F E R T I L I Z E R T E S T S F O R R A N G E

PASTURE AND FORAGE CROPS

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I. Fertilizer Problems of Forage, Range and Pasture Crops

In many areas of California the soils used for pasture, range, or for the production of hay and alfalfa are deficient in one or more plant nutrients. The fertilizer nutrients most commonly deficient are nitrogen, phosphorus and sulfur. Sometimes one of these nutrients is deficient, sometimes a different one and sometimes two or even three are deficient at the same time. In a few areas lime and potash may improve growth, either applied alone or with some other nutrient.

Legumes and grasses have rather different nutritive requirements or differ in their foraging power for nutrients. Nitrogen alone or with phosphorus stimulates grasses in most areas and legumes in a few locations. Legumes seem to have a relatively higher phosphorus and sulfur requirement than do grasses and other non-legumes. For mixed crops such as oat-vetch or pasture mixtures the relative amount or balance of nitrogen and phosphorus added are often important in determining the proportions of legumes and grasses in the forage.

A fertilizer test with forage crops may lead to the answer to one of several questions: -

1. What nutrients are acutely deficient or low in supply?
2. How much of a nutrient should be added for best results?
3. When should fertilizers be applied?
4. Where should fertilizer be put; in soil or on surface?
5. How often must applications be made?

Most fertilizer problems with forage crops involve one or more of these questions. No single test will answer all questions at once. Usually it is most important to find out first, what nutrient or nutrients are deficient and should be added to improve growth. Exploratory tests are designed to give this information. Later tests on rates of fertilization, time and method of application, should follow. To study these latter types of problems, replicated tests are usually necessary.

The matter of obtaining yields on forage crops presents many problems, particularly where pasture or range tests are involved. Obviously, a test plot area may not be grazed and still yield valid results. The same time, if a plot is completely protected and allowed to grow to maturity, no measure of the impact of grazing may be obtained. No thoroughly satisfactory method has yet been devised for obtaining yield results on pasture plots. We cannot allow the animals to graze the plot and make any measurements. Yet if we protect it completely, no studies of re-growth and recovery after grazing will be possible. Furthermore, if a plot is completely protected, the seeding of such crops as bur clover may be altered since no seeds will have been trod into the ground, as is the case where animals are allowed to graze. Until some better method is devised, we suggest that all fertilizer plots or range and pasture be protected until yield measurements or observations have been made, and then grazed.

II. Exploratory Tests -- WHAT?

A. Use of Exploratory Plots in Identifying Deficiencies. The first step in studying a fertilizer problem is to diagnose the nutrient deficiency or deficiencies present. Plant symptoms may often be recognized. Plant tissue analysis is helpful, if analytical facilities are available and if "chemical yardsticks" or deficiency levels are known for the crops concerned. Soil analysis for phosphorus may be useful for crops where data are available to interpret the chemical values obtained. In the final analysis, field tests will have to be run to verify chemical findings or visual observations.

Exploratory test plots are usually helpful in diagnosing unknown difficulties or in confirming suspected deficiencies. These tests are simple, unreplicated plots in which nutrients are applied alone and in all possible combinations. In this way it is possible to identify and evaluate both single and multiple deficiencies as well as to observe the individual and combined effects of several plant nutrients.

This type of test has been widely used by Dr. Conrad of the Division of Agronomy in cooperation with the Agricultural Extension Service. Luxury rates of fertilizers are usually employed in the hope that enough will be added to overcome soil fixation and other losses. Materials are broadcast because it is easy and rapid. A single application of fertilizer is usually made in the dormant season before growth starts. Small plots are employed to ensure reasonable uniformity of soil and to facilitate care and visual observations.

Exploratory plots have the advantage of ease of application, simplicity of design, along with ease and rapidity of inspection and evaluation. They have the limitation of measuring only gross differences in growth and are seriously affected by unsuspected variations in soil fertility within the plot area. Deficiencies may be missed if the amounts of nutrients applied are inadequate to overcome soil fixation or if water or some other factor limits growth.

