than 100 crop acres. Farms of this size may be too small to provide an adequate living. FHA county supervisors are urged to use minimum resources guides as a precaution against making loans on farms that are too small.

The median initial loan was $4,690. Approximately half of the borrowers also received supplemental loans. The median supplemental loan was $830.

The largest share of initial loan funds were used for livestock purchases, 41 percent on the average. Machinery purchases and refinancing accounted for 26 and 22 percent, respectively, of the initial loan funds. Nearly one-half of the supplemental loan funds were used for machinery purchases and about one-quarter of the supplemental loan funds were used for operating expense.

More than half of the initial loans had terms of 6½ or 7 years. The loans were set up with installments geared to anticipated farm income over the life of the loan. The chattel mortgage that secures the promissory note was renewed periodically to keep it current.

The average borrower had been on the program for about 2½ years. He started with total assets that averaged $10,339 and these had increased to $15,328 on January 1, 1955. Average net worth increased from $5,787 to $7,561. Of the 162 borrowers, 120 showed increases in net worth while 40 showed decreases. The average borrower had an owner equity in his farm business of about 50 percent on January 1, 1955. However, there was considerable variation in owner equity of individual borrowers. Nearly 20 percent had equities of less than 35 percent. This points up the relatively high debt load that these borrowers are carrying.

Income and expense records of the borrowers in 1954 showed that net farm income over farm operating expenses ranged from $2,240 in the southeast dairy and southwest livestock areas to $260 in Itasca county. Income from sources other than farming was substantial in Itasca county and the northwest crop area where it averaged $1,910 and $1,350, respectively.

Net farm income and nonfarm income provide the means for family living, capital outlays, and debt repayment. The range in this amount was not wide between areas. It ranged from $2,850 in the southeast dairy area to $2,170 in Itasca county.

The average borrower in the southwest livestock and southeast dairy areas went further into debt by $940 and $220, respectively, during 1954. Capital expenditures averaged more than the amount available for this purpose in these areas. The average borrower in the northern areas applied about $500 toward repayment of debts.

Approximately 60 percent of the borrowers who left the program during the five fiscal years 1950-54 repaid their loans in full and continued to farm. The remaining 40 percent did not become established in farming. This indicates the importance of utmost care in selection of applicants to hold losses and disappointments to a minimum.

Broadened lending authority was provided by Congress in 1956. The Farmers Home Administration can now make larger loans for longer terms, loans to part-time farmers, and loans where refinancing is the major purpose. This will enable the agency to be of greater assistance to young farmers, but successful operation will call for even more careful selection.

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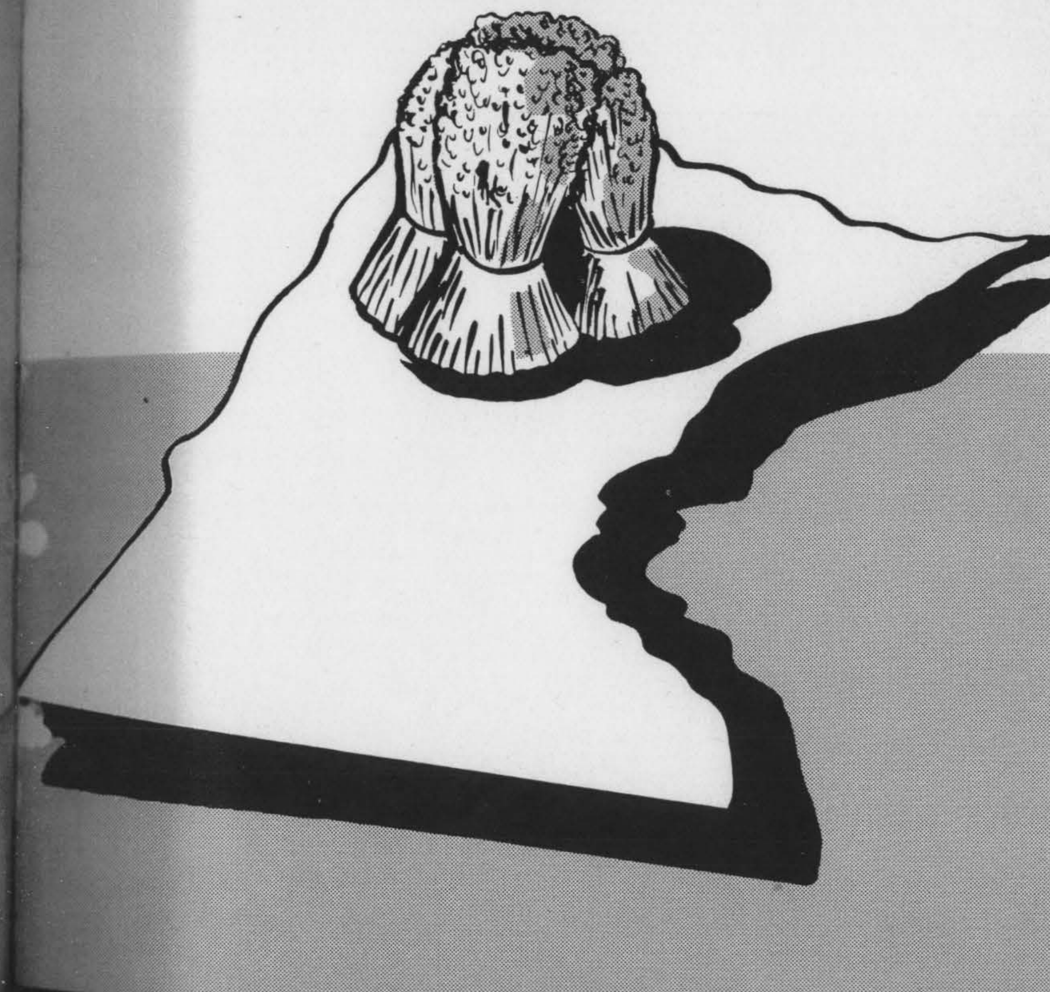
Sulfur Fertilization of Oats

