Sulfur and Phosphorus Fertilization Of Alfalfa and Clover In Northeast Oregon

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Summary and Recommendations

1. Alfalfa and clovers growing on sultur-deficient soil increase in yield, sulfur content, and crude protein when fertilized with gypsum or elemental sulfur.

2. Gypsum is an effective source of sulfur whether it is applied in the fall or early spring.

3. Fall-applied elemental sulfur is a more effective source of sulfur the first year following application than is early spring-applied elemental sulfur.

4. Elemental sulfur under nonirrigated conditions often requires one full year after application for conversion to the sulfate form to be an effective source of sulfur for alfalfa and clovers.

5. Alfalfa in the early bloom stage of growth containing less than 0.22% sulfur is sulfur deficient. Alfalfa containing between 0.22 and 0.25% sulfur may or may not be sulfur deficient. Alfalfa containing over 0.25% sulfur is not sulfur deficient. This is 5 pounds of sulfur per ton of dry alfalfa. Clovers contain slightly less sulfur than alfalfa.

6. Five to eight pounds of sulfur should be applied to sulfur-deficient soils for each ton of dry legume forage produced.

7. Gypsum and elemental sulfur have good residual value. More than one year's needs can be applied in one application.

8. The acidity of the soil should be considered when deciding whether to purchase gypsum or elemental sulfur. Elemental sulfur should not be applied to soils which are slightly or moderately acid if alfalfa is to be grown unless lime is also applied.

9. Alfalfa and clovers growing on soil deficient in available phosphorus increase in yield, phosphorus content, and crude protein when fertilized with phosphorus.

10. Alfalfa and clovers growing on soil deficient in both phosphorus and sulfur can be fertilized satisfactorily with a phosphorus fertilizer which contains an appreciable amount of sulfur.

11. Phosphorus fertilizer can be broadcast on established stands either in the fall or early spring.

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12. Phosphorus fertilizers have good residual value. Thirty-five pounds of P (80 pounds of P_2O_5) can be expected to supply phosphorus needs for more than one year.

13. A soil test is helpful in estimating whether or not alfalfa and clovers should be fertilized with phosphorus.

14. A soil test once each 3 to 5 years is valuable in determining whether the available phosphorus is being increased, maintained, or depleted.

15. Dry alfalfa forage should contain at least 0.22% phosphorus. Alfalfa grown on phosphorus-deficient soil may contain only 0.15 to 0.18% phosphorus.

16. Greater seedling vigor and improved stands are obtained when deficient soils are fertilized prior to planting. The fertilizer should be banded or worked into the seedbed.

Introduction

For over 50 years, sulfur has been known to be deficient for crop production in Oregon. Since 1920, the quantity of sulfur applied to crops has varied. In recent years interest in fertilizing with sulfur has been stimulated by observations of severe deficiency symptoms, low yields, and the need for the production of large yields with a minimum of cost.

Legumes such as alfalfa and clovers require a large amount of phosphorus for maximum growth. These crops often suffer from a lack of available phosphorus in many soils of northeast Oregon. The application of a fertilizer containing phosphorus is necessary to provide an adequate supply of this element.

Many legume stands are invaded by weeds and grasses within a few years after planting which results in lower yields and lower quality forage. Such invasions and loss of stands are much more rapid in fields which do not provide legumes with an adequate amount of the nutrients essential to plant growth. Less loss of stands from heaving during the winter have been observed in fields of healthy, vigorous plants.

The mere use of commercial fertilizer does not guarantee economical returns. The correct kind must be applied in the right amount and at the most effective time for maximum returns. Experimental work conducted by the Eastern Oregon Experiment Station has been designed to provide information for successful fertilization of alfalfa and clovers for forage production. Results of field experiments were correlated with results of laboratory soil tests and plant analyses. This recent work is summarized below and combined with the results of previous work provides a guide for the application of elemental sulfur, gypsum, and phosphorus.

Results

SULFUR

Deficiency symptoms

Visible symptoms of sulfur deficiency in legumes are not obvious or easily distinguished from some other deficiency symptoms.

In northeast Oregon, nitrogen deficiency in alfalfa--apparently caused by poor nodulation--produces symptoms which are difficult to distinguish from those produced by a lack of sulfur. Alfalfa and alsike, red, and white clovers suffering from a shortage of sulfur grow slowly and have a stunted appearance compared with plants supplied with all nutrients necessary for growth. Stems are short and small in diameter. They appear hard and woody. A field suffering from a lack of sulfur will appear to have a poor stand because of the few stems per crown. Leaf size will be small, and leaves will have a yellowish-green color. The lower leaves may drop off the plant prior to harvest. Plants properly fertilized within a deficient field will stand out prominently because of their dark green color, taller growth, and larger leaves.

