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Progress Report of Phosphate and Other Fertilizer Investigations at the Aberdeen Branch Experiment Station, University of Idaho

By

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PHOSPHATE fertilization is of great interest in Idaho at the present time; first, because soil conditions existing in the irrigated areas make it essential to successful crop production; and second, because of the great potential supply of phosphate rock within the boundaries of Idaho.

The need for information on the use of phosphates and other fertilizing materials on the irrigated farms of southern Idaho was recognized, and work was started in 1921 on the Branch Experiment Station at Aberdeen. Only small increases were obtained from phosphates at that time, and as a result no further investigations of similar nature were started until decreasing yields obtained by farmers again focused attention in 1930 on the need for further investigations to determine the cause of this decrease. Since that time, phosphate fertilization studies have been one of the major projects of this Station. Most of the fertilizer work has been done with alfalfa, red clover, potatoes, and grain. The need of phosphate fertilizer on sugar beets has been demonstrated and its use encouraged by the sugar companies and by the fertilizer department of the Anaconda Copper Mining Company. Since the need of this fertilizer in the production of sugar beets was so well demonstrated by these agencies during the years 1930 to 1932, it was decided that experimental efforts should be directed to other crops.

General Information

The Aberdeen Branch Experiment Station is located at an elevation of 4,400 feet, on the west side of the American Falls' reservoir, ½ mile from Aberdeen. The irrigation water is obtained from the Snake river through the Aberdeen-Springfield Canal. A 26-year average, 1913 to 1938 inclusive, shows a frost-free period of 109 days, May 30 to Sept. 18, and a mean annual precipitation of 8.65 inches.

The part of the Station land upon which early fertilizer tests were conducted was dry farmed until 1919 and then put under

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irrigation. Consequently the land used had been under irrigation for a much shorter period than most of the irrigated lands of southeastern Idaho. This may explain why legume crops did not show as much reduction in yields during the period 1920-1930 as those on farms of similar high lime content that had been under irrigation for a longer period.

The soil on the Aberdeen Station has been tentatively classified by E. N. Paulson, *et al*[1], as belonging to the Aberdeen Series. These soils have developed from old lake strata reduced by erosion to a lower terrace level and modified by both stream and aeolian surface deposits. At the station and in the vicinity of Aberdeen, the underlying strata is high in clay and relatively impervious to percolating water. This underlying strata is often relatively high in salts. The surface soil is somewhat shallower and more calcareous than for the more typical soils found in that area.

All of the investigational work reported in this publication was conducted on the Branch Experiment Station farm unless otherwise stated.

The size of the individual plats in the various tests varied from 1/40 to 1/2 acre, depending on the type of experiment and the amount of comparable land available. The yields were obtained, for the most part, by harvesting the entire plat. In a few cases only about one-half of the plat was harvested. All yields were then calculated to the acre basis.

Early Experimental Results

In order to determine if sulfur was a limiting factor in alfalfa production at the Aberdeen Station, an experiment was started in the spring of 1920. The results obtained with 2-year-old alfalfa are shown in Table 1, and indicate that no benefits were derived from sulfur applications.

Table 1.—Influence of sulfur on alfalfa hay production. Two cuttings per year.

Treatment	Rate per acre	Number of plats	1920 yield	1921 Residual[1] yield	Average yield
			ton	ton	ton
Untreated	....	2	7.00	5.85	6.43
Sulfur	100 lb.	2	6.79	5.93	6.36

[1]Residual will be used through this bulletin to mean the effects on the crops the second or subsequent years after the fertilizer application.

Farmers in this area reported that the alfalfa yields were slowly declining, particularly on the first land to be brought under irrigation. Since phosphorus and sulfur-containing fertilizers had been reported by other western experiment stations as increasing alfalfa yields, an experiment was established in 1921 to see if treble superphosphate, gypsum, or sulfur would give similar responses under the conditions at the Aberdeen Station. No results were obtained until 1922. Since the results obtained from the two gypsum plats

[1]Soil Survey of Blackfoot-Aberdeen Area (Bingham County), Idaho, E. N. Poulson, A. E. Poulson, and Lewis Nelson. Series 1937.

were comparable, one was changed to manure in the spring of 1923. The results are given in Table 2.

The average of four years' results indicated that gypsum, sulfur, and manure gave only slight increases in yield. Treble superphosphate, on the other hand, gave a significant increase.

Table 2.—Effect of treble superphosphate, gypsum, sulfur, and manure on alfalfa hay yields. Seeded in 1920; 2 cuttings per year. 4-year average, 1922-1925

Treatment	Rate per acre	Number of plats	Average yield	Years applied
			ton	
Untreated	....	2	4.26	....
Treble superphosphate[1]	200 lb.	3	5.10	1921, 1922, 1923, 1925
Gypsum	200 lb.	3	4.54	1921, 1923, 1925
Manure[2]	10 ton	3	4.07[3]	1923, 1925
Sulfur[1]	200 lb.	3	4.47	1921, 1925

[1]Only 100 pounds of treble superphosphate and sulfur were applied in 1921. 200 lbs. were applied the other years.
[2]Manure was not used until 1923—gypsum was applied to these plats in 1921.
[3]The average yields of the check plats for the same 3 years as reported for manure treatment was 3.85 tons.

Yields of 4-year-old alfalfa had been observed to be gradually decreasing so treble superphosphate, gypsum, ammonium sulfate, and sulfur were applied in the spring of 1930 to see what influence each would have on increasing the yields. Manure was applied at the rate of 20 tons per acre the previous winter to the entire area.

The results shown in Table 3 were similar to those obtained in the earlier experiment (*Table 2*); namely—treble superphosphate gave the greatest increase in yield. The gypsum plats showed some increase the first year, but the residual effect was very small. The ammonium sulfate gave next to the smallest increase of the materials used. This may be accounted for by the fact that under proper conditions alfalfa secures part of its nitrogen supply from the air and also the heavy manure application the previous fall supplied liberal amounts of nitrogen.

Table 3.—Effect of treble superphosphate, gypsum, sulfur, and ammonium sulfate on alfalfa hay yields. Fertilizers applied only in the spring of 1930. Two cuttings per year.

Treatment	Rate per acre	Number of plats	1930 yield	1931 Residual yield	Average yield 1930-1931
			ton	*ton*	*ton*
Untreated	....	2	2.91	2.37	2.64
Treble superphosphate	200 lb.	2	3.89	3.62	3.76
Gypsum	200 lb.	4	3.54	2.62	3.08
Sulfur	200 lb.	2	3.11	2.45	2.78
Ammonium sulfate	200 lb.	2	3.22	2.65	2.94

Influence of Age of Alfalfa on Results Obtained from Phosphate Fertilization

The test plats were laid out the full length of the field parallel to the corrugations. This was done to overcome the variation in soil brought about by leveling which brings the lime layer to the surface in the scraped areas. Phosphate deficiency is much more acute in these areas than under normal conditions.

Much greater yields were obtained by applying phosphate to a new seeding of alfalfa than to the older stand, as shown in Table 4. The residual effects the second and third year after application were still significant. Further discussion of the residual effects will be presented later in the bulletin.

Table 4.—Comparison of the response of new seeding and 3-year-old alfalfa to phosphate fertilization. Two cuttings per year.

