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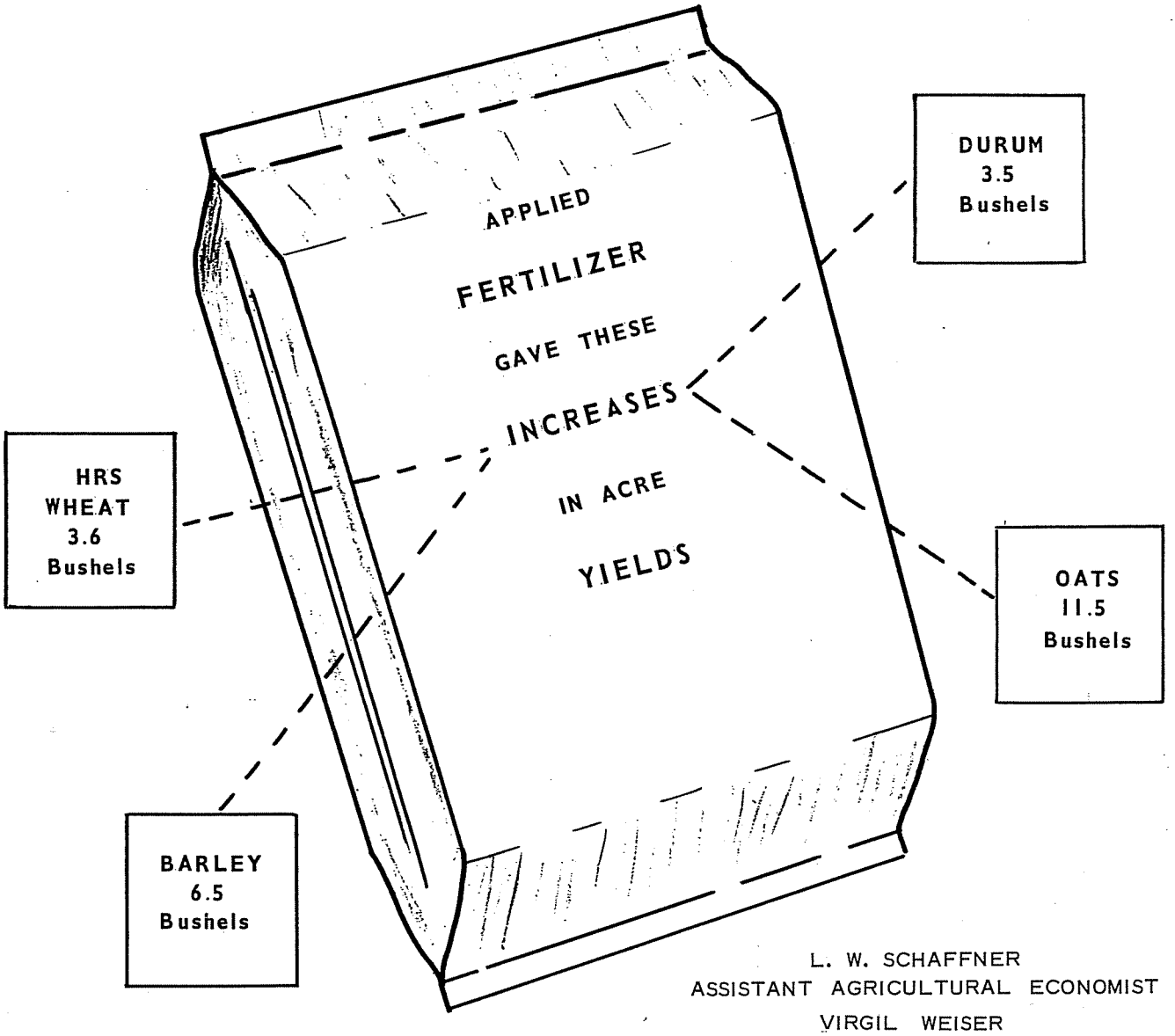
The TVA Fertilizer Farm Test-Demonstration Program in North Dakota 1957-1965



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INTRODUCTION

A fertilizer farm test-demonstration program was carried on in North Dakota for a nine-year period, from 1957 to 1965. The program was a cooperative effort by the North Dakota Agricultural Experiment Station, the North Dakota Cooperative Extension Service, and the Tennessee Valley Authority. The Agricultural Experiment Station assumed responsibility for the general development and conduct of the program and for the analysis of the results. The Cooperative Extension Service provided a soils agent who developed the crop and fertilizer plans on each of the cooperating farms, ordered the fertilizer materials, supervised fertilizer application, and helped in obtaining yield results from fertilizer by supervising the establishment of check strips in all fields fertilized. County agents selected farmers willing to cooperate in the program and helped carry out details of the program in their respective counties. The Tennessee Valley Authority furnished the fertilizer materials used in the program and provided some of the funds to cover other costs associated with administration of the program.

The objectives of the fertilizer test-demonstration program were:

1. To introduce Tennessee Valley Authority experimental fertilizers into farm programs in North Dakota.
2. To determine farmers' acceptance of these fertilizer materials.
3. To demonstrate and test the effects of recommended fertilizer treatments on individual crop yields and overall farm income.

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4. To promote resource development on North Dakota farms through improved use of fertilizers in combination with other recommended farming practices.

The fertilizer test-demonstration program was carried out in 14 counties during the 1957 to 1965 period (Figure 1). The number of farmer cooperators each year ranged from 18 to 49, with a total of 281 cooperator years. The farmers cooperating in the program agreed to:

1. Cooperate with representatives of the North Dakota State University in determining the fertilizer materials to be used and the crops to which the fertilizer would be applied.
2. Keep records of the fertilizer plots.
3. Apply all fertilizers supplied by the Tennessee Valley Authority on such crops and fields as agreed upon.
4. Leave an unfertilized check strip in each test field.
5. Make observations during the growing season, and yield determinations at harvest time, on the fertilized and unfertilized areas of the field.
6. Allow access to the farm at all times to representatives of the North Dakota State University for tours and meetings to make the information and results available to others.

Most farmers completed five years of cooperation in the test-demonstration farm program. Farmers who dropped out of the program after a year or two were replaced by other farmers. Those who dropped out did so because their farm operations did not fit into the program; they entered other business enterprises and could not devote the needed time, or for other reasons.

