Experiments with Rock Phosphate Fertilizers in Virginia

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INTRODUCTION

A series of experiments designed to find the most economical method of raising the phosphorus fertility level of soils was started in 1951 by the Agronomy Department of the Virginia Agricultural Experiment Station. Many Virginia soils are inherently poor in native phosphorus and a better method of raising the phosphorus content of such soils without sacrificing crop yields would contribute materially to their usefulness and value.

Rock phosphate is a slowly available, long lasting fertilizer being offered for sale to Virginia farmers in recent years. Its efficiency has been found to vary, depending on soil and plant factors such as the soil type, soil pH, phosphorus content of the soil, and the crops grown.

Superphosphate, on the other hand, is a quickly available phosphate fertilizer which is usually used as a standard to which other phosphate fertilizers are compared.

This publication reports the progress and results to date on field experiments comparing rock phosphate alone, superphosphate alone, and combinations of these two fertilizers used together. The crops used to measure results are corn, wheat, and red clover in a three-year rotation, and alfalfa as continuous hay.

Methods

In these experiments rock phosphate was applied as a broadcast application in the beginning and the application will be repeated each six years (at the end of two complete cycles of the three-year rotation, or six years of alfalfa). The superphosphate was applied to each crop each year by placing it in the row for corn, in the drill row for wheat, and by topdressing for red clover and alfalfa.

Rotation experiments are in progress on three soil types. One is Wellston loam, near Blacksburg, where six years of cropping (two complete cycles of a three year rotation) have been completed. The second location is on Cecil sandy loam, near Concord, Virginia, where five years of cropping have been completed. The third location is on Davidson clay loam, at the Piedmont Research Station, Orange, Virginia where five years of cropping have been completed. Only one crop is grown at each location each year.

Soil pH, Truog phosphorus, total phosphorus and the organic matter in the soils at the beginning of the experiments were as follows:

Soil Type	pH	Truog P (PPM)	Total P (PPM)	O. M. %
Wellston loam	5.0	5	350	1.9
Cecil sandy loam	5.1	6	550	2.1
Davidson clay loam	5.4	9	1100	2.0

The three soils were limed with two tons of ground limestone per acre at the beginning of the experiments.

Rock phosphate and 20 percent superphosphate have been applied to the crops in the rotations at the rates and times as follows:

Rate of Application 20% Super Phosphate lbs/acre	Rock Phosphate lbs/acre	When Applied
0	0	Annually 1/.
50	0	Annually.
125	0	Annually.
250	0	Annually.
0	1000	Initially 2/.
50	1000	Superphosphate annually and rock phosphate initially.
125	1000	Superphosphate annually and rock phosphate initially.
250	1000	Superphosphate annually and rock phosphate initially.
0	2000	Initially.
50	2000	Superphosphate annually and rock phosphate initially.
125	2000	Superphosphate annually and rock phosphate initially.
250	2000	Superphosphate annually and rock phosphate initially.

1/ Superphosphate applied annually to each crop in the rotation.
2/ Rock phosphate applied at the beginning of the experiment.

Nitrogen and potassium have been applied liberally to each crop in the rotation so that yields would be proportionate to the supply of available phosphorus under the different treatments. The amounts applied annually to the different crops have been:

Corn----------100 pounds per acre each of N and K_2O.

Wheat----------30 pounds per acre each of N and K_2O.

Red Clover----------50 pounds per acre of K_2O.

In addition to the rotation experiments, another experiment using alfalfa as the test crop on Groseclose silt loam, near Blacksburg, Virginia, has been in progress for two years. The alfalfa was seeded in late summer of 1954 and results to date, reported herein, cover two hay cuttings obtained in 1955 and the first two cuttings of the 1956 season, a total of four cuttings. The plan of fertilization is identical with that used in the rotation experiments except that in one instance a higher rate of superphosphate is included. Treatments include rock phosphate used alone at 0, 1,000, and 2,000 pounds per acre applied at the beginning of the experiment, 20 percent superphosphate at rates of 0, 50, 125, 250 and 500 pounds per acre applied annually, and all possible combinations of the two -- a total of fifteen treatments. Potassium at the rate of 150 pounds per acre of K_2O and borax at the rate of 20 pounds per acre have been applied each year. The soil had an initial pH of 6.3 and a total phosphorus content of 417 parts per million phosphorus. One ton of ground limestone per acre was applied at seeding.

