Anhydrous Ammonia and Ammonium Nitrate Fertilizers for Wheat

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SCIENCE SERVING AGRICULTURE
EXPERIMENT STATION

Bulletin No. B-493
June 1957

Comparisons of Anhydrous Ammonia and Ammonium Nitrate as Fertilizers for Wheat in Central Oklahoma

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The practice of applying anhydrous ammonia directly to the soil as a nitrogen fertilizer for agricultural crops is about 10 years old. Data was obtained on the value of anhydrous ammonia for crop production and equipment was developed for its application at the Mississippi Agricultural Experiment Station. The information was released to farmers in March, 1947. Its use grew rapidly and by 1951, there were bulk stations for distribution to farmers in 24 states, including Oklahoma. One thousand, six hundred twenty-one tons of anhydrous ammonia were distributed in Oklahoma for agricultural purposes in the 1956 fiscal year.

With anhydrous ammonia came questions regarding its use on various crops and its efficiency as compared to other, more commonly used, nitrogen fertilizer materials. This publication reports the results of two experiments in which anhydrous ammonia was used as a nitrogen source for wheat. The first study (Experiment I) was conducted at three locations in north-central Oklahoma over a period of three seasons, 1953 through 1955. The objectives of the study were: (1) To determine the efficiency of anhydrous ammonia and ammonium nitrate in their effect on yield and protein content of wheat. (2) To determine the nitrogen needs for maximum wheat production in north-central Oklahoma and (3) To determine the effect of time of application of nitrogen fertilizer on the yield and protein content of wheat.

The second study (Experiment II) was conducted at two locations; near Newkirk, in Kay County, and near Inola, in Rogers County. It was conducted over a period of two seasons, 1955 through 1956. The objectives of the study were: (1) To determine the most efficient time for applying anhydrous ammonia as a source of nitrogen for wheat in central and eastern Oklahoma and (2) To determine the nitrogen

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Table 1.—Soil type and soil test data from soils where the experiments were conducted.

Location	Soil Type	pH		Available* P_2O_5		Available** Potassium		Organic Matter		Total Nitrogen		Nitrate† Nitrogen		Nitrifiable†† Nitrogen	
		0-6	6-12	0-6 Lbs./A	6-12	0-6 Lbs./A	6-12	0-6 %	6-12	0-6 %	6-12	0-6 Lbs. N/A	6-12	0-6 Lbs. N/A	6-12
Ponca City	Bethany Silt loam	6.40	6.05	48.1	53.1	214	88	2.16	2.14	0.124	0.110	13.6	9.5	16.3	8.1
Enid	Pond Creek Silt loam	5.90	6.00	38.0	50.4	104	112	1.34	1.51	0.079	0.079	6.3	7.9	12.4	8.1
1953 Dacoma	Pond Creek Silt loam	5.90	6.30	45.0	53.0	204	148	1.83	1.80	0.107	0.118	---	--	---	--
1954 Dacoma	Pond Creek Silt loam	5.70	6.10	45.8	53.1	244	160	1.35	1.31	0.070	0.116	7.9	6.8	17.2	6.3
1955 Inola	Dennis Silt loam	4.80	4.80	25.2	9.16	26	26	1.99	2.01	0.117	0.106	12.2	8.1	0.0	0.0
1956 Inola	Parsons Silt loam	5.60	5.00	12.8	12.0	163	138	2.57	1.52	0.143	0.106	10.8	14.1	26.3	3.5
Newkirk	Bethany Silt loam	5.30	5.50	14.0	17.4	277	25.5	2.71	2.66	0.128	0.119	6.5	0.0	21.7	19.3

* P_2O_5 by 0.5 M sodium bicarbonate extraction.
** Potassium by 1.0 neutral normal ammonium acetate extraction.
† Distilled water leaching without incubation.
†† Distilled water leaching after initial distilled water leaching and two weeks incubation at 35°C.

needs for maximum wheat production in two areas, one in central and the other in eastern Oklahoma.

