Field Experiment with Gypsum
in Iowa

November, 1925

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AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

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AGRONOMY SECTION
SOILS

AMES, IOWA

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Whether gypsum, or land plaster, which was quite widely used as a fertilizer in Europe 150 years ago and later in the United States, can be profitably used on Iowa soils is the interesting question with which the experiments reported in this bulletin have to do.

As yet no final answer can be given, but this much can be said on the basis of this experimental work; Gypsum applied to some Iowa soils gave some beneficial results in oat and red clover yields and very decidedly good results in alfalfa yields. Gypsum supplies a large proportion of sulfur as well as calcium and when any crop such as alfalfa requires these elements applications of gypsum may prove profitable. This is especially true of Iowa soils, many of which are deficient in sulfur. Further, gypsum is an Iowa product, conveniently at hand and can be produced economically. The experiments suggest definitely that it is worth the while of Iowa farmers to try out this material on a limited scale. ,

COMING NEED OF SULFUR FERTILIZERS

Since recent experiments have established the importance of sulfur in soil fertility, renewed attention is being directed to the use of gypsum. Sulfur is essential for the growth of all organisms, plants as well as animals, and since the soil is the immediate source of this element for crops, the maintenance of a supply readily available to plants is of great importance.

Analyses of many soils in the United States have shown that the total sulfur content varies from 200 to 3,000 pounds per 2,000,000 pounds of surface soil. Typical soils in Iowa show a total sulfur content ranging from 719 to 938 pounds per 2,000,000 pounds of soil. Altho these soils are still fertile, just how long they will remain in this condition without sulfur fertilization is a question that is not easily answered. Sulfur is only one of the essential elements required for plant growth, but the seriousness of the sulfur problem is evidenced by the small supply in Iowa soils and by the constant removal of the element thru crop utilization and thru leaching in the drainage waters.

SULFUR IN CROPS

It is now known that crops remove considerable quantities of sulfur from the soil. This is especially true of legumes, such as alfalfa; the cruciferous plants, including cabbage and turnips; and potatoes. Four tons of alfalfa hay remove about 23 pounds of sulfur; 2 tons of clover hay utilize about 8 pounds of

sulfur; a 200 bushel crop of potatoes removes about 16 pounds of sulfur, and an average crop of cabbage contains about 40 pounds of sulfur. Maximum grain crops like corn, oats, wheat and barley require only from 8 to 16 pounds of sulfur.

SULFUR IN DRAINAGE WATER

Still another way in which sulfur disappears from the soil is thru the drainage water. A large part of the sulfur in the soil is in the organic or insoluble form, but this is constantly being changed into a soluble form thru the action of bacteria. In times of heavy rainfall, when leaching is the greatest, large amounts of soluble sulfur are carried away from the soil in the drainage water. This loss has been found to vary from 8 pounds to 281 pounds per acre annually, depending, of course, on soil conditions and on the treatment of the soil.

A careful study was made at this station to determine how much sulfur was added to the soil in the rainwater, and also how much was leached out in the drainage water. It was found that about 15 pounds of sulfur per acre reaches the soil thru precipitation on an Iowa farm each year, but there is an annual loss of over 50 pounds of sulfur in the drainage from an acre of the surface soil. In the case of the Carrington loam, one of the most important soil types in Iowa, it was shown that the loss of sulfur in the drainage amounted to 65 pounds of sulfur per acre annually.

If the amount of sulfur removed from the soil by crops (probably about 15 pounds on the average) is added to that which is leached out of the soil each year in the drainage water (an average of 50 pounds) and no additions of sulfur are made, except that supplied by the rainwater which is about 15 pounds, it is quite apparent that there is some justification for believing that sooner or later sulfur may become a limiting factor in crop production in Iowa.

WHAT IS GYPSUM?

Gypsum is a mineral containing sulfur in a form directly available to plants. Chemically, gypsum is calcium sulfate or lime sulfate, combined with water and having the formula $CaSO_4+2H_2O$. When used on the soil it supplies both calcium and sulfur to plants. If there should happen to be a sulfur deficiency in the soil, gypsum would be a very desirable material to use on the soil to remedy this condition.

Gypsum is readily obtained from numerous large deposits in Iowa, and if it should prove to be a profitable fertilizer, its use would not be prohibitive on account of transportation charges. Very elaborate treatises on the occurrence, purity and uses of the gypsum mined in Iowa are to be found in the reports of the Iowa Geological survey[1]. Anyone interested in this phase

[1]Iowa Geological Survey, Vol. 28, pp. 47-536, 1918.

of the subject may obtain useful and interesting information by writing to the Iowa Geological Survey, Des Moines.

GYPSUM NOT HARMFUL

Contrary to a general belief among farmers that gypsum produces injurious effects in the soil, there seems to be no experimental proof to warrant this assumption. Some have believed that gypsum hastens the decomposition of the organic matter in the soil. This idea has been disproven by laboratory experiments made at this station. It was formerly thought that gypsum made soils acid, but recent laboratory and field experiments made by this station, have proved conclusively that gypsum does not make soils acid.

GYPSUM CANNOT BE USED INSTEAD OF LIMESTONE

Many inquiries have been received regarding the use of gypsum on acid soils to take the place of ground limestone. Gypsum and limestone both contain the element calcium but otherwise they are very different compounds. Gypsum cannot be substituted for limestone because it possesses no alkalinity and therefore does not have the power of neutralizing the acidity in the soil. This statement is well supported by much evidence obtained from experiments carried on by this station.