Results and Discussion

Crop Yields on Wellston Loam

The application of either superphosphate or rock phosphate, or combinations of these two fertilizers, markedly increased the yields of two crops each of corn, wheat, and red clover (table 1). Thus, annual applications of 50, 125, and 250 pounds per acre of superphosphate produced average yearly increases in yield (above check) in corn of 24.3, 30.8, and 42.2 bushels per acre, respectively; in wheat of 10.1, 9.4, and 22.0 bushels per acre, respectively, and in red clover of 1,756, 3,709, and 4,996 pounds per acre, respectively (table 2). Similarly, the use of 1,000 and 2,000 pounds per acre of rock phosphate produced average yearly increases in yield (above check) in corn of 26.9 and 29.3 bushels per acre, respectively; in wheat of 14.3 and 14.7 bushels per acre, respectively; and in red clover of 3,522 and 5,340 pounds per acre, respectively (table 2). Thus, 1,000 pounds per acre of rock phosphate was approximately equivalent to annual applications of 80, 172, and 120 pounds per acre of superphosphate for corn, wheat and red clover, respectively, and 2,000 pounds per acre of rock phosphate was approximately equivalent to annual applications of 105, 177, and 280 pounds per acre of superphosphate for corn, wheat, and red clover, respectively.

Apparently, neither source of phosphorus was sufficient for maximum yields when used alone since highest crop yields in most cases resulted from combinations of the two at their highest rates (table 2). There were yield increases from rock phosphate even where superphosphate was used at the highest rate (250 pounds per acre annually) although the yield increase from rock phosphate declined as the rate of superphosphate increased (table 2).

Two of the fertilizer treatments, 250 pounds per acre of superphosphate annually and 1,000 pounds per acre of rock phosphate initially, resulted in approximately the same application of total phosphorus to the soil -- 300 pounds per acre P_2O_5 for the superphosphate and 320 pounds

Table 1. Yields of crops grown with superphosphate, rock phosphate, and combinations of the two on Wellston loam, near Blacksburg, Virginia.

Fertilization			Yields					
Rock Phosphate 1/		Super-Phosphate 2/	1951 Corn 3/ bu/acre	1952 Wheat 4/ bu/acre	1953 Red Clover 5/ lbs/acre	1954 Corn 6/ bu/acre	1955 Wheat 7/ bu/acre	1956 Red Clover 8/ lbs/acre
0	+	0	19.4	16.4	1915	19.7	25.8	1956
0	+	50	50.7	22.6	3871	37.0	39.9	3513
0	+	125	49.9	22.5	5655	50.9	39.5	5635
0	+	250	55.9	32.0	6476	68.1	54.2	7390
1000	+	0	51.0	26.8	6188	42.0	44.0	4727
1000	+	50	50.0	28.2	7420	50.5	42.9	5587
1000	+	125	68.9	30.8	7005	64.7	49.8	6713
1000	+	250	75.6	41.5	7647	80.8	51.9	7962
2000	+	0	47.5	31.1	7851	50.2	40.6	6701
2000	+	50	54.2	36.7	8064	55.6	44.9	6134
2000	+	125	74.2	32.2	7948	66.3	55.9	7438
2000	+	250	71.7	34.4	8056	77.3	55.3	7719

1/ Applied at beginning of experiment in 1951 and not repeated.

2/ Applied annually to each crop separately.

Significance of means according to Duncan's 5% multiple range test. Any two means underscored by the same line are not significantly different.

3/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

4/ Rock Phosphate 0 1000 2000; Superphosphate 0 125 50 250

5/ Interaction between rock and super; Superphosphate 0 50 125 250

6/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

7/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

8/ Interaction between rock and super; Superphosphate 0 50 125 250

Table 2. Total yield increases from three rates of superphosphate and two rates of rock phosphate in six years of cropping on Wellston loam near Blacksburg, Virginia.

Rate of 20% Superphosphate applied annually from 1951 through 1956.	Total yield increases over check due to superphosphate 1/			Total yield increases over superphosphate due to rock phosphate applied in 1951 1/					
				1000 lbs/acre rock phosphate			2000 lbs/acre rock phosphate		
lbs/acre	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (2 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (2 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (2 crops)
0	0	0	0	53.8	28.6	7044	58.6	29.4	10,681
50	48.6	20.2	3513	12.8	8.6	5623	22.0	19.0	6,814
125	61.6	18.8	7419	32.8	18.6	2428	39.6	26.0	4,096
250	84.8	44.0	9993	32.4	7.2	1755	25.0	3.4	1,917