Gypsum and elemental sulfur

Gypsum broadcast on established stands of alfalfa and clovers has proved to be a more effective source of sulfur than elemental sulfur the first year following application. Yields of the first cutting of dry-land alfalfa following gypsum application were 750 pounds per acre higher than where elemental sulfur was applied (Table 1). Elemental sulfur was of more value in irrigated fields than in nonirrigated fields. The moistening of the surface soil in late spring and early summer by irrigating provides a favorable environment for the conversion of elemental sulfur to sulfate.

Table 1. First Cutting Alfalfa Hay Yields from Fall- and Spring-Applied Gypsum and Elemental Sulfur

		Hay yields*			
		First year after application		Second year after application	
Treatment		Dryland	Irrigated	Dryland	Irrigated
		Lbs./A	Lbs./A	Lbs./A	Lbs./A
Gypsum**	(Fall)	3,300	5,100	3,800	4,700
Gypsum	(Spring)	3,100	5,200	3,700	4,600
Sulfur**	(Fall)	2,500	4,900	3,800	4,600
Sulfur	(Spring)	2,400	4,500	3,600	4,600
No gypsum or sulfur		2,200	4,100	2,600	3,100

* 15% moisture.
** Gypsum and elemental sulfur each applied at a rate to supply 50 pounds of sulfur per acre.

Elemental sulfur, the second year following application, increased alfalfa and clover yields 1,100 pounds per acre which is as much as gypsum increased yields (Table 1). Yield increase from applying elemental sulfur was much larger the second year than the first year, which is another indication that elemental sulfur the first year following application is not fully available. Apparently one full year is needed, especially in nonirrigated fields, to obtain sufficient conversion of the sulfur to adequately supply the needs of alfalfa and clovers growing on soil which is not supplying sufficient sulfur for maximum growth. Increases obtained the second year following application show that gypsum and elemental sulfur have good residual value. Enough gypsum or elemental sulfur can be applied at one time to last two or more years. Over a period of years, gypsum and elemental sulfur should produce equal yield increases when maintenance applications of sulfur are applied every two or three years.

The cost of each sulfur-bearing fertilizer, the ease of application, the possible need for liming if an acid forming fertilizer is used for many years, and the need for having the sulfur immediately available should be considered when a sulfur fertilizer is being purchased.

Time of application

Gypsum was equally effective as a fertilizer for alfalfa and clovers whether applied in the fall or in early spring (Table 1). Spring application should be as early as possible to increase the chances that several rains will occur after application to leach gypsum into the root zone. Irrigation water will move the gypsum into the root zone. Over-irrigation, however, may leach part of the gypsum out of the root zone.

Fall application of elemental sulfur was slightly more effective than spring application in increasing yield the first year (Table 1). Time of application had little effect on the value of the elemental sulfur the second year following application.

Fertilizer influence on the second cutting compared to first

Northeast Oregon has a winter type rainfall which varies from under 10 inches to over 25 inches. Where possible, irrigation or sub-irrigation is used to supply moisture during the growing season. In many of the experiments located in nonirrigated fields, yield of the second cutting of alfalfa depended primarily on the supply of available moisture. Second cutting yields were determined in those experiments where yield of the second cutting was not obviously limited by available moisture.

The second cutting was increased by fertilization nearly as much as the first cutting (Table 2). Average yield increases of the first and second cuttings were 1,500 and 1,300 pounds per acre, respectively, where gypsum was applied. An additional ton was obtained the second year as the yield increase (Table 1) was as large as the first year increase. Gypsum, costing approximately $3 per acre plus application charge, increased forage yields over two tons per acre in the first two years following application.

Table 2. Effect of Gypsum and Elemental Sulfur on Alfalfa Hay Yields the First Year After Application

Treatment		Hay yields*		Increase over check	
		First cutting	Second cutting	First cutting	Second cutting
		Lbs./A	Lbs./A	%	%
Gypsum**	(Fall)	4,900	3,000	48	100
Gypsum	(Spring)	4,700	2,600	42	73
Sulfur**	(Fall)	3,800	2,000	15	33
Sulfur	(Spring)	3,600	1,800	9	20
No gypsum or sulfur		3,300	1,500		

* 15% moisture.
** Gypsum and elemental sulfur each applied at a rate to supply 50 pounds of sulfur per acre.

Elemental sulfur, the first year after application, was no more effective in increasing the yield of the second cutting than the first cutting (Table 2). The second year following application, elemental sulfur increased the yield of the second cutting almost as much as the first cutting.