Treatment	Rate per acre	Number of plats	1932[1] Yield	1933 Residual Yield	1934 Residual Yield
			ton	*ton*	*ton*
First year after seeding					
Untreated	....	3	2.67	2.21	1.81
Treble superphosphate	200 lb.	2	4.13	3.52	2.44
Per cent increase	....	....	55.0	59.0	35.0
3-year-old Alfalfa					
Untreated	....	2	3.10	3.14	....
Treble superphosphate	200 lb.	2	3.70	3.60	....
Per cent increase	....	....	19.0	15.0	....

[1]Treble superphosphate applied in the spring of 1932 only.

It is generally recognized that feeds grown on land deficient in mineral plant nutrients are often inferior in feeding quality. Phosphate deficiencies have been evident in livestock (particularly dairy cattle) which have been fed alfalfa hay grown on phosphate deficient land. Table 5 indicates there is a marked difference in the phosphate content of hay grown on land with and without sufficient amounts of phosphate and that this difference undoubtedly manifests itself in the feeding value of the hay.

Table 5.—Chemical analyses of the second cutting of alfalfa hay grown on test plats in 1933. Hay obtained from the test reported in Table 4. Figures in per cent.

Treatment	Ash	Crude protein	Crude fat	Crude fiber	Nitrogen free extract	CaO	P_2O_5
Hay—first year after seeding							
Untreated	10.7	18.0	2.90	29.2	39.20	2.20	0.160
Treble superphosphate 200 lb. per acre	10.4	17.6	2.43	32.5	37.07	2.04	0.210
Hay—3-year-old							
Untreated	9.9	16.3	2.35	32.8	38.65	1.88	0.170
Treble superphosphate 200 lb. per acre	10.0	16.1	2.40	34.2	37.30	1.88	0.206

Comparison of Rock Phosphate with Treble Superphosphate

A comparison of the effectiveness of finely ground rock phosphate (Ruhm) with treble superphosphate, substantiates earlier observation; namely—that the use of rock phosphate should be discouraged under the conditions found in southern Idaho.

A summary of the results obtained from rock phosphate and treble superphosphate is given in Table 6. Only one application of the fertilizer was made at the beginning of the experiment. The addition of \$6.00 worth of finely ground rock phosphate (Ruhm) did not increase the yield over the untreated plats, while \$5.00 worth of treble superphosphate gave a total increase for the 2 years of 2.44 tons, making the fertilizer cost for the extra hay produced \$2.05 per ton.

Table 6.—Comparison of the influence of rock phosphate and treble superphosphate on alfalfa hay production. One-year-old alfalfa. Two cuttings per year.

	Application rate per acre	Number of plats	1935 Average yield	1935 Increase or decrease	1936 Residual Average yield	1936 Residual Increase or decrease	Total increase or decrease 2 yrs.	Cost of fertilizer application per acre[1]	Cost of fertilizer to secure ton increase in yield
	lb.		*ton*	*ton*	*ton*	*ton*	*ton*	*dollars*	*dollars*
Treble superphosphate	...	6	3.42	...	2.87	...	...	...	...
Untreated									
Finely ground rock phosphate	800	2	3.15	−0.27	2.90	0.03	−0.24	6.00	Value entirely lost
	200	6	4.48	1.06	4.25	1.38	2.44	5.00	2.05

[1]Rock phosphate at \$15.00; treble superphosphate at \$50.00 per ton.

Time of Application

Time of application has an important bearing on yields following the application of treble superphosphate. The customary prac-

Figure 1.—Second cutting alfalfa hay, Buffi Farm, 1939. Each bundle obtained from 3 square-yard areas. Residual effect of the 1938 application.

No.	Treatment	Rate per acre lbs.	Yield per acre tons
1	Untreated	......	.76
2	Rock phosphate, fine	1350	.68
3	TVA triple superphosphate	117	1.42
4	Treble superphosphate	125	1.27

tice is to apply phosphate the first year the alfalfa is grown for hay. The experiment summarized in Table 7 was started in 1934, when the alfalfa was planted with wheat as a nurse crop. Treble superphosphate was applied to two of the plats at the time of seeding. The other plats did not receive any phosphate until the spring of 1935, which was the first year that alfalfa was grown for hay.

It was estimated that the wheat receiving phosphate at the time of seeding gave an increase of 20 per cent over the plats receiving no phosphate. Hay yields for 1935 were also in favor of the plats receiving the phosphate at the time of seeding. Most of the difference took place in the first cutting. Naturally seedlings having a sufficient supply of phosphate develop into stronger plants at an earlier date. It would be assumed that similar differences in yield could not be expected in the first cutting when the available phosphate supply is at a sufficiently high level to permit full development of plants following seeding.

Table 7.—Influence of time of application of treble superphosphate on alfalfa hay yields.

Treatment.	Number of plats	1935 yield			1936 residual yield			Average yield
		1st cutting	2nd cutting	Total	1st cutting	2nd cutting	Total	
		ton	*ton*	*ton*	*ton*	*ton*	*ton*	*ton*
200 lb. per acre of Treble superphosphate applied at time of seeding wheat and alfalfa 1934	2	2.56	2.22	4.78	2.46	1.55	4.01	4.40
200 lb. per acre of Treble superphosphate applied to alfalfa in spring of 1935	2	1.79	1.99	3.78	2.29	1.72	4.01	3.90
Difference favoring application at time of seeding	...	.77	.23	1.00	.17	–.17	None	.50

Influence of Treble Superphosphate on Red Clover Seed Production

Phosphate fertilizer work with the production of red clover seed was not started until 1932, although several years prior to this time it had been observed that clover seed yields were rapidly declining. In many cases the yields dropped to 1 or 2 bushels per acre making it an unprofitable crop, and as a result there was a sharp drop in the acreage used for clover seed production.

Not only were the yields of the seed greatly increased by the application of treble superphosphate, as shown in Table 8, but the forage growth was increased in about the same proportion. A heavier growth is desirable not only because high seed yields are usually associated with heavier vegetative growth but also for controlling weeds as well as for providing additional feed. Taking the average of all the check plats for the three different methods of production and comparing them with the plats receiving 200 lb. of phosphate, there was an increase of approximately 3⅓ bushels per acre per year, which at $9.00 per bushel, the average price of clover seed, gives an increased return of $30.00 per acre. As a result of the early experiments, the use of phosphate on red clover has increased very rapidly.

Table 8.—Influence of treble superphosphate on red clover seed production.

Method of production	Treatment	1932 application No. plats	1932 application Yield	1933[1] application No. plats	1933[1] application Yield	1934 residual No. plats	1934 residual Yield	3 year average yield
			bu.		bu.		bu.	bu.
First crop for seed	Untreated	2	1.49	3	1.44	3	3.18	2.04
	Treble superphosphate 200 lb. per A.	1	3.60	6	4.21	6	4.80	4.20
Pastured until June 10[2]	Untreated	2	3.74	3	3.85	3	3.52	3.70
	Treble superphosphate 200 lb. per A.	1	7.82	6	9.40	6	8.59	8.60
Clipped June 3[2]	Untreated	2	3.93	3	5.20	3	4.02	4.38
	Treble superphosphate 200 lb. per A.	1	8.48	6	7.34	6	6.88	7.57

Average yield of all phosphated plats .... 6.79 bu.
Average yield of untreated plats .... 3.37 bu.
Average increase .... 3.42 bu.

[1]1933 application was on a different field than 1932. The 1934 results were obtained from the same plats as 1933.
[2]Dates for pasturing and clipping varied a little from year to year. Dates given are the average for the three years.

Table 9.—Influence of commercial fertilizers and manure applications on potato yields and their residual effect on potatoes and wheat.