in North Central Minnesota

C. O. ROST • C. A. EVANS • H. W. KRAMER



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Sulfur Fertilization of Oats in North Central Minnesota

C. O. Rost, C. A. Evans, and H. W. Kramer[1]

NORTH CENTRAL MINNESOTA has a considerable area of soils known to be low in both water-soluble (sulfates) and organic sulfur (*8*).[2] The boundaries have not been determined exactly, but the area centers in southern Koochiching, southern Beltrami, Hubbard, and Cass Counties. How far it extends eastward is not known, but likely it extends westward to the Red River Valley. That is, the western limit probably coincides with the eastern edge of old glacial Lake Aggasiz, since soils lying in the bed of the old lake are generally well supplied with sulfates. The prominent soils of this sulfur-deficient area belong to the Neebish-Rockwood association (*9*).

As far back as 1937 experiments showed that many legumes in this area, notably alfalfa, respond to sulfur fertilization (*2*). Also, with the use of gypsum as a sulfur fertilizer common among farmers in the area, many have reported beneficial effects on the yield of oats.

These two facts led to the series of experiments reported in this bulletin. The success of sulfur fertilization in increasing the yield of legume hays suggested that it could influence the growth and yield of non-legumes. And the observations of growers as to its effect on oats seemed to merit full investigation.

Our experimental work in North Central Minnesota was carried out over a 5-year period, 1947 through 1951. To understand the problems involved and the results obtained, however, considerable background must be first provided. First, assuming sulfur fertilization had the effect on oats reported by growers, the facts which might combine to bring about that effect should be discussed. Second, previous investigations of the effect of sulfur on legumes should be reviewed.

If there is such an effect on oats as that reported by farmers using gypsum, it could be due to one or more causes.

First, the soils in this area of Minnesota are usually sandy in texture and were originally covered by forest. The nitrogen supply in these soils is generally low. The effect of sulfur fertilization on the oats could be due, therefore, to an increased amount of nitrogen from a more vigorous growth of legumes for which gypsum is applied. This would appear to be the probable cause.

Second, there is the possibility that sulfur treatment could bring a release of potassium under chemical reactions involving "base exchange reactions." Third, the cause could be the direct effect of sulfur as a nutrient, although the amount of sulfur required by oats is relatively small.

Sulfur is an essential plant nutrient and any deficiency of it is shown by characteristic symptoms and reduced yields. Deficiency symptoms are shown first by crops having high sulfur requirements, such as the legumes. As is the case with

[1] C. O. Rost, professor emeritus, was head of the University of Minnesota Department of Soils until his retirement in 1954.

[2] Numbers in parentheses refer to Literature Cited, page 15.

Table 1. Sulfur, as pounds per acre, in precipitation at six locations in Minnesota. (Always, Marsh, and Methley)

Year	Period	Minneapolis Weather Bureau	St. Paul Campus	Page	Crow Wing	Bemidji	Becida
1936	12 months	196.72	25.96	5.51	....	3.13	
1937	9 months	79.87	22.22	6.91	9.25	4.50	3.84

nitrogen, one of the principal sources of sulfur for plant growth is in the atmosphere, where it exists as sulfur dioxide (SO_2) gas.

Sulfur may be absorbed from the air by leave of growing plants or by the soil itself, or it may be carried into the soil by water falling in the form of precipitation. Atmospheric dust may be another source of sulfur.

