.2	61.7	14.9	457.4
20.	50	50	25(N-Mar. 30)	49.8	62.0	14.7	439.1
	25		(N-half at seeding)				
21.	25	50	25(N-half Dec. 20)	52.1	61.2	14.8	464.7
	25		(N-half at seeding)				
22.	25	50	25(N-half Feb. 20)	49.2	60.8	14.8	434.9
	25		(N-half at seeding)				
23.	25	50	25(N-half Mar. 10)	49.7	61.0	15.0	447.5
	25		(N-half at seeding)				
24.	25	50	25(N-half Mar. 30)	51.0	61.4	14.9	455.4
	25		(N-half at seeding)				
25.	25	50	25(N-half Apr. 20)	52.6	61.4	14.6	471.3
Least significant difference:			5%	9.6	1.0	ns	90.9
			1%	12.7	1.3	ns	117.2

Table 5. The effect of method, time and rate of application of fertilizer on the yield of hard red winter wheat at Manhattan, 1950-51.

No	Treatment			Yield	Test Wt	Protein	
	N	P_2O_5	K_2O	bu/acre	lbs/bu	percent	lbs/acre
1.	0	0	0	30.7	59.5	11.1	204.0
2.	50	0	0	36.9	59.6	11.1	255.2
3.	0	50	0	30.9	58.9	10.9	202.2
4.	50	50	0	41.5	59.7	11.2	280.0
5.	0	0	25	29.1	59.4	11.0	196.5
6.	50	0	25	40.0	59.7	11.4	275.7
7.	0	50	25	34.6	58.9	11.0	229.4
8.	50	50	25	39.3	59.5	11.3	266.2
9.	25	0	0	34.1	59.6	11.1	227.7
10.	25	50	0	37.2	59.1	11.0	245.2
11.	25	0	25	33.5	59.6	11.2	225.0
12.	25	50	25	36.5	59.3	10.8	236.1
13.	100	0	0	40.6	59.7	12.5	304.4
14.	100	50	0	41.4	59.5	11.9	295.6
15.	100	0	25	42.2	59.7	12.4	315.6
16.	100	50	25	40.6	59.5	12.1	294.5
17.	50	50	25(N-Dec. 20)	40.5	59.7	11.2	273.8
18.	50	50	25(N-Feb. 20)	43.5	59.2	11.4	297.8
19.	50	50	25(N-Mar. 10)	40.4	59.5	11.4	277.6
20.	50	50	25(N-Mar. 30)	42.3	59.5	11.2	285.2
21.	25 25	50	(N-half at seeding) 25(N-half Dec. 20)	40.1	59.5	11.4	267.0
22.	25 25	50	(N-half at seeding) 25(N-half Feb. 20)	44.4	59.1	11.2	299.8
23.	25 25	50	(N-half at seeding) 25(N-half Mar. 10)	40.6	59.1	11.1	270.1
24.	25 25	50	(N-half at seeding) 25(N-half Mar. 30)	42.1	59.3	10.9	275.3
25.	25 25	50	(N-half at seeding) 25(N-half Apr. 20)	41.8	59.4	11.5	293.0
Least significant difference:			5%	4.9	0.6	.6	52.8
			1%	6.5	0.8	.7	68.1

Table 6. The effect of method, time and rate of application of fertilizer on the yield of hard red winter wheat at Belleville, 1950-51.

No	Treatment			Yield	Test Wt	Protein	
	N	P_2O_5	K_2O	bu/acre	lbs/bu	percent	lbs/acre
1.	0	0	0	20.2	56.6	11.9	144.2
2.	50	0	0	31.3	57.4	11.8	220.6
3.	0	50	0	22.4	57.0	11.7	156.7
4.	50	50	0	33.1	57.8	11.6	229.9
5.	0	0	25	20.8	56.6	11.9	148.1
6.	50	0	25	32.0	57.4	11.9	228.1
7.	0	50	25	20.9	56.9	11.6	144.9
8.	50	50	25	33.3	57.6	11.5	230.7
9.	25	0	0	29.3	57.4	11.6	204.4
10.	25	50	0	28.9	57.5	11.3	195.1
11.	25	0	25	26.4	57.3	11.5	181.5
12.	25	50	25	28.7	57.4	11.7	201.0
13.	100	0	0	35.8	57.2	12.3	264.2
14.	100	50	0	37.5	57.6	12.1	271.4
15.	100	0	25	34.5	56.9	12.8	263.4
16.	100	50	25	35.1	57.7	12.0	252.4
17.	50	50	25(N-Dec. 20)	37.8	57.4	12.1	275.2
18.	50	50	25(N-Feb. 20)	37.0	57.4	11.7	259.3
19.	50	50	25(N-Mar. 10)	34.9	57.2	12.3	256.6
20.	50	50	25(N-Mar. 30)	32.6	56.8	12.3	239.2
21.	25 25	50	(N-half at seeding) 25(N-half Dec. 20)	35.2	57.7	11.8	248.9
22.	25 25	50	(N-half at seeding) 25(N-half Feb. 20)	34.3	57.7	11.9	245.2
23.	25 25	50	(N-half at seeding) 25(N-half Mar. 10)	35.2	57.6	12.0	253.8
24.	25 25	50	(N-half at seeding) 25(N-half Mar. 30)	35.0	57.0	12.4	257.6
25.	25 25	50	(N-half at seeding) 25(N-half Apr. 20)	31.6	56.9	12.1	229.1
Least significant difference:			5%	3.8	1.0	.5	28.5
			1%	5.0	1.4	.7	36.7

Table 7. The effect of method, time and rate of application of fertilizer on the yield of hard red winter wheat at Mound Valley, 1950-51.

No	N	P_2O_5	K_2O	Yield bu/acre	Test Wt lbs/bu	Protein percent	Protein lbs/acre
1.	0	0	0	8.0	56.0	12.8	61.7
2.	50	0	0	7.9	56.0	13.7	64.6
3.	0	50	0	6.9	55.5	13.3	54.7
4.	50	50	0	13.5	56.4	13.1	106.6
5.	0	0	25	7.6	55.0	13.2	61.8
6.	50	0	25	9.8	55.6	14.1	82.4
7.	0	50	25	6.5	56.0	13.2	51.6
8.	50	50	25	14.2	56.8	12.5	106.4
9.	25	0	0	8.1	54.9	14.4	70.4
10.	25	50	0	10.8	55.4	13.8	84.3
11.	25	0	25	8.9	55.4	14.0	74.4
12.	25	50	25	9.4	56.2	13.0	72.2
13.	100	0	0	7.6	54.9	13.8	63.1
14.	100	50	0	17.9	56.8	13.8	148.2
15.	100	0	25	9.2	55.9	14.6	80.8
16.	100	50	25	19.8	57.3	13.5	159.7
17.	50	50	25(N-Dec. 20)	11.5	56.3	13.0	89.5
18.	50	50	25(N-Feb. 20)	11.9	57.0	13.4	95.2
19.	50	50	25(N-Mar. 10)	12.2	56.7	12.8	94.4
20.	50	50	25(N-Mar. 30)	11.9	57.0	13.2	94.1
21.	25 25	50	(N-half at seeding) 25(N-half Dec. 20)	13.1	56.4	12.6	98.7
22.	25 25	50	(N-half at seeding) 25(N-half Feb. 20)	13.5	57.0	13.0	105.0
23.	25 25	50	(N-half at seeding) 25(N-half Mar. 10)	13.8	56.5	12.7	104.7
24.	25 25	50	(N-half at seeding) 25(N-half Mar. 30)	13.2	56.4	13.1	103.8
25.	25 25	50	(N-half at seeding) 25(N-half Apr. 20)	14.1	57.1	12.9	108.9
Least significant difference:			5%	2.9	1.0	1.0	23.2
			1%	3.8	1.4	1.3	29.9

Table 8. Rank of treatments relative to the influence of fertilizer treatment on wheat yield for each location.