Both experiments were conducted during a period of below average rainfall. At the locations where Experiment I was conducted, precipitation was 70.1 percent of normal in the year ending June 30, 1953; 79.9 percent of normal in the year ending June 30, 1954; and 95.5 percent of normal in the year ending June 30, 1955. Rainfall distribution was satisfactory for wheat growth in 1953 and 1954 but in 1955, a large portion of the precipitation came in May and June, too late to save the wheat crop. In the year ending June 30, 1955, precipitation at Newkirk and Inola (sites of Experiment II) was 61.1 and 77.2 percent of normal, respectively, while in the year ending June 30, 1956, it was 57.5 percent of normal at Newkirk and 65 percent of normal at Inola.

The experiments were located on typical wheat soils of the areas. Soil type and soil test data are given in Table 1.

General Procedure

The anhydrous ammonia was metered with a Fischer-Porter flowrater. In the plowdown application in Experiment II, it was applied with a tractor-mounted applicator at plowsole depth (5-6 inches). In all other applications, it was applied with a tractor drawn distributor. It was injected at a depth of 4-6 inches through injector knives placed on 16 inch centers. The injector knives were pulled through the soil of only those plots which received applications of nitrogen as anhydrous ammonia. Where ammonium nitrate was applied (Experiment I) it was broadcast on the surface of the soil with a hand-drawn spreader.

The wheat was planted in 7-inch rows at right angles to the length of the plots allowing the ammonia distributor to be pulled across, rather than down the rows at spring top dressing. All plots at all locations received 40 pounds of P_2O_5 per acre applied with the seed at planting. It was applied to satisfy any possible phosphate deficiency without regard to soil test. All plots at Inola (Experiment II) received 40 pounds of K_2O per acre drilled immediately before planting. Potash was applied due to the low soil test in 1955 (See Table 1) and without regard to soil test in 1956.

The plots were harvested with a 7-foot self-propelled combine. Grain yields were taken and grain samples were analyzed for protein content. Yield and protein data were analyzed statistically to aid in interpretation of results.

Experiment I

Anhydrous ammonia and ammonium nitrate were compared at four rates (0, 20, 40, and 80 pounds N/A) and two dates of application (preplant in the fall and as a top dressing in early March). The experiment was set up in a split-split plot randomized block design with three replications. There were four main plots per replicate with four sub-plots per main plot, making a total of 16 treatments per replicate. Main plots were nitrogen rates, the first split was for time of application and the second was for nitrogen material. Each main plot was 32 by 300 feet and each sub-plot was 8 by 300 feet.

In experiments of this design, information obtained on the main plots is least precise, that in the first split of plots is more precise and that obtained in the second split of plots is most precise. Thus, information on nitrogen rates was obtained with least precision, that on time of application with more precision, and that for nitrogen material with most precision. In statistical analyses of the data, greater differences are required for significance between rates of application than between times of application and nitrogen materials. Likewise, greater

Table 2.—Yields of wheat on anhydrous ammonia—ammonium nitrate comparison at Ponca City, Oklahoma.

Rate of	Anhydrous Ammonia			Ammonium Nitrate			Overall
N	Fall	Spring	Av.	Fall	Spring	Av.	Av.
Lbs./A			**Bushels per acre**				
			1953				
0	23.8	25.1	24.5	24.2	24.6	24.4	24.4
20	29.8	27.4	28.6	29.2	26.5	27.9	28.2
40	31.9	27.3	29.6	29.4	26.4	27.9	28.8
80	36.0	26.9	31.5	34.6	31.1	32.9	32.2
Av.	30.4	26.7	28.6	29.4	27.2	28.3	28.4
			1954				
0	21.4	22.1	21.8	21.2	20.3	20.8	21.3
20	20.5	25.0	22.8	19.9	22.0	21.0	21.9
40	25.3	29.5	27.4	23.6	24.1	23.9	25.6
80	25.0	25.7	25.4	23.7	23.1	23.4	24.4
Av.	23.1	25.6	24.4	22.1	22.4	22.3	23.3
			1955				
0	12.4	11.7	12.1	12.5	12.1	12.3	12.2
20	10.6	10.5	10.6	11.2	10.5	10.9	10.7
40	9.7	8.9	9.3	11.1	9.3	10.2	9.8
80	9.4	9.5	9.5	9.1	8.3	8.7	9.1
Av.	10.5	10.2	10.4	11.0	10.1	10.5	10.5
			Average 3 years				
0	19.2	19.6	19.4	19.3	19.0	19.2	19.3
20	20.3	21.0	20.7	20.1	19.6	19.9	20.3
40	22.3	21.9	22.1	21.5	19.9	20.7	21.4
80	23.5	20.7	22.1	22.5	20.9	21.7	21.9
Av.	21.3	20.8	21.1	20.8	19.9	20.4	20.7

Table 3.—Protein content of wheat grain in anhydrous ammonia—ammonium nitrate comparison, Ponca City, Oklahoma.