The per cent increase in yield resulting from fertilizing was much higher with the second cutting than with the first (Table 2).

Sulfur and protein content of alfalfa

Alfalfa at the early bloom stage of growth and well supplied with available sulfur contained 0.25% or more sulfur on a dry weight basis. This is 5 pounds of sulfur per ton of hay. Some alfalfa had as much as 0.40% sulfur or 8 pounds per ton. Sulfur above 0.25% or 5 pounds per ton in dry forage cut at the early bloom stage apparently is luxury consumption and is not needed for maximum growth.

Data from six experiments, three in sulfur-deficient fields and three in nondeficient fields, are presented in Table 3 to show the effect of sulfur on forage yields. Large yield increases from the application of gypsum have been obtained in fields where the mature nonfertilized forage contained less than 0.22% sulfur. Where large yield increases were obtained from fertilizing with gypsum, the sulfur content of the forage was increased to over 0.22%. In fields where gypsum increased the yield of alfalfa very little, the sulfur content of the nonfertilized alfalfa was above 0.25%.

Table 3. Sulfur and Crude Protein Content of Alfalfa from Sulfur-Deficient and Nondeficient Fields

Sulfur		Crude protein		
Non-fertilized	Gypsum** fertilized	Non-fertilized	Gypsum** fertilized	Increase in forage*
%	%	%	%	Lbs./A
		Fields deficient in sulfur		
0.16	0.28	13.8	17.4	1,400
0.21	0.35	17.8	19.9	1,000
0.14	0.29	15.6	16.5	1,600
		Fields not deficient in sulfur		
0.27	0.39	13.8	14.5	200
0.28	0.33	18.9	18.4	300
0.40	0.36	15.9	16.0	100

* 15% moisture.
** Gypsum applied at a rate to supply 50 pounds of sulfur per acre

The critical level at which sulfur becomes deficient in alfalfa is not a single value but varies slightly with growing conditions. Limited information obtained in these experiments indicates that the level of sulfur in the plant necessary for optimum growth changes with the maturity and nitrogen content of the forage. Conclusions are (1) alfalfa in the early bloom stage containing less than 0.22% sulfur is deficient in sulfur; (2) alfalfa with 0.22 to 0.25% sulfur may or may not be sulfur deficient; and (3) alfalfa having over 0.25% sulfur is not deficient in sulfur.

Clover adequately supplied with sulfur for maximum growth had a slightly lower sulfur content than alfalfa.

Alfalfa not suffering from a deficiency of sulfur had 1 to 3% more crude protein than alfalfa suffering from a deficiency of sulfur (Table 3). Since sulfur is an essential part of protein, it is reasonable to expect that a deficiency of sulfur would adversely affect protein content. Alfalfa not suffering from a sulfur deficiency was changed very little in crude protein content by sulfur fertilization.

Estimating sulfur needs of alfalfa and clovers

An estimate of the quantity of sulfur which should be supplied to sulfur-deficient soils growing alfalfa can be derived from a knowledge of the amount of sulfur removed annually by the alfalfa and the efficiency of the fertilizer used. Alfalfa should contain at least 5 pounds of sulfur per ton and may contain as much as 8 pounds per ton. In drier areas where 2 tons or less are produced annually, the sulfur removed in the forage is 10 to 16 pounds per acre. High producing, irrigated alfalfa may take up as much as 40 pounds per acre of sulfur annually. Over 90% of the sulfur applied to alfalfa growing on very deficient soils has been recovered in the forage produced. With an efficiency of over 90%, 5 to 8 pounds of sulfur per acre should be applied for each ton of forage produced. In slightly or moderately deficient fields, the efficiency of the applied sulfur has been much lower. Even though the efficiency was lower, the amount of sulfur fertilizer applied needed to be only 5 to 8 pounds per ton of forage produced, because the additional quantity of sulfur needed by the plant and not supplied by the soil was proportionally less.

Although clover contains a slightly lower concentration of sulfur in the forage than alfalfa, the difference is so small that the sulfur needs of clovers can be considered to be the same as alfalfa.

PHOSPHORUS

Alfalfa and clover suffering from a lack of available phosphorus grow slowly before showing other visible symptoms such as purple-bronzing of a few leaves. Fertilization delayed until visible symptoms are evident results in loss of yield, lower quality forage, loss of stand, and the invasion of grasses and weeds. Experimental work has been devoted to studying the time and rate of phosphorus fertilization, residual value, and the reliability of soil tests to predict phosphorus needs. Gypsum was applied uniformly to experimental areas to eliminate sulfur as a limiting factor where phosphorus fertilization was being studied.