1/ The yield increase in each case was obtained by subtracting the yield made on the unfertilized plot from that made on the fertilized plot. For example, the increase due to 50 lbs/acre of superphosphate was obtained by subtracting the check yield from the yield made when 50 lbs/acre of superphosphate was applied. Likewise, the increase due to rock phosphate in the 1000 rock phosphate plus 125 lbs/acre superphosphate treatment was obtained by subtracting the yield made by 125 lbs/acre superphosphate alone from the yield made with the two fertilizers used together.

per acre P_2O_5 for the rock phosphate. The increased yields (above check) for the superphosphate totaled 84.9 bushels per acre of corn, 44.0 bushels per acre of wheat, and 9,993 pounds per acre of red clover hay; and the increased yields from the rock phosphate totaled 53.9 bushels per acre of corn, 28.6 bushels per acre of wheat, and 7,044 pounds per acre of red clover. The cost of the superphosphate was $22.04 and that of the rock phosphate was $8.32 (table 3), excluding the costs of application.

Increasing the rock phosphate application from 1,000 to 2,000 pounds per acre did not produce yield increases equal to those from the 250 pounds per acre of superphosphate applied annually, however. Combinations of superphosphate and rock phosphate gave the largest yield increases and appeared to be advantageous over either fertilizer used alone.

Fig. 1 - Response of red clover to 250 pounds per acre of 20% superphosphate on Wellston loam in 1956. Phosphate plot on left, no phosphate plot on right.

Crop Yields on Cecil Sandy Loam

Five crops, two of corn, two of wheat, and one of red clover have been harvested at Concord. Dry weather limited yields, particularly on the 1954 red clover crop and the 1955 corn crop. Table 4 shows the yields of the five crops with the different fertilizer treatments; table 5 shows the total yield increases due to rock phosphate and superphosphate, and table 6 shows the increased yields under the different fertilizer treatments compared to the cost of the phosphate fertilizer.

Crop response to both rock phosphate and super phosphate on Cecil soil has been less than that obtained on Wellston soil. The annual use of 50, 125, and 250 pounds per acre of superphosphate increased average yearly yields (above check) of corn by 13.4, 13.7, and 13.4 bushels per acre, respectively; and of wheat by 9.1, 15.3, and 20.6 bushels per acre, respectively. The increase in wheat yields from higher rates of superphosphate was therefore more pronounced than that of corn. The yields of red clover were so low that the effects of fertilizer were not considered to be meaningful.

The use of 1,000 and 2,000 pounds per acre of rock phosphate increased yearly corn yields (above check) by 14.4 and 16.0 bushels per acre, respectively; and wheat yields by 6.5 and 13.2 bushels per acre, respectively. Thus, 1,000 pounds per acre of rock phosphate was equivalent to approximately 35 pounds per acre of superphosphate for wheat, and 2,000 pounds per acre

Table 3. Increased yields (above check) [4] during a six-year cropping period and the cost of the phosphate, for twelve fertilizer treatments on Wellston loam near Blacksburg, Virginia.

Rock Phosphate [1] lbs/acre	Super-phosphate [2] lbs/acre	Corn bu/acre	Wheat bu/acre	Red Clover Hay lbs/acre	Cost of Phosphate Fertilizer [3]
0	50	48.6	20.3	3513	$ 4.41
0	125	61.7	18.8	7419	11.02
0	250	84.9	44.0	9993	22.04
1000	0	53.9	28.6	7044	8.32
1000	50	61.4	28.9	9136	12.73
1000	125	94.5	38.4	9847	19.34
1000	250	117.3	51.2	11,748	30.36
2000	0	58.6	29.5	10,681	16.64
2000	50	70.7	39.4	10,327	21.05
2000	125	101.4	45.9	11,505	27.66
2000	250	109.9	47.5	11,094	38.68

[1] Applied at beginning of experiment and not repeated.
[2] Applied annually.
[3] Delivered prices on bagged goods of $16.64 per ton for rock phosphate and $26.50 per ton for 18% superphosphate quoted by the American Agricultural Chemical Company, Alexandria, Virginia, on April 17, 1956. The cost of the rock phosphate was pro-rated on a six year basis in this table. Does not include cost of application.
[4] Total production of 39.1 bu/acre of corn, 42.2 bu/acre of wheat and 3871 lbs/acre of red clover hay was made without any phosphate fertilizer.

Table 4. Yields of crops grown with superphosphate, rock phosphate, and combinations of the two on Cecil sandy loam (tentative), near Concord, Virginia.