The concentration of sulfur dioxide in the air varies in different locations, being closely related to the presence or absence of coal-consuming industries. In the vicinity of these, the concentration of atmospheric sulfur may be relatively high, resulting in much larger quantities of sulfur being brought down by precipitation.

PREVIOUS INVESTIGATION

Alway, Marsh, and Methley (*2*) measured the amounts of sulfur in precipitation at a number of locations in Minnesota. A summary of their data, expressed as pounds per acre of sulfur, is given in table 1. The amounts obtained on the roof of the building which houses the Minnesota Weather Bureau in downtown Minneapolis are large. They are considerably less on the roof of the Soils Building at the St. Paul Campus, and much less in outlying localities. It is to be noted that from University's St. Paul Campus northward the amounts decrease and that in the northern part of the state they are relatively small.

Always (*1*) reported the effect of sulfur fertilization with gypsum at 200 pounds per acre on the yield of alfalfa forage at seven locations extending from southern to northern Minnesota. Increases in the yield of alfalfa shown for locations south of the Twin Cities were small, varying from 3 to 7 percent. The fields were all located on fine-textured soils. The results from locations north of St. Paul which were on sandy soils are shown in table 2.

Table 2. Effect of sulfur fertilization (gypsum) upon the yield of alfalfa at three locations.* (Alway)

Year	Number of cuttings	Untreated (tons per acre)	Treated with sulfur (tons per acre)	Increase: Tons per acre	Increase: Percent
		Coon Creek			
1923	2	0.95	0.89	0	0
1924	2	1.89	1.85	0	0
1925	2	1.94	2.08	0.14	7
1926	2	1.30	1.35	0.05	4
		Backus			
1923	1	0.69	0.61	0	0
1924	2	2.06	2.30	0.24	13
1925	2	2.03	2.70	0.67	33
		Bemidji			
1923	1	0.81	1.10	0.29	35
1924	2	1.18	1.99	0.81	69
1925	2	1.67	2.67	1.00	60
1926	2	0.84	2.16	1.32	157

* Coon Creek on Zimmerman loamy sand. Backus on Hubbard loamy sand and Bemidji on Nymore loamy sand.

At Coon Creek, located 20 miles north of St. Paul, there was no effect from sulfur fertilization. This indicated that atmospheric plus soil sulfur was ample for the crop under prevailing soil and moisture conditions. In one year of the three there was a distinct effect on the yield of alfalfa at Backus, located in Cass County. The amount of sulfur available for crops at this location could be influenced by industries located at Brainerd, about 30 miles to the south.

Yields of alfalfa were markedly increased at Bemidji in every year by sulfur fertilization, the amount of sulfur in rainfall and the soil apparently being inadequate for maximum growth. This location is distant from any sizable industrial development.

It is to be noted that all of the soils showing a response to sulfur fertilization were sandy. There are no published reports of experiments with sulfur fertilization on fine-textured soils of north central Minnesota, but observations indicate that some respond while others do not.

Nesom and Giesler (*11*) and Nesom and Graham (*10*) established a series of demonstration plots in Hubbard and Cass Counties in 1940 and 1941. These consisted of single treatments on 16 and 12 farms respectively. A summary of their results are given in table 3.

The response of alfalfa to sulfur fertilization was highly significant in both years. Including phosphate, or phosphate and potash, as well as sulfur failed to produce a further increase in yield. While fertilization with phosphate alone or a mixture of both phosphate and potash gave significant increases in both years, these were much less than obtained with sulfur alone.

Sulfur fertilization not only increases the yield of legumes in sulfur-deficient soils but the amount of sulfur in the crop as well. Alway (*1*) studied both the effect on yield and the sulfur content of the crop for the clovers as well as alfalfa. Table 4 summarizes results in 1925 on the Bemidji Experimental Field. Both the yield and the sulfur content were markedly increased.

Table 3. Effect of gypsum, phosphate, and phosphate and potash on the yield of alfalfa. (9, 10)

Treatment	16 fields, 1940, Hubbard County (tons per acre)	Average increase	12 fields, 1941, Cass County (tons per acre)	Average increase
Check	1.76	....	1.71	....
Sulfur*	2.88	1.12	2.53	.82
P	2.08	.32	2.09	.38
PK	2.10	.34	2.43	.72
KPS	2.74	.98	....	....
L.S.D. at 5%		.28		.23

* S = gypsum at 250 pounds per acre. P = 45 percent superphosphate at 100 pounds per acre. PK = 0-20-20 at 225 pounds per acre.

From many chemical analyses of crops, Alway, Marsh, and Methley (*2*) found that the sulfur content of alfalfa varied from as low as 0.07 to as much as 0.50 percent. From their studies they estimate that when adequately supplied with sulfur alfalfa should contain 0.30 percent sulfur. For a yield of 3.0 tons, at least 18 pounds of sulfur annually would be required to meet the needs of crop withdrawal.