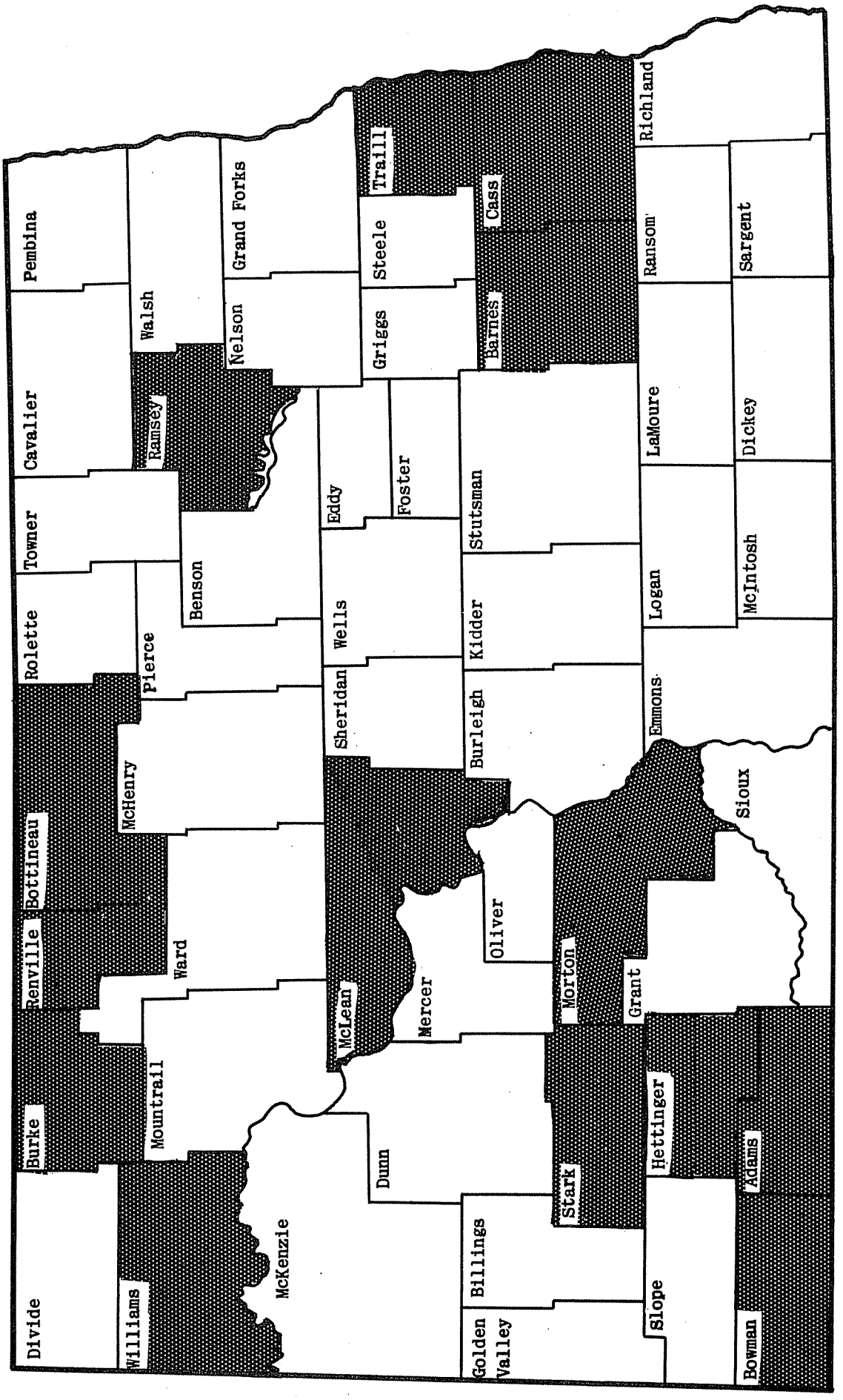

Figure 1. Location of Counties Cooperating in the TVA Fertilizer Farm Test-Demonstration Program, 1957-1965

TEST-DEMONSTRATION FARMS

Table 1 shows by counties the number of farmers cooperating in the fertilizer test-demonstration program during the nine-year period. Five years was the maximum time a farmer could be in the program. The counties and farms were selected to represent major areas in the state relative to soils, precipitation, and cropping systems. The farmer cooperators were required to have adequate and suitable equipment for applying fertilizer at uniform and accurate rates agreed upon and to employ current cultural practices.

TABLE 1. NUMBER OF FARMER COOPERATORS BY COUNTIES, 1957-1965

	Year								
County	1957	1958	1959	1960	1961	1962	1963	1964	1965
Adams	--	--	--	--	--	5	5	5	4
Barnes	3	3	3	3	3	1	--	--	--
Bottineau	--	--	--	--	--	5	5	5	5
Bowman	--	--	--	--	--	5	5	5	5
Burke	--	--	--	--	--	5	4	4	4
Cass	--	--	--	--	--	5	5	5	2
Hettinger	--	--	--	--	--	5	4	4	4
McLean	--	5	5	5	5	5	--	--	--
Morton	4	4	4	4	4	--	--	--	--
Ramsey	6	6	6	6	6	--	--	--	--
Renville	--	--	--	--	--	5	5	5	5
Stark	5	5	4	4	4	--	--	--	--
Traill	--	--	--	--	--	5	5	5	5
Williams	--	4	4	4	3	3	--	--	--
Total	18	27	26	26	25	49	38	38	34

FERTILIZER MATERIALS USED

The Tennessee Valley Authority furnished the test-demonstration fertilizer materials to the farmers cooperating in the program on a partial pay schedule of prices. The farmers also paid the freight and handling charges from producing plant to the farm.

The grades of fertilizer materials tested were:[3]

1. 0-63-0 (calcium metaphosphate)

2. 0-53-0
   0-54-0 (high analysis superphosphate)
   0-57-0

3. 20-52-0
   21-53-0 (diammonium phosphate)

4. 33.5-0-0 (ammonium nitrate)

5. 30-10-0 (ammonium phosphate-nitrate)

6. 20-20-0 (a leached zone fertilizer)

7. 25-25-0 (ammonium phosphate-nitrate)

The 33.5-0-0 fertilizer used in 1957 absorbed moisture, causing it to be lumpy. This material had to be screened before it could be applied. In following years, 30-10-0 was substituted for 33.5-0-0 because of its better physical condition.

