RESPONSE OF WHEAT TO NITROGENOUS FERTILIZERS IN THE LOW RAINFALL AREAS OF KANSAS

By

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INTRODUCTION

Great progress has been made in comparatively recent years in methods of farming in the low rainfall areas of Kansas and the United States, but there are still many unanswered questions about crop production in the dry farming areas. The first of these unanswered questions is just how stable is the fertility and how permanent the productivity of the dry land soils. These western Kansas soils are, for the most part, deep, fertile soils, recognized especially as being very rich in mineral nutrients. Although the organic matter content of these soils probably is lower than in soils of more humid regions, the nitrogen content of this organic matter is relatively higher. The nitrogen, however, is not as plentiful as are the mineral plant foods, and, consequently, would be the first limiting factor in production from the standpoint of plant nutrients.

The cropping system in western Kansas largely has been one of growing cash grain, principally wheat, either continuously or alternated with summer fallow. With the improved water conserving tillage practices and improved crop varieties, larger yields are being produced and removed, and with them larger amounts of nitrogen and other nutrients are being removed from the soil. The question has been in the minds of many as to whether a nitrogen deficiency might not already be one of the chief limiting factors in crop production in the low rainfall area. Although crop yields in years of favorable precipitation are ordinarily considerably higher than in the higher rainfall areas of the state, might they not be still higher if adequate nitrogen were available for plant use?

In the higher rainfall area of eastern Kansas the nitrogen and organic matter of soils can be maintained by growing soil improving legume crops, such as alfalfa or clover, in rotation. However, in the dry farming areas of the state the choice of crops is limited by the rainfall and this poses the question as to what the future of the low rainfall areas may be as concerns soil productivity.

It was for the purpose of securing additional information relative to the soil fertility level in the low rainfall area and the feasibility and best method of using nitrogen fertilizer in helping solve the problem, that this study of the response of wheat to applications of nitrogen fertilizer, both from the standpoint of yields and protein content of the grain, was started.

REVIEW OF LITERATURE

A review of literature on the subject of agriculture in the low rainfall areas of the world brings to light the fact that questions as to the declining fertility of the soils in the dry farming regions; the importance of fertility, especially available nitrates, in relation to available soil moisture; and possible answers to the problem of depleting soil fertility are not of recent origin but have been pondered for many years. Literature indicates that studies on these subjects were started many years ago, even before very much land in the truly low rainfall areas of Kansas was under cultivation. However, investigations by various workers in different areas in the low rainfall or dry farming regions of the United States as well as other countries did not always agree.

Some investigators (3, 32) indicated that there was little or no loss of nitrogen from the soils in semi arid regions through crop production. Stewart (32) stated that studies showed that the soils of the Cache Valley in Utah actually increased in nitrogen after 40 years of alternate crop and fallow. Whether this organic nitrogen was the result of vigorous bacterial action or drawn up from below was uncertain. Bradley (3) found in eastern Oregon that cropped dry farm soils as compared with virgin land showed no loss of nitrogen after 25 years of cultivation. On the other hand, Sievers and Holtz (28) have shown that losses of nitrogen from cropped land as compared with virgin soil in eastern Washington amounted to 22.1 percent; although, these investigators indicated that it is possible in the extremely arid regions where nitrogen losses through cropping are light, there may be sufficient free fixation of nitrogen to provide for the maintenance or even increase of the soil organic nitrogen. This view was shared by Gainey, Sewell, and Latshaw (15) who cite cases where nitrogen losses after many years of cultivation in the low rainfall areas of the United States were slight or nil. This, they stated, indicates the existence of some-nitrogen-compensating factor such as free fixation. These same investigators, in a report on their studies, present data by Swanson and Latshaw (33) on the determination of nitrogen content of virgin and cultivated soils of Kansas. The data presented indicate that as the rainfall decreases, the losses of nitrogen under grain cultivation decreases.

Many investigators (30, 19, 2, 34) have made studies which indicate that prolonged periods of dry land farming of semi arid soils results in a loss of soil organic matter and consequently of nitrogen. Loss of nitrogen and organic matter from semi arid cultivated soils is one of the major problems of dry land agriculture stated Bracken and Greaves (5), and the depleting characteristics of alternate wheat and fallow make it possible that nitrogen rather than moisture will become the limiting factor of crop production in certain dry farming areas. Alway (2) reports that studies at the Indian Head Experiment Farm in Saskatchewan show that continuous cropping with wheat, oats and barley with fallow every third year has caused a loss of about one-third of the original nitrogen content. A study made by Thatcher (34) adds further evidence to the other data indicating marked decreases in nitrogen and organic matter content of semi arid soils after having been cultivated for a period of years. He also shows that the loss is not due entirely to the removal by the crop, but a large percentage of the nitrogen is lost through leaching, through water and wind erosion, but chiefly through the process whereby oxidizing and denitrifying bacteria convert the nitrogen into gases, which in turn escape into the air. Because these processes are speeded up by the practice of fallowing Jones and Yates (19) conclude, and Alway and Trumbul (1) agree, that wherever the summer fallow system prevails in the growing of small grains the steady decrease of soil organic matter and nitrogen in significant amounts is a fact.

Decreases in organic nitrogen and organic matter in the semi arid soils as is indicated by a majority of the investigators cited above would no doubt affect the available nitrates. Many studies have been made as to what extent available nitrates are deficient in these soils as manifested by crop yields and quality of crops. There are even those workers who maintain that making nitrogen available is the most important function of summer fallowing, although most investigators in their literature emphasize the value of summer fallowing from the standpoint of storing moisture for use by the crop and minimize the role of this system of farming as a means of making nitrates available to the subsequent crop. Siever and Holtz (29) are two of the investigators most emphatic in pointing out that the more or less common belief that summer fallow tillage is valuable for the sole purpose of utilizing a two years supply of precipitation to grow one crop is not justified on the basis of field moisture studies made in eastern Washington. They further state that where the annual precipitation is 18 inches or more, summer fallow tillage is not necessary so far as the total moisture supply is concerned, and its principal value under such a condition is the greater supply of nitrates made available to the new crop. Other investigators (6, 36) indicate that one of the effects of summer fallowing is a greater liberation of plant food.

There have been numerous experiments conducted in the low rainfall areas to study the importance of available nitrates on the growing of crops, both yield and quality. A study of the urine spots on pastured wheat in central and western Kansas by Gainey and Sewell (16) indicated the possibility that available nitrogen may be a limiting factor in hard winter wheat production. Their data show that wheat from the urine spots made 2.6 times the total growth, containted 1.8 times as much nitrogen per unit weight and had actually assimilated 4.68 times as much nitrogen per plant as that from the field at large. In a subsequent study of spotted wheat fields, Gainey, Sewell, and Myers (17) reported that wheat from the urine spots yielded considerably more, provided there was adequate moisture, and the grain was significantly higher in protein content than that from the field at large. These investigators showed the differences in the crop on the spots was due to the greater supply of available nitrogen by producing apparently identical spots by the application of nitrogen fertilizer. Many of the soils studied by those workers had adequate supplies of total nitrogen and yet apparently did not supply all the available nitrogen which the growing wheat could utilize. Call (8) and Buckman (6) also found that wheat yields on the dry land farms were closely correlated with the supply of nitrates in the soil. In their investigations in eastern Washington, Siever and Holtz (29) found that, where wheat was alternated with peas in a continuous-cropping system, the yield of wheat after peas is generally as good or even better than after common summer fallow. These workers credit this increased yield to the fixing of nitrogen in the soil by the legume crop, making nitrates available to the succeeding wheat crop. Siever and Holtz also report that in eastern Washington increases in yields of wheat can be obtained by application of nitrogenous fertilizer, and suggest that a cheap supply of nitrogenous fertilizer may make continuous cropping of cereals in the low rainfall areas practicable, thus largely eliminating the necessity of summer fallowing. That available nitrogen rather than moisture may often be the limiting factor in wheat production, even though the supply of moisture is relatively small, is indicated by evidence which these investigators present to show that water is used more efficiently by the crop when fertility is not a limiting factor. They show that the number of pounds of water required to produce one pound of dry matter in the form of wheat is directly influenced by the available plant food in the soil. They present the following data:

Cropping System	Number pounds water required to grow one pound dry matter in form of wheat
After wheat	478
After Oats	400
After Corn	360
After fallow	341
After clover	310

These investigators conclude that the higher the available nitrogen, the less water it takes to grow the crop. However, they state that excessive available nitrogen often results in excessive tillering which demands a large supply of moisture, and as a consequence the crop suffers from drought and depresses the yield.