	Hutchinson		Manhattan		Belleville		Mound Valley	
Rank	Treat.	Mean	Treat.	Mean	Treat.	Mean	Treat.	Mean
1	4	54.2	22	44.4	17	37.8	16	19.8
2	25	52.6	18	43.5	14	37.5	14	17.9
3	21	52.1	20	42.3	18	37.0	8	14.2
4	19	51.2	15	42.2	13	35.8	25	14.1
5	24	51.0	24	42.1	23	35.2	23	13.8
6	7	50.4	25	41.8	21	35.2	22	13.5
7	20	49.8	4	41.5	16	35.1	4	13.5
8	23	49.7	14	41.4	24	35.0	24	13.2
9	14	49.7	23	40.6	19	34.9	21	13.1
10	18	49.5	16	40.6	15	34.5	19	12.2
11	8	49.4	13	40.6	22	34.3	20	11.9
12	22	49.2	17	40.5	8	33.3	18	11.9
13	17	49.0	19	40.4	4	33.1	17	11.5
14	12	47.4	21	40.1	20	32.6	10	10.8
15	16	45.2	6	40.0	6	32.0	6	9.8
16	10	43.8	8	39.3	25	31.6	12	9.4
17	6	41.4	10	37.2	2	31.3	15	9.2
18	3	39.5	2	36.9	9	29.3	11	8.9
19	9	39.3	12	36.5	10	28.9	9	8.1
20	2	38.6	7	34.6	12	28.7	1	8.0
21	11	38.4	9	34.1	11	26.4	2	7.9
22	13	35.7	11	33.5	3	22.4	5	7.6
23	15	34.7	3	30.9	7	20.9	13	7.6
24	5	31.9	1	30.7	5	20.8	3	6.9
25	1	27.1	5	29.1	1	20.2	7	6.5
LSD	5%	9.6		4.9		3.8		2.9
	1%	12.7		6.5		5.0		3.8

Table 9. Rank of treatments relative to the influence of fertilizer treatment on test weight for wheat at each location.

	Hutchinson		Manhattan		Belleville		Mound Valley	
Rank	Treat.	Mean	Treat.	Mean	Treat.	Mean	Treat.	Mean
1	20	62.0	15	59.7	4	57.8	16	57.3
2	19	61.7	13	59.7	22	57.7	25	57.1
3	8	61.7	6	59.7	21	57.7	20	57.0
4	12	61.6	17	59.7	16	57.7	18	57.0
5	17	61.6	4	59.7	14	57.6	22	57.0
6	10	61.5	2	59.6	8	57.6	8	56.8
7	3	61.5	9	59.6	23	57.6	14	56.8
8	7	61.4	11	59.6	10	57.5	19	56.7
9	25	61.4	16	59.5	6	57.4	23	56.5
10	24	61.4	14	59.5	12	57.4	21	56.4
11	16	61.3	19	59.5	18	57.4	24	56.4
12	18	61.2	21	59.5	9	57.4	4	56.4
13	21	61.2	20	59.5	2	57.4	17	56.3
14	4	61.0	8	59.5	17	57.4	12	56.2
15	14	61.0	1	59.5	11	57.3	7	56.0
16	23	61.0	5	59.4	13	57.2	1	56.0
17	22	60.8	25	59.4	19	57.2	2	56.0
18	1	59.8	12	59.3	24	57.0	15	55.9
19	13	59.4	24	59.3	3	57.0	6	55.6
20	5	59.3	18	59.2	7	56.9	3	55.5
21	15	59.2	22	59.1	15	56.9	11	55.4
22	11	59.1	10	59.1	25	56.9	10	55.4
23	2	58.8	23	59.1	20	56.8	5	55.0
24	9	58.8	7	58.9	1	56.6	9	54.9
25	6	58.6	3	58.9	5	56.6	13	54.9
LSD	5%	1.0		.6		.6		.6
	1%	1.3		.8		.7		.8

Table 10. Rank of each treatment relative to the influence of fertilizer treatment on percent protein of wheat at each location.

	Hutchinson		Manhattan		Belleville		Mound Valley	
Rank	Treat.	Mean	Treat.	Mean	Treat.	Mean	Treat.	Mean
1	13	15.2	13	12.5	15	12.8	15	14.6
2	23	15.0	15	12.4	24	12.4	9	14.4
3	14	14.9	16	12.1	13	12.3	6	14.1
4	19	14.9	14	11.9	19	12.3	11	14.0
5	24	14.9	25	11.5	20	12.3	10	13.8
6	15	14.8	6	11.4	14	12.1	13	13.8
7	18	14.8	18	11.4	17	12.1	14	13.8
8	21	14.8	19	11.4	25	12.1	2	13.7
9	22	14.8	21	11.4	16	12.0	16	13.5
10	4	14.7	8	11.3	23	12.0	18	13.4
11	16	14.7	4	11.2	1	11.9	3	13.3
12	20	14.7	11	11.2	5	11.9	5	13.2
13	2	14.6	17	11.2	6	11.9	7	13.2
14	6	14.6	20	11.2	22	11.9	20	13.2
15	17	14.6	22	11.2	2	11.8	4	13.1
16	25	14.6	1	11.1	21	11.8	24	13.1
17	5	14.2	2	11.1	3	11.7	12	13.0
18	10	14.2	9	11.1	12	11.7	17	13.0
19	11	14.2	23	11.1	18	11.7	22	13.0
20	12	14.1	5	11.0	4	11.6	25	12.9
21	1	14.0	7	11.0	7	11.6	1	12.8
22	8	13.9	10	11.0	9	11.6	19	12.8
23	9	13.8	3	10.9	8	11.5	23	12.7
24	3	13.7	24	10.9	11	11.5	21	12.6
25	7	13.4	12	10.8	10	11.3	8	12.5
LSD	5%	ns		.6		.5		1.0
	1%	ns		.7		.7		1.3

Table 11. Rank of each treatment relative to the influence of fertilizer treatment on pounds protein per acre for wheat at each location.

	Hutchinson		Manhattan		Belleville		Mound Valley	
Rank	Treat.	Mean	Treat.	Mean	Treat.	Mean	Treat.	Mean
1	4	479.8	15	315.6	17	275.2	16	159.7
2	25	471.3	13	304.4	14	271.4	14	148.2
3	21	464.7	22	299.8	13	264.2	25	108.9
4	19	457.4	18	297.8	15	263.4	4	106.6
5	24	455.4	14	295.6	18	259.3	8	106.4
6	23	447.5	16	294.5	24	257.6	22	105.0
7	20	439.1	25	293.0	19	256.6	23	104.7
8	18	439.1	20	285.2	23	253.8	24	103.8
9	14	439.0	4	280.0	16	252.4	21	98.7
10	22	434.9	19	277.6	21	248.9	18	95.2
11	17	433.3	6	275.7	22	245.2	19	94.4
12	8	415.0	24	275.3	20	239.2	20	94.1
13	7	407.5	17	273.8	8	230.7	17	89.5
14	12	404.7	23	270.1	4	229.9	10	84.3
15	16	396.7	21	267.0	25	229.1	6	82.4
16	10	368.2	8	266.2	6	228.1	15	80.8
17	6	365.2	2	255.2	2	220.6	11	74.4
18	2	338.4	10	245.2	9	204.4	12	72.2
19	13	326.5	12	236.1	12	201.0	9	70.4
20	9	326.4	7	229.4	10	195.1	2	64.6
21	11	323.6	9	227.7	11	181.5	13	63.1
22	3	322.6	11	225.0	3	156.7	5	61.8
23	15	308.3	1	204.0	5	148.1	1	61.7
24	5	270.0	3	202.2	7	144.9	3	54.7
25	1	251.5	5	196.5	1	144.2	7	51.6
LSD	5%	90.0		52.8		28.5		11.6
	1%	117.2		68.1		36.7		23.2

Table 12. Wheat yields in bushels per acre as affected by the addition of phosphorus, 1951.[1]

Location	50 lbs/acre Available P_2O_5	0 lbs/acre Available P_2O_5
Hutchinson	47.5	35.9
Manhattan	37.8	35.9
Belleville	30.0	28.8
Mound Valley	12.4	8.4

[1] N = 32

Table 13. Wheat yields in bushels per acre as affected by the addition of potash, 1951.[1]

Location	25 lbs/acre K_2O	0 lbs/acre K_2O
Hutchinson	42.4	41.0
Manhattan	37.0	36.6
Belleville	29.0	29.9
Mound Valley	10.7	10.1

[1] N = 32

Table 14. Wheat yields in bushels per acre as affected by various amounts of nitrogen, 1951.[1]

Location	25 lbs/acre N	50 lbs/acre N	100 lbs/acre N
Hutchinson	42.3	45.9	41.3
Manhattan	35.3	39.4	41.2
Belleville	28.3	32.4	35.7
Mound Valley	9.3	11.4	13.6

[1] N = 16

Table 15. Wheat yields in bushels per acre as affected by different times and methods of application of 50 pounds per acre of nitrogen, 1951.[1]

Time and method of application[2]	Yield
At seeding	34.1
Topdressed Dec. 20	34.7
Topdressed Feb. 20	35.5
Topdressed Mar. 10	34.7
Half drilled at seeding and half topdressed Mar. 30	34.1
Half drilled at seeding and half topdressed Dec. 20	35.1
Half drilled at seeding and half topdressed Feb. 20	35.3
Half drilled at seeding and half topdressed Mar. 10	34.8
Half drilled at seeding and half topdressed Mar. 30	34.9
Half drilled at seeding and half topdressed Apr. 20	35.2

[1] N = 16
[2] All P and K applied at seeding

Table 16. Oat yields in bushels per acre as affected by different times and methods of application of 50 pounds per acre of nitrogen, 1951.[1]