In 1958, its first year of production and use, the physical condition of the 0-54-0 material was poor, causing problems in obtaining an accurate rate of application. In 1959, most farmers would not order this material. The improvement in physical condition, especially granulation made this an acceptable fertilizer material in subsequent years.

In some years the yield responses to some of the fertilizer materials may have been adversely affected by uneven distribution due to the problems encountered in applying them.

CROPS FERTILIZED

The TVA fertilizer materials were applied primarily on soils seeded to small grains. The soils were fertilized at rates recommended and the management system used in the area. Wheat, durum, and barley planted on fallow and

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[3]The fertilizer grade refers to the minimum guarantee of the plant nutrient content in terms of total nitrogen, available phosphorus pentoxide and soluble potassium oxide.

nonfallow land were the main crops and management systems on which most of the TVA fertilizer materials were used. Other crops on which TVA fertilizer was used included oats, rye, flax, corn, alfalfa, tame and native pasture, sunflowers, sugar beets, soybeans, and spelt (emmer).

Most of the farms had soil tests for phosphate for some of their fields. The phosphate rate of application was based on these tests.

The nitrogen rates were more difficult to determine because the guides used are based on the moisture content of the soil at time of planting. The application rates were determined about three months in advance of planting, and the soil moisture content could change materially.

YIELD RESPONSES FROM FERTILIZERS

Counties cooperating in the fertilizer farm test-demonstration program were separated geographically; and the moisture conditions, soil types, and farming practices vary appreciably. The 14 counties which cooperated in the program were divided into four areas for data analysis. One area, in southwestern North Dakota, includes the counties of Adams, Bowman, Hettinger, Morton, and Stark. The second area, in northwestern North Dakota, includes Bottineau, Burke, McLean, Renville, and Williams counties. The third area is in central North Dakota and includes Ramsey and Barnes counties. The fourth area is the Red River Valley and includes Cass and Traill counties.

Weather played an important role in the yield responses from fertilizer. Some of the demonstration farms were subjected to adverse weather conditions, such as hail, drought, heavy rains which flooded or damaged crops, plus extremes in temperatures. The yield results from fields farmers indicated had hail damage were not used in this analysis. This was the only adjustment made in the results for affects of weather conditions.

The yield responses from fertilizer varied widely among fields on the same farm in the same year, among farms within a county, and among counties in the same area. Tables 2, 3, and 4 show the frequency distribution of yield responses for various recommended rates of fertilizer by crops and management practices for the four areas. Data for the southwestern area cover nine years, 1957 to 1965; the northwestern area data are for eight years, 1958 to 1965; the central area data are for six years, 1957 to 1962; and the Red River Valley area data are for four years, 1962 to 1965.

Wheat

Table 2 shows the average increases in yield from fertilizer applied to wheat grown on fallow and nonfallow land. The average yield increase for wheat grown on fallow land was 3.8 bushels per acre in the southwestern area, 2.6 bushels in the northwestern area, 4.7 bushels in the central area, and 4.2 bushels in the Red River Valley area. The average yield increase from fertilizer was lowest in the northwestern area. One factor that may have affected the lower response from fertilizer was the higher proportion of the soils testing medium and high in phosphate.

The average yield increase from fertilizer applied to wheat grown on nonfallow land was 3.3 bushels per acre in the southwestern area, 6.9 bushels in the central area, and 6.0 bushels in the Red River Valley area (Table 2). A higher increase in yield from fertilizer application is necessary for nonfallow land than for fallow land because more nitrogen fertilizer is applied, which increases the costs. For example, the average fertilizer application to wheat grown on fallow land in the southwestern area was four pounds of nitrogen and 27 pounds of available phosphate compared with 16 pounds of nitrogen and 26 pounds of available phosphate applied to wheat grown on nonfallow land.

Wheat grown on nonfallow land to which fertilizer was applied had a higher yield increase than wheat grown on fallow land in the central and Red River Valley areas. In the central area, 94 percent of fields of wheat grown on nonfallow land and fertilized had a yield increase from fertilizer of three bushels or more compared to 59 percent of the fields of wheat grown on fallow land and fertilized. Seventy-nine percent of the fields of wheat grown on nonfallow land in the Red River Valley area had a yield increase of three bushels or more from fertilizer compared to 50 percent of the fields of wheat grown on fallow land. In the southwestern area, wheat grown on fallow land had a higher yield increase from fertilizer than wheat grown on nonfallow land.

There were some negative yields from fertilizer for which there is no plausible explanation (Table 2). They may be the result of a combination of factors; such as the sample from which the yield checks were determined, date of seeding, lodging, disease, weather, etc.

Durum

The average yield increase from applied fertilizers for durum grown on fallow land was 3.3 bushels per acre in the northwestern area and 2.6 bushels in the central area (Table 3). The modal increase in the northwestern area was 2.0 to 2.9 bushels, while in the central area it was 1.0 to 1.9 bushels. For durum grown on nonfallow land, the average per acre bushel increase was 4.7 in the central area and 4.3 in the Red River Valley area. The modal yield increase was 4.0 to 4.9 bushels per acre in the central area. In the Red River Valley area 28 percent of the fields had a negative yield response in comparison to the unfertilized check strip. There was also a high proportion (33 percent) of the fields with yield increases from fertilizer of 7.0 bushels and over.