B. Fertilizer Materials Suitable for Exploratory Tests. Care must be taken in the choice of fertilizer materials for exploratory plots. Materials containing more than one nutrient should be avoided since they may lead to erroneous conclusions. For example, alfalfa or bur clover respond equally well to single superphosphate, ammonium sulfate, 16-20, sulfate of potash or elemental sulfur on some soils deficient in sulfur. Ammonium phosphate-sulfate (16-20) is a very fine fertilizer for many purposes but completely unsuited for exploratory test plot work. It is difficult to tell if increased growth from 16-20 is due to the nitrogen, phosphorus, or sulfur, or to a combined response of N+P, N+S, P+S, or N+P+S.

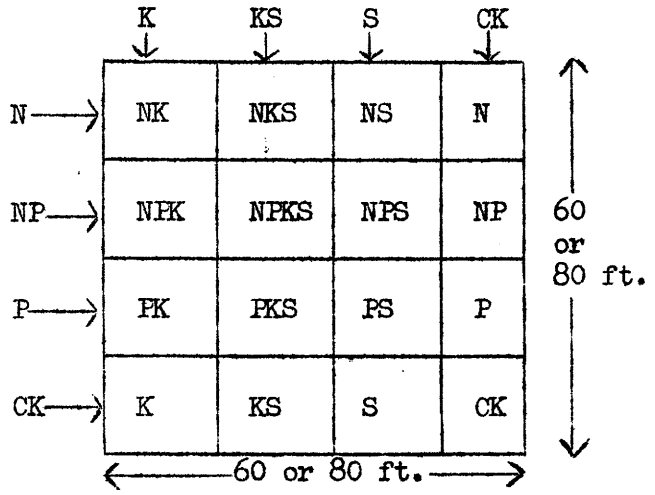
Similarly single superphosphate should be avoided because of its 8 to 9% sulfur content. While phosphorus and sulfur deficiency symptoms differ, it is sometimes difficult to tell whether the response to single superphosphate is due to the phosphorus, the sulfur or to the combined P+S effect.

A tabulation of materials to use and to avoid in exploratory plots is shown in Table I.

C. Exploratory Plot Layouts.

1. The four-element block exploratory test is probably the most generally useful design in use. Sixteen sub-plots are required to give all possible combinations of four nutrient elements. The arrangement of sub-plots may be conveniently set up in the form of a square, as indicated below:

4 Element Exploratory Plot



Basically, this is a factorial design but the nutrients are applied in strips to facilitate comparisons. Thus N, NP and P treatments are beside each other so that individual and combined effects may be seen visibly in adjoining strips. The N, NP, P and Ck strips are then crossed by K, KS and S treatments, thus giving the effects of potassium and sulfur alone and together, as well as their effect in combination with the nitrogen and phosphorus treatments. Plot size may vary with conditions. Either 20x20 or 15x15 sub-plots seem generally most satisfactory.

2. The use of strip exploratory tests involving P, K and S, offers some advantages in studying the fertilizer requirements of leguminous forage crops. It is particularly effective as a demonstration method and may be modified to give extra information not obtainable from the four-element exploratory test. Treatments include Ck, P, S, Ps and Ps plus K. These may be applied in small blocks but the effectiveness is increased if the treatments are extended as strips some distance across the field. Suggested arrangement and rates are as follows:

Strip Exploratory Plot

Nutrient supplied	Fertilizer used Material per Acre	
Ck		
P	Treble superphosphate	400 #/A
PS	Treble superphosphate	400 #/A
	Gypsum	400 #/A
PSK	Treble superphosphate	400 #/A
	Gypsum	400 #/A
	Potassium chloride	400 #/A
S	Gypsum	400 #/A
CK	--	--

This type of layout may be modified to include studies on the application of nitrogen to pastures. Nitrogen treatments may be applied across the strip at various seasons of the year. Nitrogen sources and rates may also be compared in this manner. On acid coastal soils this type of layout may be crossed with various rates of lime to get observations on the amount actually necessary to improve growth if applied alone and in combination with phosphorus and sulfur.