Rate of N	Anhydrous Ammonia Fall	Spring	Av.	Ammonium Nitrate Fall	Spring	Av.	Overall Av.
Lbs./A			Percent				
			1953				
0	10.7	10.7	10.7	10.4	10.5	10.5	10.6
20	10.6	10.9	10.8	10.4	11.0	10.7	10.7
40	11.4	12.3	11.9	10.7	10.6	10.7	11.3
80	13.2	14.7	14.0	12.7	13.3	13.0	13.5
Av.	11.5	12.2	11.9	11.1	11.4	11.2	11.6
			1954				
0	10.4	9.8	10.1	9.7	9.8	9.7	9.9
20	10.6	10.4	10.5	10.2	10.0	10.1	10.3
40	11.7	11.2	11.5	10.0	10.8	10.4	10.9
80	12.7	13.3	13.0	11.7	13.2	12.5	12.8
Av.	11.4	11.2	11.3	10.4	10.9	10.7	11.0
			1955				
0	15.8	15.1	15.5	14.1	14.8	14.5	15.0
20	16.1	16.2	16.2	16.7	15.3	16.0	16.1
40	17.2	16.7	17.0	15.8	17.2	16.5	16.7
80	18.2	18.6	18.4	18.2	18.0	18.1	18.3
Av.	16.8	16.7	16.8	16.2	16.3	16.3	16.5
			Average 3 seasons				
0	12.3	11.9	12.1	11.4	11.7	11.6	11.8
20	12.4	12.5	12.5	12.5	12.1	12.3	12.4
40	13.4	13.4	13.4	12.2	12.9	12.6	13.0
80	14.7	15.5	15.1	14.2	14.8	14.5	14.8
Av.	13.2	13.3	13.3	12.6	12.9	12.5	13.0

differences are required for significance between times of application than between nitrogen materials.

Results

Three years' data were obtained at Ponca City while only two years' results were obtained at Dacoma and Enid. At Ponca City and Enid, the experiment was located on the same sites for its duration, while at Dacoma, it was moved after the first season. The experiment was not harvested at Dacoma and Enid in 1955 due to crop failure.

Ponca City

Grain yield and protein data obtained at Ponca City are presented in Tables 2 and 3. A significant increase in yield from the application of nitrogen was obtained only in 1953. In 1954, there was a trend toward increasing yields with increasing rates of nitrogen but differences were not great enough for significance. Yields were low in 1955 and there was no difference in yield due to nitrogen application. In 1953, fall applied nitrogen gave significantly higher yields than spring applied nitrogen, while in 1954, there was a trend (not significant) toward higher yield with spring applied nitrogen than with fall applied nitrogen. In 1955, there was no difference due to time of application of nitrogen. There was no difference in the efficiency of the two nitrogen carriers in 1953. In 1954, anhydrous ammonia gave a significantly higher yield than ammonium nitrate, and in 1955, there was no difference in the efficiency of the two materials.

A combined statistical evaluation of the three seasons' yield data at Ponca City indicates that there were no significant differences in yield due to rate of nitrogen applied, time of nitrogen application, nor to nitrogen material.

In all three seasons, the protein content of the grain increased with increasing rates of nitrogen application. Spring applied nitrogen produced higher grain protein than fall applied nitrogen in 1953, but in 1954 and 1955, there were no significant differences in grain protein due to time of application of nitrogen. Anhydrous ammonia produced higher grain protein than ammonium nitrate in both 1953 and 1954 but the nitrogen carrier used had no significant effect on the protein content of the grain in 1955.

Statistical evaluation of the three seasons' grain protein data from Ponca City indicates that grain protein increased with increasing rates of nitrogen application and that neither time of nitrogen application, nor the nitrogen material used had any significant effects on grain protein.

Table 4.—Yields of wheat in anhydrous ammonia—ammonium nitrate comparison at Enid, Oklahoma.