TABLE 2. PERCENT DISTRIBUTION OF YIELD RESPONSE FROM FERTILIZER ON HARD RED SPRING WHEAT GROWN ON FALLOW AND NONFALLOW LAND, BY AREAS

Yield Response in Bushels	Fallow Land				Nonfallow Land		
	Southwestern	Northwestern	Central	Red River Valley	Southwestern	Central	Red River Valley
	- percent -						
Less Than 0	3.4	11.3	9.1	--	9.4	--	10.6
0 - .9	7.9	17.9	9.1	22.7	12.3	--	--
1.0 - 1.9	16.7	16.7	13.6	22.7	10.1	3.0	5.3
2.0 - 2.9	19.7	19.0	9.1	4.6	18.8	3.0	5.3
3.0 - 3.9	11.7	8.9	4.5	--	14.5	15.1	10.5
4.0 - 4.9	12.5	7.1	13.6	13.6	9.4	6.1	21.0
5.0 - 5.9	7.1	8.3	9.1	--	8.7	18.2	--
6.0 - 6.9	7.9	3.6	4.6	13.6	5.1	18.2	10.5
7.0 - 7.9	4.2	.6	9.1	4.6	4.4	6.1	5.3
8.0 - 8.9	3.4	2.4	4.6	9.1	3.6	6.1	10.5
9.0 - 9.9	1.7	1.8	--	--	1.5	3.0	--
10.0 and Over	3.8	2.4	13.6	9.1	2.2	21.2	21.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Number of Fields	239	168	22	22	138	33	19
Average Yield Response (Bu.)	3.8	2.6	4.7	4.2	3.3	6.9	6.0
Average Fertilizer Treatment/Acre[a]	4+27+0	3+23+0	3+30+0	11+29+0	16+26+0	28+29+0	36+25+0

[a]Average pounds of total nitrogen and available phosphate applied per acre.

The average yield response from fertilizer was higher for durum grown on nonfallow land than for durum grown on fallow land. The amount of fertilizer applied to nonfallow land also was higher, with more nitrogen being applied.

Barley

The northwestern area had 33 fields of barley on fertilized fallow land. The average yield increase was 4.3 bushels per acre. The modal group

fell in the negative or less than zero yield response range--15 percent of the fields had negative responses from the fertilizer application (Table 4).

Barley on fertilized nonfallow land was reported in each of the four areas. The average yield increase from fertilizer was 6.7 bushels per acre in the southwestern, 4.0 bushels in the northwestern, 8.3 bushels in the central, and 7.0 bushels in the Red River Valley areas (Table 4). The modal response range was 10.0 bushels and over for the southwestern, central, and Red River Valley areas. The modal yield response was negative for the northwestern area.

TABLE 3. PERCENT DISTRIBUTION OF PER ACRE YIELD RESPONSE FROM FERTILIZER FOR DURUM GROWN ON FALLOW AND NONFALLOW LAND, BY AREAS

Yield Response in Bushels	Fallow Land		Nonfallow Land	
	North-western	Central	Central	Red River Valley
	- percent -			
Less Than 0	11.1	7.4	4.8	28.2
0 - .9	15.3	14.8	--	5.1
1.0 - 1.9	10.4	22.2	4.8	5.1
2.0 - 2.9	16.7	14.8	9.5	5.1
3.0 - 3.9	6.9	7.4	19.0	2.6
4.0 - 4.9	10.4	14.8	23.8	7.7
5.0 - 5.9	7.6	14.8	19.0	7.7
6.0 - 6.9	6.2	--	9.5	5.1
7.0 - 7.9	5.6	3.8	4.8	10.3
8.0 - 8.9	2.8	--	--	2.6
9.0 - 9.9	2.1	--	--	5.1
10.0 and Over	4.9	--	4.8	15.4
	100.0	100.0	100.0	100.0
Number of Fields	144	27	21	39
Average Yield Response (Bu.)	3.3	2.6	4.7	4.3
Average Fertilizer Treatment/Acre[a]	3+22+0	4+26+0	25+30+0	26+19+0

[a]Average pounds of total nitrogen and available phosphate applied per acre.

TABLE 4. PERCENT DISTRIBUTION OF PER ACRE YIELD RESPONSE FROM FERTILIZER FOR BARLEY GROWN ON FALLOW AND NONFALLOW LAND, BY AREAS

Yield Response in Bushels	Fallow Land	Nonfallow Land			
	Northwestern	Southwestern	Northwestern	Central	Red River Valley
		- percent -			
Less Than 0	15.2	--	17.5	4.0	14.6
0 - .9	6.1	4.6	8.8	3.0	4.9
1.0 - 1.9	9.1	6.8	8.8	5.0	7.3
2.0 - 2.9	12.1	9.1	7.0	7.1	8.5
3.0 - 3.9	9.1	13.6	7.0	7.1	4.9
4.0 - 4.9	9.1	2.2	15.8	6.1	3.7
5.0 - 5.9	12.1	6.8	--	7.1	4.9
6.0 - 6.9	3.0	11.4	3.5	5.0	3.7
7.0 - 7.9	12.1	13.6	7.0	8.1	2.4
8.0 - 8.9	--	11.4	12.3	9.1	4.9
9.0 - 9.9	--	4.6	3.5	7.1	2.4
10.0 and Over	12.1	15.9	8.8	31.3	37.8
	100.0	100.0	100.0	100.0	100.0
Number of Fields	33	44	57	99	82
Average Yield Response (Bu.)	4.3	6.7	4.0	8.3	7.0
Average Fertilizer Treatment/Acre[a]	2+25+0	13+26+0	14+21+0	24+27+0	29+24+0

[a]Average pounds of total nitrogen and available phosphate applied per acre.

Summary of Yield Responses From Fertilizer For Crops on Fallow Land

Fertilizer treatments on fallow land were classed in two categories--straight phosphate treatment and nitrogen-phosphate treatment. Average results by crops and area of the state are shown in Table 5. For wheat the straight phosphate fertilizer showed as good or better response results in the southwestern and northwestern areas as the nitrogen-phosphate fertilizer. Nitrogen-phosphate fertilizer produced a better response than the straight