This yield response of wheat to large amounts of available nitrate nitrogen in the soil, or to the application of nitrogenous fertilizer, has been demonstrated by the studies of a number of investigators. Notably among these are the experiments conducted by Neidig and Snyder (21), Sievers and Holtz (27, 28, 29) and Vandecaveye and Baker (37). Vandecaveye and Baker reported that in a study they made, the yield of wheat was increased by three or four bushels for every 100 pounds of sodium nitrate fertilizer used. Doneen (12) also reported large increases in yield of wheat from the application of nitrogenous fertilizer to the soils in the Palouse area of eastern Washington. Alway (2) reported that at the Indian Head Experimental Farm in Saskatchewan the application of 100 to 200 pounds of sodium nitrate per acre caused no increase in the yield of wheat. The response that wheat may make to nitrogenous fertilizer is indicated by the report of Sievers and Holtz (29) that the less fertile hill tops in eastern Washington can be made to yield almost equally with early summer fallow land on the better slopes by the application of nitrogenous fertilizer. The literature cited would indicate that favorable response in yield of wheat to nitrogenous fertilizer can be expected if the fertilizer is judiciously applied.

Most investigators show that available nitrogen also affects the protein content of the grain although old literature reveals the fact that some investigators maintained that climate alone is responsible for protein content of the wheat grain. However, the literature reviewed showed that most investigators found that available nitrates in the soil and climate both to be important in growing high protein wheat. In addition to research workers already mentioned as finding a close correlation between nitrates in the soil and protein content of wheat, others substantiate these findings including Siever and Holtz (29) who state that low protein wheat is grown on soil low in available nitrogen. Doneen (12) showed that protein content as well as yield was influenced by the application of nitrogenous fertilizer during the growing period. This study by Doneen showed that applying the nitrogenous fertilizer after the tillering stage gave a higher nitrogen content in the grain without noticeably increasing the yields. It was also shown that excessive nitrates in the fall stimulates growth, which uses up valuable moisture leaving inadequate moisture for the crop during the critical spring period. A study made by Davidson and LeClerc (10), although made in Kentucky, gives an indication as to the response of wheat to applications of nitrogenous fertilizer, provided there is adequate moisture and naturally available nitrates are inadequate. These investigators applied nitrogen to the growing wheat crop at different stages of growth and found that when the fertilizer was applied at the very early state, that is, when the crop was about two inches high, growth was stimulated and resulted in increased yields; when applied at the time of heading the protein content of the grain was increased, but vegetative growth was not affected; while the application of nitrogen when the wheat was in the milk stage had no effect either on yield or protein content. Gainey, Sewell, and Myers (17) found that surface application of nitrogen to wheat may result in one of the following conditions, depending on the time and quantity of nitrogen applied:

1. No appreciable effect with light summer or fall applications.

2. Increased yield and decreased protein content with medium fall and light to medium early spring applications.

3. Increased yield and increased protein content with medium to heavy fall and early spring applications.

4. Decreased yield and increased protein content with very heavy fall and early spring applications.

5. Marked increase in protein content and slight effect upon yield with light to medium late spring applications.

METHODS OF EXPERIMENTATION

The experimental work reported in this thesis was conducted on the basis of cooperative tests on farms in western Kansas during the seasons of 1946-1947 and 1947-1948. Briefly, the tests consisted of making nitrogenous fertilizer applications on wheat at varying rates and at different dates for the purpose of studying the response of the wheat to the fertilizer.

The procedure for testing was outlined by the writer and the tests established on the farms of the cooperating farmers by the county agents. The county agents further cooperated by harvesting the wheat from the plots and sending it to the Department of Agronomy of Kansas State College where it was threshed and the yields calculated under the supervision of Professor A. L. Clapp. Protein determinations were made by the Department of Milling Industry.

The fertilizer used in these tests was 32.5 percent ammonium nitrate and was supplied at no charge by the Spencer Chemical Company, Kansas City, Missouri.

Each individual test, consisting of one series of plots, was established on soil as nearly uniform as possible in every way. The tests consisted of a series of eight plots, one plot for each rate and each date of application. The plots were one rod wide by four rods long in size.

The fertilizer was in most cases applied with a sodium chlorate spreader. In a very few instances the fertilizer was broadcast by hand; however, special care was taken to be accurate when this method was used. Every effort was made to eliminate any possibility of error.

Tests included broadcasting 75, 150, and 300 pounds of ammonium nitrate per acre on the stubble prior to plowing; the application of 150 pounds of the ammonium nitrate to the wheat as a winter top dressing in December; and the application of 75, 150, and 225 pounds of ammonium nitrate as a spring top dressing in March. The order of the plots in each test was check plot, 75-pound plow-under, 150-pound plow-under, 300-pound plow-under, 150-pound winter top dressing, 75-pound spring top dressing, 150-pound spring top dressing, and 225-pound spring top dressing (Fig. 1).

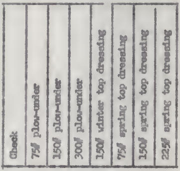

Fig. 1. Arrangement of one by four rod plots in the wheat fertility tests.

Usually only one test was established in a county. In a few counties, tests were conducted on both summer fallowed land and continuously cropped land during the 1946-1947 season. The tests during 1947-1948 season were conducted only on continuously cropped land. Comparisons between dates of application were made at the 150-pound rate.

The rod row method was used in harvesting the wheat. Ten one rod row lengths of wheat were harvested from each plot.

A comparatively large number of tests were established, but the number of tests available for study was reduced considerably for various reasons, especially in the 1948 season when several tests were completely destroyed by hail.

Precipitation during the 1946-1947 season was considerably above average in the counties in which the tests were conducted. During the 1947-1948 season the precipitation was approximately average. Therefore, neither season had the deficiency of precipitation which often occurs in this area, and so the results in these tests may not be typical of those that might normally be expected. For this reason, this study should probably be considered a progress report and not conclusive in its findings.

The precipitation data used in this study were obtained from the climatological data assembled by the United States Department of Commerce Weather Bureau.

RESULTS OF EXPERIMENTS

The data secured from two years of testing the use of nitrogenous fertilizer on wheat in the low rainfall areas of western Kansas were tablulated in a manner which would permit a study of the response of wheat to applications of available nitrogen under dry farming conditions. The response was studied both from the standpoint of yield and protein content of the grain. As evidence of what can normally be expected from the application of nitrogenous fertilizer to wheat in far western Kansas, it probably can be said that this study is not entirely typical or conclusive, since during the 1946-1947 season the precipitation was considerably above normal (Table 1). The precipitation data were obtained from the Kansas section of the Climatological Data of the United States Weather Bureau, and reveal the fact that during the period from June 1, 1946, through May 31, 1947, the counties in this study received considerably more than the average annual precipitation. The table gives the average annual rainfall for each county and the actual amount received during the 12-month period mentioned. Some of these counties received almost twice their average rainfall.

During the 1947-1948 season, the counties in which wheat fertility studies were conducted received very near average precipitation for those counties; however, there was not the deficiency of soil moisture which is very often the situation. Therefore, this study can be considered only as a progress report and not conclusive evidence as to the value of the use of commercial nitrogen as a wheat production practice in the dry farming area of the state.

The data for each of the two seasons were studied separately, and the influence of the various treatments as related to yield and protein are reported separately and in comparison one to the other.

Table 1. Monthly precipitation during the period June 1, 1946, through May 31, 1947, at the weather stations located in counties in which the wheat fertility tests were conducted.