Fertilization			Yields				
Rock Phosphate 1/		Super-Phosphate 2/	1952 Corn 3/	1953 Wheat 4/	1954 Red Clover 7/	1955 Corn 5/	1956 Wheat 6/
			bu/acre	bu/acre	lbs/acre	bu/acre	bu/acre
0	+	0	68.8	16.6	327	37.5	17.2
0	+	50	85.4	29.5	505	47.8	22.5
0	+	125	81.6	32.6	609	52.2	31.8
0	+	250	78.7	38.4	773	54.5	36.6
1000	+	0	90.1	22.3	350	45.1	24.5
1000	+	50	92.5	34.7	772	56.9	30.5
1000	+	125	91.4	32.6	802	58.0	32.8
1000	+	250	91.9	35.6	1039	58.8	36.8
2000	+	0	84.7	33.2	456	53.7	27.1
2000	+	50	88.0	35.7	1075	59.1	33.7
2000	+	125	82.1	37.8	1110	54.9	35.8
2000	+	250	95.5	36.8	1135	61.4	40.3

1/ Applied at beginning of experiment in 1952 and not repeated.

2/ Applied annually to each crop separately.

Significance of means according to Duncan's 5% multiple range test. Any two means underscored by the same line are not significantly different.

3/ Interaction between rock and super; Superphosphate 0 50 125 250

4/ Interaction between rock and super; Superphosphate 0 50 125 250

5/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

6/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

7/ Not analyzed due to low yields.

Table 5. Total yield increases from three rates of superphosphate and two rates of rock phosphate in five years of cropping on Cecil sandy loam (tentative) near Concord, Virginia.

Rate of 20% Superphosphate applied annually from 1952 through 1956. lbs/acre	Total yield increase over check due to superphosphate 1/			Total yield increases over superphosphate due to rock phosphate applied in 1951 1/					
				1000 lbs/acre rock phosphate			2000 lbs/acre rock phosphate		
	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)
0	0	0	0	28.8	13.0	23	32.0	26.5	129
50	26.8	18.2	178	16.2	13.2	267	13.8	17.4	570
125	27.4	30.6	282	15.6	1.0	193	8.8	9.2	410
250	26.8	41.2	446	17.4	2.6	266	23.6	2.1	362

1/ The yield increase in each case was obtained by subtracting the yield made on the unfertilized plot from that made on the fertilized plot. For example, the increase due to 50 lbs/acre of superphosphate was obtained by subtracting the check yield from the yield made when 50 lbs/acre of superphosphate was applied. Likewise, the increase due to rock phosphate in the 1000 rock phosphate plus 125 lbs/acre superphosphate treatment was obtained by subtracting the yield made by 125 lbs/acre superphosphate alone from the yield made with the two fertilizers used together.

Table 6. Increased yields (above check) [4] in a five year cropping period and the cost of the phosphate, for twelve fertilizer treatments on Cecil clay loam, near Concord, Virginia.

Fertilizer		Corn	Wheat	Red Clover	Cost of
Rock Phosphate [1] lbs/acre	Super-phosphate [2] lbs/acre	bu/acre	bu/acre	Hay lbs/acre	Phosphate Fertilizer [3]
0	50	26.9	18.2	178	$ 3.68
0	125	27.5	30.6	282	9.20
0	250	26.9	41.2	446	18.40
1000	0	28.9	13.0	23	6.90
1000	50	43.1	31.4	445	10.58
1000	125	43.1	31.6	475	16.10
1000	250	34.4	38.6	712	25.30
2000	0	32.1	26.5	129	13.80
2000	50	40.8	34.6	748	17.48
2000	125	36.3	39.8	692	23.00
2000	250	50.6	43.3	808	32.20

[1] Applied at beginning of experiment and not repeated.
[2] Applied annually.
[3] Delivered prices on bagged goods of $16.64 per ton of rock phosphate and $26.50 per ton of 18% superphosphate quoted by the American Agricultural Chemical Company, Alexandria, Virginia, on April 7, 1956. The cost of the rock phosphate was pro-rated on a 5 year basis in this table. Does not include cost of application.
[4] Total production of 106.3 bu/acre of corn and 33.8 of wheat was made without any phosphate fertilizer.

of rock phosphate was equivalent to approximately 100 pounds per acre of superphosphate. Yield increases in corn produced by both 1,000 and 2,000 pounds per acre of rock phosphate exceeded that produced by annual applications of 250 pounds per acre of superphosphate. Highest yields occurred from a combination of superphosphate and rock phosphate at the maximum rates of each (250 pounds per acre of superphosphate annually and 2,000 pounds per acre of rock phosphate). A comparison of yield increases from the various treatments appears to show that combination of rock phosphate and superphosphate was more practical than either used alone.