Rate of	Anhydrous Ammonia			Ammonium Nitrate			Overall
N	Fall	Spring	Av.	Fall	Spring	Av.	Av.
Lbs./A			**Bushels per acre**				
			1953				
0	20.0	20.6	20.3	20.7	20.4	20.6	20.4
20	24.4	24.4	24.4	25.9	23.5	24.7	24.6
40	25.4	26.4	25.9	27.4	23.3	25.4	25.6
80	28.6	27.0	27.8	29.0	27.1	28.1	27.9
Av.	24.6	24.6	24.6	25.8	23.6	24.7	24.7
			1954				
0	19.9	19.1	19.5	20.5	19.3	19.9	19.7
20	23.0	22.0	22.5	21.8	21.4	23.0	22.7
40	25.8	23.5	24.7	25.0	22.4	23.7	24.2
80	26.7	26.8	26.8	27.3	26.2	26.8	26.8
Av.	23.9	22.9	23.4	23.7	23.0	23.4	23.4
			Average 2 seasons				
0	20.0	19.9	20.0	20.6	19.8	20.2	20.1
20	23.7	23.2	23.5	23.8	23.8	23.8	23.6
40	25.6	24.9	25.3	26.2	22.9	24.6	24.9
80	27.6	26.9	27.3	28.2	26.7	27.5	27.3
Av.	24.2	23.7	24.0	24.7	23.3	24.0	24.0

Table 5.—Protein content of wheat grain in anhydrous ammonia—ammonium nitrate comparison, Enid, Oklahoma.

Rate of N	Anhydrous Ammonia Fall	Anhydrous Ammonia Spring	Anhydrous Ammonia Av.	Ammonium Nitrate Fall	Ammonium Nitrate Spring	Ammonium Nitrate Av.	Overall Av.
Lbs./A			**Percent**				
			1953				
0	9.7	9.5	9.6	9.6	9.6	9.6	9.6
20	9.5	10.5	10.0	9.6	10.4	10.0	10.0
40	10.5	12.1	11.3	9.6	10.3	10.0	10.6
80	11.9	13.7	12.8	11.7	11.5	11.8	12.3
Av.	10.5	11.5	10.9	10.1	10.5	10.4	10.7
			1954				
0	10.5	10.5	10.5	10.6	10.5	10.6	10.5
20	10.8	11.7	11.3	11.2	11.3	11.3	11.3
40	11.9	12.3	12.1	10.8	11.9	11.4	11.7
80	13.5	13.9	13.7	13.5	13.2	13.4	13.5
Av.	11.7	12.1	11.9	11.6	11.7	11.6	11.8
			Average 2 seasons				
0	10.1	10.0	10.1	10.1	10.1	10.1	10.1
20	10.2	11.2	10.7	10.4	10.8	10.6	10.6
40	11.2	12.2	11.7	10.2	11.1	10.7	11.2
80	12.7	13.8	13.3	12.6	12.4	12.5	12.8
Av.	11.1	11.8	11.5	10.8	11.1	11.0	11.2

Enid

Grain yield and protein data obtained at Enid are listed in Tables 4 and 5. In both 1953 and 1954, grain yields were increased by nitrogen applications. Time of nitrogen application did not affect yields significantly in either season, though there was a trend toward higher yields with fall application in both seasons. There was no difference in the efficiency of the two nitrogen carriers in either season. Statistical evaluation of the two seasons' yield data indicates that grain yields were increased by nitrogen application and that fall application of nitrogen gave significantly higher yields than spring application. The average advantage for fall over spring application, however, was only one bushel per acre. The two nitrogen carriers (anhydrous ammonia or ammonium nitrate) did not have differential effects on grain yields.

In both 1953 and 1954, grain protein was increased by application of nitrogen. In both seasons, there was a trend toward higher grain protein with spring application of nitrogen as compared to fall application. This trend was statistically significant in only the 1953 season. Anhydrous ammonia gave higher grain protein than ammonium nitrate in both seasons. Statistical evaluation of the two seasons' grain protein data indicates that nitrogen applications increased grain protein, that spring applied nitrogen gave higher grain protein than fall applied nitrogen, and that anhydrous ammonia gave higher grain protein than ammonium nitrate.