Time of application

Weather conditions are such in northeast Oregon that a producer has the possibility of broadcasting fertilizer either in the fall or in the early spring. Some fields are extremely wet in the early spring, making it difficult to broadcast fertilizer. Under wet soil conditions, fall application is more convenient.

Results of experiments show no difference in yield between broadcasting phosphorus fertilizer on established stands in the fall or in the spring before growth starts (Table 4). Yield increase of the first cutting following application was 900 pounds per acre whether the phosphorus was broadcast in the fall or early spring. Yield increase of the second cutting was 900 pounds per acre where phosphorus was fall applied and 1,000 pounds where spring applied. Winter losses from leaching, from the conversion of the phosphorus to an unavailable form, or from other means did not reduce significantly the effectiveness of the fall application. Thus, the time of application can be at the convenience of the producer.

Table 4. Effect of Time of Broadcasting Phosphorus Fertilizer on Alfalfa Hay Yields

Treatment	Hay yields* First cutting Lbs./A	Hay yields* Second cutting Lbs./A
35 lbs. P** (Fall)	4,500	3,200
35 lbs. P (Spring)	4,500	3,300
No phosphorus	3,600	2,300

* 15% moisture.
** 35 pounds of P contains the same amount of phosphorus as 80 pounds of P_2O_5.

Rate of application

Where definite deficiencies existed, alfalfa receiving 35 pounds of phosphorus (80 pounds of P_2O_5) per acre produced larger yields than where 17 pounds of phosphorus (40 pounds of P_2O_5) were applied. Higher rates of application produced little additional increase in yield the first year following application.

Residual value

The residual value of phosphorus fertilizer has been good on all soils where experiments have been located. In many experiments the yield increase of alfalfa was as large the second year as it was the first year where 35 or more pounds of phosphorus (80 pounds of P_2O_5) were applied. The higher rates of application had more residual value in the second and third year than the lower rates of application.

A second method of measuring the residual value of phosphorus fertilization is by measuring the change in available soil phosphorus. In this work each rate of phosphorus fertilizer increased the available phosphorus in the surface horizon of the soil one year following application (Table 5). An application of 35 pounds of phosphorus (80 pounds of P_2O_5) increased the available phosphorus 50%. An application of 70 pounds of phosphorus (160 pounds of P_2O_5) tripled the available phosphorus. Higher rates of application increased the available phosphorus in the soil more than the lower rates of application on a per unit basis of fertilizer applied.

These results point out that producers can apply phosphorus fertilizer in a heavy single application to last two or three years or in light annual applications.

Soil test helpful

Producers do not have to wait for deficiency symptoms of phosphorus to appear to tell them that their soil is not supplying enough available phosphorus. Soil tests have proved to be a reliable and useful tool in estimating whether or not a soil is low, medium, or high in available phosphorus. The reliability of a soil test for phosphorus has been established through correlating results of field experiments with soil testing in the laboratory. The results of this work show that a close relationship exists between the amount of available phosphorus in the surface soil (plow layer) as detected by a chemical test and the response obtained from applying phosphorus fertilizer.

Table 5. Change in Available Phosphorus in the 0 - 8 Inch Soil Horizon One Year After the Application of Phosphorus

Rate of P application Lbs./A	Available P Lbs./A
Average of 5 experiments	
0	9.4
17 (40 lbs. P_2O_5)	11.2
35 (80 lbs. P_2O_5)	14.6
52 (120 lbs. P_2O_5)	20.6
70 (160 lbs. P_2O_5)	27.0
Average of 10 experiments	
0	20.8
35 (80 lbs. P_2O_5)	30.6

Soil test prior to legume planting

The ideal time to take a soil test is prior to the planting of legumes. If a deficiency is indicated, phosphorus fertilizer can be drilled or worked into the root zone as the seedbed is being prepared. Some drills are made with fertilizer attachments that band the fertilizer a short distance from the seed. Such a method of application and placement is desirable. A few drills place the fertilizer in direct contact with the seed. Since phosphorus fertilizers are not considered to be soluble salts, small amounts of phosphorus can be placed in direct contact with the seed without injury to the young plant as it sprouts. Stand and seedling vigor will be improved where deficient soils have been fertilized prior to planting.

Phosphorus and protein content of alfalfa

Mature alfalfa growing where phosphorus was deficient in the soil had a phosphorus content of 0.15 to 0.20%. In such cases a fall or early spring application of phosphorus fertilizer--besides increasing the yield--increased the phosphorus content of the forage to 0.22% or higher. Livestock nutritionists point out that forage fed to growing or lactating cattle or sheep should contain 0.20% or more phosphorus.