There are no treatments at this location where the total phosphorus applied from the two sources is exactly equal -- the closest approach is 250 pounds per acre P_2O_5 from superphosphate versus 320 pounds per acre from rock phosphate. Yield increases from the superphosphate totaled 26.9 bushels per acre of corn and 41.2 bushels per acre of wheat, with a fertilizer cost of $18.40; those from rock phosphate totaled 28.9 bushels per acre of corn and 13.0 bushels per acre of wheat, with a fertilizer cost of $6.90. Increasing the rock phosphate to 2,000 pounds per acre produced total yield increases of 32.1 bushels per acre of corn and 26.5 bushels per acre of wheat with a fertilizer cost of $13.80.

Crop Yields on Davidson Clay Loam

Five crops, two each of corn and wheat and one of red clover have been harvested. The red clover crop was a failure due to drought and is not considered in this discussion. Drought also severely reduced the 1952 corn crop -- so much so that increased fertilization resulted in some cases in reduced yields rather than increased yields. Nevertheless, the results are included in the interest of accuracy and completeness of yield data.

Yields made with superphosphate alone, rock phosphate alone, and combinations of the two are shown in table 7. Yield increases that may be credited to superphosphate and rock phosphate are shown in table 8. Table 9 shows the total yield increase (above check) for each treatment and the cost of the phosphate fertilizer producing the increase. The annual use of 50, 125, and 250 pounds per acre of superphosphate produced average yearly increases (above check) of 2.5, 0.2, and 1.1 bushels per acre, respectively of corn; and 5.8, 8.4, and 10.9, bushels per acre, respectively of wheat.

The use of 1,000 and 2,000 pounds per acre of rock phosphate produced yearly increases (over the check) of 4.6 and 0.4 bushels per acre, respectively, of corn; and 2.0 and 4.9 bushels per acre, respectively, of wheat.

Comparing the two materials separately, 250 pounds per acre of P_2O_5 from superphosphate produced total yield increases of 2.2 bushels per acre of corn and 21.8 bushels per acre of wheat at a phosphate fertilizer cost of $18.40. The use of 1000 pounds per acre of rock phosphate produced yield increases of 9.3 bushels per acre of corn and 4.0 bushels per acre of wheat at a phosphate fertilizer cost of $6.90. Increasing the P_2O_5 application from rock phosphate from 1000 to 2000 pounds per acre did not increase yields over the 1000 pounds per acre rate, however. In fact, the yields at the 2000 pounds per acre rate were slightly lower than those resulting from the 1000 pounds per acre rate. Better response to rock

Table 7. Yields of crops grown with superphosphate, rock phosphate, and combinations of the two on Davidson clay loam, at Orange, Virginia.

Fertilization			Yields				
Rock Phosphate 1/		Super-Phosphate 2/	1952 Corn 3/	1953 Wheat 4/	1954 Red Clover 5/	1955 Corn 6/	1956 Wheat 7/
			bu/acre	bu/acre	lbs/acre	bu/acre	bu/acre
0	+	0	53.3	19.8	1127	66.6	17.8
0	+	50	55.0	26.8	1460	69.9	22.5
0	+	125	47.5	28.1	1452	72.8	26.4
0	+	250	46.2	28.5	1753	75.9	30.9
1000	+	0	40.2	19.6	1758	70.4	22.0
1000	+	50	50.7	29.0	1650	75.8	24.8
1000	+	125	52.7	27.5	2025	86.0	27.1
1000	+	250	42.8	25.9	1830	72.4	29.0
2000	+	0	42.8	22.8	1663	76.3	24.7
2000	+	50	47.8	27.7	1901	84.5	27.0
2000	+	125	51.7	29.8	2133	84.8	29.9
2000	+	250	45.0	33.7	2218	80.7	32.5

1/ Applied at beginning of experiment in 1952 and not repeated.

2/ Applied annually to each crop separately.

Significance of means according to Duncan's 5% multiple range test. Any two means underscored by the same line are not significantly different.

3/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

4/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

5/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

6/ Rock Phosphate 0 1000 2000; Superphosphate 0 250 50 125

7/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250

Table 8. Total yield increases from three rates of superphosphate and two rates of rock phosphate in five years of cropping on Davidson clay loam at Orange, Virginia.