Table 1. FERTILIZER MATERIALS FOR EXPLORATORY PLOTS

Nutrient Supplied	Materials not Suitable		Suitable Materials for Exploratory Plots				
				Rate of Application			
		Interfering Nutrient		Nutrient	Material to be Applied		
	Name	Contained	Name	per Acre	Per acre	20x80	15x60
Nitrogen (N)	Ammonium sulfate	S	Ammonium nitrate (33% N)	50# N	150 lbs.	6 lbs.	3 lbs.
	Ammonium phosphate (11-48)	P	Calcium nitrate* (15½% N)	"	322 "	13.0 "	6½ "
	Am. phosphate-sulfate (16-20)	P & S	Uramon (42% N)	"	120 "	5.0 "	2½ "
Phosphorus as (P_2O_5)	Single superphosphate	S	Treble* superphosphate (42-46% P_2O_5)	160 lbs. P_2O_5	400 lbs.	16 lbs.	8 lbs.
Potassium as (K_2O)	Potassium sulfate	S	Potassium chloride (Muriate of Potash) (60% K_2O)	300# K_2O	500 lbs.	20 lbs.	10 lbs.
Sulfur (S)	Pit Gypsum (50-70% Gyp.)	Miscellaneous impurities	Gypsum* 18% S	72# S	400 lbs.	16 lbs.	8 lbs.
			Soil Sulfur (99% S)	72# S	73 "	3 "	1½ "
Lime	Dolemitic Limestone	Mg	Ground Oystershell (90% $CaCO_3$)		2-4 Tons	160-320 lbs.	80-160 lbs.
			Hydrated Lime		1½-3 "	120-240 "	60-120 "

*Calcium is contained in treble superphosphate, gypsum and calcium nitrate but is not considered a serious contaminant for exploratory plots under most conditions.

III. Rate Tests for Forage Crops -- HOW MUCH?

A. Use and Requirements of Rate Tests. After a single nutrient deficiency has been identified, it is desirable to lay out tests to determine how much fertilizer should be applied to obtain maximum crop response. Often the most economic rate may be somewhat below the amount giving maximum response.

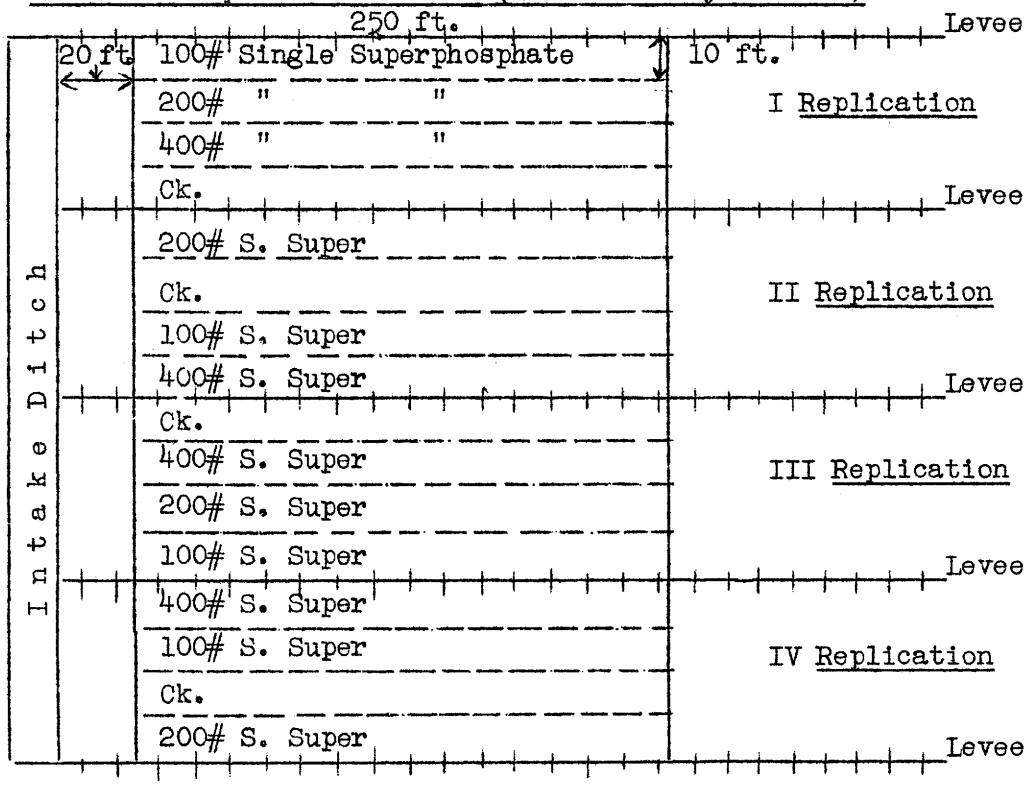
Similarly, where two nutrients have been found deficient, it is desirable to know how much of each is needed for satisfactory growth or for a desirable balance of legumes and grasses.