Dacoma

Grain yield and protein data obtained at Dacoma are listed in Tables 6 and 7. Grain yields were not affected by nitrogen applications in either season. Time of application of nitrogen, as such, had no effect on yields in either season but the yield data indicate that higher yields were obtained from ammonium nitrate in the 1954 season than from anhydrous ammonia. This apparent advantage for ammonium nitrate was due to an apparent reduction in yield by spring application of anhydrous ammonia. Observation in the field indicated that the yield reduction was due to cultivation by the anhydrous ammonia distributor rather than to the application of nitrogen. The soil was dry at the time the ammonia was applied and remained dry for some time after application. The plots which received the spring application of anhydrous ammonia suffered a reduction in stand.

Nitrogen applications increased the protein content of the grain in both the 1953 and 1954 seasons. In the 1953 season, time of application of nitrogen had no effect on grain protein while in the 1954 season, nitrogen applied in the spring increased grain protein more than that applied in the fall. In 1953, anhydrous ammonia produced slightly

Table 6.—Yields of wheat in anhydrous ammonia—ammonium nitrate comparison at Dacoma, Oklahoma.

Rate of	Anhydrous Ammonia			Ammonium Nitrate			Overall
N	Fall	Spring	Av.	Fall	Spring	Av.	Av.
Lbs./A			**Bushels per acre**				
			1953				
0	6.8	7.4	7.1	8.2	7.2	7.7	7.4
20	7.0	7.3	7.2	7.8	7.5	7.7	7.4
40	6.5	8.6	7.6	7.8	8.0	7.9	7.7
80	7.0	9.0	8.0	7.3	7.8	7.6	7.8
Av.	6.8	7.7	7.5	7.8	7.6	7.7	7.5
			1954				
0	16.2	15.2	15.7	15.8	15.6	15.7	15.7
20	18.0	14.7	16.4	18.4	18.3	18.4	17.4
40	16.5	13.4	15.0	16.5	15.8	16.2	15.6
80	16.6	13.8	15.2	16.3	18.2	17.3	16.2
Av.	16.8	14.3	15.6	16.8	17.0	16.9	16.2
			Average 2 seasons				
0	11.5	11.3	11.4	12.0	11.4	11.7	11.6
20	12.5	11.0	11.8	13.1	12.9	13.1	12.4
40	11.5	11.0	11.3	12.2	11.9	12.1	11.7
80	11.8	11.4	11.6	11.8	13.0	12.5	12.0
Av.	11.8	11.0	11.6	12.3	12.3	12.3	11.9

Table 7.—Protein content of wheat grain in anhydrous ammonia—ammonium nitrate comparison, Dacoma, Oklahoma.

Rate of	Anhydrous Ammonia			Ammonium Nitrate			Overall
N	Fall	Spring	Av.	Fall	Spring	Av.	Av.
Lbs./A			**Percent**				
			1953				
0	15.8	15.2	15.5	15.6	15.6	15.6	15.6
20	16.5	16.7	16.6	16.0	16.2	16.1	16.4
40	16.9	16.8	16.9	16.3	16.5	16.4	16.6
80	16.8	17.1	17.0	16.9	17.1	17.0	17.0
Av.	16.5	16.5	16.5	16.2	16.4	16.3	16.4
			1954				
0	14.8	14.7	14.8	14.5	14.7	14.6	14.7
20	14.6	15.8	15.2	15.3	15.2	15.3	15.2
40	15.8	16.6	16.2	15.7	15.9	15.8	16.0
80	16.4	16.7	16.5	16.6	16.9	16.7	16.6
Av.	15.4	16.0	15.7	15.5	15.7	15.5	15.6
			Average 2 seasons				
0	15.3	15.0	15.2	15.1	15.2	15.1	15.2
20	15.6	16.3	15.9	15.7	15.7	15.7	15.8
40	16.4	16.7	16.6	16.0	16.2	16.1	16.3
80	16.6	16.9	16.8	16.8	17.0	16.9	16.8
Av.	16.0	16.3	16.1	15.9	16.1	15.9	16.0

higher grain protein than ammonium nitrate, but in 1954 there was no difference in grain protein due to the nitrogen carrier used.

Statistical evaluation of the combined data for the two seasons was not made.

