EFFECT OF COARSE AND FINELY GROUND ROCK PHOSPHATE
ON THE GROWTH OF SIX LEGUMES UNDER GREENHOUSE CONDITIONS

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INTRODUCTION

Finely ground rock phosphate is a rather widely used source of phosphate fertilizer which generally contains 30 to 33 percent P_2O_5. Its chief advantages as a source of phosphorus are (1) that it costs less per pound of phosphorus than other phosphatic fertilizers and (2) the freight rates are lower per unit of phosphorus because of its higher analysis. Some disadvantages that are commonly recognized are (1) it is more slowly available than other sources of phosphorus which requires that it be applied in larger quantities, and (2) its solubility is so low that some plants do not make optimum growth when it is used as a source of phosphorus.

Large quantities of rock phosphate have been used in Illinois for soil improvement. A high percentage of this phosphorus has been applied to soils where sweet clover and alfalfa are used to supply nitrogen and maintain organic matter. Rock phosphate is an excellent source of phosphorus for sweet clover. When sweet clover residues are plowed under and are decomposed by bacterial action, the phosphorus absorbed by the legume is released for use by the following crop. The bacterial action also releases carbon dioxide, which in combination with water, acts on the rock phosphate in the soil and makes more of it available for plant use.

A number of experiments have been conducted to determine the availability of rock phosphate ground to varying degrees of fineness. It has been observed in some of these experiments that higher yields were produced from the more finely ground material. Few experiments, however, have been conducted in which the coarse material has been separated from the fine material. More information is needed on the availability of the phosphorus in coarsely ground rock phosphate free of fine material.

REVIEW OF LITERATURE

The earliest work reported in the United States on degree of fineness of rock phosphate was that of Lupton (4)[1] in Alabama. He found that consistently higher yields of seed cotton were secured from floats used in conjunction with cottonseed meal as compared with acid phosphate.

Merrill (5) in 1898 reported results of greenhouse tests using Florida rock phosphate, acid phosphate and Redonda phosphate and found that the acid phosphate gave better results in every case with the eighteen species used.

Jordan (3) reported results of experimental studies in 1913 in which he used rock phosphate which passed through 60, 80, and 100 mesh seives; through bolting cloth, and of sizes which he called fine and floats. His results indicate that fineness of division has an important influence upon the availability of ground rock phosphate to barley and rape.

Conner and Adams (2) studied the availability of rock phosphate, separated into four particle size groups equivalent to fine sand, very fine sand, silt and clay, in pot tests with radishes, barley, corn and wheat. They also compared a commercial grind containing 26.8 percent clay with a reground sample containing 75.5 percent clay. They found that the clay separate had a somewhat higher availability than the

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[1] Numbers in parentheses refer to literature cited.

reground phosphate and that the three coarser separates were of lower value in promoting increased growth of the crops studied than the commercial product. They concluded that it would not pay to grind phosphate rock finer than the commercial grade for use as a fertilizer. On the basis of monocalcium phosphate having a relative effectiveness of 100 percent, commercial rock phosphate was found to be 45.1 percent effective while the reground product had an effectiveness of 52.8 percent on the crops tested.

Roberts, Freeman and Kinney (6) in a field experiment found that similar yields were obtained from plots treated with 100 mesh and finer and 300 mesh and finer rock phosphate using a rotation of corn, wheat and hay and an average of 8 crops. In another comparison they found that 300 mesh and finer rock phosphate gave an increase of 625 pounds of hay over the 100 mesh and finer material. In comparison with superphosphate there was a 0.5 bushel increase in corn and wheat yields where superphosphate was used while there was an increase in hay yields of 293 pounds of hay per acre in favor of 300 mesh rock phosphate.

Bauer and others (1) have reported the results of two field studies in which an application of 1500 pounds per acre of four grades of rock phosphate ground to varying degrees of fineness were used. The grades used were 97 percent, 82 percent, 70 percent and 62 percent through a 200 mesh seive. Using a gross index of 100 for performance of the check plots index numbers of 132, 134, 138 and 132 for the respective grades of rock phosphate, were secured in one experiment. In the second experiment gross index numbers of 120, 120, 125 and 118 were secured for the same four grades of rock phosphate. In all cases a wheat, clover-alfalfa residues system was used.