BENEFICIAL EFFECTS OF GYPSUM

There now seems to be no doubt that the increases in yields of certain crops which have been reported from time to time from the use of gypsum, are due chiefly to its direct fertilizing action. It supplies calcium and sulfur to plants as mineral food, and certainly it is not merely a soil stimulant. But it does have certain effects on soils which mean that it must be considered both as a direct and as an indirect fertilizer. For example, laboratory experiments have repeatedly shown that gypsum has the power of making the native potassium in certain soils available to plants. If this reaction takes place under field conditions, gypsum would be a very valuable material in that it would make the purchase of expensive potassium fertilizers unnecessary.

IOWA FIELD EXPERIMENTS WITH GYPSUM

In view of the encouraging results obtained elsewhere with gypsum as a fertilizer, and to seek additional experimental evidence concerning its possible use on Iowa soils, in 1920 the Gypsum Industries Association established a research fellowship in the Soils Department at the Iowa State College to study the effects of gypsum on soils and crop growth. This fellowship was continued for four and one-half years, and during this time much data, both scientific and practical, have been accumu-

lated which will give a better understanding of the part gypsum may play in soil fertility problems.

In the spring of 1920, a number of field experiments were started to test the effect of gypsum on different crops when grown on various soil types in Iowa. A series of nine plots were laid out on the fields in Story, Webster, Hardin and Wapello counties. These fields were located near Ames, Fort Dodge, Eldora and Farson and hereafter in this discussion they will be called by the town names. The plots were all one-tenth acre except those at Ames wheih were one-fortieth acre in size. The first three fields mentioned were planted to oats, seeded with clover, while the Farson field was planted to wheat seeded with clover. Gypsum was applied to six of these plots in each field at the rate of 200, 500 and 1000 pounds per acre with and without limestone. One plot received lime alone and the two remaining plots were left untreated to serve as checks.

In a number of counties two one-tenth acre plots were added to the regular series of cooperative experimental plots of the Soils Section of the Iowa Agricultural Experiment Station. This arrangement was made in Clinton, Scott, Lee, Buena Vista, Wapello and Van Buren counties. These fields were located near Delmar, Eldridge, Sawyer, Truesdale, Agency and Stockport, respectively. The treatment for these two plots was 500 pounds of gypsum per acre with and without limestone, except on the Agency and Stockport fields which received gypsum at the rate of 200 and 500 pounds per acre.

Three years later in the spring of 1923 five more experimental fields were laid out. One was near Storm Lake in Buena Vista county, one near Grand Mound in Clinton county, one near Waverly in Bremer county and the remaining two were located near Ames in Story county. Four of these experiments were placed on alfalfa fields, two of which were old stands and the fifth field was seeded to oats and clover. A series of one-tenth acre plots was laid out on a uniform area of each field, and gypsum was applied to four plots at the rate of 50, 150, 300 and 500 pounds per acre, the object in view being to ascertain which rate of application would be the most economical. On the two fields near Ames an additional plot was treated with sulfur at the rate of 100 pounds per acre.

The results obtained from these fields are presented in full in the following pages. On account of the short duration of these experiments, the value of the results is considered to be indicative only of what may be expected if similar tests are carried out under similar conditions on a larger scale and for a longer period of time.

TABLE I

Ames Field No. 1

The effect of gypsum on yield per acre of oats and clover.

Plot no.	Treatment pounds per acre	1920 oats yield bushels per A.	Increase or decrease over nearest check	1921 clover hay yield lbs. per A.	Increase or decrease over nearest check
1	Check	44.2	..	3,000	..
2	200 lbs. gypsum	44.2	0	3,440	+440
3	500 lbs. gypsum	46.6	+2.4	3,472	+472
4	1,000 lbs. gypsum	46.3	+2.1	3,840	+840
5	200 lbs. gypsum + lime	44.5	+0.3	3,760	+500
6	500 lbs. gypsum + lime	46.6	+2.4	3,140	—120
7	1,000 lbs. gypsum + lime	49.0	+4.8	3,100	—160
8	Lime	47.6	+3.4	2,952	—308
9	Check	44.2	..	3,260	..

AMES FIELD NO. 1

This field was located on the Agronomy farm of the Iowa Agricultural Experiment Station near Ames, on the Carrington loam, the principal soil type in the Wisconsin drift soil area. It was seeded to oats and clover in the spring of 1920. The plots were laid out and the gypsum treatments were applied by hand on April 24, 1920. By applying the gypsum at this time its effect could be noted on the oat crop as well as on the young clover plants. Ground limestone at the rate of 4,000 pounds per acre was added to four of the plots in the series on May 21, 1920. Representative samples of oats taken from an area of 40 square feet from each plot were threshed and the yields per acre were calculated from these results. Total nitrogen determinations were made on these samples to see if gypsum had any effect on the protein content of the oat grain and straw. No effects were noted.

The following year, 1921, the clover on this field was harvested from each entire plot and the results were calculated as pounds of hay per acre. At the time the clover was cut samples of the hay were taken to the laboratory and analyzed for total nitrogen. The differences found, however, were too small to be significant. Samples of soil were also taken from each plot and tested for their lime requirement. It was not found in any case that gypsum had increased or decreased the acidity of the soil. This was true in all the later tests on other fields and hence the data along this line are not given.

The results obtained from this experiment, showing the effect of gypsum on yield per acre of oats and clover are given in table I.

Considering first the results given for the oat yields it will be noted that the gypsum treatments had practically no effect on the oats grown on this field. Slight gains over the checks are shown in several instances, but these were too small to be signi-

TABLE II
Fort Dodge Field
The effect of gypsum on yield per acre of oats and clover.