Rate of 20% Superphosphate applied annually from 1952 through 1956.	Total yield increase over check due to superphosphate 1/			Total yield increases over superphosphate due to rock phosphate applied in 1951 1/					
				1000 lbs/acre rock phosphate			2000 lbs/acre rock phosphate		
lbs/acre	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)	Corn bu/acre (2 crops)	Wheat bu/acre (2 crops)	Red Clover Hay lbs/A (1 crops)
0	0	0	0	9.2	4.0	631	0.8	9.9	536
50	5.0	11.7	333	1.6	4.5	190	7.4	5.4	441
125	0.4	16.9	325	18.4	0.1	573	16.2	5.2	681
250	2.2	21.8	626	6.8	4.5	77	3.6	6.8	465

1/ The yield increase in each case was obtained by subtracting the yield made on the unfertilized plot from that made on the fertilized plot. For example, the increase due to 50 lbs/acre of superphosphate was obtained by subtracting the check yield from the yield made when 50 lbs/acre of superphosphate was applied. Likewise, the increase due to rock phosphate in the 1000 rock phosphate plus 125 lbs/acre superphosphate treatment was obtained by subtracting the yield made by 125 lbs/acre superphosphate alone from the yield made with the two fertilizers used together.

Table 9. Increased yields (above check) [4] during a five year cropping period and the cost of the phosphate fertilizer for twelve fertilizer treatments on Davidson clay loam, on the Piedmont Research Station, Orange, Virginia.

Fertilizer					
Rock Phosphate 1/ lbs/acre	Super-phosphate 2/ lbs/acre	Corn bu/acre	Wheat bu/acre	Red Clover Hay lbs/acre	Cost of Phosphate Fertilizer 3/
0	50	5.0	11.7	333	$ 3.68
0	125	0.4	16.9	325	9.20
0	250	2.2	21.8	626	18.40
1000	0	9.3	4.0	631	6.90
1000	50	6.6	16.2	523	10.58
1000	125	18.8	17.0	898	16.10
1000	250	4.7	17.3	703	25.30
2000	0	0.8	9.9	556	13.80
2000	50	12.4	17.1	774	17.48
2000	125	16.6	22.1	1006	23.00
2000	250	5.8	28.6	1091	32.20

1/ Applied at beginning of experiment and not repeated.
2/ Applied annually.
3/ Delivered prices on bagged goods of $16.64 per ton of rock phosphate and $26.50 per ton of 18% superphosphate quoted by the American Agricultural Chemical Company, Alexandria, Virginia, on April 7, 1956. The cost of the rock phosphate was pro-rated on a 5 year basis in this table. Does not include cost of application.
4/ Total production of 119.9 bu/acre of corn and 37.6 bu/acre of wheat was made without any phosphate fertilizer.

phosphate was obtained in later years at this location than was obtained in the early years immediately following the lime application.

Alfalfa Yields on Groseclose Silt Loam

The yield of alfalfa hay secured under each fertilizer treatment and yield increases that may be credited to rock phosphate and superphosphate are given in table 10. Table 11 shows the amount of yield increase over the check secured from each fertilizer treatment and the cost of the fertilizer necessary to produce this increase. The use of 50, 125, 250, and 500 pounds per acre of superphosphate (annually) produced yield increases (above check) of 1,055, 2,092, 4,480 and 4,638 pounds per acre, respectively. The use of 1,000 and 2,000 pounds per acre of rock phosphate produced yield increases (above check) of 788 and 3,355 pounds per acre, respectively. Thus, 1,000 pounds per acre of rock phosphate was approximately equivalent to 40 pounds per acre of superphosphate annually, and 2,000 pounds per acre was approximately equivalent to 190 pounds per acre of superphosphate annually. Highest yields occurred from the use of 500 pounds per acre superphosphate annually combined with 2,000 pounds per acre of rock phosphate but that was probably not the most profitable combination since 500 pounds per acre of superphosphate annually was not greatly superior to 250 pounds per acre annually, either with or without rock phosphate. A combination that appeared to be among the more efficient was 250 pounds per acre of superphosphate annually combined with 2,000 pounds per acre rock phosphate, producing 5,522 pounds per acre more than the check, at a phosphate fertilizer cost of $13.78 (table 11). Figure 4 is a graphical representation of yields with all the fertilizer treatments used.

Fig. 2 - Alfalfa responding to rock phosphate on Groseclose silt loam in 1957. Rock phosphate on right, no rock phosphate on left. Both plots received superphosphate.

Fig. 3 - A good phosphate treatment on alfalfa in 1956 on Groseclose silt loam, one ton of rock phosphate (once in 6 years) combined with an annual application of 125 pounds per acre of 20% superphosphate.

Table 10. Alfalfa yields and yield increases from four rates of superphosphate and two rates of rock phosphate in four cuttings on Groseclose silt loam near Blacksburg, Virginia.