TABLE 5. SUMMARY OF FERTILIZER TREATMENTS AND YIELD INCREASES FROM FERTILIZER FOR CROPS GROWN ON FALLOW LAND, BY AREAS

Area and Crop	Time Period	Number of Fields	Average Fertilizer Treatment[a]	Average Yield Increase
			lbs.	bu.
Southwestern Area				
HRS Wheat	1957-1965	149	0+28+0	3.8
HRS Wheat	1957-1965	90	10+26+0	4.0
Durum	1957-1965	3	0+21+0	2.1
Durum	1957-1965	15	8+21+0	4.1
Barley	1957-1965	12	0+31+0	5.6
Barley	1957-1965	10	9+22+0	7.4
Northwestern Area				
HRS Wheat	1958-1965	112	0+25+0	2.7
HRS Wheat	1958-1965	56	8+20+0	2.4
Durum	1958-1965	99	0+23+0	3.1
Durum	1958-1965	45	8+21+0	3.8
Barley	1958-1965	26	0+25+0	4.3
Barley	1958-1965	7	9+24+0	2.6
Central Area				
HRS Wheat	1957-1962	15	0+30+0	3.3
HRS Wheat	1957-1962	7	11+28+0	7.5
Durum	1957-1962	13	0+30+0	2.0
Durum	1957-1962	14	9+23+0	3.2
Barley	1957-1962	4	0+36+0	6.8
Barley	1957-1962	4	11+28+0	7.8
Red River Valley Area				
HRS Wheat	1962-1965	2	0+28+0	2.2
HRS Wheat	1962-1965	20	13+29+0	4.4
Durum	1962-1965	2	0+30+0	4.4
Durum	1962-1965	8	10+26+0	3.1
Barley	1962-1965	2	0+30+0	1.4
Barley	1962-1965	4	18+35+0	8.0

[a]Pounds of total nitrogen and available phosphate applied per acre.

phosphate fertilizer in the central and Red River Valley areas. There was no consistent trend by crops or by areas from using a straight phosphate fertilizer versus a nitrogen-phosphate fertilizer. The numbers of observations

compared in Table 5 are not large enough in most cases to give a reliable guide as to the type of fertilizer to use on fallow land in the various areas of the state.

Fields of hard red spring wheat and durum grown on fallow land which had a phosphate soil test were tabulated to show the yield response by the amount of phosphate in the soil. The data were classified into phosphate soil test results of very low, low, medium, and high. The average increase in yield from fertilizer and the average amounts of fertilizer applied are shown in Table 6. The yield responses from fertilizer were higher for the very low and low phosphate soil tests with a yield increase of 3.9 and 3.1 bushels per acre, respectively. The medium phosphate soils had a 2.5 bushel per acre yield increase from fertilizer, and the high phosphate soils had a per acre yield increase of 2.5 bushels.

TABLE 6. AVERAGE CHECK YIELD IN BUSHELS PER ACRE, AVERAGE YIELD INCREASE PER ACRE FROM FERTILIZER FOR WHEAT GROWN ON FALLOW LAND, AND FERTILIZER APPLIED TO SOILS TESTING VERY LOW, LOW, MEDIUM, AND HIGH IN PHOSPHATE, 1958-1965

Phosphate Soil Test	Number of Fields	Check Yield Bu./Acre	Yield Increase In Bushels Per Acre	Fertilizer Applied[a]
Very Low	97	23.7	3.9	2+27+0
Low	54	25.6	3.1	5+24+0
Medium	91	30.9	2.5	4+22+0
High	30	27.1	2.5	5+18+0

[a]Average pounds of total nitrogen and available phosphate applied per acre.

This study points out that there are other factors affecting crop responses from fertilizer besides the rate of application, type of fertilizer used, and the soil test for phosphate. In this program, where recommended

rates of fertilizer were used and many of the fields had a phosphate soil test, a high proportion of the yield increases was not large enough to cover the cost of the fertilizer applied. Using wheat grown on fallow land as an example, 28 percent of the fields in the southwestern area, 38 percent in the northwestern area, 23 percent in the central area, and 41 percent in the Red River Valley area had yield responses that would not cover the cost of the fertilizer. The question arises as to what the factors are and how they affect the yield response from fertilizer in the various areas of the state. These factors would include too little or too much precipitation, stored soil moisture at seeding, temperatures during the growing season, soil type, nutrients available in the topsoil, nutrients released from the subsoil, time of seeding, chemical reactions between the fertilizer and chemicals in the soil, insects, and diseases.

PRECIPITATION

Yields of small grain on dryland farms in North Dakota are limited more frequently by insufficient water than by any other factor. The total supply of water cannot be controlled except by irrigation. Studies show that water can be utilized more efficiently by wheat when the crop is fertilized.[4]

Small grain yields and responses from fertilizer also are affected by the supply of water when crops are grown on nonfallow land and nitrogen is used in the fertilizer mixture applied. The amount of moisture in the soil at time of seeding is a guide used to determine the rate of nitrogen fertilizer to apply to a small grain crop grown on nonfallow land.[5]

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[4]Bauer, A. and R. A. Young, "Fertilized Wheat Uses Water More Efficiently," North Dakota Farm Research, Volume 24, Number 3, North Dakota State University, Fargo, North Dakota, January-February, 1966, pp. 4-11.

[5]Bauer, A., R. A. Young, and J. L. Ozbun, "Stored Soil Moisture and Seasonal Rainfall--Its Effect on Yield Responses of Small Grains to Fertilizer," Guide for Profitable Fertilizer Use, North Dakota Agricultural Experiment Station and Extension Service, Fargo, North Dakota (Prepared for Twelfth Annual Fertilizer Dealer Conference), November 30, 1960, pp. 3-16.

To give background data on the water supply during the period of the fertilizer farm test-demonstration program, the annual and growing season rainfall is shown in Table 7 for the four areas of the state where the fertilizer demonstrations were located. This shows only a part of the water supply picture. No attempt was made to estimate the amount of water stored in the soil at seeding time for each year of the test-demonstration program.

The long-term average precipitation is not a good measure of the moisture supply available for growing small grains. This measure may understate or overstate the amount of water actually available for maximum crop production. About the only comparison that can be made of the data in Table 7 is the number of years the actual rainfall fell above or below the long-term average. If the rainfall was below the long-term average, one might assume that the water supply was limiting at some stage of the growing season.

In the southwestern area there were three years in which the growing season rainfall fell below the long-term average. The annual rainfall was below the long-term average four years. It is important to note that the years in which the total growing season and the annual rainfall were below the long-term average fell in consecutive order. This also was true in the northwestern and central areas. In the southwestern area, the growing season rainfall was below the long-term average in 1959, 1960, and 1961. In the northwestern and central areas, the growing season rainfall was below the long-term average in 1958, 1959, 1960, and 1961. In the Red River Valley area, 1963 was the only year the growing season rainfall fell below the long-term average. During the four years the fertilizer test-demonstration program was active in the Red River Valley area, excessive moisture was more of a problem than not enough moisture.