Time and method of application[2]	Yield
At seeding	49.0
Topdressed in late May	46.8
Half drilled at seeding and half topdressed late May	47.3

[1] N = 12
[2] All P and K applied at seeding

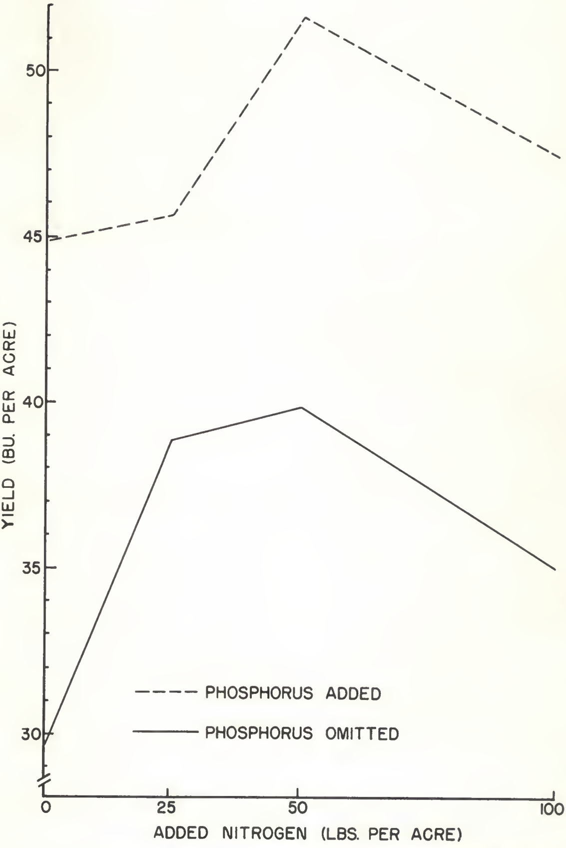

Fig. 1. The influence of 50 pounds per acre of P_2O_5 from superphosphate upon yield response from various amounts of added Nitrogen at Hutchinson, Kansas - 1951.

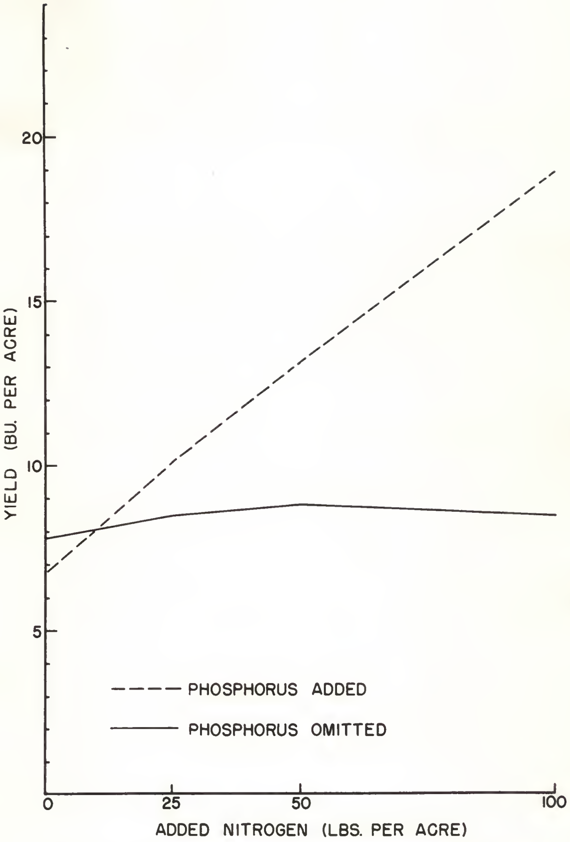

Fig. 2. The influence of 50 pounds per acre of P_2O_5 from superphosphate upon yield response from various amounts of added Nitrogen at Mound Valley, Kansas - 1951.

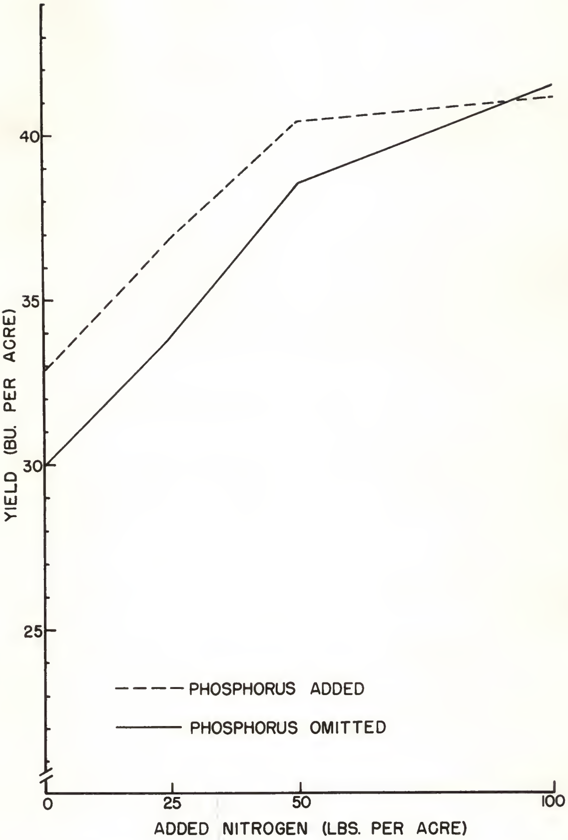

Fig. 3. The influence of 50 pounds per acre of P_2O_5 from superphosphate upon yield response from various amounts of added Nitrogen at Manhattan, Kansas - 1951.

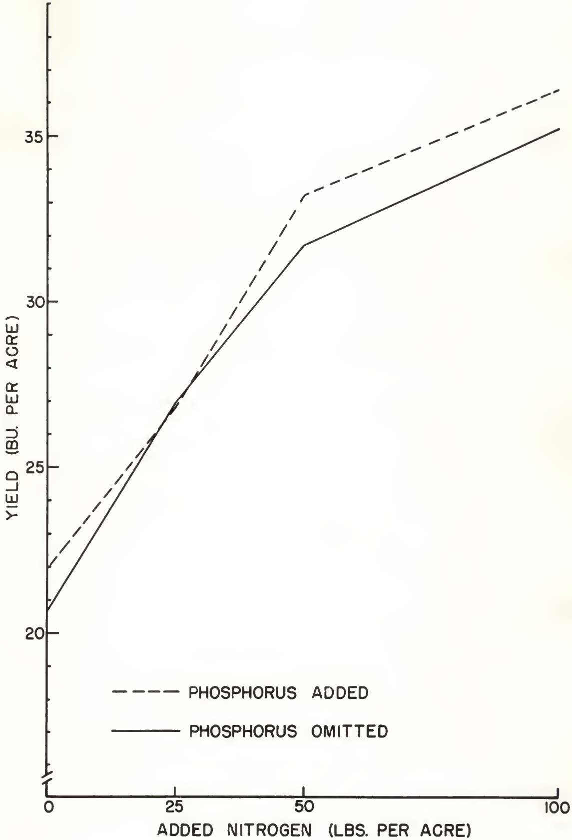

Fig. 4. The influence of 50 pounds per acre of P_2O_5 from superphosphate upon yield response from various amounts of added Nitrogen at Belleville, Kansas - 1951.

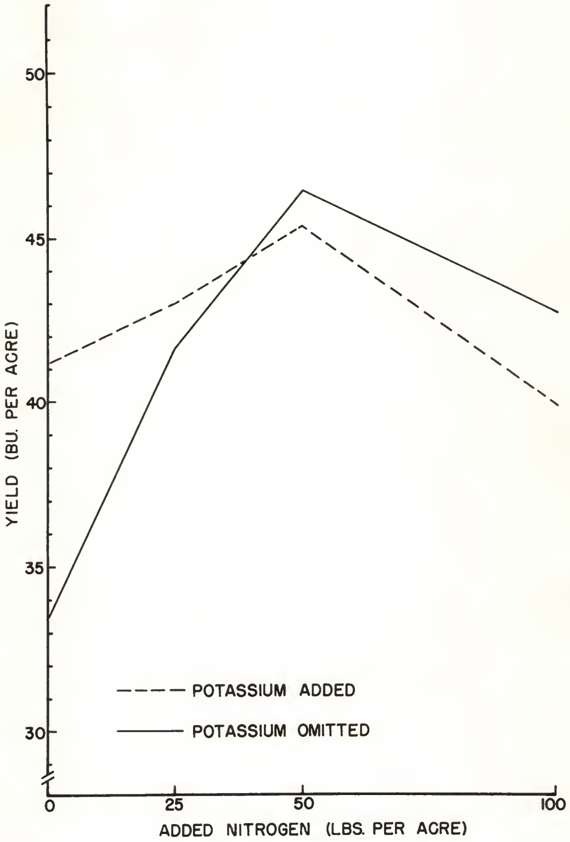

Fig. 5. The influence of 25 pounds per acre of K_2O upon yield response from various amounts of added Nitrogen at Hutchinson, Kansas - 1951.