Treatment	Rate per acre	No. of plats	1932[1] Yield Cwt. per acre	1932[1] Yield Perc'tge No. 1's	1933[1] Residual yield Cwt. per acre	1933[1] Residual yield Perc'tge No. 1's	Average yield for 2 years Cwt. per acre	Average yield for 2 years Perc'tge No. 1's	Wheat 1934 residual yield Bu. per acre
Untreated	...	4	171.3	75.8	244.0	83.6	207.7	79.7	56.2
Probable error[2]	...	...	9.2	...	11.9	...	...	...	...
Manure	10 ton	2	217.2	69.8	327.0	84.7	272.1	75.2	67.2
Manure and treble superphosphate	10 ton, 211 lb.	2	208.7	64.2	325.0	83.7	266.9	73.9	73.1
Treble superphosphate	152 lb.	2	183.2	74.9	251.0	85.7	217.1	80.3	68.5
Treble superphosphate and ammonium sulfate	164 lb., 164 lb.	2	181.3	75.1	247.0	89.8	214.2	82.4	68.0
Complete fertilizer (5-20-5)	264 lb.	2	183.6	74.6	239.0	82.9	211.3	78.7	60.0
Complete fertilizer (5-20-5)	578 lb.	2	180.6	42.3	245.0	85.1	212.8	79.2	70.0

[1]Date of planting: 1932—May 24; 1933—May 10.

[2]The probable error of the mean is a statistical method of stating the variation in yield of the various check plats due to soil variability, stand, irrigation, etc. It has been established that the increases due to the fertilization treatment must be at least three times the probable error before the increases can be considered significant. For example, the untreated yielded 171.3, which, plus three times the probable error equals 198.9 sacks. A yield above 198.9 would be signifiicant, whereas a yield between 171 and 199 would not be significant as an increase within this range could be attributed to factors other than the fertilizer added. Thus the probable error of the mean is a method of considering the influence of the variable factors that may have influenced the results obtained.

Response of Potatoes to Fertilization

Since potatoes are an important crop in Idaho, fertilization work was started on this crop in 1932. The land used for this experiment had never received any phosphate fertilizer. A growth of 10 to 12 inches of red clover was plowed under in the late spring The plats receiving manure received the application before plowing, and the other fertilizers were applied with a fertilizer attachment at the time of planting. The yields were reduced, however, in 1932 by a killing frost on September 9.

Table 9 shows the results obtained in 1932 and also the residual effect of fertilizer additions on potatoes in 1933 and on wheat yields in 1934. No significant differences in yield of potatoes were observed except from those plats receiving manure. However, there were significant differences in the wheat yields not only from the manure application, but also from the commercial fertilizers with the exception of the light application of complete fertilizer.

In 1935, treble superphosphate, potassium sulfate, and a complete fertilizer, (5-15-5) were applied to potatoes at planting time with a fertilizer attachment. No benefits were obtained from any of the materials applied in this test, as shown in Table 10.

Table 10.—Influence of treble superphosphate, potassium, and a complete fertilizer on potato yields in 1935.

Treatment	Rate per acre	Number of plats	Yield cwt.	Percentage No. 1's
Untreated	....	8	243	65.8
Treble superphosphate	275	6	236	62.7
Potassium sulfate	380	4	234	66.7
Complete fertilizer 5-15-5	360	6	244	63.9

Fertilizer Placement Studies on Potatoes

The cropping history of the field used in this test was as follows: Sugar beets in 1933 with treble superphosphate at the rate of approximately 80 pounds per acre; the field was seeded to alfalfa in 1934 and received 150 lb. per acre of treble superphosphate in 1936. In May 1938, when the alfalfa was approximately 12 inches high, it was plowed under as a green manure crop. The manure, 16 tons per acre, which was applied to half the test area, was put on previous to irrigation and plowing.

Fertilizers were applied by two different methods as well as on two different dates as may be seen in Table 11. The plats having the fertilizer applied with the planter received their application on May 25. The plats having the fertilizers applied with the cultivator received the application on July 6, after the potatoes had received one irrigation. The fertilizer was placed about 10 inches to each side and slightly below the level of the seed piece.

Ammonium sulfate gave a slight increase both on the plats receiving manure and on those not receiving manure. The various treatments gave considerably higher yields on the area that had

Table 11.—Effect of fertilizer placement on manured and unmanured land on yields of potatoes

Fertilizer Treatment	With Manure				Without Manure				Average of manured and non-manured plats for treatment	
	No. of plats	Rate per acre	Yield per acre	No. 1's	No. of plats	Rate per acre	Yield per acre	No. 1's	Yield per acre	No. 1's
		lb.	cwt.	%		lb.	cwt.	%	cwt.	%
Checks	5	...	383.1	82.7	6	...	361.8	86.0	372.5	84.4
Probable error	.	...	9.6	....	.	...	4.9	...	...	..
Treble superphosphate applied with planter[1]	2	137.7	403.1	83.0	2	138.0	382.6	87.2	392.9	85.1
Treble superphosphate applied with cultivator[2]	2	108.3	413.4	82.8	2	108.3	353.6	83.0	383.5	82.9
Triple superphospsate applied with planter	2	139.1	395.2	83.5	2	139.6	354.3	86.2	374.8	84.9
Triple superphospsate applied with cultivator	2	133.4	382.1	82.0	2	133.4	376.1	84.2	379.1	83.1
Ammonium sulfate applied with planter	2	170.0	411.7	92.1	2	173.0	407.0	83.0	409.4	87.6
Ammonium sulfate applied with cultivator	1	88.0	450.9	77.5	2	88.0	381.3	84.7	416.1	81.1
Soil Aid applied with planter	1	157.9	396.4	84.7	1	170.7	344.1	84.4	370.3	84.6
Average of all treatments	.	...	404.5	83.5	.	..	370.1	84.8	387.3	84.2

[1]Fertilizer applied with planter fertilizer attachment at time of planting, May 25, 1938.
[2]Fertilizer applied with cultivator fertilizer attachment July 6, after first irrigation.

Figure 2.—Cultivator fertilizer attachment used in side dressing potatoes.

received an application of manure than on the area that had not. The manure plats yielded 404.5 sacks per acre as compared with 370.1 sacks per acre for the non-manure plats, or an increase of 34.4 sacks. This is considered rather significant since even the check plats had exceptionally high yields.

Recommendations will always have to be more or less general until individual problems are carefully analyzed. The work that has been done with fertilization of potatoes does indicate, (and this checks with many reports of growers who do testing on their own farms), that when potatoes are grown in a balanced rotation in which the legumes have had sufficient available phosphorus for proper development that the use of phosphate is not profitable. Potatoes grown on land where nitrogen is out of balance with phosphorus or in excess of requirements, frequently have a tendency of being smooth-skinned (lack of netting) and irregular in shape. Land that has received extra heavy applications of manure or that has been used for stack yards presents such a problem. Under such conditions, an application of from 100 to 200 pounds of 43 to 45 per cent available phosphate to the potato crop at planting time may prove very desirable and profitable. Yield, netting or russeting of skin, as well as quality and percentage of No. 1's may be increased.

Nitrogen Fertilization Studies

Some investigational work on the use of nitrogen has been conducted on the Branch Station farm and on farms near Aberdeen. The work on private farms was under direct supervision of the superintendent of the Branch Station and was carried on in cooperation with the Shell Chemical Company.