Alway *et al.* (*2*) have also shown that the soil itself may absorb sulfur in the form of sulfur dioxide from the air. They exposed thin layers of two soils from the sulfur-deficient area of Minnesota in several locations and determined the amounts of sulfur absorbed. The data for three locations (A) on the roof of the Weather Bureau building in downtown Minneapolis (B) on the roof of the Soils Building at the St. Paul Campus and (C) 5 feet above ground surface in a University Farm orchard are shown in table 5. The larger amounts were absorbed in downtown Minneapolis where the atmospheric content of sulfur was the highest, but very appreciable amounts were absorbed at other locations.

Several areas other than Minnesota are known to be deficient in sulfur. In most cases the legumes responded to treatment while response of other crops was somewhat variable. The literature was reviewed by Crocker (*7*) in 1945. Since then several interesting papers have been published. Volk *et al.* (*12*) found sulfur to increase cotton yields when used as a supplement with nitrogen, phosphate and potash. He also reported no effect of gypsum on the release of potassium from base exchange reactions.

Sulfur increased clover yields when applied with phosphate on Florida sands. No effects were noted on the Bahia grass seeded with the clover (*3*). In 1950 Conrad (*4*) reported the results of work with sulfur in California. In addition to the response of legumes to sulfur, some non-legumes also responded. Wheat grain yield was significantly increased on plots on which wheat-without-legume followed vetch in the rotation. Application of sulfur was made 3 years ahead of wheat. Non-legumes grown in the greenhouse were found to respond to sulfur if nitrogen was supplied also. Earlier he had found highly significant increases in yield of non-legumes on plots which previously had been seeded to burr clover and fertilized with elemental sulfur (*5*). Recent work in Alberta by Carmach, *et al.* (*6*) showed significant increases on legumes but barley failed to respond to the fertilizer.

Tolman and Stakir (*13*), investigating problems in the production of sugar beet seed in Oregon, found a striking interaction response of sulfur and nitrogen both on plant development and seed production. An application of sulfur did not affect seed production when nitrogen was not applied and the response to nitrogen was much greater in the presence of sulfur treatment.

Table 5. Amounts of sulfur absorbed by two soils exposed in different locations in 1937

Location*	Length of time	Pounds per acre of Sulfur: Nebish loam	Nymore loamy sand
A*	Jan. 1 to Nov. 3	81.0	69.3
B	Jan. 1 to Sept. 1	14.6	69.3
C	Apr. 1 to Nov. 4	10.9	8.0

* A—roof of building housing U. S. Weather Bureau, Minneapolis. B—Roof of Soils Building, St. Paul Campus, University of Minnesota. C—5 feet above ground surface in orchard, St. Paul Campus.

EXPERIMENTAL METHODS

To test the accuracy of observations of growers regarding the effects of sulfur fertilization on oats in North Central Minnesota, we conducted a series of experiments over a 5-year period, 1947 to 1951, inclusive.

In the first year, seven fields of oats received applications of 200 pounds per acre of gypsum on duplicate plots. As the result of some indication of a gypsum effect, ten fields were selected for study the second year. Eight treatments were randomized on two blocks. The treatments: gypsum at 200 pounds, muriate of potash at 200 pounds, 45 percent superphosphate at 240 pounds per acre, applied singly and in all possible combinations.

Table 4. Effect of sulfur fertilizers on the yields and sulfur content of alfalfa and clovers grown at Bemidji, 1925. (Alway)

Crop	Yield per acre: Unfertilized	Yield per acre: Sulfur (gypsum)	Sulfur content, 1st cutting: Unfertilized	Sulfur content, 1st cutting: Sulfur
Alfalfa	2.45 tons	3.36 tons	0.16%	0.36%
Sweetclover	0.91	1.33	0.14	0.44
Medium red clover	0.75	2.54	0.12	0.23
Mammoth clover*	0.89	1.38	0.15	0.25
Alsike clover	0.95	2.21	0.15	0.30

* Crop grown in 1926.

Table 6. Average yield and composition of oat grain and straw from seven fields treated with gypsum*

Treatment	per acre	Increase	Protein	Sulfur	Potash	Soil Analysis: Sulfate sulfur	Soil Analysis: Organic sulfur	Soil Analysis: Nitrogen
Gypsum	52.1 bu.	14.2%	12.11%	0.190%	0.392%	......	......	...... %
None	45.6	......	12.32	0.224	0.389	2.6 ppm.	118.5 ppm.	0.197%
Gypsum	0.72 tons	8.1%	3.93%	0.210%	0.162%	......	......	...... %
None	0.66	......	3.82	0.151	0.171	2.6 ppm.	118.5 ppm.	0.197%

* Statistical analysis showed no significant increase in yields from the two treatments.