TABLE 7. PRECIPITATION IN INCHES FOR THE GROWING SEASON, ANNUAL, AND LONG-TERM AVERAGE, BY AREAS, 1957-1965

Year and Area	Growing Season				Annual Precipitation
	May	June	July	Total	
Southwestern Area					
1957	1.88	7.30	1.96	11.14	20.02
1958	.51	3.86	3.72	8.09	13.32
1959	1.85	2.69	.84	5.38	12.76
1960	2.88	3.99	1.04	7.91	12.67
1961	1.78	1.83	2.42	6.03	13.08
1962	5.89	2.50	3.76	12.15	18.93
1963	2.48	5.22	2.48	10.18	18.57
1964	2.14	6.36	2.09	10.59	17.03
1965	4.57	3.10	2.77	10.44	18.21
Long-term Average	1.94	3.74	2.34	8.02	15.15
Northwestern Area					
1958	.36	2.05	2.07	4.48	10.15
1959	1.66	3.61	.87	6.14	17.32
1960	1.95	2.04	1.33	5.32	10.74
1961	1.09	.71	1.41	3.21	9.52
1962	5.07	3.60	2.47	11.14	18.05
1963	3.14	5.70	3.77	12.61	20.32
1964	1.82	5.50	2.39	9.71	17.14
1965	5.78	2.80	2.71	11.29	18.94
Long-term Average	1.80	3.43	2.13	7.36	14.64
Central Area[a]					
1957	1.90	4.70	3.46	10.06	23.03
1958	1.25	3.28	3.38	7.91	14.54
1959	2.34	3.58	1.98	7.90	16.87
1960	3.58	2.20	1.40	7.18	17.14
1961	.78	1.42	2.74	4.94	14.82
1962	5.04	1.96	5.95	12.95	22.84
Long-term Average	2.23	3.35	2.70	8.28	17.52
Red River Valley Area					
1962	5.32	2.56	5.62	13.50	23.91
1963	1.76	1.81	3.17	6.74	14.30
1964	1.13	5.76	1.96	8.85	22.03
1965	3.74	3.14	5.21	12.09	25.90
Long-term Average	2.42	3.50	2.80	8.72	18.68

[a]The central area is an average of the Devils Lake and Valley City reporting stations.

COSTS AND RETURNS FROM FERTILIZER

Yield differences between fertilized and unfertilized crops are not an adequate measure of fertilizer results. For example, a 10.0 bushel yield increase of oats from fertilizer looks like a good response but may actually show a loss to the investment in fertilizer because oats is a relatively low value crop. Three factors must be considered when analyzing the profitability of fertilizer use:

1. The yield response from fertilizer.
2. The cost of the fertilizer applied.
3. The price or value of the additional crop produced.

Yield response from fertilizer by crops and management practices (fallow and nonfallow rotations) has been discussed. Cost of the fertilizer materials in this analysis was 14 cents per pound for nitrogen (N) and 10 cents per pound for phosphate (P_2O_5). These prices were determined from the price paid for commercial fertilizer used by the test-demonstration farmers in 1965. These costs also include an allowance for the extra labor in handling the fertilizer and for the machine costs to apply the fertilizer.

The price or the value of the additional crop produced by applying fertilizer is important. In this analysis the price used for small grains was the October 15 price received by farmers for each year (Appendix Table 1).

Table 8 shows the average results from recommended fertilizer treatments by crops and management practices for the test-demonstration farms. These results include a nine-year average (1957-1965) for the southwestern area, an eight-year average (1958-1965) for the northwestern area, a six-year average (1957-1962) for the central area, and a four-year average (1962-1965) for the Red River Valley area. Results shown in Table 8 indicate that crops

TABLE 8. AVERAGE FERTILIZER TREATMENT, YIELD RESPONSES, COSTS, AND RETURNS TO FERTILIZER INVESTMENT, BY CROPS AND CROPPING PRACTICES AND BY AREAS

Crop and Cropping Practice	Number of Fields	Ave. Fert. Treatment Per Acre[a]	Ave. Fert. Yield Per Acre	Ave. Yield Response Per Acre	Average Fertilizer Cost	Ave. Net Return Per Acre	Percent Profit
			bu.	bu.	dol.	dol.	
			Southwestern Area				
Fallow Land							
HRS Wheat	149	0+28+0	24.2	3.8	2.83	3.97	140
HRS Wheat	90	10+26+0	23.9	4.0	3.99	2.58	65
Total Wheat	239	4+27+0	24.1	3.8	3.27	3.45	105
Nonfallow Land							
HRS Wheat	138	16+26+0	22.7	3.3	4.75	1.44	30
Barley	44	13+26+0	38.3	6.7	4.36	1.08	25
Oats	31	16+24+0	59.4	10.2	4.68	.10	1
			Northwestern Area				
Fallow Land							
HRS Wheat	112	0+25+0	31.1	2.7	2.49	2.32	93
HRS Wheat	56	8+20+0	27.8	2.4	3.02	1.26	42
Total Wheat	168	3+23+0	30.0	2.6	2.67	1.97	74
Durum	99	0+23+0	36.2	3.1	2.32	4.24	182
Durum	45	8+21+0	39.2	3.8	3.18	3.55	112
Total Durum	144	3+22+0	37.2	3.3	2.59	4.02	155
Barley	26	0+25+0	53.4	4.3	2.47	.86	35
Nonfallow Land							
Barley	57	14+21+0	43.6	4.0	4.01	-.85	-21

- continued -

TABLE 8. AVERAGE FERTILIZER TREATMENT, YIELD RESPONSES, COSTS, AND RETURNS TO FERTILIZER INVESTMENT, BY CROPS AND CROPPING PRACTICES AND BY AREAS (continued)