Weather station	1946 - 1947												Total for 12 mos.	Average annual precip.
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May		
Hill City Graham County	2.11	1.98	1.43	8.10	6.29	2.38	0.00	0.62	0.45	2.16	1.17	4.26	30.95	20.26
Jetmore Hodgeman County	1.48	0.22	1.75	4.19	6.99	2.32	T	0.45	0.05	0.98	2.40	4.46	25.29	20.49
Liberal Seward County	0.89	1.83	4.10	1.34	8.44	3.35	0.03	0.54	0.04	0.79	3.18	5.13	29.56	20.05
Hoxie Sheridan County	2.62	4.77	0.54	4.29	7.55	2.85	T	0.55	0.53	0.95	1.18	2.87	28.70	20.11
Syracuse Hamilton County	1.71	0.44	1.29	1.71	2.98	3.43	T	0.37	0.22	1.61	1.83	4.68	20.27	17.67
Goodland Sherman County	1.85	5.20	0.53	0.66	1.67	2.63	0.01	0.29	0.31	0.68	1.50	3.63	18.96	18.70
Garden City Finney County	4.16	0.11	1.86	3.29	6.09	3.93	T	0.44	0.09	1.22	2.50	4.45	28.14	18.45
Greensburg Kiowa County	0.72	0.65	2.49	0.54	3.63	2.97	0.12	0.64	0.05	2.62	5.62	3.79	23.84	23.14
Elkhart Morton County	2.55	2.10	3.13	2.83	4.70	2.75	0.01	0.48	T	1.12	1.62	4.89	26.18	16.47
Lakin Kearny County	2.85	0.11	3.95	3.80	5.90	4.04	T	0.43	0.16	1.11	2.13	4.49	28.96	15.85
Tribune Greeley County	1.91	3.34	1.43	0.60	3.60	4.27	T	0.34	0.51	2.25	1.50	6.05	25.80	15.84

Table 2. Precipitation by periods from June 1, 1946, through May 31, 1947, at the weather stations located in counties in which the wheat fertility tests were conducted.

Weather Station	June 1 through Aug. 31, 1946	Sept. 1, 1946 through Feb. 28, 1947	March 1 through May 31, 1947	Total
Hill City Graham County	5.52	17.84	7.59	30.95
Jetmore Hodgeman County	3.45	14.0	7.84	25.29
Liberal Seward County	6.82	13.74	9.10	29.66
Hoxie Sheridan County	7.93	15.77	5.00	28.70
Syracuse Hamilton County	3.44	8.71	8.12	20.27
Goodland Sherman County	7.58	5.57	5.81	18.96
Garden City Finney County	6.13	13.84	8.17	28.14
Greensburg Kiowa County	3.86	7.95	12.03	23.84
Elkhart Morton County	7.78	10.77	7.63	26.18
Lakin Kearny County	6.90	14.33	7.73	28.96
Tribune Greeley	6.68	9.32	9.80	25.80

1947 Yield Studies

Plow-under Experiments. A study of the results of applying ammonium nitrate to wheat by plowing under the fertilizer prior to seeding reveals that all treatments on continuously cropped wheat gave quite large increases over no treatment with the exception of one test, that being in Hodgeman County (Table 3).

Table 3. The response in yield of wheat on continuously cropped land to the application of 150 pounds of ammonium nitrate plowed under prior to seeding. 1947.

County	No treatment	150# ammonium nitrate (32.5%) plowed under	Increase in bushels
Graham	8.9	19.2	10.3
Hodgeman	29.8	31.2	1.4
Seward #1	24.9	36.4	11.5
Seward #2	24.2	40.4	16.2
Sheridan	21.7	40.8	19.1
Average	21.9	33.6	11.7

The Hodgeman test gave an increase in favor of the treated plot of only 1.4 bushels per acre. Treatment in the other tests gave increases ranging from 10.3 bushels in Graham County to 19.1 bushels in Sheridan County. In attempting to account for the variations in response to the same treatments in different locations, the possibility of the influence of moisture was studied.

The precipitation received in each county concerned during the 12-month period from June 1, 1946, to May 31, 1947, was studied. There was no apparent relationship between yield variations and total precipitation, since the total precipitation did not vary by counties in the same order as did the wheat yields. Also, all counties received considerably above average precipitation, no county receiving less than 25 inches which should be adequate to produce an above average wheat yield. However, there was an apparent trend for the response of wheat to the nitrogen treatments varying with the rainfall received during the three-month period, June through August, prior to seeding. Unlike the situation for the 12-month period, the total precipitation from June 1 through August 31 was not above average. According to Flora (42) western Kansas receives an average of approximately 8 inches of moisture between June 1 and August 31 (Fig. 2).

In 1946 the counties listed in Table 3 varied from about average to considerably below in rainfall during this period (Table 2). The response to the plow-under applications of nitrogen varied in the same order as did the total amount of moisture received during the summer season (Table 4). In Hodgeman County where the wheat yield increase due to the fertilizer was only 1.4 bushels; rainfall during the three-month period immediately prior to seeding was only 3.45 inches. On the other hand Sheridan County had a total of 7.93 inches of precipitation during this period and here the increase in yield of wheat for the fertilized plot over the untreated plot was 19.1 bushels. The rainfall in Graham County was 5.52 inches and the wheat yield increase 10.3 bushels; while in Seward County the precipitation totaled 6.82 inches and one test resulted in a yield increase for the treatment plot of 11.5 bushels per acre and another an increase of 16.2 bushels.

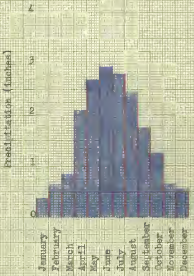

Fig. 2. Seasonal distribution of precipitation for western Kansas

From the data on this test, it would appear that the success of the results that are obtained by the practice of applying nitrogen prior to seeding would depend on whether or not the newly seeded crop had adequate soil moisture to utilize the added available nitrates. All counties received very heavy but similar amounts of rainfall during the fall months and the precipitation was similar in the counties during the remainder of the growing season. The yield of the untreated plot in the Hodgeman test was higher than that in the other tests, which might indicate that the smaller response to treatment may have been due to a higher natural fertility in that soil. However, the application of nitrogenous fertilizer in the spring did result in an increase in yield of almost 10 bushels per acre as revealed by the data presented in Table 6.

Table 4. The relationship between precipitation during June, July, and August, 1946, and response of wheat to plow-under application of 150 pounds of 32.5 percent ammonium nitrate on continuously cropped land.

County	Precipitation June 1 - Aug. 31	Increase in yield due to fertilizer
Hodgeman	3.45	1.4
Graham	5.52	10.3
Seward #1	6.82	11.5
Seward #2	6.82	16.2
Sheridan	7.93	19.1

The plow-under tests on summer fallow (Table 5), on the average gave smaller increases in yield than did the same tests on continuously cropped land, although a test in Seward County gave an 8.5 bushel per acre increase and a test in Hamilton County favored the treated plot by seven bushels per acre. In two tests, Hodgeman #1 and Sherman, there was a slight decrease in yield on plots receiving the application of ammonium nitrate. However, when comparing the yields of the untreated plots, those on the summer fallowed land were considerably higher than those on continuously cropped land. The yields from the fertilized plots on the continuously cropped land compared very favorably with the fertilized plots on summer fallowed soil. These results indicate that available nitrogen rather than moisture was the limiting factor in production in most instances and that the requirements for available nitrogen was met to a considerable extent by nitrates being made available through the practice of fallowing. It should be noted, however, that precipitation was fairly adequate subsequent to planting.

Table 5. The response in yield of wheat on summer fallowed land to the application of 150 pounds of ammonium nitrate plowed under prior to seeding, 1947.

County	No treatment	150# ammonium nitrate (32.5%) plowed under	Increase in bushels
Hamilton	28.2	35.2	7.0
Hodgeman #1	28.2	27.6	-0.6
Hodgeman #2	30.9	34.2	3.3
Seward	33.2	41.7	8.5
Sherman	33.5	32.6	-0.9
Average	30.8	34.26	3.4

Winter and Spring Top Dressings. All comparisons in response of wheat to nitrogen applications at different seasons were made on the basis of 150 pounds of ammonium nitrate per acre. The reason for using the 150-pound rate for comparison was because that was the one rate common to all date treatments, and a study of results indicated that the 150-pound application per acre was adequate to give optimum returns on most western Kansas soils.