In the third and fourth years, six and eight fields, respectively, were treated with gypsum at 200 pounds and ammonium nitrate at 125 pounds per acre. Four treatments—untreated, sulfur, nitrogen, and nitrogen and sulfur—were randomized on eight blocks in each field. Thus there were eight replications of each treatment.

The same experiment was repeated in the fifth year at the one field on which the increase in the yield of oats from sulfur fertilization closely approached significance in 1949. The crop preceding the oats on these fields was either oats, corn, or potatoes. In no case did the oats follow a legume or have an application of manure.

EXPERIMENTAL RESULTS

In the first year, the experimental plots were not sufficiently replicated to permit statistical analysis of the results. However, each of the seven fields showed some increase in the yield of grain—the range being from 2.7 to 10.7 bushels per acre, or a percentage increase of 4.8 to 24.0, with an average of 14.2 (table 6). Straw yields were increased on six of the seven fields, the percentage increases varying between 4.3 and 18.7, averaging 8.1 percent.

Sulfur fertilization did not appreciably change the composition of the grain, that from the untreated plots tending to be slightly higher in protein and sulfur and slightly lower in phosphorus. Likewise gypsum had no effect on straw protein and phosphorus but definitely increased sulfur.

Since the results from the seven fields indicated the possibility of an effect on the yield of oats from sulfur fertilization, ten fields were selected in 1948 the following year. On the latter, not only sulfur fertilizer in the form of gypsum was used but phosphate and potash as well. The fertilizers were used singly and in all possible combinations.

Statistical analyses of the results from the ten individual fields showed a significant increase in yield for sulfur fertilization on only one field (table 7). Phosphate and a combination of phosphate and potash produced signicant increases on the group of nine fields which did not respond to sulfur fertilization. There was no indication that the inclusion of gypsum along with the phosphate and potash fertilizer was any more effective than these fertilizers alone.

Table 7. Average yield of oats and increases from treatment* on 10 fields on north central Minnesota

Fields	Untreated	S	SP	SPK	SK	P	PK	K	L.S.D. 5% level
9 non-responsive	38.4	1.4	3.6	4.1	4.3	5.0†	5.3†	4.0	4.6
1 responsive	33.4	14.6†	14.7†	4.0	5.3	19.9†	9.5	13.9†	13.1

* S = gypsum at 200 pounds; P = 45 percent superphosphate at 240 pounds; and K = muriate of potash at 200 pounds per acre.

† Significant increase at 5 percent level.

Table 8. Analysis of soils from fields used in the third, fourth, and fifth year trials (1949-51)

Field	M. Eq.	pH	N	P	K	Sulfate S	Organic S	Total S
			(percent)	pounds per acre				
1	4.5	5.8	0.110	165	87	2.7	93.6	96.3
2	6.1	5.9	0.075	65	87	5.0	82.0	87.0
3	4.8	5.8	0.040	125	87	3.7	50.4	54.1
4	5.6	5.7	0.060	120	100	3.2	41.8	45.0
5	8.0	5.8	0.100	50	85	4.7	82.8	87.5
6	12.6	5.9	0.110	50	85	6.2	152.4	158.4
7	9.4	5.4	....	75	100	10.1	117.0	127.1
8	11.0	5.0	....	65	87	4.1	130.0	134.1
9	5.3	5.3	....	80	85	6.0	67.0	73.0

On the one responsive field the increase from sulfur fertilization was 14.4 bushels per acre, but this was exceeded by phosphate alone with an increase of 19.7 bushels. The combination of sulfur and phosphate produced the same increase as sulfur alone. Thus there was no significant difference between sulfur and phosphate fertilization when alone or in combination. Straw yields in this season were not significantly increased by any treatments.

The data obtained in the two seasons 1947 and 1948, indicated that there was an occasional field on which sulfur fertilization would increase the yield of oats. Trials in these two seasons would suggest that about one field in ten would be responsive.

Sulfur fertilization was beneficial for legumes on many fields in the area and this suggested that the beneficial effect on oats observed by growers was due to the larger supply of nitrogen fixed by the more vigorous growth of legumes. Experiments in the third, fourth, and fifth seasons—1949 to 1951 inclusive—were designed to test the effect of nitrogen, and nitrogen and sulfur combined. In 1949 and 1950 plots on six and eight fields, respectively, were treated with gypsum at 200 pounds per acre and ammonium nitrate at 125 pounds per acre. Four treatments were used: untreated, sulfur, nitrogen, and sulfur plus nitrogen. These were randomized on eight blocks on each field. The same experiment was repeated on one field in 1951.

