Response to Nitrogen and Phosphate Fertilizers in the Intermountain Area

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The question of soil fertility is broad in scope and includes a great many different farming practices such as crop rotation, the use of barnyard manure, the use of green manures, the use of commercial fertilizers, judicious use of irrigation water, and the utilization of crop residues. Neglect or abuse of any one of these factors may result in a gradual decline in soil fertility to the point where crop production is no longer profitable.

In many of our sugar beet producing areas the growing season is comparatively short and it is important that the young beet plant become established early and that early leaf and root development be rapid. Then, if maximum yields are to be obtained, the beet must be kept growing at a maximum rate. Adequate supplies of nitrogen and phosphorus favor rapid plant growth and development. In the area covered by the tests reported in this paper these are the two elements which are most frequently limiting factors.

The purpose of the fertilizer tests conducted in Utah, Tdaho, South Dakota, and Washington during the 1945 season was to determine the relative deficiency of nitrogen and phosphorus on farms producing sugar beets and to obtain information from which recommendations for commercial fertilizer practices could be based.

Experimental Methods

Grower strip tests were run in each factory district. These tests consisted of plots 16 rows wide and of sufficient length to give a 5- to 6-ton load from each treatment. Each test included both nitrogen and phosphate fertilizers. Nitrogen was supplied by using ammonium sulphate, and phosphate was supplied by using treble-superphosphate. These two fertilizers were applied alone and in combination with varying rates of each fertilizer. The amounts of each fertilizer compared both alone and in combination were: None, 200 pounds per acre, and 400 pounds per acre. The complete combination of fertilizers included in each test may be seen in the tables.

The fertilizers were applied with a side-dresser within 2 to 3 weeks following thinning. Generally the fields were watered within a week to 10 days of when the fertilizer was applied.

At harvest time the beets from each treatment were hauled to the

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dump and the average tare percentage from the entire plot was applied to each treatment. No attempt will be made to make a detailed tabular report of each of these 55 tests. However, a general summary of the results from each is given.

Experimental Results

General Summary of Results from Tests.

There were 18 tests in Utah, 21 in Idaho, 8 in South Dakota, and 8 in Washington.

There were significant responses to fertilizer applications in 14 of the 18 tests in Utah. In only one instance did the most profitable response occur from the use of phosphate alone. In eight of the tests it was more profitable to apply 400 pounds of ammonium sulphate per acre than to apply 200 pounds of the same fertilizer. Net returns per acre from increased yields ranged from $4.27 to $78.08 per acre and averaged $22.23 per acre.

There were significant responses to commercial fertilizer applications in 18 of the 21 tests in Idaho. In only two tests did the most profitable response occur from the use of phosphate alone. In 12 tests 400 pounds of ammonium sulphate was more profitable than a smaller amount. The net return per acre from the increased yields varied from $8.16 to $35.63 per acre. The average net return was $19.41 per acre.

There were significant responses in five of the eight tests in South Dakota. In one test the greatest and most profitable response resulted from the application of 400 pounds of phosphate fertilizer per acre. This farm was the most heavily manured farm in the Belle Fourche district. In the other tests applications of ammonium sulphate up to 400 pounds were profitable. Net returns from increased yields varied from $4.00 to $35.50 per acre and averaged $16.84 per acre. Lack of response on two fields was due largely to insufficient irrigation.

There were significant responses in yield from all the tests in Washington. In only one test did the greatest responses come from phosphate alone. This was a very heavily manured farm which illustrates again that phosphate fertilizers are needed to balance out a manure program. In all but one test 400 pounds of ammonium sulphate gave profitable increases over that obtained with 200 pounds of ammonium sulphate. The net return per acre from increased yields ranged from $8.84 to $76.96 per acre and averaged $37.45.

These tests point out the importance of following a balanced fertilizer program to insure maximum returns for money invested. Recommended fertilizer practice in the Utah-Idaho Sugar Company area includes the use of a mixed fertilizer of 16-20-0 composition with recommended amounts varying from 300 to 600 pounds per acre, depending on the area and the farmer's manure program.