Rock Phosphate 1/ lbs/acre	Super-phosphate 2/ lbs/acre	1955-1956 Alfalfa Hay Yields 3/ 5/ lbs/acre	Yield increases over check due to superphosphate 4/ lbs/acre	Yield increases (lbs/A) over Super-phosphate due to rock phosphate 4/	
				1000 lbs/acre rock phosphate	2000 lbs/acre rock phosphate
0	0	3630	0	788	3355
0	50	4685	1055	1104	1993
0	125	5722	2092	2030	2111
0	250	8110	4480	725	1042
0	500	8268	4638	1157	1212
1000	0	4418			
1000	50	5789			
1000	125	7752			
1000	250	8835			
1000	500	9425			
2000	0	6985			
2000	50	6678			
2000	125	7833			
2000	250	9152			
2000	500	9481			

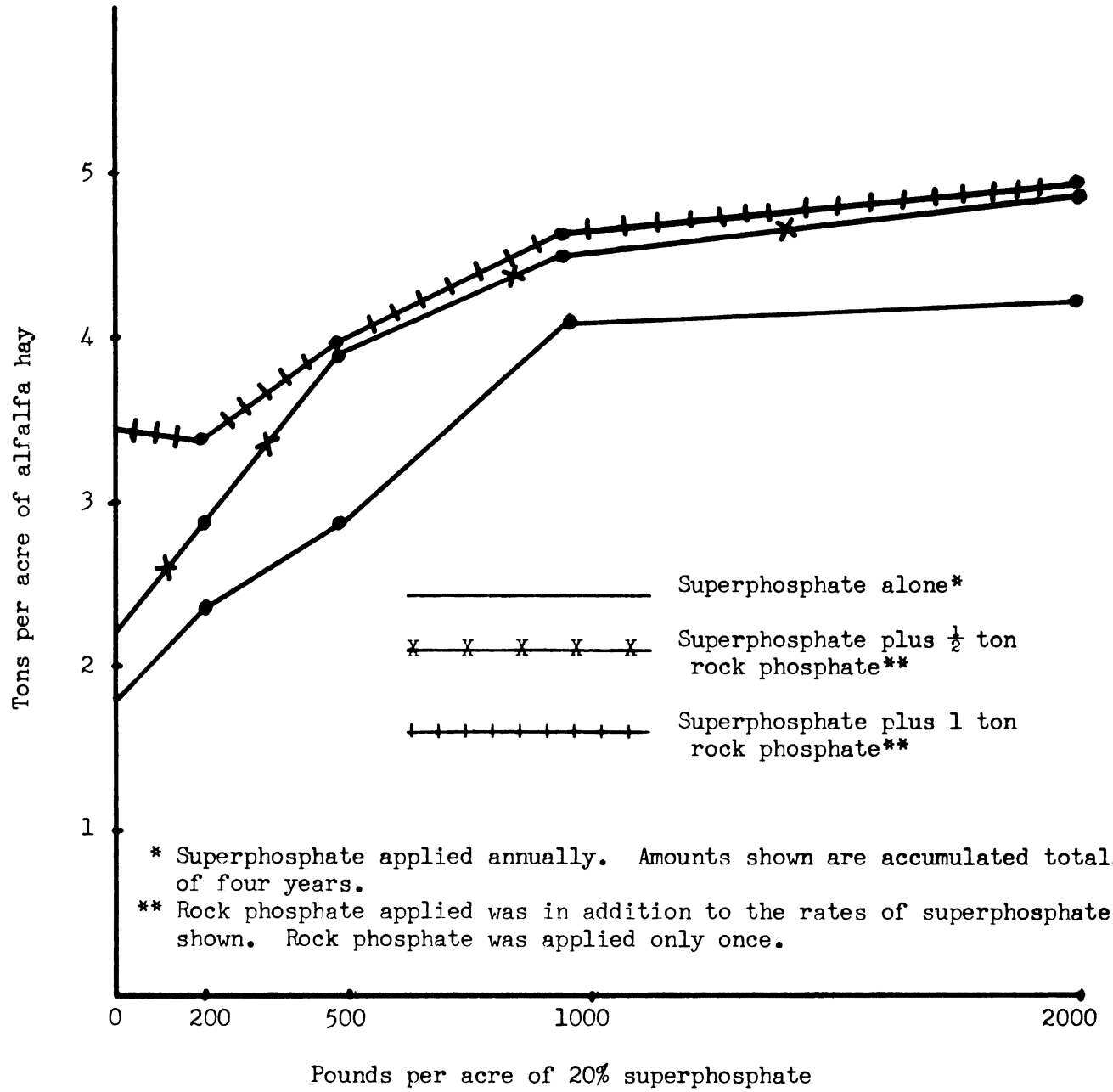
1/ Applied in 1954 at beginning of experiment and not repeated.
2/ Applied annually.
3/ Includes 1955 yields and two cuttings of 1956.
4/ The yield increase in each case was obtained by subtracting the yield made on the unfertilized plot from that made on the fertilized plot. For example, the increase due to 50 lbs/acre of superphosphate was obtained by subtracting the check yield from the yield made when 50 lbs/acre of superphosphate was applied. Likewise, the increase due to rock phosphate in the 1000 rock phosphate plus 125 lbs/acre superphosphate treatment was obtained by subtracting the yield made by 125 lbs/acre superphosphate alone from the yield made with the two fertilizers used together.
Significance of means using Duncan's 5% multiple range test. Any two means underscored by the same line are not statistically different.
5/ Rock Phosphate 0 1000 2000; Superphosphate 0 50 125 250 500