Nondeficient alfalfa and clovers will have a slightly higher crude protein content than phosphorus-deficient forage. The amount of increase of protein content is somewhat proportional to the yield increase obtained. Alfalfa receiving an adequate amount of phosphorus will be more leafy which may account for the protein increase. Phosphorus and sulfur fertilization is not a guarantee of high-protein hay. Other management practices, particularly time of cutting, are more influential on the protein content of the final product than fertilization.

Efficiency of phosphorus fertilizer

One method of determining the efficiency of phosphorus fertilizer is to obtain the difference in phosphorus contained in the fertilized and nonfertilized forage produced. This assumes that the additional phosphorus in the fertilized alfalfa comes from the fertilizer. In these experiments the average uptake of P in the nonfertilized alfalfa was 10 pounds per acre (5,200 pounds of forage containing 0.19% P). The average uptake of P in the phosphorus-fertilized alfalfa was 15 pounds per acre (6,700 pounds of forage containing 0.22% P). The difference--5 pounds--is assumed to have come from the 35 pounds of phosphorus applied as fertilizer.

This gives an efficiency of less than 15% the year of application. In these experiments the phosphorus recovered the second and third year following application of the fertilizer would more than double the efficiency obtained the first year. However, these and other workers' experiments lead to the conclusion that the efficiency of phosphorus fertilizer would seldom reach 50%. Much of the phosphorus not recovered by the plants is converted to forms unavailable to growing plants.

Methods

The results reported are from 25 experiments and 40 observational trials conducted in Baker, Grant, Union, and Wallowa counties. These experiments and trials, located in both dryland and irrigated fields, concentrated on fertilizing with sulfur and phosphorus. These two elements seriously limit legume yields in much of northeast Oregon. Deficiencies of other elements necessary for forage legume production are not widespread or obvious.

Gypsum and elemental sulfur were broadcast on established stands of alfalfa and clovers at an equal weight of sulfur per acre. Yields were measured to: (1) determine the increase in yield possible from fertilizing with these materials; (2) determine which was the most effective source of sulfur; (3) compare fall versus early spring application; and (4) provide plant samples for sulfur and nitrogen analyses. Time of fall fertilization was October or early November; spring fertilization was between April 1 and April 15. Yields were obtained just prior to the time the producer harvested the field. Usually the alfalfa was in one-fourth bloom. Plant samples consisting of the entire above ground portion were taken from each plot during harvest.

In the rate of sulfur application studies, gypsum was broadcast in the fall on established stands at rates of 10, 20, 30, and 40 pounds of S per acre.

Similar methods were used to study the need for phosphorus fertilization. Concentrated superphosphate was the source of phosphorus. Soil samples were taken prior to fertilizer application in all of the experiments. In several experiments soil samples were taken one year after fertilizer application to determine any change in available phosphorus.

Each experiment usually contained four replications and could be statistically analyzed to determine if the applied fertilizer had a significant effect on yield. First-cutting yields were obtained from the various treatments in each experiment; second-cutting yields were obtained from the experiments in which the lack of soil moisture did not obviously reduce yields. Yields the second year following fertilizer application were determined in many experiments.

Materials

Gypsum and elemental sulfur are the sulfur-bearing fertilizers usually applied on alfalfa and clover fields. Gypsum, sometimes called land-plaster, is calcium sulfate but may contain magnesium sulfate as an impurity. The sulfur content of gypsum varies from 16 to 18%. Gypsum contains enough calcium to neutralize the acid effect of the sulfur it contains. Gypsum has no effect on the pH of the soil.

Elemental sulfur, sometimes called soil sulfur, is 95 to over 99% sulfur. Materials sold as fertilizers are of various particle sizes. The elemental sulfur used in these experiments consisted of a mixture of particle sizes none of which were larger than 8 mesh. Elemental sulfur must be oxidized to sulfate before it is available to plants. Continued application of elemental sulfur will reduce the pH of the soil; thus, it is not advisable to apply elemental sulfur to soil which is slightly or moderately acid if alfalfa is to be grown, unless lime can be applied to neutralize the acid effect of the elemental sulfur.

Concentrated superphosphate is a concentrated phosphorus fertilizer which contains 19 to 21% phosphorus (44 to 48% P_2O_5). Single superphosphate contains 8 to 9% phosphorus (18 to 20% P_2O_5) and 9 to 10% sulfur. Single superphosphate is often used as a source of phosphorus and sulfur where both of these elements are needed.