Trials were conducted on a total of nine fields during the 3-year period. Five of the eight experiments in 1950 were on the same fields used in 1949 but were on new locations adjacent to the land used in 1949. Three additional fields were selected for trials in 1950. The one experiment in 1951 was on a new location on field 1.

On these fields care was taken to eliminate all variations other than soil and rainfall in so far as possible. The gypsum and ammonium nitrate were taken from the same lot, the grain was seeded at 2 bushels per acre with one drill which had been calibrated in advance, and the same seed was used on all fields.

The fields selected were located in Beltrami, Hubbard, and Cass Counties, Minnesota. The fields were mainly sands in texture (table 8) and the soils were acid in reaction. The nitrogen content was low in three and very low on three. Nitrogen was not determined on the remaining three fields. Sulfate sulfur was low in the

Table 9. Rainfall in inches at two locations in north central Minnesota

Year	Bemidji May	June	July	3-month total	Park Rapids May	June	July	total 3-month
1949	4.86	2.87	13.44	21.77	3.02	2.32	6.61	11.95
1950	4.43	5.94	2.61	12.98	5.20	2.05	3.66	10.91
1951	1.91	2.81	2.78	7.50	3.90	3.25	2.79	9.94

Table 10. Average yield of oat grain and increase or decrease obtained by sulfur and nitrogen fertilization

Field	Location	Year	Average yield in bushels per acre* CK	S	N	NS	Effect of sulfur S-CK	NS-N	Effect of nitrogen N-CK	NS-S	L.S.D. 5%	1%
1	1	1949	4.1	6.0	14.0	17.6	1.9	3.6	9.9	11.6	2.0	2.7
	2	1950	21.6	20.8	23.4	25.8	−0.8	2.4	1.8	5.0	3.8	5.2
	3	1951	43.0	54.1	50.6	50.0	11.1	−0.6	7.6	−4.1	6.9	9.4
2	1	1949	5.4	8.2	17.0	19.7	2.8	2.7	11.6	11.5	4.0	5.5
	2	1950	18.8	22.8	25.6	31.2	4.0	5.6	6.8	8.4	4.9	6.6
3	1	1949	7.9	9.3	12.2	13.8	1.4	1.6	4.3	4.5	3.0	4.0
	2	1950	25.3	28.7	36.4	38.9	3.4	2.5	11.1	10.2	5.2	7.1
4	1	1949	6.0	9.7	12.5	17.7	3.7	5.2	6.5	8.0	5.1	7.0
	2	1950	26.7	26.3	31.2	34.1	−0.4	2.9	4.5	7.8	3.0	4.1
5	1	1949	36.3	33.6	41.7	45.3	−2.7	3.6	5.4	11.7	6.4	8.7
	2	1950	20.9	25.8	32.7	36.8	4.9	4.1	11.8	11.0	3.7	5.2
6	1	1949	32.5	34.9	46.8	48.1	2.4	1.3	14.3	13.2	5.9	8.1
7	1	1950	63.0	68.0	64.9	63.5	5.0	−1.4	1.9	−4.5	(N.S.)	(N.S.)
8	1	1950	38.0	42.0	47.1	49.6	4.0	2.5	9.1	7.6	4.2	5.8
9	1	1950	23.0	23.0	28.4	36.3	0.0	7.9	5.4	13.3	4.3	5.9

* Each figure is the average of 8 replicates.

Table 12. Average yield of oat straw on fifteen locations with increases or decreases from fertilization with sulfur and nitrogen

Field	Location	Year	Average yield in tons per acre CK	S	N	NS	Effect of sulfur S-CK	NS-N	Effect of nitrogen N-CK	NS-S	L.S.D. 5%	1%
1	1	1949	0.30	0.36	1.03	1.31	0.06	0.28	0.73	0.95	0.19	0.25
	2	1950	0.51	0.45	0.70	0.89	−0.06	0.19	0.19	0.44	0.06	0.08
	3	1951	1.00	1.24	1.45	1.57	0.24	0.12	0.45	0.33	0.29	0.40
2	1	1949	0.29	0.35	1.00	1.11	0.06	0.11	0.71	0.76	0.14	0.19
	2	1950	0.71	0.65	1.05	1.40	−0.06	0.35	0.34	0.75	0.21	0.28
3	1	1949	0.44	0.49	1.59	1.52	0.05	−0.07	1.15	1.03	0.14	0.19
	2	1950	0.80	0.78	1.26	1.26	−0.02	0.00	0.46	0.48	0.21	0.28
4	1	1949	0.39	0.35	1.26	1.73	−0.04	0.47	0.87	1.38	0.20	0.27
	2	1950	0.86	0.85	1.55	1.74	−0.01	0.19	0.69	0.89	0.18	0.25
5	1	1949	1.40	1.29	2.44	2.66	−0.11	0.22	1.04	1.37	0.25	0.34
	2	1950	0.65	0.77	1.45	1.70	0.12	0.25	0.80	0.93	0.17	0.24
6	1	1949	1.27	1.39	2.14	2.18	0.12	0.04	0.83	0.79	0.15	0.21
7	1	1950	2.06	2.00	2.22	2.42	−0.06	0.20	0.16	0.42	(N.S.)	(N.S.)
8	1	1950	1.06	1.06	1.44	1.56	0.00	0.12	0.38	0.50	0.16	0.22
9	1	1950	0.79	0.76	1.93	2.29	−0.03	0.36	1.14	1.53	0.46	0.62