The response that wheat made to the application of 150 pounds of ammonium nitrate as a winter top dressing on continuously cropped land varied all the way from a decrease of two bushels per acre to a yield increase of 14.3 bushels (Table 6).

Table 6. The response in yield of wheat on continuously cropped land to the application of 150 pounds of 32.5 percent ammonium nitrate applied as a winter top dressing and as a spring top dressing. 1947.

County	No treatment	Winter top dressing	Spring top dressing
Finney	30.8	33.0	36.3
Hamilton	35.0	34.7	41.7
Hodgeman	29.8	27.8	39.6
Kiowa #1	25.9	24.6	26.1
Kiowa #2	17.5	31.7	25.1
Sheridan	21.7	36.0	43.8
Average	26.67	31.3	35.43

The instances where the response to treatment was a slight loss in yield or an insignificant increase, namely the Finney, Hamilton, Hodgeman, and Kiowa #1 tests, were those where the yield of the untreated plots was already quite high. The untreated plots in these cases yielded from 25.9 to 35 bushels per acre. The yields of the untreated plots in the Kiowa #2 and Sheridan tests were considerably lower and here the increases due to the fertilizer was in excess of 14 bushels per acre in both instances. The yield of the untreated plots would indicate that the soils on which large increases were affected by treatment were lower in fertility, at least in respect to available nitrogen. For further evidence that the natural fertility of the soil in Kiowa #1 may be responsible for the negative response to fertilizer, the results of the rate of application of ammonium nitrate as a spring top dressing were studied (Table 12). This table reveals that at the 75-pound per acre application the Kiowa #1 gave an increase of 6.5 bushels per acre, the 150-pound application gave no increase, and the 225-pound application actually depressed the yield, indicating that if available nitrogen was deficient in this soil it apparently was not deficient to the same degree as in the other soils studied.

In the same tests where the winter top dressing application of the ammonium nitrate resulted in no increase in yield, the same rate of fertilizer applied as a top dressing in March gave increases of from 5.5 to 9.8 bushels per acre (Table 6). One exception to this was the Kiowa #1 test which gave no increase either from the winter application or spring application. The greatest response to the spring top dressing was in Sheridan County where the yield on the treated plot was 43.8 bushels per acre as compared to 21.7 bushels for the untreated plot, an increase of 22.1 bushels. The response to the spring top dressing was very similar in all tests except the Kiowa #1 and Sheridan tests. On the whole the application of ammonium nitrate as a spring top dressing gave better response than did the fertilizer applied as a winter top dressing on continuously cropped land as far as yields were concerned.

Table 7. The response in yield of wheat on summer fallowed land to the application of 150 pounds of 32.5 percent ammonium nitrate applied as a winter top dressing and as a spring top dressing. 1947.

County	No treatment	Winter top dressing	Spring top dressing
Hamilton	28.2	31.8	30.9
Hodgeman #1	28.2	29.4	28.7
Hodgeman #2	30.9	29.9	25.5
Morton	42.0	40.8	39.0
Average	32.32	32.97	31.0

Where wheat growing on summer fallowed land was top dressed with 150 pounds of ammonium nitrate per acre the yields from the untreated plots were quite high and the fertilizer treatment affected the yield very little (Table 7). The test in Hamilton County resulted in an increase of 3.6 bushels in favor of the winter top dressing over the check plot and 2.7 bushels increase for the spring top dressing. The Hodgeman #1 test showed no significant response to treatment, while both the Hodgeman #2 and Morton County tests showed decreases due to the application of the fertilizer. These reductions in yield due to the fertilizer were more pronounced on plots where the nitrogen was applied as a spring top dressing. The reduction in the Hodgeman test being 5.4 bushels and that in the Morton test being 3 bushels per acre.

Plow-under Versus Spring Top Dressing. The number of tests in which the plow-under method of applying the fertilizer could be compared with applying the nitrogen as a spring top dressing was limited; however, the data are presented in Tables 8 and 9. Table 8 reveals that on continuously cropped land the application of 150 pounds of ammonium nitrate gave excellent response in increased wheat yields, both when applied by the plow-under method and as a spring top dressing. In these particular tests the spring top dressing resulted in higher yields than did the plow under treatments. The fact that the spring top dressing treatment increased the yield of wheat in the Hodgeman County test from 29.8 bushels to 39.6 bushels serves as evidence that the small increase of 1.4 bushels affected in this same test by the plow-under application was not due to the fact that this particular soil was already completely adequate in fertility.

Table 8. The response in yield of wheat on continuously cropped land to the application of 150 pounds of ammonium nitrate plowed under prior to seeding and as a spring top dressing. 1947.

County	No treatment	Plowed-under	Spring top dressing
Hodgeman	29.8	31.2	39.6
Sheridan	21.7	40.8	43.8
Average	25.75	36.0	46.7

Table 9. The response in yield of wheat on summer fallowed land to the application of 150 pounds of ammonium nitrate plowed under prior to seeding and as a spring top dressing. 1947.

County	No treatment	Plowed-under	Spring top dressing
Hamilton	28.2	35.2	30.9
Hodgeman #1	28.2	27.6	28.7
Hodgeman #2	30.9	34.2	25.5
Average	29.1	32.3	28.36

In comparing the results of the two methods of applying the fertilizer on summer fallow wheat, the trend is reversed from that on continuously cropped wheat, although neither gave very high returns over the untreated plots (Table 9). The three plots of spring top dressing on fallow resulted in one plot showing a small increase, one with no significant increase, and one plot with a sizeable decrease of 5.5 bushels per acre. The plow-under plots resulted in one yield increase of seven bushels per acre, one increase of 3.3 bushels, and one plot with no significant difference. When considered as a whole the plow-under application gave the better yield returns on fallowed soil.

Rates of Application. A study was made of the response of wheat to the various rates of nitrogen fertilizer applied with a view to learning the amount of elemental nitrogen needed in the low rainfall soils to bring the fertility into balance for highest possible production of wheat. Rate studies were made both on the plow-under tests and spring top dressing, and on continuous cropping and fallow.

The response to the various rates of ammonium nitrate plowed under prior to seeding is shown in Tables 10 and 11. The rates used were 75, 150, and 300 pounds of 32.5 percent ammonium nitrate per acre. The average of all tests on continuous cropping showed a progressive increase in yield with increases in rate of fertilizer applied, as revealed by the data in Table 10. The increase from the 75-pound treatment over no treatment was approximately 10 bushels per acre. The 150-pound and 300-pound treatments each resulted in an additional four bushel increase, making the total average increase for the heaviest rate of approximately 18 bushels or an increase of practically 100 percent over the 19.9 bushel yield of the untreated plot. When the individual tests are considered, the story is similar but the majority of tests do not favor the 300-pound rate to as great an extent as do the average yields. The Graham County test alone gave an extremely large increase in favor of the 300-pound rate of application, and this one test influences the average results to a great extent. The tests, other than the Graham test, tended to respond with a sizeable yield increase for the 75-pound application. The increases varied from about 9.5 to 13 bushels. The 150-pound application increased the yield of wheat by from two to six bushels over the 75-pound rate. However, in these same tests the 300-pound rate increased the yield as much as two bushels over the 150-pound rate in only one test, and in the Seward #2 test decreased the yield four bushels per acre under that of the 150-pound plot. The test in Graham County is interesting in that the 300-pound application of fertilizer gave by far the best returns, the wheat on the 300-pound plot yielding 36.6 bushels per acre as compared with 19.2 bushels for the 150-pound plot and 13.7 bushels for the 75-pound plot. An even more interesting fact revealed by the data in Table 10 is that, while the untreated plot in the Graham test yielded only 8.9 bushels per acre as compared with 21.7, 24.2 and 24.9 bushels for the other untreated plots, the application of 300 pounds of ammonium nitrate per acre brought the yield of wheat on the Graham County soil up to substantially the same level as the best yields in the other three tests. This indicates that the Graham test was conducted on soil very low in available nitrogen, due to a low organic matter content or possibly a heavy stubble from the preceding crop tying up the nitrates.

Table 10. The response in yield of wheat on continuous cropping to various rates of 32.5 percent ammonium nitrate plowed under prior to seeding. 1947.