The liquid ammonia, used as the source of nitrogen, was fed into the irrigation water in definite regulated amounts. The irrigation was carried on in the regular manner except that an attempt was made to reduce or eliminate the runoff from the field on the irrigation to which the liquid ammonia was applied and in most cases this was accomplished.

The summarized results of the cooperative tests for 1937 and 1938 are shown in Tables 12 and 13.

Table 12.—Results obtained from cooperative experiments on the use of liquid ammonia as a source of nitrogen on the Branch Experiment Station and selected farms in the Aberdeen area.

Crop	Cooperator	Year	Untreated	Liquid Ammonia[1]	Increase
				Yield in tons	
Sugar beets	Frank Slaugh	1937	21.66	23.15	1.49
	E. E. Toevs	1937	17.85	19.61	1.76
	Utah-Idaho Sugar Co.	1938	20.84	21.81	.97
	Frank Slaugh	1938	21.59	23.89	2.30
Average			20.49	22.12	1.63
				Yield in bushels	
Beans	Byron Hayden	1937	33.8	38.1	4.3
				Yield in cwt.	
Potatoes	Branch Station	1938	247.0	268.0	21.0
			80.9[2]	79.0[2]	

[1]Applied at rate of 75 pounds per acre. This amount is equivalent in nitrogen content to 300 pounds ammonium sulfate.

[2]Per cent no. 1's.

In all instances nitrogen fertilization, the year of application, increased the yields of the index crops. While an average increase in yield of sugar beets was only 1.63 tons, it must be remembered that the average yield of the unfertilized plats was 20.49 tons, which is much higher than the average yield of sugar beets in this area. This high yield would indicate that the soils of the tested areas were in a comparatively high state of fertility although no application of manure had been made to the land that year or the previous one. If such increased yields can be obtained under these conditions, it seems logical to assume that nitrogen fertilization might be practical under conditions of lower levels of soil fertility or in cases where it is impossible to obtain manure at a reasonable cost.

Table 13.—Comparison of the influence of liquid ammonia and manure on potato yields in 1937 and their residual effect on wheat in 1938. Branch Station farm.

Treatment	Rate per acre	Number of plats	Potatoes—1937		Wheat—1938
			Yield cwt.	Percentage No. 1's	Residual[1] bushels
Untreated	.....	1	234.2	62.5	71.7
Liquid ammonia	75 lb.	2	279.4	62.1	68.8
Manure	10 ton	2	283.6	60.7	80.0
Liquid ammonia and manure	75 lb. 10 ton	1	308.0	59.6	82.7

[1]Calculated by harvesting 8 square yard samples from each plat.

On the basis of the 1937 potato experiment (*Table 13*), the results obtained from a 75-pound application of liquid ammonia were comparable with those obtained from a 10-ton application of sheep manure. In both cases the average increase in yield was 45 and 49 sacks per acre, respectively. When both manure and liquid ammonia were applied the increase was 73 sacks per acre. These results seem to indicate that a high nitrogen level on land well supplied with available phosphate is desirable in potato production.

The residual effect of the manure on the wheat yields is quite pronounced, while in the case of the liquid ammonia no increase was observed. This would indicate that the potato crop utilized practically all the nitrogen supplied in the liquid ammonia the year of application.

Effect of Phosphate and Manure in Crop Rotations

The rotation experiments were started in 1929 with the primary idea of determining the influence of the various legumes and of manure on the succeeding crops. Six rotations were established as follows:

1. Alfalfa, alfalfa, potatoes, wheat and alfalfa.
2. Alfalfa, alfalfa, potatoes and manure, wheat and alfalfa.
3. Peas, peas, potatoes, wheat.
4. Peas, peas, potatoes and manure, wheat.
5. Red clover, red clover, potatoes, wheat and red clover.
6. Red clover, red clover, potatoes and manure, wheat and red clover.

Rotations 1, 3, and 5 were without manure, and rotations 2, 4, and 6 received 10 tons of sheep manure once in the rotational cycle, this being applied in the spring to the plats to be plowed for potatoes that year. The alfalfa and red clover of both the manured and unmanured plats were permitted to grow to a height of about 12 inches and then were plowed under as green manure for the succeeding potato crop.

In 1932 it was observed that red clover and alfalfa in both series made a very limited growth. The cause was attributed to phosphate deficiency. The true value of the various legumes in the different rotations could not be ascertained so long as this condition existed. It was therefore decided to make phosphate applications at the rate of 125 pounds per acre to all plats in both series every two years. The applications were made in 1933, 1935, and 1937. Table 14 gives the comparative yields of crops in each rotation for three years prior to the use of phosphate and for the crop years following the first application of phosphate. Figure 3 gives a graphic picture of the results in Table 14. Yields for the year 1931 were omitted as there was a shortage of irrigation water.

Table 14.—Crop yields as influenced by rotational practices and application of manure and treble superphosphate. 1929-1938[1] inclusive.

Rotation containing	Years	Series I with manure	Series II without manure	Increase favoring manure
	Potatoes			
Alfalfa	Av. 1929, 1930, and 1932	245 cwt.	147 cwt.	98 cwt.
	Av. 1933-1938, inclusive	272	262	10
	Increase due to phosphate	27	115	
Red clover	Av. 1929, 1930, and 1932	209	126	83
	Av. 1933-1938, inclusive	277	239	38
	Increase due to phosphate	68	113	
Peas	Av. 1929, 1930, and 1932	204	142	62
	Av. 1933-1938, inclusive	217	207	10
	Increase due to phosphate	13	65	
	Wheat			
Alfalfa	Av. 1929, 1930, and 1932	59.4 bu.	40.6 bu.	18.8 bu.
	Av. 1933-1938, inclusive	72.2	69.7	2.5
	Increase due to phosphate	12.8	29.1	
Red clover	Av. 1929, 1930, and 1932	57.8	36.1	21.7
	Av. 1933-1938, inclusive	70.4	57.1	13.3
	Increase due to phosphate	12.6	21.0	
Peas	Av. 1929, 1930, and 1932	50.7	42.0	8.7
	Av. 1933-1938, inclusive	65.9	60.2	5.7
	Increase due to phosphate	15.2	18.2	
	Alfalfa			
Alfalfa	1932	2.73 ton	1.78 ton	0.95 ton
	Av. 1933-1938, inclusive	4.55	4.29	0.26
	Increase due to phosphate	1.82	2.51	
	Red Clover			
Red clover	Av. 1929, 1930, and 1932	2.50 bu.[2]	1.46 bu.	1.04 bu.
	Av. 1933-1938, inclusive	8.89	7.93	0.96
	Increase due to phosphate	6.39	6.47	
	Peas			
Peas	Av. 1929, 1930, and 1932	23.6 bu.	21.9	1.70
	Av. 1933, 1934, 1937, 1938[3]	33.9	34.3	−0.40
		10.3	12.4	

[1]1931 yield omitted. Yields suffered for lack of water.
[2]Series I seeded in 1929. Two-year average yield 1930 and 1932.
[3]1935 strong wind rolled and mixed peas two days after cutting. 1936 peas scalded.