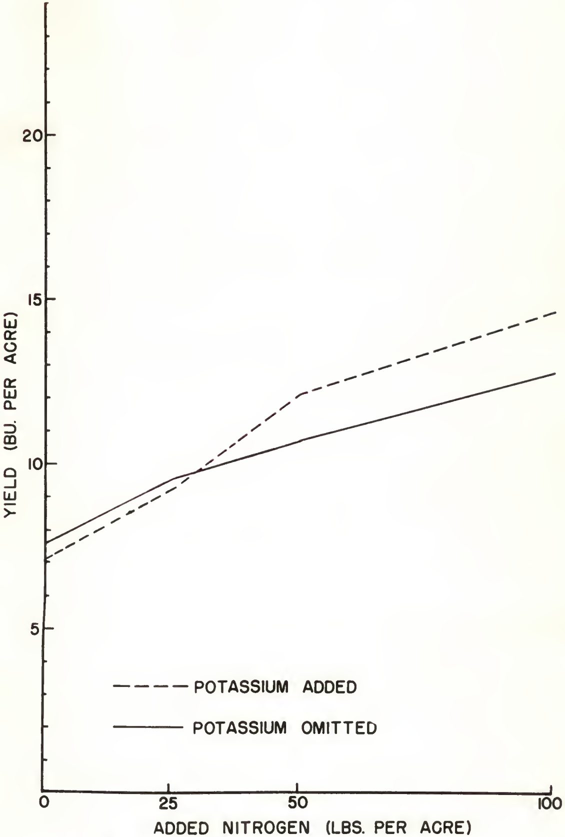

Fig. 6. The influence of 25 pounds per acre of K_2O upon yield response from various amounts of added Nitrogen at Mound Valley, Kansas - 1951.

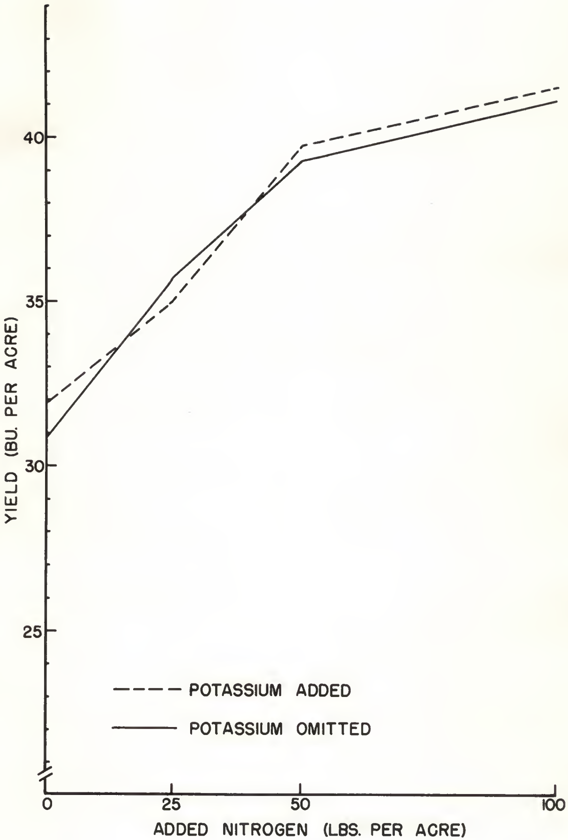

Fig. 7. The influence of 25 pounds per acre of K_2O upon yield response from various amounts of added Nitrogen at Manhattan, Kansas - 1951.

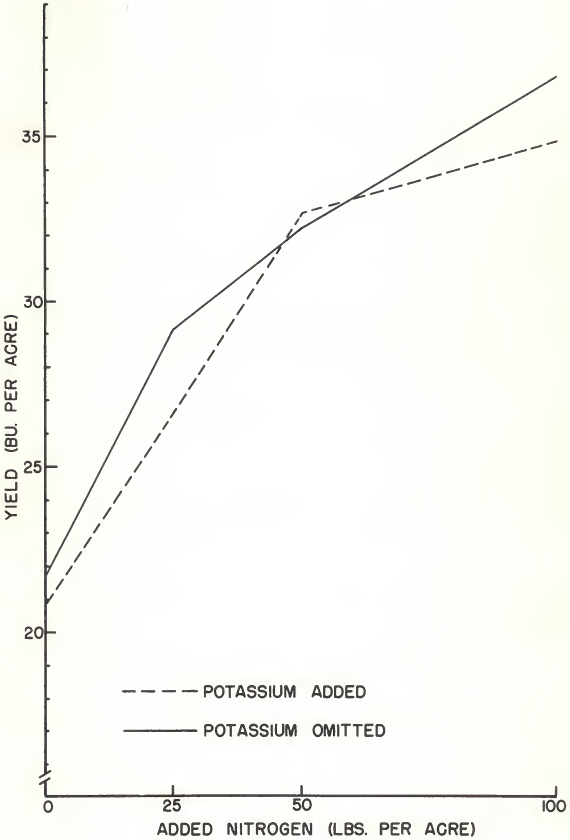

Fig. 8. The influence of 25 pounds per acre of K_2O upon yield response from various amounts of added Nitrogen at Belleville, Kansas - 1951.

Table 17. Statistical analyses of wheat yield data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Mound Valley		
Treatments	24	1098.00	45.75	10.98***
Blocks	3	7.65	2.55	.61
Error	72	300.10	4.17	
Total	99	1405.75		
		Manhattan		
Treatments	24	1715.47	71.48	6.00***
Blocks	3	103.09	34.36	2.88*
Error	72	857.44	11.91	
Total	99	2676.00		
		Hutchinson		
Treatments	24	5177.90	215.75	4.95***
Blocks	3	176.28	58.76	1.35
Error	72	3137.44	43.58	
Total	99	8491.62		
		Belleville		
Treatments	24	2778.10	115.75	18.10***
Blocks	3	345.10	115.03	17.97**
Error	72	460.48	6.40	
Total	99	3583.69		

*** Significant at .1% level
** Significant at 1% level
* Significant at 5% level

Table 18. Statistical analyses of wheat test weight data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Manhattan		
Treatments	24	6.166	.2569	1.42
Blocks	3	1.086	.3620	2.00
Error	72	13.00	.1806	
Total	99	20.25		
		Mound Valley		
Treatments	24	48.68	2.028	3.85***
Blocks	3	1.083	.3609	.68
Error	72	37.94	.5269	
Total	99	87.70		
		Hutchinson		
Treatments	24	120.8	5.034	10.19***
Blocks	3	8.556	2.852	5.77**
Error	72	35.58	.4942	
Total	99	164.9		
		Belleville		
Treatments	24	11.80	.4917	3.17***
Blocks	3	1.480	.4934	3.18*
Error	72	11.16	.1550	
Total	99	24.44		

*** Significant at .1% level
** Significant at 1% level
* Significant at 5% level

Table 19. Statistical analyses of percent protein of wheat data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Hutchinson		
Treatments	24	21.35	.8896	1.802
Blocks	3	92.07	30.69	62.18***
Error	72	35.54	.4936	
Total	99	148.96		
		Manhattan		
Treatments	24	19.73	.8220	5.44***
Blocks	3	.90	.2999	1.98
Error	72	10.88	.1511	
Total	99	31.51		
		Mound Valley		
Treatments	24	2.93	1.220	2.58***
Blocks	3	2.68	.8942	1.89
Error	72	34.04	.4728	
Total	99	39.65		
		Belleville		
Treatments	24	11.46	.4776	4.07***
Blocks	3	.65	.2164	1.84
Error	72	8.45	.1174	
Total	99	20.56		

*** Significant at .1% level

Table 20. Statistical analyses of pounds per acre of protein for wheat at each location.

Source of variation	Degrees of freedom	Sum of squares	Variance	F
		Hutchinson		
Treatments	24	453221.7	18884.2	4.574**
Blocks	3	57062.3	19020.8	4.607
Error	72	297236.7	4128.3	
Total	99	807520.7		
		Manhattan		
Treatments	24	111993.7	4666.4	3.35**
Blocks	3	7820.9	2607.0	1.87*
Error	72	100422.7		
Total	99	220237.2		
		Belleville		
Treatments	24	164260.2	5177.5	12.80**
Blocks	3	17609.9	5868.0	14.50**
Error	72	29121.8	404.5	
Total	99	210991.0		
		Mound Valley		
Treatments	24	66877.7	2786.6	10.40**
Blocks	3	356.6	118.9	.442
Error	72	19354.0	268.8	
Total	99	86588.3		

** Significant at 1% level
 * Significant at 5% level

Table 21. The effect of method, time and rate of application of fertilizer on the yield of oats at Manhattan, 1951.