County	No treatment	75# ammonium nitrate	150# ammonium nitrate	300# ammonium nitrate
Graham	8.9	13.7	19.2	36.6
Seward #1	24.9	33.3	36.4	38.4
Seward #2	24.2	38.4	40.4	36.4
Sheridan	21.7	34.7	40.8	42.3
Average	19.92	30.0	34.2	38.4

The data in Table 10, on the whole, seem to indicate that in most cases the application of more than 150 pounds of ammonium nitrate per acre is of doubtful value and that the optimum rate probably is somewhere between 75 and 150 pounds per acre when incorporated into the soil prior to seeding.

Table 11. The response in yield of wheat on summer fallow to various rates of 32.5 percent ammonium nitrate plowed under prior to seeding.

County	No treatment	75# ammonium nitrate	150# ammonium nitrate	300# ammonium nitrate
Hamilton	28.2	32.2	35.2	34.4
Seward #2	33.2	57.1	41.7	38.0
Sherman	33.5	33.0	32.6	38.8
Average	31.6	40.76	36.5	37.06

The three tests comparing the different rates of fertilizer plowed under on summer fallowed land followed no particular trend. Yield data presented in Table 11 reveal that of the three tests, one favored the 75-pound rate, one the 150-pound rate, and one the 300-pound rate. The Seward #2 test, which gave the greatest response to the fertilizer treatment, very definitely favored the lighter application. In this test the application of fertilizer in excess of 75 pounds per acre tended to depress the yield below the best yield obtained by the light rate.

Table 12 reveals the same trend in response of wheat, on the average, to various rates of nitrogenous fertilizer applied as a spring top dressing on continuously cropped land as was true for the plow-under applications. The rates applied as spring applications were 75, 150, and 225 pounds per acre, and on the average the application of 75 pounds of fertilizer per acre resulted in a considerable increase over no treatment, the 150 and 225 pound rates each gave slight additional increases but not proportionate with the increase in fertilizer applied.

Table 12. The response in yield of wheat on continuously cropped land to various rates of 32.5 percent ammonium nitrate applied as a spring top dressing. 1947.

County	No treatment	75 pounds am. nitrate	150 pounds am. nitrate	225 pounds am. nitrate
Finney	30.8	36.6	36.3	37.3
Hamilton	35.0	39.2	41.7	39.1
Kearny	34.7	45.6	46.0	55.0
Kiowa #1	25.9	32.4	26.1	22.1
Kiowa #2	17.5	24.3	25.1	27.5
Sheridan	21.7	37.0	43.8	43.2
Average	27.6	35.8	36.5	37.35

A study of the individual tests in this series of tests tabulated in Table 12 reveals the fact that some soils reached greatest yields on the plots treated with 75 pounds of fertilizer and decreased from that high yield with each additional increase in rate of fertilization. Three of the tests showed relatively small increases from the application of 150 pounds over the 75-pound rate, and little or no further response from the heaviest rate of fertilizer application. The Kearny County test gave considerably higher yields on the 225-pound fertilizer plot than on any of the other plots. This can be explained by the fact that this test was located on the sandy soils of south Kearny County, and this soil, being low in organic matter and consequently in nitrogen, responds more readily to nitrogenous fertilizer. As was mentioned in the discussion of the winter and spring top dressing experiments at the 150-pound rate, the soil in Kiowa #1 was apparently well supplied with organic matter and available nitrogen, since it gave little response to the application of fertilizer. Table 12 indicates that the wheat yield in the Kiowa #1 test was increased 6.5 bushels per acre by the 75-pound application of ammonium nitrate and additional increases in rate of fertilizer depressed the yield until at the 225-pound rate, the yield of wheat was lower than on the untreated plot. In this series of tests on continuously cropped land the optimum rate of applying fertilizer for best returns apparently was in the range between 75 and 150 pounds per acre on the hard land, with the sandy soils giving best results at heavier rates than 150 pounds per acre, as would be expected. The same was true for the plow-under tests.

Table 13. The response in yield of wheat on summer fallow to various rates of 32.5 percent ammonium nitrate applied as a spring top dressing. 1947.

County	No Treatment	75 pounds am. nitrate	150 pounds am. nitrate	225 pounds am. nitrate
Greeley	46.7	64.2	42.3	42.3
Hamilton	28.2	32.0	30.9	32.1
Morton	42.0	32.2	39.0	35.4
Average	38.96	42.8	40.55	36.6

Only three comparable tests were available for studying the rate of applying nitrogenous fertilizer as a top dressing on summer fallow wheat. The data for these tests are presented in Table 13 and reveal that where any positive response to the fertilizer was obtained the highest yields were obtained on the plots receiving only 75 pounds of fertilizer per acre. In Morton County there was a negative response of the wheat to the application of fertilizer on fallowed land. All treated plots showed a decrease in yield from the untreated plot. The untreated plot in the Morton County test produced the very high yield of 42.0 bushels per acre and the application of ammonium nitrate reduced the yield as much as 9.8 bushels per acre.

1947 Protein Studies

Protein percentage determinations were made on the grain from thirteen of the tests harvested in 1947, for the purpose of studying the effect of the nitrate applications on the protein content of the wheat.

The effect of ammonium nitrate plowed under prior to seeding in 1946 on the protein content of the subsequent crop is shown in Tables 14 and 15.

Table 14. The effect of the application of 150 pounds of ammonium nitrate plowed under prior to seeding on the protein content of the wheat grain grown on continuously cropped land. 1947.

	No treatment		150# am. ni. plowed under	
County	Yield	Protein percent	Yield	Protein percent
Graham	8.9	11.7	19.2	11.0
Seward #2	24.2	10.1	40.4	10.9
Sheridan	21.7	11.2	40.8	10.3
Average	18.26	11.0	33.46	10.7

Table 15. The effect of the application of 150 pounds of 32.5 percent ammonium nitrate applied prior to seeding on summer fallowed land on the wheat grain harvested. 1947.

County	No treatment		150# am. ni. plowed under	
	Yield	Protein percent	Yield	Protein percent
Hamilton	28.2	10.7	35.2	11.3
Sherman	33.5	15.1	32.6	15.9
Average	30.85	12.9	33.9	13.6

The differences in protein content of wheat produced on treated and untreated plots was very slight. The protein content of the wheat harvested from the fertilized plots on the summer fallowed land was slightly higher in each case than that from the check plots, but the difference was probably not significant. The application of nitrogen apparently had no significant effect on the wheat produced on continuously cropped land. The protein content of the grain grown on continuously cropped land was very low and remained fairly constant even though the yield of wheat was increased much by the incorporation of nitrogenous fertilizer into the soil prior to seeding.

The response of wheat, both in yield and protein content of the grain, to the application of 150 pounds of ammonium nitrate as a winter top dressing is tabulated in Table 16 for the continuously cropped wheat and in Table 17 for the fallowed wheat.

Table 16. The effect of the application of 150 pounds of 32.5 percent ammonium nitrate as a winter top dressing and as a spring top dressing on continuously cropped land on the protein content of the wheat harvested. 1947.

County	No treatment		Winter top dressing		Spring top dressing	
	Yield	Protein %	Yield	Protein %	Yield	Protein %
Finney	30.8	11.4	33.0	13.0	36.3	13.6
Hamilton	35.0	10.9	34.7	13.6	41.7	13.4
Kiowa #1	25.9	10.6	24.6	14.6	26.1	13.1
Kiowa #2	17.5	10.3	31.7	12.2	25.1	10.7
Sheridan	20.7	11.2	36.0	14.3	43.8	13.4
Average	26.2	10.9	32.0	13.5	34.6	12.8

The data presented in Tables 16 and 17 indicate that the application of the nitrogen both as a winter top dressing and as an early spring top dressing, very definitely increased the protein content of the grain harvested. A study of the results on the continuously cropped land reveals the fact that in these tests the winter top dressing was somewhat more effective than the spring top dressing in the matter of increasing the protein content of the wheat, which is the reverse of the results obtained in respect to yield. As was previously pointed out the winter top dressing treatments in 1947 were less effective in increasing yields than were the spring applications. However, a study of the protein percentages and yields does not indicate a tendency for the protein percentage to decrease with the increase in yield, which often occurs when available nitrates are inadequate at certain stages in the growth of the wheat plant as has been pointed out by Gainey, Sewall, and Myers (14) as well as other investigators. This indicates that where yields were increased by the application of fertilizer, the added supply of available nitrates was also sufficient to increase the nitrogen content of the wheat itself. The data in Table 16 reveal that the application of 150 pounds of ammonium nitrate as a winter top dressing on continuously cropped wheat resulted in an increase of the protein percentage of the grain from an average of 10.9 percent for the untreated plots to 13.5 percent. This is an increase of 2.6 percentage points. The average protein percentage of the grain harvested from the plots receiving the spring top dressing was 12.8 percent, an increase of 1.9 percentage points over the untreated plots. The highest increase secured from treatment in any single test was obtained by winter top dressing in the Kiowa #1 test, where the protein percentage of the grain was increased from 10.6 percent to 14.6 percent. This is an increase of four percentage points which is an increase of approximately 38 percent in the protein content of the grain due to the nitrogen fertilizer.