It will be noted that earlier differences favoring manure have been largely eliminated by the use of a soluble phosphate fertilizer. All plats gave increased returns from the use of phosphate, but it is difficult to measure the actual effect of phosphate by comparing the yields for the period from 1929 to 1932 with those from 1933 to 1938, because climatic factors as well as management factors may have been more favorable during one period than the other. A great deal of benefit from phosphate no doubt is indirect. By improving conditions for legume development, more organic matter in the form

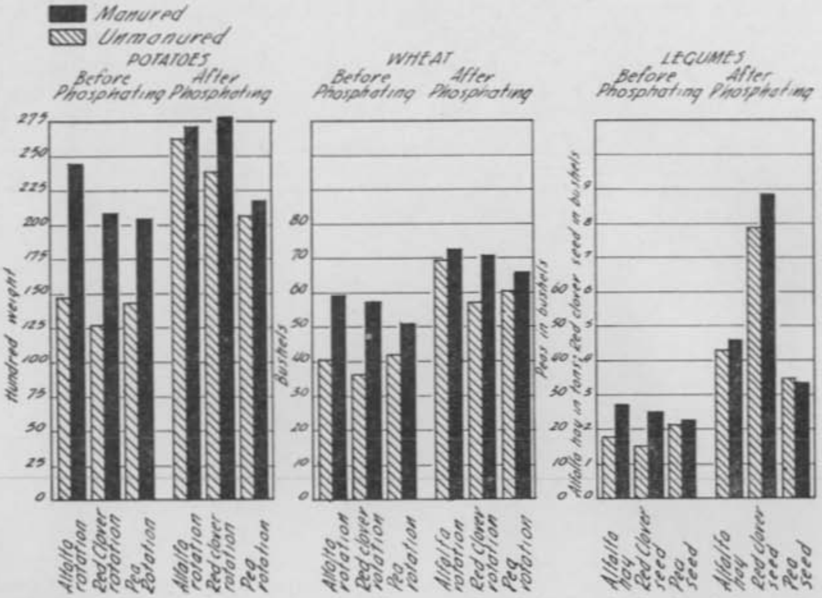

Figure 3.—Effect of manure and treble superphosphate on yields of potatoes, wheat, and legumes.

of roots, crowns, and nitrogen nodules is available to be incorporated into the soil. This additional organic matter not only increases the fertility but also improves the physical condition of the soil. This is of great importance for all crops and of special importance in the production of potatoes.

The questions that are repeatedly asked are: First, to what crop in the rotation is it most profitable to apply the phosphate fertilizer? and, second, is it profitable to use phosphate fertilizers on potatoes? It has already been indicated that the fertilization of the legume in the rotation is probably more desirable and effective under most conditions. This is further illustrated in Table 15. It will be noted in summarizing the potato yields according to the time that the phosphate fertilizer was applied that the plats receiving the fertilizer in the spring before the potatoes were planted produced 19 sacks less than the plats to which the phosphate was applied to the legume crop the preceding year. Wheat, on the other hand, responded to the direct application of phosphate.

Table 15.—Average yield of potatoes and wheat, common to all rotations in the rotation experiment, for the years the phosphate was applied directly and for the years it was applied to the preceding crop.

	Average potato yields, all plats		Average wheat yields, all plats	
	1933, 1935, 1937 years of application	1934, 1936, 1938 years after application	1933, 1935, 1937 years of application	1934, 1936, 1938 years after application
Series with manure	243 cwt.	266 cwt.	71.0 bu.	68.0 bu.
Series without manure	228 cwt.	244 cwt.	65.0 bu.	59 7 bu.
Average of both series	236 cwt.	255 cwt.	68.0 bu.	63.9 bu.

Study on Application Rates of Treble Superphosphate

Since it has been definitely established that some type of available phosphate fertilizer is necessary to maintain yields on many irrigated farms, the next problem that arises is what amount should be applied and how often should applications be repeated. The ordinary practice has been to apply 125 pounds of treble superphosphate per acre every other year when seeded to legumes, and supplemental applications when the land is planted to sugar beets.

The general plan of the experiment is to follow a 6-year rotation: 3 years alfalfa, 2 years of potatoes, and 1 year of wheat as a nurse crop for alfalfa. Alfalfa is to be grown on one half of the test area and potatoes and wheat in regular order on the other half. Treble superphosphate is to be applied in three series at the rates of 75, 125, 200, and 300 pounds per acre, the first phosphate to be applied in the late fall or early spring after the establishment of alfalfa with the wheat as a nurse crop. One series is to receive only one application at the above rate during the rotation cycle; another two yearly consecutive applications; and the third to receive three yearly consecutive applications. The influence of the phosphate fertilizer on the potatoes and wheat will be residual only.

The rate of application study was started in 1936. Alfalfa wilt appeared in the field in 1938 so it was not feasible to leave the alfalfa for 3 years as originally planned. Instead of making a reapplication on two series as first planned, only one series was reapplied in 1938. This alfalfa was plowed up for potatoes in the spring of 1939. Alfalfa, which was more resistant to wilt, was planted with wheat as a nurse crop on the other half of the test area in 1938. The regular plan will then be followed on the new seeding.

The results obtained on alfalfa to date are shown in Table 16. From the standpoint of the alfalfa, the result so far has shown the greatest average increase is from the 300 pound application of treble superphosphate, but when the cost is considered, the most economic returns are from the 75 lb. and 125 lb. applications. Since the potatoes and wheat do not receive any phosphate fertilizers but only the residual from the application to the alfalfa, it is possible that when the residual years are considered, the higher rates may be as economical as the lower rates of phosphate application.

Table 16.—Comparison of various application rates of treble superphosphate on yields of alfalfa hay.

Treatment	Rate per acre lbs.	Number of plats	One application 1937 Yield 1937 ton	One application 1937 Residual yield 1938 ton	Number of plats	One application 1937 Another application 1938 Yield 1937 ton	One application 1937 Another application 1938 Yield 1938 ton
Untreated	...	6	4.10	4.02	2	4.87	4.85
Probable error	...	.	.22	.23	.	.47	.23
Treble superphosphate	75	2	5.69	5.17	1	5.10	5.36
"	125	2	5.75	5.12	1	5.91	6.09
"	200	2	5.57	5.32	1	5.59	5.42
"	300	2	5.99	5.90	1	5.84	6.11

Investigations of the Various Kinds of Phosphate Fertilizers

Since sustained crop production is, in part at least, dependent on phosphate fertilization in southern Idaho, it was thought desirable to obtain results from various phosphate fertilizer products in order to determine the most economic one to use under such conditions. The products compared were rock phosphate from Idaho and Tennessee, Anaconda treble superphosphate, the Tennessee Valley Authority[1] products triple superphosphate, meta phosphate, and fused phosphate, and Bureau of Chemistry and Soils calcined phosphate.[2]

A brief discussion of the various phosphate fertilizers compared in these experiments is given below.

Rock phosphate. The rock phosphate from the mine is ground to varying degrees of fineness. Ordinary rock phosphate will all pass through a 60-mesh screen and the finely ground material will pass through a 200-mesh screen. The total phosphoric acid content varies from 30-34 per cent of which 2.5-5.5 per cent is considered available.

Anaconda treble superphosphate. Ground rock phosphate is treated with sulphuric acid in proper proportion. The resulting phosphoric acid is separated and used to treat more ground rock phosphate. The resulting mixture is allowed to cure and then ground to the desired fineness. This product contains 45 per cent total phosphoric acid of which 43 per cent is considered available.

TVA triple superphosphate. Rock phosphate is mixed with coke and silica, then heated to high temperatures. The evolved phosphorus is burned and the fumes passed into water, forming phosphoric acid. This acid is then used to treat more ground rock phosphate. The resulting mixture is allowed to cure and then ground to the desired fineness. This product contains 48 per cent total phosphoric acid of which 46 per cent is considered available.