Experiment II

Nitrogen, as anhydrous ammonia, was applied at rates of 0, 20, 40, 80, and 160 pounds per acre. It was applied at 6 dates: plowdown, (at the time the land was broken); at planting; in February or early March; one-half at plowdown, one-half at planting; one-half plowdown, one-half in February or early March; and one-half at planting and one-half in February or early March. The experiment was set up in a split plot design with three replications. Main plots were rates of nitrogen and sub-plots were time of application of nitrogen. Each main plot was 150 feet long and 51 feet wide. Sub-plots were 150 feet long by 8.5 feet wide. For the same reason as stated in Experiment I, more precise information was obtained on dates of application than on rates of application. The experiment was conducted on "new" sites each year.

Results

Two years' data were obtained at Inola while only one years' results were obtained at Newkirk. The experiment was not harvested at Newkirk in 1955 due to crop failure.

Inola

Grain yield and protein data obtained at Inola are presented in Tables 8 and 9. Wheat yields were not affected by rate of nitrogen application in either season. Time of application of nitrogen had no effect on wheat yields in 1955; however, in 1956, in every case when nitrogen was applied in the spring, yields were decreased. This yield

Table 8.—Influence of time and rates of anhydrous ammonia on yield of winter wheat, Inola, Oklahoma, 1955 and 1956.

				Time of Application			
Rate of N	Plowdown	Fall	Spring	Plowdown Fall	Plowdown Spring	Fall Spring	Av.
Lbs./A			**Bushels per acre**				
			1955				
20	28.4	27.6	30.4	28.7	30.2	29.9	29.2
40	28.5	29.8	26.9	28.7	27.3	29.1	28.4
80	28.5	28.2	29.4	26.6	30.8	28.6	28.7
160	26.2	25.1	26.1	26.8	29.9	27.0	26.7
Av.	27.9	27.7	28.2	27.5	29.6	28.6	
	Average yield of 4 check plots in 1955 was 28.6 bushels per acre.						
			1956				
20	29.1	28.6	22.5	29.5	21.4	19.6	25.1
40	31.2	29.2	20.7	28.8	19.9	29.2	24.8
80	33.2	30.5	25.3	29.5	23.6	23.0	27.5
160	30.7	28.7	21.3	31.0	20.9	21.5	25.7
Av.	31.1	29.3	22.4	29.7	21.5	20.8	
	Average yield of 4 check plots in 1956 was 28.4 bushels per acre.						

40 pounds per acre of K_2O applied on all plots previous to planting.
40 pounds per acre of P_2O_5 applied on all plots with the seed at planting.

Table 9.—Influence of time and rates of anhydrous ammonia on the protein content of the grain, Inola, Oklahoma, 1955 and 1956.

				Time of Application			
Rate of N	Plowdown	Fall	Spring	Plowdown Fall	Plowdown Spring	Fall Spring	Av.
Lbs./A				**Percent**			
				1955			
20	14.4	14.6	13.9	14.6	14.2	14.2	14.3
40	14.4	14.4	14.0	14.7	14.0	15.5	14.4
80	15.0	15.2	14.3	14.9	14.8	15.1	14.9
160	15.6	15.9	15.2	15.4	14.7	15.3	15.3
Av.	14.8	15.0	14.4	14.9	14.4	14.8	
	Average percent protein of 4 check plots in 1955 was 13.7.						
				1956			
20	14.0	14.1	14.9	13.8	13.8	14.5	14.2
40	13.9	14.2	15.0	14.0	15.0	15.4	14.6
80	14.1	14.3	15.1	14.2	14.8	15.6	14.7
160	14.6	15.6	15.8	15.0	15.8	16.2	15.5
Av.	14.2	14.6	15.2	14.2	14.9	15.4	
	Average percent protein of 4 check plots in 1956 was 14.2.						

decrease was due to injury to the stand by cultivation by the ammonia distributor rather than to the effect of the applied nitrogen. The soil was dry when the spring application of anhydrous ammonia was made and cultivation at that time reduced the stand of wheat materially.

In both seasons, grain protein increased with increasing rates of nitrogen through 160 pounds per acre. In 1955, grain protein contents from plowdown, plowdown-fall and fall applications were higher than those from spring and plowdown-spring applications. In 1956, however the fall-spring, spring, and plowdown-spring applications yielded higher grain protein than the plowdown and plowdown-fall applications. This reversal may be at least partially explained by the fact that yields were decreased by spring application of nitrogen. There was more dilution of the nitrogen available with the higher yields.

Table 10.—Influence of time and rates of application of anhydrous ammonia on yield of winter wheat, Newkirk, Oklahoma, 1956.