Table 17. The effect of the application of 150 pounds 32.5 percent ammonium nitrate as a winter top dressing and as a spring top dressing on summer fallowed land on the protein content of the wheat harvested. 1947.

	No treatment		Winter top dressing		Spring top dressing	
	Yield	Protein %	Yield	Protein %	Yield	Protein %
Hamilton	28.2	10.7	31.8	11.7	30.9	12.0
Morton	42.0	11.2	40.8	12.8	39.0	12.3
Average	35.1	10.9	36.3	12.2	34.95	12.1

Both winter and spring top dressings of wheat after fallow (Table 17) also resulted in increases in protein content of the wheat. However, a study of Tables 16 and 17 reveals the fact that the increase in protein content by treatment over the untreated was not as pronounced on fallow wheat as it was on continuously cropped wheat. The average increase for treatment being only 1.25 percentage points. There was also no indication that the wheat responded any more to winter top dressing than to spring top dressing as far as protein content is concerned. Both times of application gave approximately the same protein response.

The influence of the rate of applying ammonium nitrate to wheat as a spring top dressing was studied and the data are presented in Tables 18 and 19. The studies of treatment on continuously cropped land revealed trends in protein response not entirely like the yield response, where very substantial increases were affected by the application of 75 pounds of fertilizer per acre, smaller additional increases by the 150-pound applications, and still smaller additional increases by the application of 225 pounds per acre. Table 18 reveals that in these tests the protein content of the grain was increased consistently with each increase in rate of fertilizer application. One test, the Kearny County test, showed a slight decrease in protein content on all treated plots as compared to the check plot.

The tests on summer fallowed land showed a tendency (Table 19) for the 75- and 150-pound rates to effect close to the same response as pertains to protein content, with the 225-pound plots being approximately equal to the check plots in protein content.

Table 18. The effect of the application of various rates of ammonium nitrate as a spring top dressing on continuously cropped land on the protein content of the wheat harvested. 1947.

County	No treatment	75 pounds am. nitrate	150 pounds am. nitrate	225 pounds am. nitrate
Finney	11.4	12.2	13.6	14.1
Hamilton	10.9	12.1	13.4	14.6
Kearny	11.4	10.1	10.5	10.7
Kiowa #1	10.6	11.8	13.1	14.4
Kiowa #2	10.3	10.5	10.7	11.2
Sheridan	11.2	11.6	13.4	14.7
Average	10.9	11.4	12.4	13.3

Table 19. The effect of the application of various rates of ammonium nitrate as a spring top dressing on summer fallowed land on the protein content of the wheat harvested. 1947.

County	No treatment	75 pounds am. nitrate	150 pounds am. nitrate	225 pounds am. nitrate
Greeley	11.4	12.9	13.0	11.1
Hamilton	10.7	11.1	12.0	11.8
Morton	11.2	13.3	12.3	10.8
Average	11.1	12.4	12.4	11.2

In the report on a study of the cause of spotted wheat fields made from 1929-1934, Gainey, Sewell, and Myers concluded that surface application of nitrogen to wheat on soils subject to spotting, might result in any one of the following conditions, depending upon the time and quantity of nitrogen applied:

1. No appreciable effect with light summer or fall applications.

2. Increased yield and decreased protein content with medium fall and light to medium early spring applications.

3. Increased yield and increased protein content with medium to heavy fall and early spring applications.

4. Decreased yield and increased protein content with very heavy fall and early spring applications.

5. Marked increase in protein content and slight effect upon yield with light to medium late spring applications.

In comparing the study made by the writer with the study of the investigators cited above, the 1947 tests show the following:

1. Fall applications of 150 pounds ammonium nitrate on continuous wheat increased yield substantially with no appreciable effect on the protein content.

2. The fall application to summer fallow wheat gave slight increase in yield and slight, probably insignificant, increase in protein content.

3. The 150-pound winter top dressing decreased yields and increased protein, gave no appreciable response in yield but increased protein, or increased both yield and protein of wheat on continuously cropped land.

4. Both the winter and the spring top dressings on summer fallow wheat gave no appreciable difference in yield and increased protein.

5. The spring applications of 150 pounds of ammonium nitrate increased yields and increased protein on continuously cropped land.

A study of these responses reveals that they are similar in many respects to responses of wheat to nitrogenous fertilizer reported by the above investigators in their study.

1948 Yield Studies

The wheat fertility studies in 1948 were all conducted on continuously cropped land. The moisture conditions were not as favorable as during the preceding season; nevertheless, the counties in which tests were conducted and studied received approximately average precipitation for those counties. In other words, moisture conditions during the season were considerably more favorable than they are in the area in some years.

The rainfall during the 12-month period, June 1, 1947, through May 31, 1948, and the average annual rainfall for each county in the study is given in Table 20. This table reveals that precipitation in the counties was very close to average. The table also shows that the distribution over the 12-month period followed fairly closely the normal pattern of precipitation distribution as illustrated in Fig. 2, except that April was unusually dry in all counties.

Table 20. Monthly precipitation during the period June 1, 1947, through May 31, 1948, at the weather stations located in counties in which the wheat fertility tests were conducted.

Weather Station	1947-1948 June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total for 12 mo.	Average annual precip.
Oberlin Decatur County	51.4	2.10	1.20	0.95	1.01	1.10	1.03	0.24	0.39	1.05	0.37	2.98	17.56	20.86
Hill City Graham County	5.87	1.76	1.60	0.05	0.95	2.75	1.05	0.30	1.16	2.37	0.56	5.08	23.50	20.26
Syracuse Hamilton County	1.57	4.56	3.14	0.91	0.55	0.30	0.68	0.39	0.52	1.72	0.04	2.79	17.17	17.67
Elkhart Morton County	1.92	3.62	1.04	0.23	1.24	1.14	1.40	0.25	1.78	1.73	T	3.38	17.73	16.47
Pratt Pratt County	2.86	2.29	3.04	1.00	0.41	1.29	3.06	0.79	3.06	2.33	0.86	0.54	21.53	24.53
Atwood Rawlins County	4.88	2.33	0.49	1.14	0.37	1.12	1.26	0.40	0.66	2.42	0.31	4.77	20.15	18.70
Liberal Seward County	4.60	1.71	0.85	0.11	0.92	1.04	1.05	0.48	2.17	1.69	0.23	3.01	17.85	20.05

Table 21. Precipitation by periods from June 1, 1947, through May 31, 1948, at the weather stations located in counties in which the wheat fertility tests were conducted.

Weather Station	June 1 through Aug. 31, 1947	Sept. 1, 1947 through Feb. 29, 1948	March 1 through May 31, 1948	Total
Oberlin Decatur County	8.44	4.72	4.40	17.56
Hill City Graham County	9.23	6.26	8.01	23.50
Syracuse Hamilton County	9.27	3.35	4.55	17.17
Elkhart Morton County	6.58	6.04	5.11	17.73
Pratt Pratt County	8.19	9.61	3.73	21.53
Atwood Rawlins County	7.70	4.95	7.50	20.15
Liberal Seward County	7.16	5.77	4.92	17.85

Plow-under Experiments. A study of the results of plowing under 150 pounds of ammonium nitrate per acre prior to seeding the wheat crop in the fall of 1947, reveals the fact that in all tests there was some increase in yields for treatment over no treatment (Table 22). The data also reveal that yields in these tests were smaller on untreated plots than they were on the plots harvested in 1947, and that increases in yield due to fertilizer treatments were less spectacular than the increases the preceding year.