Types of Response

In general the response from the fertilizers applied could be classified into three types: 1. Response from both nitrogen and phosphate fertilizer, with the greatest response occurring where the two were applied in combination; 2. Response to nitrogen only, indicating that there was sufficient phosphate present to satisfy plant requirements completely; and 3. Response to phosphate only, indicating that there was sufficient nitrogen present to satisfy plant requirements.

Examples of tests which gave a response to both nitrogen and phosphate fertilizers are given in table 1. The data indicate that in these tests where there was response from both nitrogen and phosphate fertilizers when these were applied separately, the response was additive when the two fertilizers were applied in combination. Frequently the response was greater than the additive response of the two applied alone. In almost all cases 200 pounds of treble-superphosphate per acre provide a better balance between nitrogen and phosphate than did the 400 pound application. This was shown by the fact that yields averaged 1 ton per acre less when 400 pounds of treble-superphosphate was applied than when 200 pounds was applied. It is not known whether this would have continued to be true if the application of ammonium sulphate had been increased to 600 or 800 pounds per acre. Of the combinations tried 400 pounds of ammonium sulphate and 200 pounds of treble-superphosphate per acre was the most profitable.

Examples of tests which gave response to nitrogen only are given in table 2. The data indicate that there was sufficient phosphate present to satisfy the demands of the plant but that nitrogen was definitely a limiting factor in plant growth. Under these conditions applications of additional phosphate either gave no response or actually decreased yields. For example: On the basis of the average of the eight tests applications of 400 pounds of ammonium sulphate per acre increased yields 3.36 tons per acre, but application of 400 pounds of treble-superphosphate per acre decreased yields an average of .77 tons per acre. In every case the decrease due to applications of phosphate fertilizer was in proportion to the increase from applications of nitrogen fertilizer. It would appear that nitrogen deficiency became more severe as the phosphate level was raised. Under these conditions applications of nitrogen fertilizer alone gave a better balance and greater increase in yield than did combined applications of nitrogen and phosphate fertilizers.

The importance of keeping fertilizer elements in balance was also indicated by the tests which responded to phosphate fertilizers but

Table 1.—Tons beets per acre, showing the individual and combined response of nitrogen and phosphate fertilizers.

Location of test		Amount of Nitrogen and Phosphate Fertilizer applied per acre									[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
	N.	None	200	400	None	None	200	400	200	400		
	P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho												Dollars
Ralph Harmer		17.37	18.46	18.57	17.38	18.14	19.22	20.26	18.79	19.44	2.89	16.79
W. E, Bennion		23.02	24.08	26.16	24.02	23.34	24.91	26.96	26.88	25.74	3.94	28.34
Lester Herndon		14,45	15.02	15,57	14.82	15.23	16.20	16.62	15.64	15.45	2.17	8.87
V. C. Webb		10.79	12.99	15.07	13.80	12.68	13.75	16.54	14.00	15.69	5.75	48.25
Glen Johnson		10.85	12.14	13,82	11.73	11.45	13.23	14.34	13.72	14.24	3.49	23.39
Washington												
Hilmer Nielson		26.95	30.77	31.45	29.98	28.64	31.78	33.08		29.49	6.13	52.32
John Golob		21.29	24.36	27.67	23.64	25.26	28.04	29.65	24.19	29.83	8.54	76.96
Hilsop Sheep Co.		24.05	27.26	25.62	25.80	26.73	27.39	28.05	25.58	26.33	4.00	29.00
Wm. Schilperoot		25.98	26.47	26.88	24.52	24.83	27.70	29.08	28.37	28.16	3.10	18.99
Average		19.53	21.17	22.13	20.62	20.67	22.34	23.60	20.98	22.63	4.07	29.77

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P=Pounds per acre of phosphate fertilizers (treble superphosphate).
[1]May or may not be most profitable treatment.
[2]May or may not be largest increase in yield due to fertilizer application. Cost of fertilizer and harvesting costs deducted from profit figure.

which gave no response to nitrogen fertilizer. Examples of this type of response are given in table 3. It is evident that these tests indicate a condition in which just the opposite relationship is indicated from those in table 2. From the average of these four tests, 400 pounds of treble-superphosphate per acre gave an average of 2.29 tons of beets per acre, but applications of 400 pounds of ammonium sulphate per acre gave an average decrease of 1.87 tons per acre.