Rate tests should be laid out in such a way that carry-over effects in the second and third year may be observed and measured.

On irrigated alfalfa where 6 to 10 tons may be cut in 4 to 6 cuttings, precision methods should be employed. Differences hardly visible to the eye may be of economic importance. With lower valued pasture and hay crops larger differences may be necessary to be important economically, and differences not visible probably are not important. All rate test plots will have to be harvested in order to get yield results that mean anything.

B. Rate Tests for Single Element Deficiencies. Very satisfactory rate tests have been carried out on alfalfa using a randomized block design. Field tests in Merced County have shown that accurate results may be obtained by mowing strips $2\frac{1}{2}$ x 87 ft. (1/200 Acre) for a measure of yield. The layout employed in Merced County plots is shown below.

Alfalfa Phosphorus Rate Test (Merced County - Wolfe)



In the Merced County plots 4 treated areas 10' x 250' were laid out beside each other near head of water run in a 50' border check. Each replication with 4 subplots was placed in a separate border check and always at the head of the run of water to eliminate variations due to water supply. By increasing length of plots to 250 ft. a good demonstration was obtained. It was possible to move all of the 87 foot harvested areas in a replication up or down the border-check to avoid poor spots in the stand that were not apparent when the plot was put out.

Data from a plot of this design are reliable and may be examined critically and analyzed statistically.

B. Rate Tests for Multiple Deficiencies

Commonly two nutrient elements are deficient and tests are desirable to determine how much of each nutrient must be added to obtain good production and desirable composition. On pastures and range the elements most commonly deficient are nitrogen and phosphorus. Occasionally nitrogen and sulfur are both deficient, and sometimes both phosphorus and sulfur should be added. In a few cases nitrogen, phosphorus and sulfur have been found deficinet, while on some acid soils lime appears to give benefit but usually only when applied in conjunction with phosphorus, nitrogen or both.

When more than two nutrients are deficient, rate test plots become difficult and often quite complicated. In such cases special plot layouts will be necessary and design will be varied to meet the conditions. No standard layout is recommended at present.

1. Crossed Block Layouts often give good results when two nutrients are deficinet. Tests of this type have been used considerably on grain or grain hay and on oat-vetch hay with good results. Where nitrogen and phosphorus are to be studied the following layout may be employed:

	Ck	20 lbs. P_2O_5/A	40 lbs. P_2O_5/A	80 lbs. P_2O_5/A
Ck	Ck	P_{20}	P_{40}	P_{80}
15 lbs.N	N_{15}	$N_{15}P_{20}$	$N_{15}P_{40}$	$N_{15}P_{80}$
30 lbs.N	N_{30}	$N_{30}P_{20}$	$N_{30}P_{40}$	$N_{30}P_{80}$
45 lbs.N	N_{45}	$N_{45}P_{20}$	$N_{45}P_{40}$	$N_{45}P_{80}$