Plot no.	Treatment pounds per acre	1920 oats yield bushels per A.	Increase or decrease over nearest check	1921 clover hay pounds per A.	Increase or decrease over nearest check
1	Check	52.4	..	2,960	..
2	200 lbs. gypsum	66.0	+13.6	3,220	+260
3	500 lbs. gypsum	56.5	+4.1	3,270	+310
4	1,000 lbs. gypsum	51.0	—1.4	3,340	+380
5	200 lbs. gypsum + lime	57.8	+5.4	2,750	—210
6	500 lbs. gypsum + lime	57.8	+5.4	2,860	—100
7	1,000 lbs. gypsum + lime	61.9	+9.5	2,750	—210
8	Lime	46.9	—5.5	3,120	+160

ficant. The soil over this field must be very uniform if the regularity of these yields is any criterion.

When gypsum was used without lime, it increased the yield of clover hay grown on this field. The 200 pound application was just as effective as the 500 pound treatment, the increases over the nearest check being a little over 400 pounds for each of these treatments. The 1,000 pounds of gypsum per acre increased the yield over the check by 840 pounds. The 200 pound gypsum treatment with lime produced an increase of 500 pounds of hay over check plot number 9, but the 500 and 1,000 pound gypsum plus lime treatments showed small decreases in yield of clover hay. The plot receiving lime alone gave a decrease in yield of 308 pounds of hay when compared with the adjacent check plot.

FORT DODGE FIELD

This field was located on the farm of T. F. Breen, about six miles north of Fort Dodge in Webster county. The soil type was Carrington loam and showed a lime requirement of three tons of ground limestone per acre. The oats were planted on April 7, and clover was seeded on April 22, 1920. The plots were laid out, the gypsum treatments applied by hand, and ground limestone, at the rate of five tons per acre, was added to those plots receiving lime, on April 17, 1920. Representative samples of the oats taken from an area totaling 20 square feet were harvested from each plot and yields per acre were calculated from these results. Nitrogen determinations were made on these samples to study the effect of the gypsum treatments on the protein content of this crop, and again no differences were secured.

The yields of oats and clover hay obtained from this field are presented in table II.

The application of 200 pounds of gypsum alone gave an increase of 13.6 bushels of oats per acre over the yield on the check plot. A small gain was also noticed on the plot receiving

500 pounds of gypsum. The large application of gypsum failed to show an increase in the yield of oat grain. When gypsum was used with lime there was an apparent increase in oat production, but on account of the low yield on the plot receiving lime alone no satisfactory comparison can be made for the gypsum plus lime plots.

All of the gypsum treatments without lime showed a small gain of about 300 pounds of clover hay per acre over the check. When gypsum was used with lime there was a slight decrease in yield when compared either with the check plot or the plot receiving lime alone. It seems safe to conclude that gypsum had very little if any effect on the production of clover hay on this field, the variations noted being undoubtedly attributable to the normal variations in the soil.

ELDORA FIELD

This field was located on the farm of the State Training School for Boys near Eldora in Hardin county. The soil type was Carrington loam and it showed a lime requirement of about two tons of ground limestone per acre. The field selected for this experiment was seeded to oats and clover. All of the plots were on a very uniform piece of land, except the check plot, number 9, which was slightly higher than the others and hence the yields for this plot are not given. Gypsum was applied to the oats by hand on May 20, 1920, and lime was applied to the limed plots about a month later. Representative samples, as in the case of the Fort Dodge field, were harvested from each plot and analyzed for nitrogen content, but no variations were noted.

The clover was harvested on this field by cutting a strip across the plots, representing one-thirtieth of an acre on each plot. The hay was in excellent condition when it was weighed. The results obtained on this field are given in table III.

Gypsum seemed to cause a marked increase in the production of oats on the Eldora field. The 200 pound application gave a gain of 8.2 bushels of oats; the 500 pound treatment with gypsum, a gain of 4.8 bushels; and on the plot receiving the large application of gypsum, there was an increase of 15 bushels of oats per acre when compared with the check plot. The 500 pounds of gypsum and lime gave an increase of 11.2 bushels of oats per acre, while the 200 and 1,000 pound gypsum treatments with lime showed only small increases over the plot receiving lime alone.

Very little can be said regarding the effect of gypsum on the clover grown on the Eldora field. On the plot receiving 1,000 pounds of gypsum without lime there seemed to be a depressing effect, but the same amount of gypsum used with lime showed a gain of 1,410 pounds of hay per acre over the plot

TABLE III
Eldora Field
The effect of gypsum on yield per acre of oats and clover.

Plot no.	Treatment pounds per acre	1920 oats yield bushels per A.	Increase or decrease over nearest check	1921 clover hay yield pounds per A.	Increase or decrease over nearest check
1	Check	48.3	..	4,620	..
2	200 lbs. gypsum	56.5	+8.2	4,860	+240
3	500 lbs. gypsum	53.1	+4.8	4,470	—150
4	1,000 lbs. gypsum	63.3	+15.0	3,390	—1230
5	200 lbs. gypsum + lme	57.8	+9.5	5,400	+780
6	500 lbs. gypsum + lime	65.3	+17.0	5,460	+840
7	1,000 lbs. gypsum + lime	55.1	+6.8	6,720	+2100
8	Lime	54.1	+5.8	5,310	+690

receiving lime alone, and an increase of 2,100 pounds over the check plot. The 200 and 500 pound applications of gypsum with and without lime had very little effect on the growth of clover on this field.