In each of these tests the initial nitrogen level was high, and additional nitrogen evidently increased the deficiency of phosphate which in each case was the limiting factor. The one thing common to each of these four tests was that the land on which they were located had been heavily manured over a period of several years. The results of these tests stress the fact that phosphate fertilizer is essential in balancing out a manure program.

Discussion

The results of the fertilizer tests conducted in 1945 indicate the importance of having a proper balance between nitrogen and phosphate fertilizers. Raising the level of one element when another was deficient generally resulted in yields lower than those from the unfertilized plots. This result has been recognized by many different workers during the past 100 years.

The importance of a balance of mineral elements was first recognized by Sprengel (7)[2]. In 1845 he stated that no matter how favorable all other factors of growth might be, too great a deficiency or too great an excess of any single constituent necessary for the growth of plants would cause the soil to be unproductive. Liebig *(3)* enlarged on Sprengel's ideas and developed the so-called law of the minimum. According to this law the deficiency of one nutrient element in the soil retards the assimilation of other nutrient elements below the limits obtainable under conditions of most favorable growth. It has been shown by subsequent investigators that the absorption of increasing amounts of nutrient elements by the crop does not proceed in simple proportions, as assumed by Liebig, but that the law of diminishing returns brings absorption of nutrient and yield of crop to a final maximum beyond which further applications of fertilizer are not only ineffective but may be injurious. In 1909 Mitscherlich *(4)* published the results of his work and showed growth curves for each of the nutrient elements for several crops. He also found that if too great an addition of one element was combined with too great a deficiency of another element a condition of unbalance was produced that led to a decrease instead of an increase in yield. In 1927 Lagatu and Maume

[2]Italic numbers in parentheses refor to literature cited.

Table 2.—Tons beets per acre, showing response to nitrogen fertilizer on fields where there was no deficiency of phosphate. Applications of additional phosphate actually decreased the nitrogen response.

	Amount of Nitrogen and Phosphate Fertilizer applied per acre										[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
	N.	None	200	400	None	None	200	400	200	400		
Location of test	P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho												Dollars
Karl Webb		12.49	14.25	15.36	12.25	12.44	13.49	12.90	13.80	13.90	2.87	26.66
Jesse Dye		12.68	14.39	16.02	12.11	11.38	14.31	15.03	14.60	15.63	3.34	26.93
Bill J. Webb		11.25	14.38	15.31	11.88	9.05	12.50	14.87	12.60	13.44	4.06	34.85
E. C. Rhodehouse		12.37	13.12	14.44	13.33	11.88	11.53	13.02	12.74	13.29	2.07	12.97
E. M. Bacon		9.98	11.56	12.18	9.96	10.24	11.80	11.65	11.82	11.88	2.20	14.40
So. Dakota												
Geo. Jeffrey		9.53	11.68	12.01	10.49	10.01	11.01	11.27	10.60	10.90	2.48	19.96
Washington												
Maurice Rowe		15.19	18.00	18.81	15.48	14.59	16.81	18.74	18.74	18.67	3.62	30.01
Oscar Syverson		20.56	25.03	26.76	19.42	18.32	22.51	25.89	23.73	26.19	6.20	56.40
Average		13.00	15.30	16.38	13.11	12.23	14.24	15.42	14.81	15.48	3.36	27.16

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P=Pounds per acre of phosphate fertilizer (treble superphosphate).
[1]May or may not be most profitable yield.
[2]Calculated from most profitable treatment. Cost of fertilizer and harvesting costs deducted from profit figure.

Table 3.—Tons beets per acre, showing response to phosphate fertilizer on fields where there was sufficient nitrogen. Applications of additional nitrogen actually depressed the phosphate response.