Crop and Cropping Practice	Number of Fields	Ave. Fert. Treatment Per Acre[a]	Ave. Fert. Yield Per Acre	Ave. Yield Response Per Acre	Average Fertilizer Cost	Ave. Net Return Per Acre	Percent Profit
			bu.	bu.	dol.	dol.	
			Central Area				
Nonfallow Land							
HRS Wheat	33	28+29+0	31.5	6.9	6.75	6.25	93
Barley	99	24+27+0	35.1	8.3	6.05	.56	9
			Red River Valley Area				
Nonfallow Land							
Durum	39	26+19+0	37.1	4.3	5.48	1.19	22
Barley	82	29+24+0	51.5	7.0	6.48	-.65	-10
			All Areas				
Fallow Land							
HRS Wheat	278	0+27+0	27.6	3.3	2.70	3.25	120
HRS Wheat	173	10+24+0	26.6	3.6	3.77	2.50	66
Total Wheat	451	4+26+0	27.2	3.4	3.11	2.96	95
Durum	117	0+24+0	35.1	3.0	2.40	3.94	164
Durum	82	8+22+0	35.9	3.7	3.33	3.52	106
Total Durum	199	3+23+0	35.4	3.3	2.78	3.76	135
Barley	44	0+28+0	50.6	4.7	2.75	1.09	40
Barley	25	11+25+0	51.1	6.2	4.04	.99	24
Total Barley	69	4+27+0	50.8	5.3	3.22	1.05	33
Nonfallow Land							
HRS Wheat	201	20+26+0	25.1	4.1	5.39	2.12	39
Durum	80	23+22+0	32.7	3.9	5.31	1.63	31
Barley	282	22+25+0	42.2	6.8	5.50	0.00	0
Oats	59	18+22+0	68.2	12.5	4.81	.84	17

[a]Pounds of total nitrogen and available phosphate applied per acre.

grown on fallow land gave a higher return per dollar invested in fertilizer than did crops grown on nonfallow land.

Costs and returns data in Table 8 were calculated only by the crops and management practices for which data were available for a minimum of 25 fields. Crops grown on fallow land were separated into two classes, those receiving straight phosphate fertilizer and those receiving nitrogen-phosphate fertilizers. Only the southwestern and northwestern areas had sufficient field trials of crops on fallow land to be included in Table 8.

The percent profit from straight phosphate fertilizer was greater than the profit from nitrogen-phosphate fertilizer for hard red spring wheat and durum on fallow land in both the southwestern and northwestern areas (Table 8). In the southwestern area the percent return from the investment in a straight phosphate fertilizer for hard red spring wheat was 140 percent compared to 65 percent for the nitrogen-phosphate fertilizers. The percent profit from fertilizer means that each $1.00 invested in a straight phosphate fertilizer used on hard red spring wheat returned $2.40, while $1.00 invested in the nitrogen-phosphate fertilizer gave a return of $1.65. In the northwestern area, the percent return on the investment in fertilizer was 93 percent for the straight phosphate fertilizer compared to 42 percent for the nitrogen-phosphate fertilizers. For durum in the northwestern area, the return from the investment in the straight phosphate fertilizer was 182 percent compared to 112 percent for the nitrogen-phosphate fertilizers.

Another measure of the return from fertilizer is the average net return per acre. This is shown in Table 8. The average net return per acre from fertilizer is additional income to the farmer, since the fertilizer costs have been taken out. The average of all the areas showed that the use of

fertilizer at recommended rates on fallow land gave additional $2.96 per acre for wheat, $3.76 for durum, and $1.05 for barley. The average per acre net return from fertilizer on nonfallow land was $2.12 for wheat, $1.63 for durum, and $.84 for oats. These extra dollars are important, especially during a period of increasing farm costs.

Table 8 also shows that the crops grown on fallow land in the southwestern and northwestern areas gave a higher return from the investment in fertilizer than the crops on nonfallow land. The summary for all areas, in Table 8, shows that the straight phosphate fertilizer gave the highest returns for hard red spring wheat, durum, and barley on fallow land; and the returns from fertilizer for crops on fallow land were greater than for the same crops grown on nonfallow land.

The results in Table 8 would indicate to a farm operator, who has limited capital to invest in fertilizer, that he fertilize crops in the following order:

1. Durum on fallow land.
2. Hard red spring wheat on fallow land.
3. Hard red spring wheat on nonfallow land.
4. Barley on fallow land.
5. Durum on nonfallow land.
6. Oats on nonfallow land.
7. Barley on nonfallow land.

Yield response from fertilizer and price received for the product produced during the 1957 to 1965 period were the two factors influencing the above results. The cost of the fertilizer was held constant in the analysis over the nine-year period. Recommended rates of fertilizer were used.

How low can the price of the crop produced go before it will not pay to apply fertilizer? If one could expect an average yield increase from fertilizer of 3.4 bushels per acre for hard red spring wheat grown on fallow land and the fertilizer costs remained about the same as they have been the last couple of years, the price of wheat could drop to $.92 per bushel before it would not pay to fertilize wheat. For wheat on nonfallow land, and assuming a 4.1 bushel per acre average yield increase from fertilizer, the price of wheat could drop to $1.32 per bushel before the returns from the extra bushels produced would not cover the cost of the fertilizer applied. If a lower or higher yield increase from fertilizer is expected, this would affect the price necessary to break even with the cost of the fertilizer application.

The probability of obtaining a positive return on an investment in fertilizer is greater for crops grown on fallow land than for crops grown on nonfallow land (Table 9). For example, returns from 68 percent of the fields of wheat grown on fallow land more than covered the cost of the fertilizer, while returns from 59 percent of the fields of wheat grown on nonfallow land more than covered the fertilizer cost.

About two-thirds of the fields of hard red spring wheat and durum on fallow land gave a positive return from the investment in fertilizer compared to slightly more than one-half of the nonfallow fields. Fifty-five percent of the barley on fallow fields which were fertilized gave a positive return compared with 46 percent of the nonfallow fields.

Table 10 shows the percent distribution of the returns from the fertilizer investment by crops and management practices for the nine-year period, 1957 to 1965. Twenty-seven percent of the durum fields and 18 percent of the fields of hard red spring wheat on fallow land gave a return on the investment

in fertilizer of 251 percent and over. In other words, a dollar spent for fertilizer returned at least $2.51 over and above the cost of the fertilizer.