FARSON FIELD

This field was located on a farm belonging to R. E. Hinds near Farson in Wapello county. The soil type was Grundy silt loam, a dark brown to black soil which covers a large area in southeastern Iowa. A four year rotation of corn, oats, wheat and clover was followed on this field and it was planted to wheat in the fall of 1919. Clover was seeded in the wheat in the spring of 1920. The soil showed a lime requirement of two and one-half tons of limestone per acre. Eight one-tenth acre plots were added to a series of experimental plots of the Soils Section of the Iowa Agricultural Experiment Station. These plots were treated as follows:

PLOT NO.	TREATMENT
1	Check (Of the regular Soils Section Series)
2 and 5	Gypsum 200 lbs. + Lime 5 tons per acre
3 and 6	Gypsum 500 lbs. + Lime 5 tons per acre
4 and 7	Gypsum 1,000 lbs. + Lime 5 tons per acre
8 and 9	Lime 5 tons per acre.

Gypsum was applied to the wheat and clover on May 7, 1920, and lime was added a few days later. The wheat yields for 1920 were not obtained on this field.

During the last week in September 1920, five more plots were laid out on a uniform portion of this same field, three of which were top-dressed with gypsum at the usual rates. The other two plots served as checks. The stand and condition of the clover on these plots was excellent at this time.

The results obtained on the duplicate plots of the Farson field receiving gypsum and lime in the spring of 1920, and also those secured from the use of gypsum applied in the fall of

1920 are found in table IV. The clover was cut from an area representing one-thirtieth of an acre, and the results are calculated on the acre basis.

Where gypsum was used without lime on this field, small effects were observed for the gypsum treatments, except in the case of the 500 pound application which showed an increase of 460 pounds of clover hay per acre over the check plot. When gypsum was used with lime, larger yields of clover hay were produced than with lime alone. These increases stand out prominently. With the 200 pounds of gypsum, the gain over the check plot amounted to 760 pounds; the 500 pounds of gypsum showed a gain of 550 pounds; while the 1,000 pound treatment with gypsum and lime produced a gain of only 380 pounds of clover hay. The plot receiving lime alone showed a decrease of 240 pounds of hay when compared with the check plot. The smallest treatment with gypsum plus lime seemed to be the most effective rate of application on this field.

The results obtained on the Farson field show clearly that the best results cannot be secured from the use of gypsum on certain soils if they are acid. Therefore to give this material a fair trial, the field should first be limed, if it is acid, before the gypsum is applied.

TRUESDALE FIELD

This field was located on the farm of J. M. Horlacher near Truesdale in Buena Vista county. The soil type was Carrington loam and showed a lime requirement of two tons of ground limestone per acre. A rotation of corn, corn, oats and clover was followed on this field which was in oats seeded with clover in 1920. Two one-tenth acre plots were added to the series of plots of the Soils Section. The last plot of the regular series served as a check, and gypsum was applied by hand to the two

TABLE IV
Farson Field
The effect of gypsum with and without lime on red clover.

Plot no.	Treatment pounds per acre	1921 yield clover hay pounds per A.	Increase or decrease over nearest check
1	Check	4,760	..
2 and 5	200 lbs. gypsum + lime, spring 1920*	5,520	+760
3 and 6	500 lbs. gypsum + lime, spring 1920*	5,310	+550
4 and 7	1,000 lbs. gypsum + lime, spring 1920*	5,140	+380
8 and 9	Lime, spring 1920*	4,520	—240
11	200 lbs. gypsum, fall 1920	4,070	+40
12	500 lbs. gypsum, fall 1920	4,490	+460
13	1,000 lbs. gypsum, fall 1920	4,140	+110
10 and 14	Check*	4,030	..

*Average of two plots.

TABLE V
Truesdale Field
The effect of gypsum on yield per acre of oats and clover.

Plot no.	Treatment pounds per acre	1920 oats bushels per A.	Increase or decrease over nearest check	1921 clover hay pounds per A.	Increase or decrease over nearest check
1	Check	56.5	..	4,268	..
2	500 lbs. gypsum	56.1	—0.4	4,007	—261
3	500 lbs. gypsum + lime	59.2	+2.7	4,187	—81

plots at the rate of 500 pounds per acre, and lime at the rate of four tons per acre was added to one plot on May 18, 1920. When the oats were ripe, an area representing 40 square feet was harvested from each of the three plots, and when the hay was ready to cut, an area representing 500 square feet of clover was harvested from each plot. The results obtained on this field, showing the yields of oats and clover hay in pounds per acre, are given in table V.

Examining the data in this table it may be seen that the 500 pound gypsum treatment had no effect on the production of oats on this soil, but when this amount was used with lime, a slight gain was noted. This increase, however, was probably not large enough to be of any significance. When gypsum was used either with or without lime it had no effect on the yield of red clover grown on this field. The results obtained on the Truesdale field indicate that this particular soil is not, at the present time, in need of a sulfur fertilizer for oats or clover.

SAWYER FIELD

This field was located on the farm of G. K. Manny near Sawyer in Lee county. The soil type was Grundy silt loam and it showed a lime requirement of four tons of ground limestone per acre. A rotation of corn, corn, oats and clover was followed on this field which was in oats in 1920. Two one-tenth acre plots were added to the regular series of plots of the Soils Section as usual and gypsum was applied to both plots on May 5, 1920. Lime was not added to the one plot until after the oats were harvested. Instead of being in clover the following year,

TABLE VI
Sawyer Field
The effect of gypsum on yield per acre of oats and rye

Plot no.	Treatment pounds per acre	Oats 1920 bushels per A.	Increase or decrease over nearest check	Rye 1921 bushels per A.	Increase or decrease over nearest check
1	Check	34.3	..	20.9	..
2	500 lbs. gypsum	50.9	+16.6	31.5	+10.6
3	500 lbs. gypsum	61.1	+26.8	..	..
4	500 lbs. gypsum + lime	..	..	24.2	+3.3

this field was seeded to rye. The results, showing the effect of gypsum on the production of oats and rye grown on this field, are given in table VI.