No	Treatment N	Treatment P_2O_5	Treatment K_2O	Yield bu/acre	Test Wt lbs/bu	Protein percent	Protein lbs/acre
1.	0	0	0	47.9	35.2	12.8	195.7
2.	50	0	0	58.6	35.0	13.6	255.2
3.	0	50	0	51.3	35.4	11.7	193.0
4.	50	50	0	58.9	35.0	13.0	245.6
5.	0	0	25	48.4	35.0	12.5	194.1
6.	50	0	25	56.8	35.4	12.8	233.8
7.	0	50	25	51.0	35.6	12.2	198.6
8.	50	50	25	61.8	34.4	12.9	255.0
9.	25	0	0	55.0	34.8	12.8	226.6
10.	25	50	0	57.2	35.3	12.2	223.0
11.	25	0	25	55.5	35.2	12.3	218.7
12.	25	50	25	55.8	35.1	13.1	235.5
13.	100	0	0	60.6	33.1	13.8	268.0
14.	100	50	0	59.9	35.2	13.3	255.8
15.	100	0	25	59.1	33.6	13.9	262.8
16.	100	50	25	58.6	34.4	13.7	256.6
17.	25	50	25(N-topdressed)	56.5	34.5	13.3	240.9
18.	50	50	25(N-topdressed)	53.8	33.8	13.8	238.6
19.	100	50	25(N-topdressed)	56.4	32.3	13.9	252.8
20.	25 25	50	25(N-half at seeding) (N-half topdressed)	58.3	34.5	13.9	258.2
Least significant difference:			5%	5.2	ns	1.1	29.4
			1%	6.9	ns	1.4	38.0

Table 22. The effect of method, time and rate of application of fertilizer on the yield of oats at Belleville, 1951.

No	Treatment N	P_2O_5	K_2O	Yield bu/acre	Test Wt lbs/bu	Protein percent	Protein lbs/acre
1.	0	0	0	21.3	37.8	11.8	80.1
2.	50	0	0	37.2	38.8	12.4	147.6
3.	0	50	0	19.9	37.4	11.9	75.7
4.	50	50	0	40.4	39.2	12.1	156.4
5.	0	0	25	15.8	38.5	12.4	62.4
6.	50	0	25	39.6	38.6	12.2	155.1
7.	0	50	25	20.7	38.0	12.0	79.7
8.	50	50	25	40.8	39.0	12.2	159.0
9.	25	0	0	27.9	38.8	11.9	107.0
10.	25	50	0	30.6	38.8	11.6	112.8
11.	25	0	25	28.2	39.0	11.8	106.6
12.	25	50	25	30.8	38.9	11.6	114.6
13.	100	0	0	44.8	38.4	13.4	193.2
14.	100	50	0	49.4	38.1	13.1	206.9
15.	100	0	25	44.8	38.8	13.4	190.9
16.	100	50	25	46.9	39.2	13.2	198.1
17.	25	50	25(N-topdressed)	32.8	38.0	11.6	122.2
18.	50	50	25(N-topdressed)	40.0	39.4	12.5	159.9
19.	100	50	25(N-topdressed)	48.6	39.0	13.8	215.4
20.	25 25	50	25(N-half at seeding) (N-half topdressed)	40.0	39.5	11.8	150.6
Least significant difference:			5%	3.6	1.1	.6	16.2
			1%	4.7	ns	.7	20.9

Table 23. The effect of method, time and rate of application of fertilizer on the yield of oats at Thayer, 1951.

No	Treatment			Yield	Test Wt	Protein	
	N	P_2O_5	K_2O	bu/acre	lbs/bu	percent	lbs/acre
1.	0	0	0	39.1	27.2	11.7	147.3
2.	50	0	0	45.1	27.6	12.4	178.8
3.	0	50	0	39.4	28.6	11.8	147.8
4.	50	50	0	38.0	28.1	12.0	145.7
5.	0	0	25	42.1	27.9	11.8	157.0
6.	50	0	25	42.5	28.6	12.0	163.1
7.	0	50	25	34.8	28.4	11.3	126.5
8.	50	50	25	45.3	28.7	11.7	169.3
9.	25	0	0	35.9	28.2	11.8	134.3
10.	25	50	0	41.9	27.8	11.6	156.0
11.	25	0	25	34.5	28.0	11.7	129.5
12.	25	50	25	40.0	28.8	11.4	146.9
13.	100	0	0	48.0	26.8	13.1	199.3
14.	100	50	0	47.0	27.5	12.5	192.3
15.	100	0	25	47.4	27.6	12.9	196.4
16.	100	50	25	51.0	28.8	12.5	203.9
17.	25	50	25(N-topdressed)	42.4	28.0	12.1	163.6
18.	50	50	25(N-topdressed)	47.6	27.5	12.7	194.4
19.	100	50	25(N-topdressed)	45.8	27.0	12.9	188.9
20.	25 25	50	25(N-half at seeding) (N-half topdressed)	44.4	28.3	12.6	178.6
Least significant difference:			5%	9.4	.8	.7	39.0
			1%	12.5	1.1	1.0	50.4

Table 24. Rank of each treatment relative to the influence of fertilizer treatment on yield of oats at each location.

	Manhattan		Belleville		Thayer	
Rank	Treatment	Mean	Treatment	Mean	Treatment	Mean
1	8	61.8	14	49.4	16	51.0
2	13	60.6	19	48.6	13	48.0
3	14	59.9	16	46.9	18	47.6
4	15	59.1	13	44.8	15	47.4
5	4	58.9	15	44.8	14	47.0
6	2	58.6	8	40.8	19	45.8
7	16	58.6	4	40.4	8	45.3
8	20	58.3	18	40.0	2	45.1
9	10	57.2	20	40.0	20	44.4
10	6	56.8	6	39.6	6	42.5
11	17	56.5	2	37.2	17	42.4
12	19	56.4	17	32.8	5	42.1
13	12	55.8	12	30.8	10	41.9
14	11	55.5	10	30.6	12	40.0
15	9	55.0	11	28.2	3	39.4
16	18	53.8	9	27.9	1	39.1
17	3	51.3	1	21.3	4	38.0
18	7	51.0	7	20.7	9	35.9
19	5	48.4	3	19.9	7	34.8
20	1	47.9	5	15.8	11	34.5
LSD	5%	5.2		3.6		9.4
	1%	6.9		4.7		12.5

Table 25. Rank of each treatment relative to the influence of fertilizer treatment on test weight of oats at each location.

Rank	Manhattan Treatment	Manhattan Mean	Belleville Treatment	Belleville Mean	Thayer Treatment	Thayer Mean
1	7	35.6	20	39.5	12	28.8
2	3	35.4	18	39.4	16	28.8
3	6	35.4	4	39.2	8	28.7
4	10	35.3	16	39.2	3	28.6
5	1	35.2	8	39.0	6	28.6
6	11	35.2	11	39.0	7	28.4
7	14	35.2	19	39.0	20	28.3
8	12	35.1	12	38.9	9	28.2
9	2	35.0	15	38.8	4	28.1
10	4	35.0	9	38.8	11	28.0
11	5	35.0	10	38.8	17	28.0
12	9	34.8	2	38.8	5	27.9
13	17	34.5	6	38.6	10	27.8
14	20	34.5	5	38.5	2	27.6
15	8	34.4	13	38.4	15	27.6
16	16	34.4	14	38.1	14	27.5
17	18	33.8	7	38.0	18	27.5
18	15	33.6	17	38.0	1	27.2
19	13	33.1	1	37.8	19	27.0
20	19	32.3	3	37.4	13	26.8
LSD 5%		ns		1.1		.8
LSD 1%		ns		ns		1.1

Table 26. Rank of each treatment relative to the influence of fertilizer treatment on percent protein at each location.

	Manhattan		Belleville		Thayer	
Rank	Treatment	Mean	Treatment	Mean	Treatment	Mean
1	15	13.9	19	13.8	13	13.1
2	19	13.9	13	13.4	15	12.9
3	20	13.9	15	13.4	19	12.9
4	13	13.8	16	13.2	18	12.7
5	18	13.8	14	13.1	20	12.6
6	16	13.7	18	12.5	14	12.5
7	2	13.6	5	12.4	16	12.5
8	14	13.3	2	12.4	2	12.4
9	17	13.3	8	12.2	17	12.1
10	12	13.1	6	12.2	4	12.0
11	4	13.0	4	12.1	6	12.0
12	8	12.9	7	12.0	3	11.8
13	1	12.8	3	11.9	5	11.8
14	6	12.8	9	11.9	9	11.8
15	9	12.8	1	11.8	1	11.7
16	5	12.5	11	11.8	8	11.7
17	11	12.3	20	11.8	11	11.7
18	7	12.2	10	11.6	10	11.6
19	10	12.2	12	11.6	12	11.4
20	3	11.7	17	11.6	7	11.3
LSD	5%	1.1		.6		.7
	1%	1.4		.7		1.0

Table 27. Rank of each treatment relative to the influence of fertilizer treatment on pounds of protein per acre for oats at each location.