Table 22. The response in yield of wheat to the application of 150 pounds of 32.5 percent ammonium nitrate plowed under prior to seeding. 1948.

County	No treatment	150 pounds ammonium nitrate plowed under
Hamilton	15.7	26.6
Morton	13.2	16.0
Rawlins	20.1	23.9
Graham	15.7	20.1
Average	16.2	21.5

One test, the Hamilton County test, gave a very substantial increase in yield, producing 26.6 bushels per acre on the treated plot as compared with 15.7 bushels on the check plot. This test, however, was located in a field at the edge of the sandhills south of Syracuse, and this very sandy soil being naturally low in organic matter, responds more readily to nitrogen treatments. The other tests each showed approximately the same increase of three to four bushels per acre for the treated over the untreated plots. In their consistency of response to the fertilizer treatments the 1948 tests also differed from the 1947 tests, since the tests the preceding year varied considerably in their response to the plow-under application of ammonium nitrate. Nitrogen applications on the 1947 crop gave increases ranging from 1.4 to 19.1 bushels per acre. Since this response of the 1947 crop varied with the rainfall received during the summer season just prior to seeding, the rainfall for the three months prior to seeding the 1948 crop was studied. The climatological data for the counties concerned, taken from the United States Weather Bureau report, are tabulated in Table 21 and indicate that all counties concerned received close to normal rainfall during June, July, and August preceding the seeding of the 1948 crop. There was less variation between counties as to rainfall. The yield increase differences due to nitrogen treatment occurred in the same order by counties as did the summer rainfall differences (Table 23); however, the differences in yield increases were so small as to be probably insignificant. Therefore, in these particular tests it can be said that where soil types were similar the application of 150 pounds of ammonium nitrate applied prior to seeding gave small but similar increases.

Table 23. The relationship between precipitation during June, July, and August, 1947, and response of wheat to plow-under applications of 150 pounds of 32.5 percent ammonium nitrate on continuously cropped land.

County	Precipitation June 1 - Aug. 31	Increase in yield due to fertilizer
Morton	6.58	2.8
Rawlins	7.70	3.8
Graham	9.23	4.4
Hamilton	9.27	10.5

Winter and Spring Top Dressings. Table 24 tabulates the yield results obtained in the tests where the wheat was given a winter top dressing of 150 pounds of nitrogenous fertilizer.

Table 24. The response in yield of wheat to the application of 150 pounds of 32.5 percent ammonium nitrate as a winter top dressing. 1948.

County	No treatment	150# ammonium nitrate winter top dressing
Rawlins	20.1	23.1
Seward #1	34.7	30.1
Seward #2	23.6	16.7
Pratt	29.2	28.9
Graham	15.7	10.6
Decatur	21.5	41.3
Average	24.13	25.14

Four of the six tests indicated that the application of the fertilizer depressed the yields. The greatest drop in yield was in the Seward #2 test where the yield dropped from 23.6 bushels to 16.7 bushels per acre. The decreases in yield in the other tests where the fertilizer gave negative responses range from 0.3 of a bushel to as much as 5.1 bushels per acre. The fertilizer application increased the yield in Rawlins County from 20.1 bushels to 23.1 bushels. For some reason which is not clear to the writer, the winter top dressing increased the yield in Decatur County from 21.5 bushels for the check plot to 41.3 bushels, an increase of 19.8 bushels per acre. In this same test the spring top dressing plot yielded only 25.[illegible] bushels (Table 25), an increase of only 4.3 bushels per acre. No apparent reason for the outstanding response to the fertilizer in Decatur County was found in studying the precipitation chart for the season. The total rainfall for the year and the pattern of seasonal distribution was similar to that of the other counties.

The wheat responded to the spring application of fertilizer very much like it did to the winter top dressing, as is revealed in Table 25. The average of all tests indicated that the fertilizer had no favorable influence on the yield, in fact, there was a very slight decrease. A study of the individual tests indicates a trend very similar to that apparent in the winter application tests. Most tests gave slight increases or slight decreases in yield of wheat on the fertilized plots in comparison to the untreated plots; indicating no very significant response, either positive or negative, of wheat to the nitrogen applied in the spring.

Table 25. The response in yield of wheat to the spring top dressing of 150 pounds of 32.5 percent ammonium nitrate per acre. 1948.

County	No treatment	150# ammonium nitrate spring top dressing
Morton	13.2	15.9
Seward #1	34.7	35.2
Seward #2	23.6	14.8
Pratt	29.2	27.6
Decatur	21.5	25.8
Average	24.44	23.86

The Seward #2 test showed a decided decrease in yield of the treated plot as compared to the untreated. The untreated plot produced 23.6 bushels per acre as compared with only 14.8 bushels for the fertilized plot, a reduction of 8.8 bushels per acre. A negative response, of practically the same magnitude, was also obvious on the winter fertilized plot in the Seward #2 test as indicated in Table 24. Indications are that the soil in this test already had adequate available nitrogen for the moisture available and, therefore, the additional nitrogen produced excessive tillering and consequently a drought condition. In the majority of the 1948 winter and spring top dressing tests, it may be said that the fertilizer had no appreciable effect on the yield.

A direct comparison between the winter and spring applications was made in some of the counties and the results are presented in Table 26.

Table 26. The response in yield of wheat to the application of 150 pounds of 32.5 percent ammonium nitrate applied as a winter top dressing and as a spring top dressing. 1948.

County	No treatment	Winter top dressing	Spring top dressing
Seward #1	34.7	30.1	35.2
Seward #2	23.6	16.7	14.8
Pratt	29.2	28.9	27.6
Decatur	21.5	41.3	25.8
Average	27.5	29.25	25.85

Only the Decatur County test gave an increase in yield for the winter application. Except for that test, the results indicate that the top dressing applications either effected no appreciable difference in yield or resulted in slight decreases and that there was no consistent advantage in favor of either time of application.

Rates of Application. Only the fall plow-under applications of fertilizer gave consistent positive results in the 1948 fertility tests and these yield increases were small. The 150-pound applications of fertilizer gave the greatest returns in the plow-under application tests as revealed in Table 27.

Table 27. The response in yield of wheat to various rates of 32.5 percent ammonium nitrate plowed under prior to seeding. 1948.

County	No treatment	75 pounds am. nitrate	150 pounds am. nitrate	300 pounds am. nitrate
Hamilton	15.7	20.7	26.2	27.4
Rawlins	20.1	21.5	23.9	22.7
Graham	15.7	12.4	20.1	15.3
Average	17.16	18.2	23.4	21.8

1948 Protein Studies

The protein content of the grain of a limited number of tests harvested in 1948 was determined to further study the trend in the effect of the fertilizer on the composition of the grain. The response of the wheat, in yield and protein content, to the application of 150 pounds of the nitrogenous fertilizer as plow-under, winter and spring applications is presented in Table 28, 29, and 30. A study of the data reveals that, almost without exception, the treated plots produced wheat grain with a higher protein content than that of the untreated plots. In two of the winter top dressing tests, the Rawlins and Decatur, there was no real difference in protein percentage of wheat from treated and untreated plots. The data reveal no apparent relationship between yield and protein content in these particular tests.

The 150-pound plow-under application of fertilizer resulted in an increase in yield and in protein content.

Table 28. The effect of plowing under 150 pounds of ammonium nitrate prior to seeding on the yield and protein content of the wheat harvested. 1948.

County	No treatment		150# am. ni. plowed under	
	Yield	Protein percent	Yield	Protein percent
Rawlins	20.1	15.3	23.9	16.2
Graham	15.7	12.2	20.1	15.4
Average	17.9	13.75	22.0	15.8

Table 29. The effect of applying 150 pounds of ammonium nitrate as a winter top dressing on the yield and protein content of the wheat harvested. 1948.