The 500 pound gypsum treatment brought about a very marked increase in the production of oats on the Sawyer field. The average gain for the two plots over the check plot was 21.7 bushels of oats per acre. These results are all the more surprising in view of the very high acidity of this soil, altho it is well known that this crop is not very sensitive to an acid condition in the soil. It seems that there is a need for a sulfur fertilizer like gypsum on this particular soil.

The effect of the gypsum treatments was still noticeable the following year on the rye. On the plot receiving gypsum alone, the yield of rye was increased by 10.6 bushels, while on the plot receiving gypsum and lime the increase over the check was only 3.3 bushels.

In all probability gypsum would show to even greater advantage if it were used on either clover or alfalfa growing on this soil. For these legume crops, the plot receiving lime and gypsum would probably produce more hay than the plot receiving gypsum alone.

DELMAR AND ELDRIDGE FIELDS

The Delmar field in Clinton county was located on the farm of Henry Lassen. The Eldridge field was on the farm of E. B. Calderwood near Eldridge in Scott county. Both of these fields were on Muscatine silt loam which is a good dark brown to black soil well adapted to corn, hay, barley, oats and potatoes. A rotation of corn, corn, wheat and barley was followed on the Delmar field, while on the Eldridge field a rotation of corn, oats, barley and clover was practiced. Each of these fields was in barley in 1920. Two plots were added to the regular Soils Section series and gypsum was applied to each plot at the rate of 500 pounds per acre about May 1, 1920. Lime was not added to the one plot, which should have received lime, until after the barley was harvested, so plots 2 and 3 are really duplicates. The results obtained from these fields, showing the effect of gypsum on the production of barley, are found in table VII.

TABLE VII
Delmar and Eldridge Fields
The effect of gypsum on yield per acre of barley

Plot no.	Treatment pounds per acre	1920 Delmar bushels per A.	Increase or decrease over nearest check	1920 Eldridge bushels per A.	Increase or decrease over nearest check
1	Check	24.5	..	19.0	..
2	500 lbs. gypsum	24.5	0	23.6	+4.6
3	500 lbs. gypsum	27.6	+3.1	21.8	+2.8

TABLE VIII
Agency and Stockport Fields
The effect of gypsum on yield per acre of clover hay.

Plot no.	Treatment pounds per acre	1921 Agency clover hay pounds per A.	Increase or decrease over nearest check	1921 Stockport clover hay pounds per A.	Increase or decrease nearest check
1	Check	4,657	...	2,272	...
2	200 lbs. gypsum	4,830	+173	2,176	—96
3	500 lbs. gypsum	4,554	—103	2,336	+64

On the first plot receiving gypsum on the Delmar field, the same amount of barley was produced as on the check plot, but on the second gypsum treated plot there was an increase of 3.1 bushels of barley per acre over the check. This gain is so small, however, that it is negligible.

Gypsum seemed to increase the production of barley grown on the Eldridge field, both plots receiving gypsum showing small increases over the check plot. The clover on this field was turned under the following spring for corn and no more results were obtained from this experiment.

AGENCY AND STOCKPORT FIELDS

In the spring of 1921, an attempt was made to study the effect of a top dressing of gypsum on clover which was to be harvested the same year that the gypsum was applied. Two fields of the Soils Section, one near Agency in Wapello county on the farm of N. O. Johnson, and the other near Stockport in Van Buren county on the farm of J. C. Silver, were in clover in 1921 and afforded an opportunity for this study. The Agency field was on Grundy silt loam and the Stockport field on Grundy clay loam. Two plots were added to the regular series of the Soils Section as usual, but gypsum was added at the rate of 200 and 500 pounds per acre. The applications of gypsum were made on these fields May 13 and 14, 1921. The results obtained from these experiments are included in table VIII.

On the Agency field the 200 pounds of gypsum showed a slight gain in the yield of clover over that on the check plot, but the larger application did not produce as good a yield as the check. On the Stockport field all of the results for the three plots were nearly the same, showing that gypsum was without effect on the clover grown on this soil. It is well known that for best results gypsum should be applied as early as possible in the spring when growth begins. For this reason it is entirely possible that the gypsum applications were made too late to permit the gypsum to have any effect on the clover on these fields.

STORM LAKE FIELD

An experimental field to test the effect of gypsum on the yield of oat grain and straw was placed on the farm of Bert Schulke near Storm Lake in Buena Vista county. The soil type on this field was Carrington silt loam, the surface soil to a depth of 12 inches being a dark brown moderately heavy silt loam. Five plots, 66 feet square, were marked off on a level representative area of the field and gypsum was applied in the amounts noted in table IX on April 28, 1923. The preceding week Green Russian oats and red clover were sown, following discing in of corn stubble. The seed was sprouting when the gypsum was applied but no seedlings had broken thru.

Samples were cut from the plots on July 23, about three days before the grain was mature. The stand was slightly uneven, particularly on the check plot, from which two additional areas were cut when the samples were taken. The results obtained from this experiment are shown in table IX.

It is apparent from the data presented in table IX that while the larger applications of gypsum gave the greatest increases of straw, they produced practically no increases in grain. The smaller applications of gypsum, on the other hand, gave not only appreciable increases in straw, but also decided increases in grain. These increases amounted to 8 bushels of oats per acre in the case of the 50 pound application of gypsum, and 10 bushels for the 150 pound treatment with gypsum. From the standpoint of the total crop, or straw plus grain, each of the various treatments gave an increase over the check of approximately 25 percent or 1,000 pounds of grain and straw per acre.