TVA meta phosphate. The phosphorus fumes, produced as for TVA triple superphosphate, mixed with dry air are passed through

[1]Will be referred to as TVA.
[2]Will be referred to as Bureau calcined.

a column of finely ground rock phosphate which is heated above 2000 degrees Fahrenheit. The resulting mixture is allowed to cool and reground to desired fineness. This product contains 64 per cent total phosphoric acid of which 62 per cent is considered available.

TVA fused phosphate. Dry steam is passed through rock phosphate heated to at least 2732 degrees Fahrenheit. When cool, it is ground to desired fineness. This product contains 29 per cent total phosphoric acid of which 27 per cent is considered available.

Bureau calcined. Ground rock phosphate is heated to approximately 2550 degrees Fahrenheit, in the presence of water vapor. When cool, the material is ground to desired fineness. This product contains 37 per cent total phosphoric acid of which 34 per cent is considered available.

1937 Results

Applications of the various phosphate products were made in November 1936 to alfalfa which had been seeded in 1934. Crop yields were taken in 1937 and residual yields in 1938, as shown in Table 17. The rates of application of the different fertilizers were made so as to apply approximately the same amount of available phosphoric acid as was contained in 125 pounds of treble superphosphate, which is considered the usual rate for use on alfalfa in this section. Although the land used was not as uniform as desired in that there was considerable variation in lime content, and it

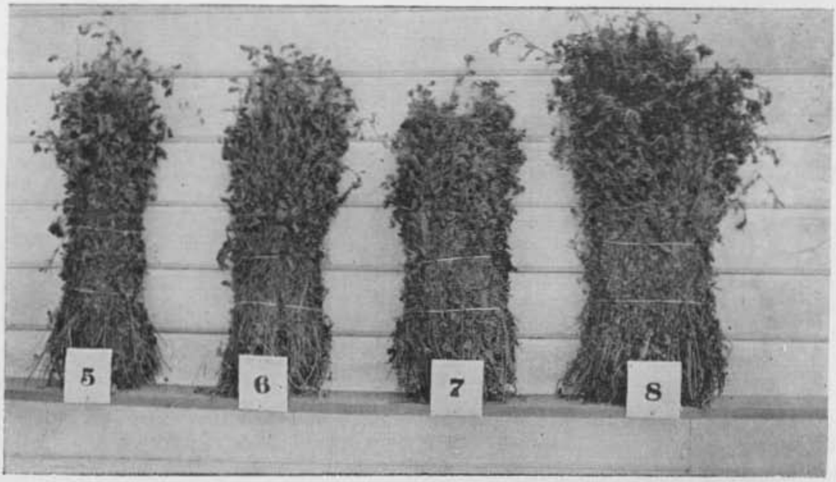

Figure 4.—Second cutting alfalfa hay, Buffi Farm, 1939. Each bundle obtained from 3 square-yard areas. Residual effect of the 1938 application.

No.	Treatment	Rate per acre	Yield per acre
		lbs.	tons
5	Untreated	......	.76
6	TVA fused phosphate	208	.83
7	TVA meta phosphate	90	.91
8	Treble superphosphate	125	1.27

was somewhat uneven for irrigation, treble and TVA triple superphosphate gave increased average yields for both years of 30 per cent and 37 per cent respectively over untreated plats. The cost per ton of hay produced above the yields of the untreated plats was $1.22 for treble superphosphate, $1.11 for TVA triple superphosphate, and $15.00 for Bureau calcined. No benefit was obtained from the other phosphate fertilizers.

Table 17.—Comparison of the effect of the various phosphate fertilizers on alfalfa hay yields the year of application and the residual effect the year after application; 3 cuttings per year.

Treatment	Rate per acre	Number of plats	1937 Yield	1938 Residual yield	Average yield	Total increase over untreated for both years	Cost of fertilizer per application	Cost of fertilizer to secure 1 ton increase in yield
	lb.		*ton*	*ton*	*ton*	*ton*	*dollars*	*dollars*
Untreated	...	7	4.71	3.74	4.23	...	...	...
Probable error	...	...	0.24	0.15	0.18	...	...	...
Treble superphosphate	125	3	6.08	4.94	5.51	2.56	3.13	1.22
TVA triple superphosphate	132	1	6.62	4.99	5.81	3.16	3.52	1.11
TVA Meta phosphate	90	2	4.79	3.61	4.20	none	3.13	value entirely lost
TVA fused phosphate	208	1	4.62	3.61	4.12	none	3.13	value entirely lost
Bureau-calcined phosphate	172	1	5.01	3.66	4.34	0.22	3.30	15.00
Rock phosphate[1]	470	2	4.78	3.59	4.19	none	3.53	value entirely lost
Rock phosphate[1]	2450	3	4.74	3.51	4.13	none	18.38	value entirely lost

[1]Includes regular grinding, finely ground, and Ruhm Phosphate.

Additional Work on Phosphate Carriers—1938

Not enough suitable land for all fertilizer work was available on the Branch Station farm so it was necessary to look for other land that could be used for additional work in the testing of the various phosphate carriers. Fortunately, a suitable field was located about 8 miles north of Aberdeen in the heart of the alfalfa seed-growing area on the Joe Buffi farm. This 4-acre field was very desirable in every respect for such an experiment; the land lay perfectly for irrigation, was very uniform in soil type and was quite uniformly deficient in available phosphate. This field had been seeded to alfalfa with a nurse crop in 1936 and in 1937 was used for hay production. In 1938 it was pastured with sheep along with an adjacent alfalfa field until the forepart of June.

The alfalfa did not resume growth until about three weeks after the sheep were taken off because of a heavy infestation of alfalfa weevil. A spray of calcium arsenate was applied July 7 to check the weevil and it was not until about a week later that growth actually got started.

Phosphate applications were made during the latter part of May. The rate of application was determined on the basis of the amount of available phosphoric acid present in the phosphate fertilizers. The rate used in most cases was calculated to supply the same amount of available phosphoric acid per plat as was applied in the 125 to 250 pound applications of treble superphosphate. The 300-pound application of rock phosphate, however, was based on an equivalent cost using $21 per ton for rock phosphate, the price at the time the experiment was started (average price for rock phosphate since then has been approximately $15 per ton). The price for treble superphosphate was $50 per ton. There was no rock phosphate plat comparable to the 250-pound application of treble superphosphate. The soil aid was applied at the rate recommended by the manufacturers; the quoted price was $60 per ton.

The treble superphosphate and the TVA triple superphosphate gave exceptional increases as shown in Table 18, and they gave very similar results for both rates of application. The 125-pound rate of treble superphosphate gave an increase of 142 per cent, which compares very favorably with the equivalent rate of application of TVA triple superphosphate which gave an increase of 138 per cent. The 250-pound application of treble superphosphate gave an increase yield of 161 per cent whereas the equivalent rate of TVA triple superphosphate gave an increase of 170 per cent. The lighter application gives the greatest return per investment; how-

Table 18.—Comparison of the effect of various phosphate fertilizers on alfalfa hay yields on the Buffi farm. Aberdeen Branch Station.