Table 11. Increased yield of alfalfa (above check)[5] during a two year cropping period and the cost of the phosphate for fourteen fertilizer treatments on Groseclose silt loam near Blacksburg, Virginia.

Fertilizer		Alfalfa Hay [3]	Cost of
Rock Phosphate [1]	Super-Phosphate [2]	lbs/acre	Phosphate Fertilizer [4]
0	50	1055	$ 2.20
0	125	2092	5.50
0	250	4480	11.00
0	500	4638	22.00
1000	0	788	1.39
1000	50	2159	3.59
1000	125	4122	6.89
1000	250	5205	12.39
1000	500	5795	23.39
2000	0	3355	2.78
2000	50	3048	4.98
2000	125	4203	8.28
2000	250	5522	13.78
2000	500	5851	24.78

1/ Applied at beginning of experiment and not repeated.
2/ Applied annually.
3/ Yields secured in four cuttings (two in 1955 and two in 1956).
4/ Delivered prices on bagged goods of $16.64 per ton for rock phosphate and $26.50 per ton for 18% superphosphate quoted by the American Agricultural Chemical Company, Alexandria, Virginia, on April 7, 1956. The cost of the rock phosphate was pro-rated on a six year basis in this table. Does not include cost of application.
5/ An alfalfa production of 3630 lbs/acre was made without any phosphate fertilizer.

Figure 4 Alfalfa hay produced with rates of superphosphate alone, rock phosphate alone, and combination of the two fertilizers on Groseclose silt loam. Yield period covers 4 cuttings, 2 in 1955 and 2 in 1956.



SUMMARY AND CONCLUSIONS

Experiments using superphosphate as the only source of phosphorus, rock phosphate as the only source, and combinations of the two fertilizers have been in progress for six years in Virginia. The experiments are located on Wellston loam near Blacksburg, Cecil sandy loam in Campbell County, and Davidson clay loam at Orange. The crops grown are corn, wheat, and red clover, in a three-year rotation.

Another experiment, on Groseclose silt loam near Blacksburg, compares the two fertilizers alone and in combination on alfalfa as continuous hay.

Continuation of the experiments will be necessary to reach final conclusions on the relative values of the two fertilizers. This publication reports results obtained to date and the following conclusions have been reached from the data presented:

1. Responses to both rock phosphate and superphosphate have been obtained with all crops at all locations except when lack of rainfall limited yields severly.

2. Generally, where crop response to one fertilizer occurred, response to the other also occurred. The response to the two fertilizers when used together has been largely additive, no important interactions having occurred except with corn on Davidson clay loam. Here neither material was very effective when used separately but some combinations of the two gave sizeable yield increases, particularly 125 pounds per acre of superphosphate in combination with either 1,000 or 2,000 pounds per acre of rock phosphate.

3. Wellston loam has been the most responsive soil to rock phosphate, Davidson clay loam the least responsive, and Cecil sandy loam intermediate.

4. A combination of the two fertilizers appeared to result in greater crop response in relation to the fertilizer cost than either alone.

5. One ton of rock phosphate (once in 6 years) produced yield increases approximately equivalent to those produced by 100, 175, and 280 pounds per acre of superphosphate (annually) in corn, wheat, and red clover, respectively, on Wellston loam.

6. One ton of rock phosphate (once in 6 years) was approximately equivalent to 100 pounds per acre of superphosphate (annually) for wheat, on Cecil sandy loam. Corn yields produced by a ton of rock phosphate on this soil exceeded the equivalent of 250 pounds per acre of superphosphate.

7. One ton of rock phosphate (once in 6 years) was approximately equivalent to 200 pounds per acre of superphosphate (annually) for alfalfa on Groseclose silt loam.