The results obtained on the Storm Lake field indicate that this soil may be deficient in available sulfur, and further tests are desirable to show the effect of gypsum on other crops like clover or alfalfa growing on this same soil.

AMES FIELD NO. 2

Three one-fortieth acre plots were laid out in an alfalfa field in the spring of 1921 on the Agronomy Farm of the Iowa Agricultural Experiment Station. The soil type was Carrington loam, and it showed a lime requirement of two tons of ground limestone per acre. Two of these plots were top-dressed with gypsum on April 14, one at the rate of 200 and the other at the rate of 500 pounds per acre. The alfalfa at this time was just starting its early spring growth. Samples representing an area of 392 square feet were harvested from each plot at the first cutting, but the hay from the entire plots was cut for the second and third crops.

The results for the three cuttings, showing the effect of gypsum on the production of alfalfa on this field, are given in table X.

TABLE IX

Storm Lake Field

The effect of gypsum on the yield of oats, 1922

Plot no.	Treatment pounds per acre	Grain				Straw		Total Crop	
		Yield lbs. per acre	Increase or decrease over nearest check	Yield bu. per acre	Increase or decrease over nearest check	Yield lbs. per acre	Increase or decrease over nearest check	Yield lbs. per acre	Increase or decrease over nearest check
1	500 lbs. gypsum	1,100	0	34	0	2,900	+1,000	4,000	+1,000
2	300 lbs. gypsum	1,150	+50	36	+2	2,800	+900	3,950	+950
3	Check	1,100	..	34	..	1,900	..	3,000	..
4	150 lbs. gypsum	1,400	+300	44	+10	2,500	+600	3,900	+950
5	50 lbs. gypsum	1,350	+250	42	+8	2,600	+700	3,950	+950

TABLE X

Ames Field No. 2

The effect of gypsum on the yield of alfalfa, 1922

Plot no.	Treatment pounds per acre	Yield per acre						Total yield per A. tons	Increase or decrease over nearest check
		First crop lbs.	Increase or decrease over nearest check	Second crop lbs.	Increase or decrease over nearest check	Third crop lbs.	Increase or decrease over nearest check		
1	Check	1,820	..	3,856	..	5,200	..	5.43	..
2	200 lbs. gypsum	2,284	+464	4,164	+308	5,392	+192	5.92	+0.49
3	500 lbs. gypsum	2,108	+288	3,868	+12	5,568	+368	5.77	+0.34

The gypsum treatments increased the yield of alfalfa hay at each cutting, but the effect was most pronounced at the first cutting. The 200 pound application increased the yield of the first crop of alfalfa by 464 pounds over the check, and the 500 pounds of gypsum increased the yield of the first cutting by 288 pounds. At the second cutting, the smaller treatment of gypsum increased the yield over the check by 308 pounds, while the larger application showed practically no increase. An increase of only 192 pounds was secured at the third cutting of alfalfa on the plot receiving 200 pounds of gypsum, and a gain of 368 pounds was obtained on the plot receiving 500 pounds of gypsum.

The total yields for the three cuttings showed an increase for the 200 pound gypsum treatment of 964 pounds of hay, while for the 500 pound application, the increase over the check was 668 pounds.

Analyses for protein in the hay from the second and third cuttings were made and it was found that gypsum did not increase the protein content of the alfalfa which was grown on this field.

GRAND MOUND FIELD

This experiment was conducted on the farm of H. M. Stueland near Grand Mound in Clinton county. The soil type was Carrington fine sand, and tho a minor type, it was selected because of the difficulty it usually presents to the establishment of a stand of alfalfa. The field had previously been in meadow, corn, corn and oats. It was manured, limed and seeded to alfalfa late in the summer of 1922. Two months later, when the gypsum was applied, the stand was well distributed but not uniform, many of the plants being but 1 or 2 inches high, while others were from 6 to 12 inches, due probably to the variations in hardness of the seed used.

A strip of the most uniform portion of the field was selected for the plots, which were made 66 feet square. The level of the first three plots was about six feet above that of the fifth, the fourth plot being on the intervening slope. The gypsum was applied October 28, 1922.

Continued drought prevented the late development of the alfalfa and only one cutting was obtained.

The results secured from this field, showing the effect of gypsum on the yield of alfalfa, are shown in table XI.

From the data shown in table XI it may be readily seen that all of the gypsum treatments produced increases in the yield of alfalfa hay over that on the check plot. The smallest application of 50 pounds of gypsum per acre showed a gain of almost one ton of hay, or an increase amounting to nearly 100 percent. The 300 pound treatment increased the yield by 1,350

TABLE XI
Grand Mound Field
The effect of gypsum on yield per acre of alfalfa.

Plot no.	Treatment pounds per acre	1923 yield per acre first cutting pounds	Increase or decrease over nearest check
1	500 lbs. gypsum	3,000	+600
2	300 lbs. gypsum	3,800	+1350
3	Check	2,450	...
4	150 lbs. gypsum	3,000	+550
5	50 lbs. gypsum	4,400	+1950

pounds, while the 150 and 500 pound applications of gypsum showed an increase of 550 pounds of hay over the yield of the untreated plot.

Analyses for protein did not show any effect from the gypsum treatment.

The results obtained on this field indicate rather strongly that this particular soil type may respond to sulfur fertilization on young alfalfa fields. Gypsum on this soil may prove to be a very profitable material, not only thru increasing the yield of alfalfa, but also by building up the fertility of the soil by promoting greater root development of the alfalfa plants and subsequently increasing the nitrogen supply in the soil.