Rank	Manhattan Treatment	Manhattan Mean	Belleville Treatment	Belleville Mean	Thayer Treatment	Thayer Mean
1	13	268.0	19	215.4	16	203.9
2	15	262.8	14	206.9	13	199.3
3	20	258.2	16	198.1	15	196.4
4	16	256.6	13	193.2	18	194.4
5	14	255.8	15	190.9	14	192.3
6	2	255.2	18	159.9	19	188.9
7	8	255.0	8	159.0	2	178.8
8	19	252.8	4	156.4	20	178.6
9	4	245.6	6	155.1	8	169.3
10	17	240.9	20	150.6	17	163.6
11	18	238.6	2	147.6	6	163.1
12	12	235.5	17	122.2	5	157.0
13	6	233.8	12	114.6	10	156.0
14	9	226.6	10	112.8	3	147.8
15	10	223.0	11	106.6	1	147.3
16	11	218.7	9	107.0	12	146.9
17	7	198.6	1	80.1	4	145.7
18	1	195.7	7	79.7	9	134.3
19	5	194.1	3	75.7	11	129.5
20	3	193.0	5	62.4	7	126.5
LSD	5%	29.4		16.2		39.0
	1%	38.0		20.9		50.4

Table 28. Oat yields in bushels per acre as affected by the addition of phosphorus, 1951.[1]

Location	50 lbs/acre Available P_2O_5	0 lbs/acre Available P_2O_5
Manhattan	56.7	55.1
Belleville	34.3	31.4
Thayer	42.1	41.8

[1] N = 24

Table 29. Oat yields in bushels per acre as affected by the addition of potash, 1951.[1]

Location	25 lbs/acre K_2O	0 lbs/acre K_2O
Manhattan	55.8	56.1
Belleville	32.4	33.4
Thayer	42.2	41.8

[1] N = 24

Table 30. Oat yields in bushels per acre as affected by various amounts of nitrogen, 1951.[1]

Location	25 lbs/acre N	50 lbs/acre N	100 lbs/acre N
Manhattan	55.8	58.9	59.4
Belleville	28.9	38.8	44.6
Thayer	38.1	42.7	48.4

[1] N = 16

Table 31. Statistical analyses of oat yield data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Manhattan		
Treatments	19	1144.64	60.24	4.52*
Blocks	3	1093.49	364.50	
Error	57	759.46	13.32	
Total	79	2997.60		
		Belleville		
Treatments	19	7987.71	420.41	66.36***
Blocks	3	310.38	103.46	
Error	57	361.09	6.33	
Total	79	8659.19		
		Thayer		
Treatments	19	1663.98	87.58	1.972*
Blocks	3	4685.63	1561.88	
Error	57	2531.43	44.41	
Total	79	8881.04		

*** Significant at .1% level
* Significant at 5% level

Table 32. Statistical analyses of oat test weight data for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Thayer		
Treatments	19	27.36	1.44	2.62**
Blocks	3	45.75	15.25	27.72**
Error	57	31.35	.55	
Total	79	104.46		
		Manhattan		
Treatments	19	55.29	2.91	1.68
Blocks	3	25.65	8.55	4.94**
Error	57	98.61	1.73	
Total	79	179.55		
		Belleville		
Treatments	19	23.37	1.23	1.95*
Blocks	3	61.50	20.50	32.53**
Error	57	35.91	.63	
Total	79	120.78		

** Significant at 1% level
* Significant at 5% level

Table 33. Statistical analyses for percent protein of oats for each location.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
		Belleville		
Treatments	19	34.77	1.83	12.2***
Blocks	3	6.39	2.13	14.2**
Error	57	8.55	.15	
Total	79	50.71		
		Thayer		
Treatments	19	21.47	1.13	4.18***
Blocks	3	1.56	.52	1.92
Error	57	15.39	.27	
Total	79	38.42		
		Manhattan		
Treatments	19	34.39	1.81	3.07***
Blocks	3	11.22	3.74	6.34**
Error	57	33.63	.59	
Total	79	79.24		

*** Significant at .1% level
** Significant at 1% level

Table 34. Statistical analyses of pounds protein per acre for oats at each location.

Source of variation	Degrees of freedom	Sum of squares	Variance	F
		Belleville		
Treatments	19	166689.5	8773.1	66.7**
Blocks	3	5541.5	1847.2	14.0**
Error	57	7491.4	131.4	
Total	79	179722.4		
		Manhattan		
Treatments	19	45504.5	2394.9	5.52**
Blocks	3	35333.7	11777.9	27.14**
Error	57	24736.9	434.0	
Total	79	105575.1		
		Thayer		
Treatments	19	45507.2	2395.1	3.14**
Blocks	3	73550.4	24516.8	32.20**
Error	57	43447.1	762.2	
Total	79	162504.7		

** Significant at 1% level

DISCUSSION

Hutchinson Wheat Test

Precipitation data for the season are presented in Table 3. The total rainfall for the entire season was considerably above the average for that county. Although the precipitation during the early stages of growth was slightly less than normal, apparently it had no effect on yield of grain.

Statistical analysis of yield data, Table 17, showed highly significant differences between treatments. Table 8 shows that in general those treatments which included 50 pounds of nitrogen and 50 pounds of P_2O_5 per acre gave greater increases in yields than those treatments which did not include this combination of nitrogen and phosphorus. This table also shows that phosphorus had a greater influence than nitrogen on yield as evidenced by treatments 13 and 15. These two treatments both contained 100 pounds of nitrogen but no phosphorus and they were significantly lower yielding than 15 other treatments.

This greater influence of phosphorus is undoubtedly due to the previous cropping system. Since the land had been broken out of alfalfa two years previous to this experiment, it can be concluded that the soil was relatively high in available nitrogen and low in available phosphorus. Examination of the soil analyses data, Table 1, shows the soil to be high in organic matter and low in available phosphorus, so the results were what might have been expected with regard to the soil analysis.

Highly significant differences in test weights were obtained between treatments. In general, those treatments containing no nitrogen or the 25 pound rate of application and those treatments which had half of the nitrogen topdressed showed a tendency to have lower test weights. Those treatments which included the larger applications of nitrogen tended to show higher test weights.

No significant differences were obtained for percent protein of the grain at this location, but there were significant differences in pounds of protein per acre as given in Table 20. In general, those treatments which included 50 pounds per acre of nitrogen and 50 pounds per acre of phosphorus gave higher yields of protein per acre. Those treatments which contained no phosphorus tended to show smaller yields of protein as a result of lower yield.

Manhattan Wheat Test

Precipitation at Manhattan for the entire period was considerably above normal, so apparently moisture was not a limiting factor.

Table 17 shows that highly significant differences were obtained in yields of grain. Those treatments containing the larger applications of nitrogen in combination with 50 pounds of available P_2O_5 per acre gave the higher yields as indicated in Table 8. Treatments containing only 25 pounds per acre of nitrogen or treatments containing no nitrogen gave the smaller yields at Manhattan.

Differences in test weight for the various treatments were not significant at even the 5 percent level, as indicated in

Table 18. However, those treatments which contained the higher rates of nitrogen and no phosphorus tended to have slightly higher test weights.

Differences in percent protein between the treatments were highly significant. Those treatments (13, 16, 15, 14) which included the higher amounts of nitrogen gave greater percentages of protein than treatments containing no nitrogen or those containing a smaller amount of nitrogen in combination with 50 pounds per acre of phosphorus. Significant differences also were obtained between treatments for pounds of protein produced per acre. Those treatments (5, 3, 1, 7, 9, 11) containing little or no nitrogen gave the smallest yield and also produced the least amount of protein. Treatments containing larger applications of nitrogen, alone or in combination with phosphorus, in general gave higher yields and also produced more pounds of protein per acre.

Phosphorus and potassium used alone or together, without added nitrogen, did not significantly increase or decrease the yield, test, weight, percent protein or pounds per acre of protein at Manhattan.

Belleville Wheat Test

Precipitation at Belleville for the entire growing period was much greater than normal so wheat production was not limited by insufficient moisture.

Differences in yield between treatments were found to be highly significant. Treatments containing the larger applications of nitrogen, alone or in combination with phosphorus, gave significantly greater yields than treatments containing no nitrogen or smaller amounts of nitrogen.