		Amount of Nitrogen and Phosphate Fertilizer applied per acre									[1]Maximum increase in tons per A.	Net return[2] per acre from most profitable increase in yield
	N.	None	200	400	None	None	200	400	200	400		
Location of test	P.	None	None	None	200	400	200	200	400	400		
Utah and Idaho											Tons	Dollars
Carl Marcuren		15.36	14.87	14.87	15.81	16.75	17.88	16.77	16.19	16.28	2.50	17.40
S. H. Blake		23.40	22.53	22.87	23.41	25.07	25.89	24.48	25.31	25.16	2.49	17.29
So. Dakota												
Fred Kiel, Sr.		7.82	6.60	6.67	9.98	11.65	10.98	10.39	9.29	10.74	3.83	35.60
Washington												
Maurice Rowe		28.90	24.44	23.59	28.81	31.18	29.04	31.74	29.00	29.02	2.28	14.68
Average		18.37	17.11	17.00	19.49	21.16	20.94	20.84	19.69	20.30	2.29	14.79

N=Pounds per acre of nitrogen fertilizer (ammonium sulphate).
P—Pounds per acre of phosphate fertilizer (treble superphosphate).
[1]May or may not be most profitable yield.
[2]Calculated from most profitable treatment. Cost of fertilizer and harvesting costs deducted from profit figures.

(2) published work in which they correlated studies using balanced and unbalanced fertilizers with chemical analyses of leaves of the plants being studied. Their experiments showed that an excess of some nutrients diminished the absorption of a deficient element to the point that there was less of it in the plant than was present when the plant was grown on unfertilized soil. The general effect of the increase of one element in the nutrient solution was to cause a decrease in the leaf content of the other two elements measured. This work was substantiated by Thomas (*8*) who used foliar diagnostic methods in his work with complete and unbalanced fertilizers on potatoes. This type of correlated work was carried further by Opitz, Rothsack and Margenroth (*5*) in Germany. They worked with barley and used varying rates of potash, phosphorus, and nitrogen fertilizers both separate and in combination. These investigators analyzed the total plant and found essentially the same thing as did Lagatu and Maume (*2*), i. e. applications of unbalanced fertilizers produced yields of crop inferior to those obtained from an unfertilized plot. Browne (*1*) summarizes the work of several investigators by staling that the mineral composition of plants can be affected only within certain limits. An increase of one constituent is offset by the decrease of another. Too great an excess as well as too great a deficiency of a particular nutritive element brings with it injury to the crop, which is reflected in lowered vitality and diminished yield.

In view of the fact that one element cannot be substituted for another and that an excess of one nutrient element actually interferes with the proper utilization of others, it becomes of increasing importance that fertilizer recommendations be based on comprehensive information and that fertilizer practice be adapted, insofar as possible, to meet the needs on each individual farm. To meet this problem, fertilizer studies should include a study of soil type, cropping history, fertilizer and cultural practices, and demands of the crop being grown. Schreiner (*6*) summarizes this problem as follows: "Evaluation of the fertility of a soil and of the quality and quantity of a fertilizer required for profitable yield and quality of crop is indispensable to economic fertilizer usage and essential to efficient crop production. Three general types of procedures are being used for this evaluation—plot tests with specific crops in the field, pot tests with field crops or selected test crops, and laboratory procedures involving chemical and biological factors."

Probably no one of these procedures is best under all conditions, and probably all three types of tests can advantageously be used in surveying fertilizer requirements.

Summary

Field tests with nitrogen and phosphate fertilizers conducted in Utah, Idaho, South Dakota, and Washington indicated a general deficiency of nitrogen and phosphate. On many farms the nitrogen level was so low that applications of phosphate not only gave no response but actually decreased yields. In a few cases phosphate was so deficient that applications of nitrogen fertilizer alone injured the crop. These cases generally occurred where the farmer had been following a heavy manure program. On farms where there was a response to both nitrogen and phosphate fertilizers, the yield increase on plots receiving both fertilizers was greater than the combined increase of the two added separately.

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