soil from all fields. It was lowest in field 1 and highest in field 7. Little relation between the content of organic sulfur and response to sulfur fertilization could be observed.

Weather conditions in the area in which the experiments were located were generally favorable during the three-year period. Rainfall was ample (table 9) and temperatures were generally favorable, being near normal in 1949 and 1951 and somewhat lower than normal in 1950. The yields of oats on four fields in 1949 were very low due to an epidemic of aphids. The two remaining fields in that year were not so seriously affected.

From sulfur fertilization on field 1 in 1949, the increase in yield of oats closely approached statistical significance and was clearly significant in location 3 on the same field in 1951 (table 10). Sulfur fertilization increased the yield of oats on field 5 in 1950, also. Sulfur used alone had no significant effect on yield of oats on the remaining fields, although increases approaching significance were obtained on field 1 in 1949 and field 8 in 1950.

When combined with nitrogen, sulfur was more effective in five of the fifteen trials, yields of grain from the nitrogen-sulfur combination being significantly higher than nitrogen alone. This increase occurred on five of the nine locations and indicates that when sufficient nitrogen is available to the crop, sulfur may become a limiting nutrient element.

Nitrogen alone increased the yie'd of grain very significantly in nine of the trials and significantly (5 percent level) in three, leaving only three in which there was no significant increase (table 10).

The yield of oat straw was not increased significantly by the use of sulfur alone—although increases at location 1, field 6, in 1949 and location 3, field 1, in 1951 closely approached significance (table 11). When sulfur was combined with nitrogen there were significant increases in the yield of straw over those obtained by applying nitrogen alone on seven of the fifteen locations. This again supports the probability that sulfur may be a limiting nutrient element when an adequate amount of nitrogen is present.

Nitrogen alone greatly increased the yield of oat straw. At only one location did it fail to produce a significant increase. When sulfur and nitrogen were combined the yields of straw were again increased significantly over those of nitrogen alone at seven locations. Three of these locations were the same as those on which grain yields were significantly increased by the sulfur-nitrogen combination.

As a measure of quality the bushel weights of the grain was employed. In order to make the test uniform, the samples of grain were dried in a low temperature oven and then allowed to come into equilibrium with the moisture in the air before bushel weights were determined.

The bushel weight (table 12) showed that sulfur used alone significantly increased bushel weight at five of the fifteen locations. When used with nitrogen the influence of sulfur was overshadowed by nitrogen, which had the general effect of lowering bushel weight. At only one location did nitrogen alone or nitrogen plus sulfur significantly increase bushel weight. In many instances these treatments significantly decreased the weight per bushel below that from unfertilized plots. It is to be noted from table 12 that in only a few instances did the bushel weight fall below 32 pounds.

Table 12. Average bushel weights of oats from fifteen locations with increases or decreases from fertilization with sulfur and nitrogen

			Average bushel weight, pounds				Effect of sulfur		Effect of nitrogen		L.S.D.	
Field	Location	Year	CK	S	N	NS	S-CK	NS-N	N-CK	NS-S	5%	1%
1	1	1949	32.75	34.62	32.72	32.87	1.87	0.15	−0.03	−1.75	1.04	1.41
	2	1950	35.50	35.50	34.50	31.25	0.00	−3.25	−1.00	−4.25	1.70	2.32
	3	1951	39.00	39.25	39.00	39.00	0.25	0.0	0.0	−0.25	(N.S.)	(N.S.)
2	1	1949	32.87	34.87	34.87	34.12	2.00	−0.75	2.00	−0.75	1.35	1.84
	2	1950	31.37	33.25	31.12	31.88	1.88	0.76	−0.25	−1.37	(N.S.)	(N.S.)
3	1	1949	31.25	32.75	31.87	32.25	1.50	0.38	0.62	−0.50	1.34	2.09
	2	1950	37.12	36.88	35.75	35.50	−0.24	−0.25	−1.37	−1.38	0.17	0.21
4	1	1949	29.87	31.37	31.25	32.75	1.50	1.50	1.38	1.38	(N.S.)	(N.S.)
	2	1950	37.62	37.50	37.25	37.12	−0.12	−0.13	−0.37	−0.38	(N.S.)	(N.S.)
5	1	1949	36.00	37.25	36.00	34.37	1.25	−1.63	0.00	−2.88	0.93	1.27
	2	1950	34.25	36.12	32.25	32.12	1.87	−0.13	−2.00	−4.00	1.33	1.81
6	1	1949	37.25	37.25	35.00	35.00	0.00	0.0	−2.25	−2.25	0.93	1.27
7	1	1950	35.25	35.62	33.62	32.62	0.37	−1.00	−1.63	−3.00	2.16	2.94
8	1	1950	35.25	35.75	34.75	35.25	0.50	0.50	−0.50	−0.50	(N.S.)	(N.S.)
9	1	1950	31.00	31.88	30.62	30.62	0.88	0.00	−0.38	−1.26	(N.S.)	(N.S.)