TABLE 9. PERCENTAGE OF THE TOTAL FIELDS CHECKED FOR YIELD RESPONSE FROM FERTILIZER THAT GAVE A YIELD INCREASE TO MORE THAN COVER THE FERTILIZER COST, BY CROPS AND MANAGEMENT PRACTICE, 1957-1965

Crop	Management Practice			
	Fallow		Nonfallow	
	Number of Fields	Percent	Number of Fields	Percent
Hard Red Spring Wheat	451	68	201	59
Durum	199	66	80	55
Barley	69	55	282	46
Oats	--	--	59	58

A wide range in the percent profit or loss on the fertilizer investment is shown by the data in Table 10. Durum on fallow land had the widest range, varying from a minus 786 percent to a positive 1,958 percent return for the investment in fertilizer.

The data in Table 10, on percent return from the investment in fertilizer for the nine-year period, 1957 to 1965, show that the probability of at least doubling the investment in fertilizer was 40 percent for hard red spring wheat, 49 percent for durum on fallow, 33 percent for barley on fallow, 28 percent for hard red spring wheat on nonfallow, 23 percent for durum on nonfallow, 15 percent for barley on nonfallow, and 22 percent for oats on nonfallow land.

SUMMARY

The Tennessee Valley Authority farm test-demonstration fertilizer program was carried on in North Dakota for the nine-year period, 1957 to 1965

TABLE 10. PERCENT DISTRIBUTION OF THE RETURNS FROM FERTILIZER BY CROPS AND MANAGEMENT PRACTICES FOR ALL TVA TEST-DEMONSTRATION FARMS, 1957-1965

Percent Profit or Loss	Wheat Fallow	Wheat Nonfallow	Durum Fallow	Durum Nonfallow	Barley Fallow	Barley Nonfallow	Oats Nonfallow
			- percent -				
Loss							
251 - Over	1.1	.8	3.0	5.0	2.9	1.1	1.7
226 - 250	.2	1.2	--	2.5	--	--	--
201 - 225	.9	.4	.5	--	--	.7	1.7
176 - 200	--	--	1.0	--	1.4	1.4	--
151 - 175	1.1	.8	1.5	5.0	1.4	1.1	--
126 - 150	1.8	4.5	2.5	1.3	1.4	1.4	1.7
101 - 125	.9	1.2	1.0	5.0	1.4	3.5	--
76 - 100	6.0	9.0	4.0	2.5	8.7	8.5	10.2
51 - 75	5.1	4.5	3.5	6.2	8.7	9.6	8.5
26 - 50	8.4	7.3	5.6	6.2	11.6	12.8	6.8
0 - 25	6.9	9.0	11.1	11.2	7.3	13.8	11.8
Profit							
1 - 25	7.7	9.4	5.0	6.2	8.7	11.3	10.2
26 - 50	7.1	9.8	4.0	11.2	4.4	8.9	11.8
51 - 75	6.2	8.1	5.0	8.8	2.9	6.7	1.7
76 - 100	6.8	6.5	3.5	6.2	5.8	4.6	11.8
101 - 125	4.4	6.9	4.0	3.8	7.3	4.3	10.2
126 - 150	4.9	4.5	4.0	2.5	8.7	3.9	--
151 - 175	4.4	2.0	2.5	1.3	1.4	1.4	1.7
176 - 200	2.9	2.4	5.6	1.3	5.8	1.1	1.7
201 - 225	2.9	2.0	3.0	--	2.9	1.1	--
226 - 250	2.4	1.6	2.5	1.3	--	.7	3.4
251 - Over	17.9	8.1	27.2	12.5	7.3	2.1	5.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Range in Returns	-487% to 1,698%	-334% to 861%	-786% to 1,958%	-443% to 422%	-349% to 357%	-429% to 534%	-205% to 563%

to introduce Tennessee Valley Authority experimental fertilizer in farm programs in North Dakota and to determine farmers' acceptance of these fertilizer materials. The program was carried on in 14 counties in various parts of the state.

The results of the farm test-demonstrations indicate that fertilizer can be used as a tool to increase the farm income by increasing the production from a given amount of land and, thereby, decreasing the per unit production costs. It is difficult to estimate how much fertilizer has increased farm income because no data are available for the acreage of the various crops fertilized. Complete farm records were kept on each farm the first three years of the farm test-demonstration program. The returns from fertilizer from crop yield increases accounted for about 11 percent of the total net farm income during this period for the farms in the test-demonstration program.

The program pointed up the need for applying all the available technology associated with fertilizer use. This includes soil sampling and testing, soil moisture determination, good cropping systems, proper tillage, weed control, timeliness of all operations, and other good farm management practices. Check strips should be left to obtain an accurate estimate of fertilizer performance.

The test-demonstration farmers used much of the available technology. Yet, in a single year, there was a wide range on the same farm and between farms in the same area in yield responses and returns from the investment in fertilizer. For example, in southwestern North Dakota in 1965 the percent profit from fertilizer for hard red spring wheat grown on fallow land using recommended rates of phosphate fertilizer varied from a minus 211 percent to a plus 273 percent. The range in returns from fertilizer for hard red spring wheat grown on fallow land on one farm in the southwestern area in 1965 ranged from a minus 20 percent to a plus 212 percent. On another farm the range was from a minus 77 percent to a plus 140 percent.

More research is needed on the factors which affect the crop yield responses to fertilizer so that the probability of obtaining a profit from the fertilizer investment can be more accurately predicted.

Fertilization of wheat and durum grown on fallow land generally gave the highest returns to the dollar invested in fertilizer. The probability of obtaining a profit from the fertilizer investment also was greater for wheat and durum grown on fallow land, with about two-thirds of the fields having a yield response that more than covered the cost of the fertilizer.

APPENDIX

APPENDIX TABLE 1. OCTOBER 15 CASH GRAIN PRICES USED TO CALCULATE RETURNS FROM FERTILIZER FOR THE YEARS 1957 TO 1965

Year	Wheat	Durum	Barley	Oats
		- dollars per bushel -		
1957	2.00	1.99	.85	.46
1958	1.84	1.95	.79	.41
1959	1.90	2.12	.79	.52
1960	1.80	1.91	.71	.43
1961	2.04	3.16	.99	.55
1962	2.10	2.23	.78	.49
1963	2.03	2.09	.77	.49
1964	1.45	1.36	.83	.50
1965	1.44	1.28	.94	.48