County	No treatment		150# ammonium nitrate	
	Yield	Protein percent	Yield	Protein percent
Rawlins	20.1	15.3	23.1	15.0
Seward #1	34.7	14.9	30.1	16.1
Pratt	29.2	12.1	28.9	15.8
Graham	15.7	12.2	10.6	15.3
Decatur	21.5	11.0	41.3	10.7
Average	24.24	13.1	26.8	14.58

Table 30. The effect of applying 150 pounds of 32.5 percent ammonium nitrate as a spring top dressing on the yield and protein content of the wheat harvested. 1948.

County	No treatment		150# ammonium nitrate	
	Yield	Protein percent	Yield	Protein percent
Seward #1	34.7	14.9	35.2	16.2
Pratt	29.2	12.1	27.6	13.8
Decatur	21.5	11.0	25.8	12.1
Average	24.46	12.66	27.53	14.03

The 1948 tests then gave the following results:

1. Applications by plow-under ammonium nitrate increased both yield and protein content.

2. Some winter applications increased yields and had no appreciable effect on protein, while others showed decrease or no effect on yield and increased the protein content of the grain.

3. The early spring application of nitrogenous fertilizer for the most part had no appreciable effect on the yield but increased protein content of the grain.

These results are in accord with the findings reported by Gainey, Sewell, and Myers (14).

SUMMARY

Nitrogenous fertilizer tests were conducted on wheat in the dry farming area of western Kansas durin the 1946-1947 and 1947-1948 seasons. Applications of 32.5 percent ammonium nitrate were plowed under prior to seeding the wheat, winter top dressed, and early spring top dressed. Rates of 75, 150, and 300 pounds of the fertilizer were applied by plowing-under, 150 pounds as a winter top dressing, and 75, 150, and 225 rates as early spring top dressings. Yield and grain protein determinations were made on the tests.

Precipitation during the 1946-1947 season was considerably above average in the counties in which the tests were conducted. During the 1947-1948 season the precipitation was about average. Since neither season had the moisture deficiency which often occurs in this area, this study should probably be considered a progress report and not conclusive in its findings.

1947 Studies

A study of the 1947 results revealed that at the 150-pound rate all the plow-under treatment plots gave considerable increases in yield over untreated on continuous wheat. There was a wide variation between tests as to the magnitude of the increases due to nitrogen. There was a tendency for the yield increases to vary with the amount of rainfall received during the summer season just prior to seeding. Those tests where there was adequate moisture in the soil, as judged by the summer rainfall, to utilize the additional amount of available nitrogen supplied through the application of fertilizer, returned very substantial yield increases; whereas, in those tests where the summer rainfall was considerably below average the yield increases were smaller.

The plow-under treatments on summer fallow wheat gave smaller increases on the average than did the same tests on continuously cropped land. In some cases there was a slight decrease in yield due to the treatment.

The yields from the plow-under treatment plots on continuous wheat compared favorably with the yields of the fertilized plots on summer fallowed soil, indicating that available nitrogen rather than moisture was the limiting factor of production in most instances in 1947.

Wheat was less responsive in yield to winter top dressing than to either plow-under or early spring applications, although in two of the tests winter applications resulted in large increases over no treatment. The untreated plots in these two tests gave lower yields than those in the other tests indicating a lower fertility for those soils than for the others in this series of tests.

Frequently in the same tests where the winter top dressing applications of ammonium nitrate resulted in no increase in yield, the same rate of fertilizer applied in March gave increases of from 5.5 to 9.8 bushels per acre; while other soils responded to neither winter or spring top dressing. The greatest response to spring top dressing was in Sheridan County where the yield on the treated plot was 43.8 bushels per acre compared to 21.7 bushels for the untreated plot.

Spring top dressing of summer fallowed wheat affected the yield very little.

Spring top dressing applications of nitrogenous fertilizer resulted in higher yields in 1947 than did the plow-under treatments on continuously cropped land.

The rate of application studies indicated that on the average in the plow-under tests the 75-pound rate gave a very substantial increase in yield of about 10 bushels per acre, the 150-pound rate gave an additional 4 bushel increase, and the 300-pound rate another 4 bushel increase. However, in most instances the data indicate that the most practical rate probably is somewhere between 75 and 150 pounds per acre on continuously cropped land.

The response to various rates of application of the nitrogen as a spring top dressing followed the same pattern as was found in the plow-under tests. The response varied with the soils but in most instances the optimum rate for best returns was in the range between 75 and 150 pounds per acre on hard land, with sandy soils giving best results at heavier rates than 150 pounds per acre. Where treatment gave a positive response on summer fallow, the 75-pound rate gave highest yields.

The protein studies of the 1947 tests revealed that the plow-under applications of 150 pounds ammonium nitrate on continuous wheat increased yields substantially with no appreciable effect on the protein content. This treatment on fallow wheat gave slight increase in yield and no significant increase in protein content.

A study of the individual tests indicate that winter application increased protein content in all instances, but varied in yield response, giving decreased yields, no response, or increased yields.

Both winter and spring applications on summer fallow increased protein with no appreciable effect on yield.

The spring top dressing in 1947 increased yields and protein on continuously cropped land.

1948 Studies

The moisture conditions during the 1947-1948 season were average, but not as favorable as during the preceding season.

The plow-under treatments gave small but consistent increases over no treatment in the crop harvested in 1948. Rainfall in counties where these tests were conducted was very nearly the same during the summer season preceding seeding.

In most tests in 1948, the application of nitrogenous fertilizer as a winter top dressing depressed the yields of wheat. However, in the Decatur County test, for some unknown reason, the yield of wheat was increased from 21.5 bushels to 41.3 bushels per acre.

The wheat responded to the spring application of fertilizer very much like it did to the winter application, indicating no very significant response in yield to the fertilizer. The Seward #2 test showed a decided decrease in yield of the treated plot. A negative response of practically the same magnitude was obvious on the winter fertilized plot in the Seward #2 test, indicating that this soil already had adequate available nitrogen for the moisture available, and the additional nitrogen depressed the yields.

Only the fall plow-under application of nitrogen gave consistent positive results in the 1948 fertility tests.

Protein studies revealed that the plow-under nitrogen applications increased protein content, as well as yield, of the 1948 wheat crop.

Some of the winter applications increased yields and had no appreciable effect on protein, while others showed decreases or no effect on yield and increased the protein content of the grain.

The early spring applications of nitrogen for the most part had no appreciable effect on the yield but increased the protein content of the grain.

CONCLUSIONS

Although the seasons during which these tests were conducted were not typical for western Kansas from the standpoint of precipitation, some conclusions can be drawn from the studies made.

Deficiency of available nitrogen frequently is the limiting factor in wheat production on many soils in the low rainfall areas of Kansas. Evidence of this deficiency is shown by the response of winter wheat to the application of nitrogenous fertilizer in increased yields and protein content of the grain.

These soils vary considerably in response to applications of nitrogenous fertilizer, indicating a difference in soil fertility. Results of the experiments reported in this thesis indicate that the soils low in fertility can be treated profitably with nitrogenous fertilizer in seasons when precipitation is above average. However, the value of nitrogenous fertilizer depends upon the amount of precipitation received during the season, and, judging by the 1948 experimental results, the use of fertilizer would probably not be feasible in years of below average precipitation in western Kansas.

When conditions are favorable for the use of nitrogen fertilizer, the most practical rate of application on hard land is somewhere between 75 and 150 pound per acre. Sandy soils give best results with rates heavier than 150 pounds per acre. Good results can be expected both from plow-under treatments prior to seeding and from early spring top dressing.

Wheat on summer fallow gives comparatively little response to nitrogen treatment, while wheat on continuously cropped land can be made to yield favorably with good summer fallow wheat by the application of nitrogenous fertilizer. This indicates that one value of summer fallowing is making nitrates available for the new crop.

The response of wheat to nitrogenous fertilizer plowed under prior to seeding depends on the soil moisture available at seeding time. This fact leads to the conclusion that on dry land soils where available nitrogen is limited, the value of summer fallowing is due both to moisture storage and making nitrates available. Both are essential for best results.

Protein content of the grain is increased by applications of nitrogenous fertilizer with more certainty than is the yield. In most instances the fertilizer treatments in these experiments resulted in higher protein content. However, there is a tendency for the protein increase to be smaller with very large increases in yield. Protein content of the grain may be increased even though there is no increase in yield, or even a yield decrease.

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