Rate of N	Plowdown	Fall	Spring	Time of Application Plowdown Fall	 Plowdown Spring	 Fall Spring	Av.
Lbs./A			**Bushels per acre**				
20	25.6	23.6	24.2	24.8	23.0	23.4	24.1
40	25.1	24.4	23.6	23.6	23.1	23.7	23.9
80	26.3	24.8	25.8	24.5	25.8	24.1	25.2
160	24.4	23.5	23.5	23.5	25.3	23.3	23.9
Av.	25.4	24.1	24.3	24.1	24.3	23.6	24.3
		Average yield of 6 check plots 24.6.					

40 pounds per acre of P_2O_5 applied on all plots with the seed at planting.

Newkirk

Grain yield and protein data obtained at Newkirk are presented in Tables 10 and 11. Grain yields were not affected by rate of nitrogen application. The yields from the plowdown applications of nitrogen were significantly higher than those from the other times of application. The increase for plowdown application over the average of the other times of application, however, was only 1.3 bushels per acre. Grain protein was high at Newkirk in 1956. The average for all treatments was 17.4 percent. The 160 pound nitrogen rate increased grain protein over the other rates of application but there were no differences in grain protein between the 20, 40, and 80 pound nitrogen rates. Time of nitrogen application did not affect grain protein at Newkirk in 1956.

Table 11.—Influence of time and rates of anhydrous ammonia on the protein content of the grain, Newkirk, Oklahoma, 1956.

Rate of N	Plowdown	Fall	Spring	Time of Application Plowdown Fall	 Plowdown Spring	 Fall Spring	Av.
Lbs./A			**Percent**				
20	17.1	17.8	17.4	17.0	17.5	16.8	17.3
40	16.6	18.0	17.8	17.6	17.3	16.8	17.3
80	16.5	17.0	17.1	17.8	17.2	17.1	17.1
160	18.4	18.0	17.1	18.8	17.9	18.1	18.1
Av.	17.2	17.7	17.3	17.6	17.5	17.2	17.4

Discussion and Conclusions

These experiments were conducted over a rather short period of time, at only a few locations, and during a period of extreme drouth conditions. The results do not give conclusive answers to all of the questions set up in the objectives but they do furnish some useful information. The results of Experiment I indicate that anhydrous ammonia is as efficient a carrier of nitrogen for wheat as ammonium nitrate. In fact, in some instances anhydrous ammonia was slightly more efficient than ammonium nitrate. The slight advantage for anhydrous ammonia could have been due to placement since anhydrous ammonia was placed in the root zone while ammonium nitrate was placed on the surface of the soil where it stayed until sufficient precipitation fell to carry it into the root zone. One would not expect ammonia nitrogen to be any more or less efficient than a mixture of ammonia and nitrate nitrogen in the nutrition of a wheat plant.

The attempts to establish the proper time to apply nitrogen fertilizer for highest grain yield and protein content were somewhat fruitless; however, the results indicate that if anhydrous ammonia is to be used as the nitrogen carrier, it probably should be applied before planting to insure that there will be no loss in stand due to cultivation by the ammonia distributor. The extent of injury to stand by cultivation apparently depends on the moisture content of the soil, the firmness of rootbed, the stage of development of the plants, and the lapse of time from application until precipitation is received. None of these can be predicted at planting time so the safest approach is to apply anhydrous ammonia previous to planting.

Results of other experiments[1] showed a slight advantage for spring over fall application of nitrogen when ammonium nitrate was the source of nitrogen. Spring application also has the advantage of allowing the crop prospects to be assessed in the early spring before buying nitrogen fertilizer. This is especially important in an area where yields, as well as nitrogen response, are often controlled by climate.

The nitrogen needs for maximum grain yields and grain protein cannot be predicted from these studies due to their rather short duration and to the small number of soils studied. The results do show, however, that yield response to nitrogen fertilizer may be obtained in some seasons during periods of below average rainfall. Further research on nitrogen needs, with emphasis on a method for predicting response to nitrogen, by soil test, soil moisture, or a combination of the two, is needed.

[1] Eck, Harold V. and Bobby A. Stewart, "Wheat Fertilization Studies in Western Oklahoma." Progress Report. 1951-52 and 1952-53. Okla. Agri. Exp. Sta. Bul. No. B-432.