Treatment	Rate per acre	Number of plats	1938 second & third cuttings	Calculated[1] to three cuttings	Increase over untreated
			ton	ton	ton
Untreated	...	14	1.14	1.90	...
Probable error	...	..	.08	...	...
Treble superphosphate	125	2	2.76	4.60	2.70
Treble superphosphate	250	2	2.97	4.95	3.05
TVA triple superphosphate	117	2	2.71	4.52	2.62
TVA triple superphosphate	234	2	3.07	5.12	3.22
TVA Meta phosphate	90	2	2.19	3.65	1.75
TVA Meta phosphate	180	2	2.24	3.73	1.83
TVA fused phosphate	208	2	1.22	2.03	0.13
Bureau Calcined phosphate	164	2	1.91	3.18	1.28
Rock phosphate (fine)	300	2	1.34	2.23	0.33
Rock phosphate (fine)	1350	2	1.08	1.80	none
Soil Aid	300	2	.89	1.48	none

[1]Calculated on the basis of 40 per cent for the first cutting, 40 per cent for the second cutting and 20 per cent for the third cutting. Under average conditions the third cutting yields only about one-half as much as the first and second cuttings.

ever, the heavier rate in all probability may be profitable if the residual effect for one or two years is taken into consideration.

TVA meta and Bureau calcined, while giving substantial increases in this experiment, apparently are not so well adapted to soil conditions common to these irrigated sections. Other experimental work with these carriers, tabulated in Table 17, did not give results comparable to the results obtained in this experiment.

TVA fused and the light application of rock phosphate gave only slight increases, while soil aid and the heavier application of rock phosphate gave no improvement in appearance of the plants or in the yield obtained.

Figure 5.—Second cutting alfalfa hay, Buffi Farm, 1939. Each bundle obtained from 3 square-yard areas. Residual effect of the 1938 application.

No.	Treatment	Rate per acre	Yield per acre
		lbs.	tons
13	Untreated	......	.72
14	Soil Aid	300	.69
15	Treble superphosphate	125	1.27
16	Treble superphosphate	250	2.07

Residual Influence of Fertilizers

One of the important considerations in the use of phosphate or other fertilizers is the so called residual effect; that is, the effect on the crops the period following the year of application. This point is of particular importance when we consider the cost of the fertilizer application. If increased yields are obtained the second or third year after the fertilizer application, the cost per unit increase decreases. This is shown in Table 19, which summarizes the residual yields where they were obtained.

Considering the six tests with alfalfa where residual results were obtained, the average increase in yield the second year after application of treble superphosphate was only slightly less than the first year. Thus one should consider the residual results in determining whether fertilization is profitable. A 200-pound application of treble superphosphate at $50 per ton would cost $5.00. The average increase for the year that the fertilizer was applied was 1.34 tons at a cost of $3.38 per ton of extra hay produced. The second year 1.22 tons more hay was produced or a total for both years of 2.56 tons for the 200-pound application of treble superphosphate at a cost of only $1.77 per ton of extra hay, considering only the cost of the fertilizer.

In the two experiments, which included rock phosphate, the fertilizer cost of treble superphosphate per ton increase of alfalfa for both years was $1.64 while the money invested in rock phosphate gave no return on the investment as the yield was not increased. Similarly the residual result for the various phosphate fertilizers other than treble and triple superphosphate (*Table 17*) showed no increased yield over the untreated plats.

In the one experiment with red clover seed where residual results were obtained, the fertilizer cost per bushel increase of seed the year of application was $1.44, which was reduced to $0.75 per bushel when the residual results were considered.

The residual effect of the readily available nitrogen fertilizers was not as great as the treble superphosphate. The results obtained from only one test (*Table 13*) show no residual effect from the use of liquid ammonia while with manure the increase the second year was significant.

Table 19.—Summary of the residual effects of treble superphosphate and rock phosphate on legume crops.

Treatment and number of tests	Year of fertilizer application: Rate per acre	Year of fertilizer application: Yield per acre	Year of fertilizer application: Increase over untreated	Year of fertilizer application: Cost per application	Year of fertilizer application: Cost of fertilizer to secure a unit increase in yield	Residual: Yield per acre	Residual: Increase over untreated	Summary, both yrs.: Total increase from fertilizer application	Summary, both yrs.: Cost of fertilizer to secure a unit increase in yield
Alfalfa	*lb.*	*ton*	*ton*	*dollars*	*dollars*	*ton*	*ton*	*ton*	*dollars*
Av. 6 tests[1]									
Untreated	...	3.69	...	...	...	3.38	...	...	...
Treble superphosphate	181	5.03	1.34	4.53	3.38	4.60	1.22	2.56	1.77
Av. 2 tests[1]									
Untreated	...	4.28	...	...	...	3.45	...	...	...
Treble superphosphate	150	5.55	1.27	3.75	2.95	4.71	1.26	2.53	1.48
Rock phosphate	1240	4.22	none	9.30	value entirely lost	3.33	none	none	value entirely lost
Red clover seed									
1 test		*bu.*	*bu.*			*bu.*	*bu.*	*bu.*	
Untreated	...	3.50	...	...	...	3.57	...	...	...
Treble superphosphate	200	6.98	3.48	5.00	1.44	6.76	3.19	6.67	0.75

[1]Different rates were used in these tests. The rates given in the table are the average of the different rates.

Discussion

It has been found by the Department of Agricultural Chemistry of the Idaho Agricultural Experiment Station[1] that there is a definite relationship between the amount of free lime found in the surface soil and the availability of the soil phosphates. As the free lime content increases, the availability of the soil phosphate decreases. It has been further observed that the lime content of the surface soils has been gradually increasing under the soil management systems that are being followed at the present time. In some cases the amount of free lime in the surface soil may be in excess of 10 per cent. The exact cause of this increase in lime content in the surface soil is not definitely known, but it is thought to be due to two general factors: first, the irrigation water contains considerable lime; and second, there may be an upward movement of lime from lower levels. This last factor would be materially aided by tillage operations.

The investigational work to date seems to indicate that the lack of available phosphorus may become of increasing importance as the land is farmed for longer periods of time. The response of alfalfa on the Aberdeen Branch Station was much less pronounced when phosphates were first applied as compared to the response in more recent years. This suggests that (1) the amount of available soil phosphorus has been reduced by plant removal, (2) conditions in the soil have changed so as to render the phosphate in the soil unavailable, or that it may be a combination of both factors.

It has been definitely established that the presence of a plentiful supply of available phosphorus is directly related to the development of a good root system which increases the feeding area of the plant. Phosphate on alfalfa and red clover favors root development which is of special benefit for the cultivated crops which ordinarily follow in a rotation. The influence on red clover seed production is definitely proven by the great increase obtained by phosphating.

Phosphate experiments in the production of alfalfa seed have not been undertaken under strictly controlled conditions. Applications have been made and certain effects have been observed on various farms in the vicinity of the station. In some instances a definite increase in seed production was noted; in other trials, no difference was noted in the amount of seed set and only slight differences in vegetative growth. The fact that the old stands of alfalfa have developed a much deeper root system would modify results of a phosphate fertilizer application when compared with a similar treatment on a younger stand of alfalfa used either for seed or hay. Excessive vegetative growth, as a rule, is not conducive to a seed crop that will mature before danger of frost. Phosphate fertilization of younger stands increases vegetative growth which

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[1]Science Serves Idaho Agriculture. Annual Report. Idaho Agr. Exp. Station Bulletin No. 221; page 8. 1937.

may not always prove desirable in that it delays seed setting and maturity. In some of the alfalfa seed-growing areas, a week's difference in harvest time often means the loss of a crop by a freeze.