Highly significant differences in test weight were obtained between the various treatments as evidenced in the statistical analyses table. There does not seem to be any definite trend as to what is responsible for the significant differences in test weights. The four highest treatments (4, 22, 21, 16) all contained at least 50 pounds of nitrogen and 50 pounds of available P_2O_5 per acre. On the other hand, two of the four lowest ranking treatments also contained 50 pounds of nitrogen and 50 pounds of available P_2O_5 per acre.

It can be noted from Tables 8 and 9 that four of the seven treatments (21, 16, 4, 23) which gave the highest yield also ranked in the upper seven with regard to test weight.

Four of the seven lowest yielding treatments (3, 7, 1, 5) also were included in the seven treatments which produced the lowest test weight.

Only two treatments (15, 24) gave a significant increase in percent protein over the no treatment. Only treatment 10 was significantly lower than no treatment in percent protein. Significant differences between treatments also were obtained for pounds of protein per acre. Only treatments 3, 5 and 7 failed to show significance at either the 5 percent or the 1 percent level of significance.

Mound Valley Wheat Test

Precipitation at this location was approximately five inches below normal for the entire growing period. October and November received only .51 and .10 inch of rainfall, respectively, and March only 1.07 inches, so moisture conditions may not have been ideal for wheat at this location.

One other factor should be pointed out. These plots were damaged by a severe windstorm during ripening and grain losses on some of the plots were very high. Since those plots which received phosphorus in the treatment were more mature, they undoubtedly lost more grain than those plots not receiving phosphorus.

None of the treatments was significantly lower yielding than no treatment and thirteen treatments produced yields significantly greater than no treatment. The higher yielding treatments all included 50 or 100 pounds of nitrogen per acre with 50 pounds of available P_2O_5.

Only plots receiving treatments 9 and 13 produced wheat with a significantly lower test weight than no treatment and only treatments 16, 25, 20, 18 and 22 had test weights significantly higher than the check.

None of the treatments produced grain significantly lower in percent protein than no treatment. Seven treatments were significantly higher in percent protein than the check. The four treatments producing the highest percent protein all included nitrogen but did not include phosphorus. Thirteen treatments were significant in increasing the pounds of protein per acre. These thirteen treatments included all the treatments which had all or part of the nitrogen applied as topdressing. None of the treatments was significantly inferior to no treatment in quantity of protein produced per acre.

Manhattan Oat Test

Rainfall during the oat growing season at Manhattan was far above normal.

All treatments produced higher yields than no treatment with all but three of them being significantly higher. The three treatments which were not significantly higher were 3, 5 and 7 which contained no nitrogen. Plots receiving the 50 and 100 pound applications of nitrogen at time of planting tended to produce more grain than plots receiving only 25 pounds of nitrogen per acre or those plots receiving greater amounts of nitrogen with all or half of it being topdressed.

No significance between treatments was found in test weight of oats at Manhattan but treatments were significantly different in their influence on percent protein.

Only one treatment (3) produced oat grain having a protein content significantly lower than no treatment and only three treatments (15, 19, 20) were significantly higher than no treatment. Treatments producing the higher protein content grain tended to be those treatments containing the greater amounts of nitrogen with or without phosphorus.

Significant differences between treatments were also obtained for pounds of protein per acre. Five treatments failed to be significantly greater than no treatment. Three of these five treatments (3, 5, 7) contained no nitrogen and the other two treatments

(10, 11) contained only 25 pounds of nitrogen per acre.

Belleville Oat Test

Abundant moisture was available for the oat growing season at this location as indicated in Table 3. Significant increases in yields were obtained between treatments. Three treatments (3, 5, 7) yielded less than no treatment with treatment 5 being significantly lower. All other treatments, however, showed significantly higher yields, even at the 1 percent level, than no treatment. All treatments, except treatment 2, which contained 50 pounds of nitrogen per acre were significantly higher yielding than those treatments containing only 25 pounds of nitrogen per acre. Furthermore, all treatments containing 100 pounds per acre of nitrogen were significantly higher yielding than treatments containing only 50 pounds of nitrogen per acre.

Influence on the test weight of oats by the various treatments was significant only at the 5 percent level at this location. Seven treatments gave significantly greater test weights than no treatment. All of these significant treatments, with the exception of treatment 11, contained 50 or 100 pounds of nitrogen per acre in combination with 50 pounds of available P_2O_5 per acre.

Protein content of the grain also was increased due to the various treatments. None of the treatments was significantly inferior to no treatment and eight treatments produced grain having a significantly higher protein content than no treatment. The five treatments which included 100 pounds of nitrogen per acre had a significantly higher protein content than the next ranking treatments.

Highly significant differences between treatments were obtained for pounds of protein produced per acre. Only treatments 3, 5 and 7 failed to show any significance with all other treatments being significant at the 1 percent level. Treatments containing the 100 pound application of nitrogen per acre produced the larger yields, the higher protein content and the larger amount of protein in pounds per acre.

Thayer Oat Test

Although rainfall during March was relatively low at this location, the remaining months of the growing period received a sufficient amount of rainfall to favor high yields of oats.

Differences in yield as affected by the treatments was significant at the 5 percent level only as shown in Table 31. Four treatments produced an average yield lower than no treatment but none was significantly lower. Only treatment 16 gave a significant increase in yield over no treatment.

Eleven treatments gave significantly higher test weights than no treatment. There does not seem to be any definite trend as to what particular fertilizer element or combination of elements is responsible for increasing the test weights in this case. Inspection of Table 25 shows that four of the five treatments which included 100 pounds of nitrogen per acre were not significantly different than the no treatment in regard to test weight.

Protein content of the grain was affected significantly by treatments as shown in the statistical analyses table. Eight treatments produced grain having a significantly higher protein content than the no treatment. A common feature of these eight treatments was that they all included 50 or 100 pounds of nitrogen per acre. None of the treatments produced a significantly lower protein content than no treatment.

Significant differences were also obtained at Thayer for the amount of protein produced per acre. Only six treatments were significantly higher in this respect, with five of the six treatments being those treatments which included 100 pounds of nitrogen per acre. None of the treatments was significantly lower than no treatment in amount of protein produced per acre.

SUPPLEMENTAL COMPARISONS

Other comparisons were also made for the wheat and oats which include the remaining tables and figures. Table 12 is a comparison of yield of wheat at the four locations as influenced by the application of phosphorus. The yield indicated under the first column includes the mean of treatments 3, 4, 7, 8, 10, 12, 14 and 16 for each location. Since each of these treatments was replicated four times, each mean listed is the average of 32 values. The second column for this table includes the mean of all those treatments which did not include phosphorus.

Differences due to the inclusion of phosphorus in the treatments was relatively small at Manhattan and Belleville. The inclusion of 50 pounds of available P_2O_5 per acre gave an average increase from 35.9 bushels to 47.5 bushels per acre at Hutchinson, and from 8.4 bushels to 12.4 bushels at Mound Valley. Differences at Mound Valley may have been greater had it not been for the windstorm mentioned previously.

A similar comparison is made in Table 13 showing the influence of 25 pounds of added K_2O per acre on the yield of wheat. It is noted from this table that the inclusion of potassium apparently had very little influence on the yield at any location.

Since these two tables just discussed compare only mean values of treatments with and without phosphorus and potassium, it was necessary to show the effects these elements had on yields when used in combination with the three rates of nitrogen. The effects of added phosphorus when used with the three rates of nitrogen are shown in Figs. 1, 2, 3 and 4.

Fig. 1, for the experimental field at Hutchinson, shows that for all rates of nitrogen added (0, 25, 50 and 100 pounds per acre) the inclusion of phosphorus gave pronounced increases in yield. The greatest influence of phosphorus, as indicated by this table, appears to be at the 0 and 50 pound rate of application of nitrogen.

The data for the Manhattan test as given in Fig. 3 and for the Belleville test given in Fig. 4 do not show such marked increases due to the inclusion of phosphorus in the treatment. At Manhattan the addition of 50 pounds of phosphorus per acre gave very small increases at the 0, 25 and 50 pound level of added nitrogen, but gave no increase in yield at the 100 pound level of added nitrogen. The inclusion of phosphorus at Belleville gave practically no increase in yield at any level of added nitrogen.

Increases in yields of wheat at Mound Valley due to added phosphorus show a steady and very pronounced increase with increasing amounts of added nitrogen as shown in Fig. 2. It is also indicated by Fig. 2 that treatments containing nitrogen but no phosphorus were quite ineffective in increasing yields of wheat.

Figs. 5, 6, 7 and 8 show the response due to added potassium at the three levels of added nitrogen.

Figs. 7 and 8 for the Manhattan and Belleville fields show practically no differences in yield due to the inclusion of potash at any increment of applied nitrogen. Fig. 6, for the Mound Valley test, shows that the inclusion of potassium increased yields slightly at the 50 and 100 pound rate of added nitrogen but showed no difference in yield at the 0 or 25 pound rate of added nitrogen.