WAVERLY FIELD

This field was located on the farm of Fred C. Peters near Waverly in Bremer county on Carrington loam. It was planted to potatoes in 1921. In the latter part of June, 1922, a heavy application of manure was disced in and the field seeded to alfalfa. When the gypsum was applied, November 4, the stand was excellent, being thickly established, 6 to 10 inches high, and practically free of weeds. Plots 60 by 72.6 feet were extended lengthwise over the entire field. One-half of each plot received limestone at the rate of four tons per acre.

The stand of alfalfa at the time of harvest was not entirely satisfactory, and results were secured only for one cutting. These results, showing the yields of hay per acre, are given in table XII.

The 50 pound application of gypsum without lime yielded the same amount of hay as the check, but the other treatments without lime showed very marked increases in yield of hay over that on the untreated plot. The 150 pound treatment increased the yield by 1,000 pounds; the 300 pound application gave a gain of 800 pounds, and the largest application of gypsum produced 1,400 pounds of hay more than the check plot. The results obtained with gypsum and lime were not as satisfactory as those without lime. Only the large application of 500 pounds of gypsum with lime produced a decided gain over the yield of the

TABLE XII
Waverly Field
The effect of gypsum on yield per acre of alfalfa.

Plot no.	Treatment pounds per acre	1923 yield per acre first cutting pounds	Increase or decrease over nearest check
1	50 lbs. gypsum	1,700	
2	150 lbs. gypsum	2,700	+1000
3	Check	1,700	
4	300 lbs. gypsum	2,500	+800
5	500 lbs. gypsum	3,100	+1400
6	50 lbs. gypsum + lime	1,500	—200
7	150 lbs. gypsum + lime	1,700	
8	Limestone	1,500	—200
9	300 lbs. gypsum + lime	1,700	+200
10	500 lbs. gypsum + lime	2,300	+800

plot receiving lime alone. This increase amounted to 800 pounds. Whatever may have been the action of gypsum in this experiment, the limestone tended to decrease the effect.

The percentages of protein in the alfalfa hay from the different plots was determined and it was found that gypsum had no effect.

AMES FIELD NO. 3

To investigate the effect of gypsum on a well established stand of alfalfa, this test was laid out on the farm of J. L. Harper near Ames in Story county. The soil type was O'Neill sandy loam which is a minor terrace type much in need of organic matter. The field was seeded to alfalfa in 1919 and reseeded the following year. Limestone applied at the rate of two tons per acre in 1920 gave good results. The sulfur and gypsum were applied April 10, 1923, to the plots which were 43.5 by 100 feet in size. The series of six plots occupied all of the field except one end approaching a steep slope, where the clay and gravel underlying the surface soil out-cropped.

Results were obtained from this field for the first two crops only. The second crop developed poorly and in order to obtain data as accurate as possible the entire stand of each plot was cut and weighed.

The results obtained from this experiment are found in table XIII. These data show that all of the gypsum treatments and the sulfur gave considerable increases in alfalfa at the first cutting. The smallest application of gypsum gave the greatest increase, which amounted to 1,300 pounds of hay per acre. Gypsum at 150 pounds and sulfur at 100 pounds per acre gave somewhat smaller increases, while the larger additions of gypsum yielded a gain of 800 pounds of hay over the untreated plot.

Results of the second cutting show that sulfur had the greatest effect, this plot producing 600 pounds more hay than the check plot. The larger applications of gypsum also gave in-

TABLE XIII
Ames Field No. 3
The effect of gypsum on the yield of alfalfa, 1923

Plot no.	Treatment pounds per acre	Yield per acre					
		First crop pounds	Increase or decrease over nearest check	Second crop pounds	Increase or decrease over nearest check	Total pounds	Increase or decrease over n'r's't check
1	100 lbs. sulfur	5,400	+1,100	1,700	+600	7,100	+1,700
2	500 lbs. gypsum	5,100	+800	1,350	+250	6,450	+1,050
3	300 lbs. gypsum	5,100	+800	1,450	+350	6,550	+1,150
4	Check	4,300	...	1,100	...	5,400	...
5	150 lbs. gypsum	5,400	+1,100	950	—150	6,350	+950
6	50 lbs. gypsum	5,600	+1,300	1,050	—50	6,650	+1,250

creases. The plots receiving the smaller treatments with gypsum were located near the slope and outcrops mentioned previously, and undoubtedly moisture became a limiting factor here.

The total yields for both cuttings show that the sulfur treatment gave an increase of nearly one ton of hay over the check, while each of the different applications of gypsum gave an increase of approximately one-half ton.

Slight increases in protein content were found on the 100 pound application of sulfur and the largest application of gypsum, but in general the percentages did not vary a great deal from that in the crop on the check.

AMES FIELD NO. 4

This field was placed on the farm of H. H. Harper near Ames in Story county. The object of the experiment was to test the effect of gypsum and sulfur on a young stand of alfalfa. The soil type was Carrington loam and it showed a lime requirement of one-half ton of limestone per acre. No lime, therefore, was added to this field. One-tenth acre plots were laid out on a uniform portion of the field and the various treatments noted in table XIV were applied April 13, 1923. Cuttings were made June 15, July 21 and September 6. On each of these dates the stand over the entire field was excellent, being uniform, heavy and free from weeds. The results obtained from this field, showing the effect of gypsum and sulfur on the yield of alfalfa, are given in table XIV.