CONCLUSIONS

1. Previous investigations had shown that sulfur fertilization on many soils in North Central Minnesota increased the yield of legume hays. This suggested that sulfur, as a nutrient element, could influence the growth and yield of non-legumes.
2. Sulfur fertilization increased the yield of oats on occasional fields in north central Minnesota.
3. The bushel weight (or quality) of oats was increased by sulfur fertilization on one third of the fields of the same area even though the yield of grain may not have been increased.
4. Oat straw yields were not significantly increased by sulfur fertilization unless accompanied by an application of nitrogen fertilizer.
5. When accompanied by an application of nitrogen fertilizer sulfur significantly increased the yield of grain on five and straw on seven of the fifteen fields above those obtained with nitrogen alone.
6. Nitrogen fertilizer alone greatly increased the yields of oat grain and straw but reduced the bushel weight of the grain.
7. Results indicate that some fields in north central Minnesota require applications of both sulfur and nitrogen for maximum yields of oats.
8. Treatment of the soil with gypsum did not appreciably affect protein or phosphorus content of the grain. It tended to lower the sulfur content of the grain.
9. Sulfur fertilization tended to lower the phosphorus content of the straw but increased the amount of sulfur.

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than 100 crop acres. Farms of this size may be too small to provide an adequate living. FHA county supervisors are urged to use minimum resources guides as a precaution against making loans on farms that are too small.

The median initial loan was $4,690. Approximately half of the borrowers also received supplemental loans. The median supplemental loan was $830.

The largest share of initial loan funds were used for livestock purchases, 41 percent on the average. Machinery purchases and refinancing accounted for 26 and 22 percent, respectively, of the initial loan funds. Nearly one-half of the supplemental loan funds were used for machinery purchases and about one-quarter of the supplemental loan funds were used for operating expense.

More than half of the initial loans had terms of 6½ or 7 years. The loans were set up with installments geared to anticipated farm income over the life of the loan. The chattel mortgage that secures the promissory note was renewed periodically to keep it current.

The average borrower had been on the program for about 2½ years. He started with total assets that averaged $10,339 and these had increased to $15,328 on January 1, 1955. Average net worth increased from $5,787 to $7,561. Of the 162 borrowers, 120 showed increases in net worth while 40 showed decreases. The average borrower had an owner equity in his farm business of about 50 percent on January 1, 1955. However, there was considerable variation in owner equity of individual borrowers. Nearly 20 percent had equities of less than 35 percent. This points up the relatively high debt load that these borrowers are carrying.

Income and expense records of the borrowers in 1954 showed that net farm income over farm operating expenses ranged from $2,240 in the southeast dairy and southwest livestock areas to $260 in Itasca county. Income from sources other than farming was substantial in Itasca county and the northwest crop area where it averaged $1,910 and $1,350, respectively.

Net farm income and nonfarm income provide the means for family living, capital outlays, and debt repayment. The range in this amount was not wide between areas. It ranged from $2,850 in the southeast dairy area to $2,170 in Itasca county.

The average borrower in the southwest livestock and southeast dairy areas went further into debt by $940 and $220, respectively, during 1954. Capital expenditures averaged more than the amount available for this purpose in these areas. The average borrower in the northern areas applied about $500 toward repayment of debts.

Approximately 60 percent of the borrowers who left the program during the five fiscal years 1950-54 repaid their loans in full and continued to farm. The remaining 40 percent did not become established in farming. This indicates the importance of utmost care in selection of applicants to hold losses and disappointments to a minimum.

Broadened lending authority was provided by Congress in 1956. The Farmers Home Administration can now make larger loans for longer terms, loans to part-time farmers, and loans where refinancing is the major purpose. This will enable the agency to be of greater assistance to young farmers, but successful operation will call for even more careful selection.

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Planning Farms for Increased Profits

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