At Hutchinson the addition of potash gave a considerable increase in yield when no nitrogen was applied, but showed practically no difference in yield at the 25 and 50 pound rate of added nitrogen. When potash was included with the 100 pound application of nitrogen there was a small tendency to decrease the yield. The increase due to 25 pounds per acre of potassium when no nitrogen was added was probably because the soil was deficient in readily available potassium. When nitrogen was also added the ammonium ion of the ammonium nitrate compound probably effected the release of some of the fixed potassium and thereupon the potassium requirements of the plants were satisfied by this release.

Table 28 presents a comparison of oat yields as affected by the addition of phosphorus. Here again the figures indicated in the first column are the means of those treatments (3, 4, 7, 8, 10, 12, 14, and 16) which included 50 pounds of available P_2O_5 per acre. The second column includes the means of those treatments not containing phosphorus. Each yield listed is the average of 24 values. As this table indicates, there was practically no response at Manhattan or Thayer on oat yield due to the inclusion of phosphorus in the treatments. Including a phosphatic fertilizer at Belleville tended to give a slight increase in yield over those treatments not containing phosphorus.

The response of oat yield due to potassium is given in Table 29. It is readily seen that the inclusion of potassium in the treatments had practically no effect on the yield of oats at any location.

Yields of wheat and oats as affected by various amounts of nitrogen added are presented in Tables 14 and 30. The data here suggest that the largest increments in yields of wheat are obtained with 50 pounds per acre of added nitrogen. Application of 100 pounds of nitrogen per acre gave slightly larger yields than the 50 pound rate at all locations except Hutchinson. The decrease in yield of wheat at Hutchinson due to the 100 pound rate of added nitrogen was what could be expected because of the past cropping system.

Similar data for the oat tests are presented in Table 30. At Belleville and Thayer, additional increments of nitrogen tended to give increases in yield. At Manhattan, however, the 100 pound rate of added nitrogen was practically the same as the 50 pound rate. An explanation of these results at Manhattan might be that prior to 1948 the land on which these plots were located received large applications of manure.

The effect of time and method of applying 50 pounds of nitrogen per acre on the yield of wheat and oats is given in Tables 15 and 16. Each yield listed is the average of the means for all locations. Since the maximum difference in yield of wheat as affected by time of application of 50 pounds per acre of nitrogen is only 1.4 bushels per acre, it is apparent that no one time or method is advantageous over any other with regard to yield as indicated by the results of this experiment.

The same comparison for yield of oats tends to show a slight advantage in applying the 50 pounds of nitrogen per acre at seeding time.

Since additional expense and time are required for top-dressing, it appears obvious that it would be more profitable to apply all fertilizer at seeding time, as far as yields are concerned, based on the results of this experiment.

Rank correlations of the treatments between locations were determined for the yield and test weight of wheat and for the yield of oats. Although there were some significant shifts in the rank of treatments as they affected wheat yields, there was a significant rank correlation between each pair of locations except Hutchinson and Belleville.

In only one instance was there a significant correlation among the ranks of treatments at the four locations as they affected the test weight of wheat. This one instance was a significant negative correlation between Manhattan and Hutchinson. In view of this, no general statement can be made as to which treatments produce wheat having a superior or inferior test weight.

Significant rank correlations for treatments between locations were obtained in every case for yield of oats. These correlations were generally higher than the rank correlations for wheat yields, indicating that the oat treatments interacted less with locality.

SUMMARY AND CONCLUSIONS

Wheat Experimental Plots

1. Highly significant differences in yields were obtained between treatments at all locations.

2. Treatments 1 (0-0-0), 3 (0-50-0), and 5 (0-0-25) gave relatively poor yields at all locations. Treatment 7 (0-50-25) was poor except at Hutchinson where it ranked sixth and was not significantly lower yielding than the highest ranking treatment.

3. Treatments 14 (100-50-0), 23 (25, 25-50-25), and 24 (25, 25-50-25) were always in the top ten with regard to average yield. No other treatments had this feature.

4. At Mound Valley, treatments 16 (100-50-25) and 14 (100-50-0) were so superior in promoting yield that there was a statistically significant "break" between these two and the lower ranking treatments.

5. At Belleville, treatments 1, 3, 5, and 7 (no nitrogen treatments) were significantly inferior to the lowest ranking among the other 21 treatments.

6. The inclusion of a phosphatic fertilizer showed very little increase in yield at Manhattan and Belleville but gave pronounced increases at Hutchinson and Mound Valley, especially when in combination with 50 pounds per acre of nitrogen.

7. Application of potassium showed very little effect on the yield of wheat at any location except Hutchinson where it gave a marked increase when no nitrogen was added.

8. Increasing the amount of nitrogenous fertilizer gave

small increases in yield at all locations except Hutchinson where 100 pounds per acre of added nitrogen decreased the yield.

9. Statistically significant treatment differences on test weight were obtained at all locations except Manhattan. However, no particular treatments stand out as in the case of wheat yields.

10. In general, treatments which included 100 pounds of nitrogen per acre produced wheat grain of a higher protein content. Only once did the 100 pound application of nitrogen at Hutchinson and Belleville produce grain having a significantly higher protein content than no treatment. At Manhattan the treatments containing 100 pounds of nitrogen per acre were all significantly superior to every other treatment in producing a high protein content grain.

11. Treatments 18, 14, and usually 16 (except at Hutchinson) were always in the ten top ranking treatments in pounds of protein produced per acre.

Oat Experimental Plots

1. Significant treatment effects on yield of oats were obtained at all locations.

2. Treatments 8 (50-50-25), 13 (100-0-0), 14 (100-50-0), 15 (100-0-25) and 16 (100-50-25) were in the upper seven in order of average yield at all three locations.

3. Treatments 1, 3, 5 and 7 (no nitrogen treatments) were always in the lower half of the array of mean yields and at Manhattan and Belleville these treatments made up the four lowest ranking treatments.

4. Treatment differences were not too effective in producing significant changes in test weight of oats.

5. There was a pronounced location x treatment interaction for test weight of oats. At Thayer, four of the five treatments containing 100 pounds of nitrogen were not significantly better than no treatment. At Belleville, two of these five treatments were significantly better than no treatment and at Manhattan, the treatment effects on test weight were statistically insignificant.

6. In general, plots receiving 100 pounds of nitrogen per acre ranked high in protein content. This was especially true at Belleville where the plots receiving 100 pounds of nitrogen were significantly superior to every other treatment in percent protein of the grain. At Manhattan, however, three of the treatments containing 100 pounds of nitrogen failed to produce significantly higher protein content grain than no treatment.

7. At no location did the addition of phosphorus give any appreciable increase or decrease in the yield of oats. The same was true for potassium.

8. Treatments 13, 14, 15, and 16 always ranked in the upper five treatments with regard to pounds of protein produced per acre.

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INVESTIGATION OF SMALL GRAIN RESPONSE TO VARIOUS APPLICATIONS OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZERS ON SEVERAL KANSAS SOILS

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Four groups of wheat and three groups of oat experimental plots were established at various locations in the eastern half of Kansas. The two main objectives were:

(1) To obtain information relative to the best time, rate and method of applying nitrogen fertilizers to wheat and oats.

(2) To obtain additional information concerning the use of phosphorus and potassium in combination with various rates of nitrogen.

The experimental plots were established in a randomized block design. Chemical analyses of the soil were made for each location. Yield in bushels per acre, test weight, percent protein of the grain and pounds per acre of protein were determined for each individual plot at each location. The data were then analyzed statistically and comparisons made.

The results of the experiment are summarized as follows:

Wheat experimental plots:

(1) Highly significant differences were obtained in yields of wheat at all locations. In general, treatments which included a combination of nitrogen and phosphorus produced the highest yields of grain.

(2) Applications of potassium had very little effect on yield except at Hutchinson where it gave a marked increase when no nitrogen was added.

(3) Significant differences in test weight were obtained at all locations except at Manhattan. However, no particular treatments stand out as in the case of yields.

(4) In general, treatments which included 100 pounds of nitrogen per acre produced grain of a higher protein content.

(5) Treatments which produced the higher yields per acre also produced the greater amount of protein per acre.

(6) Time of application of the nitrogen fertilizers had very little effect on the yield of grain.

Oat experimental plots:

(1) Statistically significant treatment effects were obtained for yield, percent protein, and pounds of protein per acre at all locations. Treatment differences in test weights were not significant at Manhattan.

(2) Treatments containing the larger applications of nitrogen produced the highest yields and in general grain of a higher protein content. These same treatments also resulted in more pounds of protein per acre.

(3) At no location did the inclusion of phosphorus or potassium result in any appreciable increase or decrease in the yield of oats.

(4) Time of application of nitrogen tended to favor its application at planting time so far as yield of grain was concerned.