Many potato growers are of the opinion that red clover land is much inferior to alfalfa land for potato production. In some instances there seems to be justification for this opinion, particularly when red clover was grown on land deficient in available phosphate. It has been found that when red clover is properly fertilized the potato crop following it is much improved and approaches that of alfalfa land. The addition of manure has a further beneficial effect, as illustrated in the rotation experiment, Tables 14 and 15, and Figure 3. Potatoes grown on red clover land that had been properly phosphated and had received an application of barnyard manure before plowing gave approximately the same yield as potatoes grown on alfalfa land having the same treatment.

The residual effects on legume yields the first year after the application of soluble phosphates have been slightly smaller than the yields obtained immediately following the application. Since further carryover is noted the third year, the total cost of application should be spread over at least a two-year period. Considering the cost of making the applications, it seems advisable to make them large enough to carry over the benefits for two years. The residual effect or carryover will vary with the crop that is being grown. Legume crops take more phosphate from the soil than many of the other crops. The amount to be applied will also vary with the phosphate deficiency and lime contents of the soils.

There are many problems relating to phosphates and other fertilizers on which additional investigational work must be done. However, the work carried on at the Aberdeen Branch Station to date furnishes a basis on which some of these problems may be partially answered in a preliminary way.

Where in the rotation should one apply a phosphate fertilizer? The results so far indicate that phosphate should be applied to the legume in the rotation and if there is sufficient available phosphate present in the soil for normal legume crop development, no great benefit is obtained by applying phosphate to potatoes following legumes. If beets are planted the second or third year after plowing out alfalfa, phosphate should be applied.

Placement of fertilizer is another factor of great importance. Phosphate on alfalfa is usually applied with a broadcast spreader, but if row crops are to be grown, the use of a fertilizer attachment on the drill is a more efficient and economical way. For other fertilizers, especially nitrogen, there is a question whether it is best to apply at seeding time or to side dress with a fertilizer attachment on the cultivator. Side dressing with a fertilizer attachment on the cultivator gives an opportunity to correct any plant food deficiencies which may become apparent the early part of the growth period.

Balance of plant nutrients in the soil and its influence on fertilization practices is another problem that will in all probability become of increasing importance. In the case of potatoes, for instance, if there is an excessive amount of available nitrogen, as an old stack yard, the addition of phosphate tends to balance this condition with a result of smoother tubers and more desirable netting of skin. While investigation to date has not included potash, it is recognized that with continued high production potash may become out of balance or a limiting factor in plant growth. It is planned to include potash fertilizers in future fertility investigations. Newer work on plant nutrition has shown that other elements may not be present in sufficient available amounts to give best crop yields; for example, iron, manganese, boron, and others have been found to be essential. These will also be investigated as far as personnel and funds will permit.

Preliminary analyses[1] indicate that the TVA triple and Anaconda treble show a high percentage of the available phosphate in the water soluble fraction. In contrast to the above statement the other phosphate fertilizers studied show only a very low percentage of the available phosphate in the water soluble fraction. When these various phosphate fertilizers were applied under actual field conditions to high lime soils in the Aberdeen area in quantities sufficient to supply the same relative amounts of available phosphate as determined by the citrate method, the increases in yield obtained were very different. For example in Table 17 and 18 the increases obtained from treble superphosphate and TVA triple superphosphate were much greater, in general, than the increases obtained from other phosphate fertilizers. This would indicate that in high lime soils the plant is unable to utilize that fraction of the available phosphate not soluble in water. Probably the water soluble fraction is a truer indication of the phosphate availability of a phosphate fertilizer when applied to high lime soils than the citrate soluble fraction. Work is being planned to further investigate this problem.

Under the conditions existing at the Aberdeen Branch Station, it is felt that the conclusions drawn and the recommendations made from the experiments conducted are justified. It is recognized that while some of the conclusions reached were based on a relatively small number of experiments, they were, however, conducted under carefully controlled conditions and have been found to correlate exceptionally well with the ideas of the most progressive and best farmers of the locality.

Summary

(1) Fertilizer investigations have been one of the active projects at the Aberdeen Branch Station. Phosphorus, nitrogen, potassium, and sulfur carrying fertilizers have been studied, as well as manure in relation to yields obtained in definite rotations.

[1]Unpublished data; Department of Agricultural Chemistry, University of Idaho.

(2) No significant increases have been obtained to date from the use of gypsum or sulphur on alfalfa.

(3) The amount of free lime present in a soil influences crop response to phosphate fertilization. The higher the lime content, the greater is the possibility that phosphate fertilization is advisable.

(4) The response of alfalfa to phosphate fertilization was less pronounced at the beginning of the experiments than in more recent years. This would indicate that there is in southern Idaho a definite relationship between the length of time land is under cultivation and the amount of available phosphorus in the soil. This may be due to either an increase in the lime in the surface soil, a decrease in soil phosphate, or a combination of both.

(5) The application of available phosphates at the time of seeding legumes is recommended if the land is low in available phosphorus. Not only does the fertilization aid in the development of thrifty legume plants, but it also increases the yield of the cereal nurse crop.

(6) The average yields of red clover seed were more than doubled by the use of treble superphosphate. In the red clover seed-producing areas, phosphate fertilization is a recommended practice.

(7) The work with phosphate fertilization of potatoes indicates that when potatoes are grown in a balanced rotation in which the legumes, particularly red clover and alfalfa, have had sufficient available phosphorus for proper development, the use of available phosphate fertilizers to potatoes is not profitable. However, where nitrogen is out of balance with phosphorus or in excess of plant requirements, an application of from 100 to 200 pounds of some type of available phosphate fertilizer is desirable.

(8) In spite of the high average yields of potatoes obtained on the Branch Experiment Station, the addition of a nitrogenous fertilizer on land of at least average fertility and in proper rotation gave profitable returns. The addition of barnyard manure or a nitrogenous fertilizer, where manure is not available in sufficient quantities, is recommended for the average land used for potato production.

(9) The value of legumes in rotations is definitely improved by the application of available phosphates to the legumes in that the following cultivated crops benefit from the improved legume growth by the greater amount of organic residues and nitrogen returned to the soil when the legume is plowed up.

(10) Where 75, 125, 200, and 300 pounds of treble superphosphate per acre were applied on alfalfa, the 300-pound application gave the greatest increase in yield, but the most economic returns were obtained from the 75- and 125-pound applications. However, if we consider residual effect from the heavier application and from the effect of increased organic matter produced, then the higher rate should be considered.

(11) Results obtained to date indicate that the more available phosphate carriers, such as treble superphosphate and TVA triple superphosphate, give the most economic returns under the conditions studied. TVA meta and Bureau of Chemistry and Soils calcined gave some increases but not sufficient to warrant their use as long as the price relationship to the more available forms remains the same. TVA fused, and various forms of rock phosphate have not given any consistent increases, and on the high lime soils their use is definitely discouraged.

(12) The residual effect of the available phosphate and manures have been sufficiently great to warrant consideration in determining benefits obtained from their use. On the other hand, the residual effect of the less available phosphate carriers, as rock phosphate and TVA fused, has been consistently low.

(13) Phosphate fertilization of sugar beets is recognized as desirable and is now generally practiced throughout the beet growing areas of Idaho. Common practice is to apply fertilizer at the time of seeding. Rates vary from 60 to 120 lbs. per acre depending somewhat on the type of application. The lighter rate application is practiced when fertilizer is placed with seed.

(14) Because of the wide variation in soil fertility, soil tilth, soil management, and rotational practices throughout the irrigated areas of southern Idaho, it may be necessary to modify the recommended practices to suit local conditions.

(15) The work reported is of the nature of a progress report; further work has been planned to verify the findings and also to work on the new relationships.