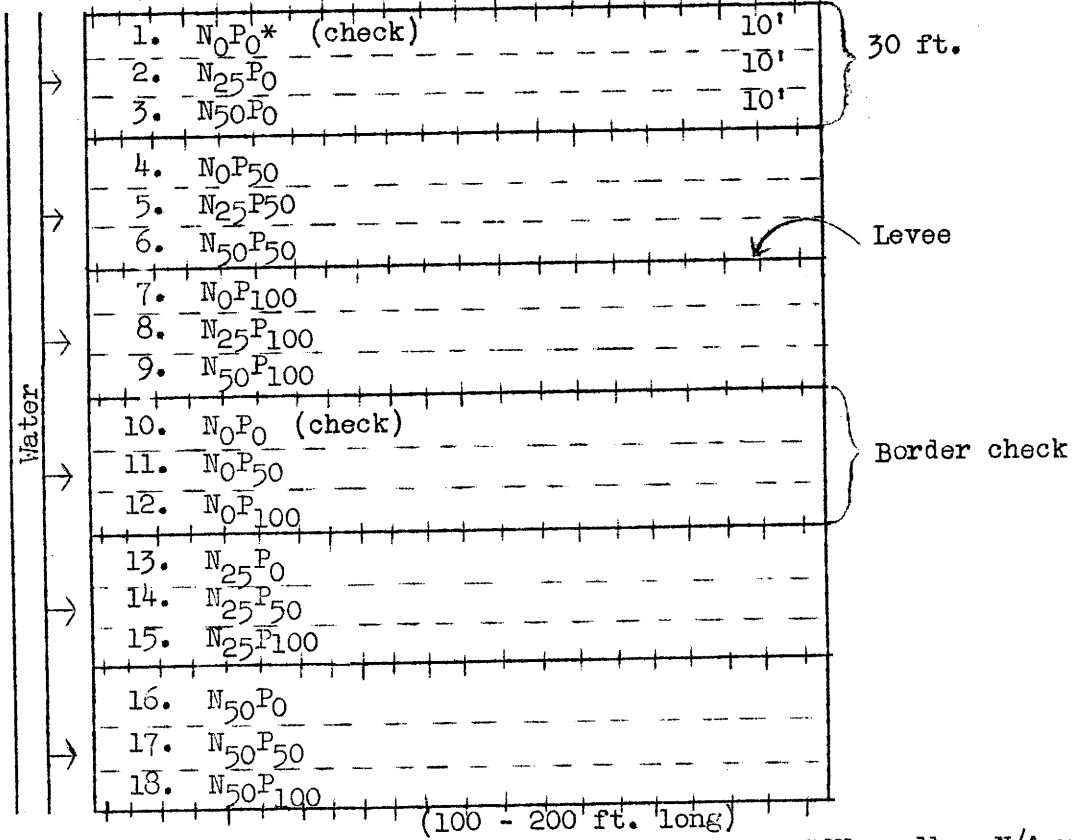
80' or 60' (vertical)

80' or 60' (horizontal)

The principle of this test is to lay out one nutrient in strips with ascending rate (here N) of application and to cross these strips with rate strips of the second nutrient (here P). A single unreplicated plot may make a fairly good demonstration but there should be 3 to 4 replications if reliable yields are to be obtained. A convenient (but statistically unsound) method of replication is to rotate the layout 90° for each replication thus changing the direction of the strips of each nutrient in each successive replication. Yields may be taken by cutting strips 2 to 3 feet wide across each square by a mowing machine or by cutting quadrats. This type of layout has advantage of ease of application and compactness but is often hard to interpret and is seriously affected by variations in soil, slope and irrigation.

2. Split Plot Strip Layouts make good demonstrations and offer many advantages, particularly for irrigated crops. The principle of this type of test is to vary the rates of one nutrient while holding the second one constant and then vary the second nutrient while holding the first one constant. This may be illustrated by the following plot diagram:

Split Plot Layout for N & P Rate Tests



*{N as lbs. N/Acre
{P as lbs. P_2O_5/Acre

In this layout the treatments are deliberately set up in ascending order to simplify comparisons between treatments and increase effectiveness as a demonstration to be shown farmers. Thus if we wish to see the effect of increasing nitrogen alone we may compare strips 1, 2 and 3. If we wish to show the effect of increasing nitrogen after adding 50 lbs. P (as P_2O_5) we may compare strips 4, 5 and 6. At the highest phosphorus rate, P_{100}(100# P_2O_5 (/Acre)) we may see the effect of increasing nitrogen by comparing strips 7, 8 and 9.

The second replication (strips 10-18) is set up to show the effects of increasing phosphorus alone (strips 10,11 and 12) with 25# N per Acre (strips 13, 14 and 15) and with 50# N (strips 16,17 and 18).

As outlined here this layout is poorly designed statistically but it does offer advantages in ease of inspection, simplicity of design and visual demonstration of results. This layout has only two replications and may not be analyzed statistically because of design. It has been laid out in such a way that many valid comparisons may be made and yield figures from cut strips certainly will give an honest estimate of the effects of the nutrients upon yield and composition.

It is preferable on irrigated lands that this type of test be laid out with 3 treatment strips per border check. Each treatment strip should be not less than 8 ft. wide and 100 ft. long. If only narrow checks (8 - 10 ft.) are available use one check for each treatment. On non-irrigated land a plot of this type should leave strips running up the slope of the hill to reduce errors from soil variability.

If a precision test is desired 4 replications will be necessary and design should be made by randomizing and repeating the layout in treatments ~~1 — 9~~ 10 to 18 where the main plots were nitrogen treatments and the sub-plots were the phosphorus treatments.

Dimensions of plots of various acre fractions are shown in Table 2. This may prove useful information in laying out test plots.