An examination of the data in table XIV shows that in all cases the heaviest application of gypsum gave the most substantial increases at each cutting, the total increase over the check for this plot being one and one-half tons. The plot receiving sulfur produced the next largest increase which amounted to almost one ton over the yield of the untreated plot. The 300 pound application of gypsum failed to show an increase for the first crop, but very decided gains were observed for this treatment for the second and third crops. The total increase over

TABLE XIV

Ames Field No. 4

The effect of gypsum on the yield of alfalfa, 1923

Plot no.	Treatment pounds per acre	Yield per acre						Total tons	Increase or decrease over nearest check
		First crop lbs.	Increase or decrease over nearest check	Second crop lbs.	Increase or decrease over nearest check	Third crop lbs.	Increase or decrease over nearest check		
1	100 lbs. sulfur	5,000	+150	4,150	+1,150	2,000	+400	5.57	+0.85
2	500 lbs. gypsum	5,600	+750	4,650	+1,650	2,250	+650	6.25	+1.53
3	300 lbs. gypsum	4,850	0	3,700	+700	1,900	+300	5.22	+0.5
4	Check	4,850	..	3,000	..	1,600	..	4.72	..
5	150 lbs. gypsum	4,650	—200	3,350	+350	1,450	—150	4.72	..
6	50 lbs. gypsum	5,000	+150	3,750	+750	1,150	—450	4.95	+0.22

the check for plot No. 3 was 1,000 pounds. The 150 pounds of gypsum had practically no effect on the alfalfa, the total yield on the plot receiving this treatment being exactly the same as that obtained from the check plot. The smallest application of gypsum showed a slight gain in yield of hay at the first cutting; a very decided increase of 750 pounds at the second cutting; but a loss of 450 pounds at the third cutting. On this plot, however, there was a total gain of 450 pounds of hay over the check.

The percentage of protein in the alfalfa hay was slightly increased by the 500 and 150 pounds of gypsum, but other treatments showed no effect on the protein content.

Judging from the yields of alfalfa hay obtained from the check plot, this field may be considered to be in a high state of fertility, but the increases secured from the plots treated with gypsum indicate strongly that there is a deficiency in available sulfur for the maximum production of alfalfa. Further experimentation would have been very desirable on this field, because the results from just the one year are suggestive in demonstrating that gypsum, especially at the rate of 500 pounds per acre would prove profitable for alfalfa.

DISCUSSION OF RESULTS

Considering the results presented in the foregoing tables as a whole, it may be noted that on some of the fields very noticeable increases in yields of oats were secured from the use of gypsum, while on other fields no beneficial effects were obtained. The same statement may be made regarding the effect of gypsum on the production of red clover, but very positive results were obtained from the use of gypsum on all of the alfalfa fields. This may probably be accounted for by the fact that alfalfa requires relatively larger amounts of sulfur for its growth than these other crops. It seems quite likely, on the other hand, that where gypsum produced such large increases in yields of oats, as on the Sawyer and Storm Lake fields, even more striking results would have been obtained if alfalfa had been grown on these fields.

No attempt is made to draw definite conclusions from the results obtained on the different experimental fields reported in this bulletin. Neither was it deemed advisable to calculate the value of the increases in yields of oats, clover and alfalfa which were caused by the gypsum treatments. For this purpose it is obvious that the experiments should have been carried on for a period of years. But in view of the ever-increasing demand for information on the use of gypsum as a fertilizer for Iowa soils, it seemed desirable to publish these results at the present time. It is believed, furthermore, that they furnish sufficient

indications upon which may be based future suggestions and recommendations to farmers who are particularly interested in the needs of their soils for sulfur carrying fertilizers.

THE NEED OF IOWA SOILS FOR SULFUR AS INDICATED BY THE FIELD EXPERIMENTS

Inasmuch as the supply of sulfur in Iowa soils is low, and since relatively large amounts of this element are lost annually from Iowa soils thru the drainage water, it seems that the use of sulfur carrying fertilizers will be necessary in the future if crops are to be properly nourished. In general, the field results give rather definite indications of value from the use of gypsum at the present time on oats and clover, but more particularly on alfalfa, when grown on certain types of soil. The soils which responded to gypsum fertilization in these tests are Carrington loam, Carrington silt loam, Carrington fine sand, Grundy silt loam and O'Neill sandy loam. Only comparatively few of the soil types found in Iowa were represented in these experiments, and it is quite possible that many other soil types would respond to sulfur fertilization.

Many alfalfa growers in Iowa, and especially those whose farms are located on one or more of the soil types mentioned above, may find it profitable to test gypsum on a small area. They could then ascertain the advisability of using this material on a larger area. The Soils Section of the Iowa Agricultural Experiment Station urges interested farmers to make such tests on their own farms under their particular soil conditions. It is suggested that these tests be made on alfalfa because in the field experiments this crop was the only one to produce consistently higher yields from the use of gypsum. Then, again, results can be obtained more quickly with alfalfa than any other crop, and since it is a very heavy sulfur feeder, it is apt to respond more readily to a sulfur fertilizer if the soil on which it is growing happens to be deficient in available sulfur.

Directions for carrying out field tests on the farm are given in Circular 97 of the Iowa Agreiultural Experiment Station. In order to test gypsum alone it would be desirable to lay out at least three plots of uniform size as described in the circular. These plots may then be treated as follows: No. 1, Check; No. 2, Gypsum 200 pounds per acre; No. 3, Check. It is very important to make the gypsum applications in the early spring. Gypsum should not be used in greater amounts than is actually required by the crop, since it is slowly soluble and is likely to be leached away in the drainage water. The 200 pounds of gypsum would add about 40 pounds of sulfur per acre and this amount would be sufficient for a maximum crop of alfalfa.