MATERIALS AND METHODS

This experiment was conducted in an effort to determine the response, under greenhouse conditions, of various legume crops to coarse and finely ground rock phosphate and to different methods of application. Sweet clover, alfalfa and crimson clover were planted in 10 inch clay pots.[1] A sufficient number of 10 inch pots was not available, consequently big hop and Ladino clover and Korean lespedeza were planted in 9 inch pots. Twenty pounds of soil were required to fill the 10 inch pots and 15 pounds to fill the 9 inch pots. Distilled water was used exclusively until the first crop was harvested. Tap water was used to produce the second crops of alfalfa and Ladino clover. The moisture content of the soil was maintained at practically 20 percent throughout the experiment. The plants were grown in the greenhouse on the Agronomy Farm, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

The soil used in the experiment was a Zaneis sandy loam, collected ½ mile south of the water tower on the south side of Lake Carl Blackwell west of Stillwater, Oklahoma. It contained 3 parts per million of phosphorus easily soluble in 0.2N sulfuric acid and had a pH of 6.1. The area from which

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[1] Note: Experience has shown that it is better to use glazed pots in an experiment of this nature, for the reason that in the glazed pots moisture losses through the side are reduced to a minimum.

the soil was collected was supporting a fair stand of native and triple awn grasses. It was screened through a 3/8 inch screen to remove clods and undecomposed roots and mixed thoroughly before it was placed in the pots.

The crops used in the investigation were Ladino Clover, (Trifolium repens L.); Evergreen Sweet Clover, (Melilotus alba Desr.); Dixie Crimson Clover, (Trifolium incarnatum L.); Buffalo Alfalfa, (Medicaga sativa L.); Big Hop Clover, (Trifolium agrarium L.) and Climax Korean Lespedeza (Lespedeza stipulacea). All seed were inoculated with commercial legume inoculant. The first five mentioned crops were seeded on December 5, 1947. However, a poor stand was obtained in pots planted to big hop clover. These pots were reseeded on January 7, 1948. Korean lespedeza was also seeded on this date. In most cases seedling emergence was complete in 6 to 7 days.

Coarse and fine rock phosphate was obtained from a commercial rock phosphate, 85 percent of which was guaranteed by the manufacturer to pass a 100 mesh sieve. Several methods of separating the different size particles were tried. It could not be sieved in its dry condition since the smaller particles soon clogged the sieve openings. An air separation using various rates of feeding was then tried. The equipment used in the air separation was a conventional electrically powered 4 inch fan type blower equipped with a nozzle that allowed the current of air to escape in a flat stream. The material to be separated was fed from above so that it fell into the stream of air as it escaped from the blower. This allowed the larger and heavier particles to settle out first while the lighter particles were carried further away. The effect of distance from the fan and rate of feeding on the percentage of coarse material in the sample are shown in table I.

Table I Effect of air current on separation of coarse and fine particles of rock phosphate.

Distance sample was collected from fan nozzle	Rate of feeding and percent of material* held on a 200 mesh seive	
	Fast rate	Slow rate
3-4 ft.	11.3	18.5
4-6 ft.	15.0	22.2
6-8 ft.	18.4	22.4
8-10 ft.	14.2	15.8

* 5.3 percent of the commercial sample was held on a 200 mesh seive.

It will be observed that there was some increase of coarse material in the portion of the sample which dropped near the fan.

Since there is a tendency for the fine material to flocculate into granules and to adhere to the larger particles the method used to obtain complete separation of the material coarser than 200 mesh was to wash the fine rock phosphate through a 200 mesh seive with tap water. If small amounts of material are used it is relatively easy to secure coarse particles free of finer material. The diameter of particles held on a 200 mesh seive was greater than 0.0029 inch.

The total phosphorus content of the commercial material was 30.2 percent P_2O_5 and the rate of application 400 pounds per acre. The coarse rock phosphate contained 26.5 percent P_2O_5 consequently it was necessary to add an additional amount of this material so that all pots would receive an equal amount of P_2O_5.[2] The 10 inch pots received 2.23 grams of commercial rock phosphate and 2.575 grams of 100 to 200 mesh material. This rate of application gave 0.6745 grams of P_2O_5 per pot on the basis of the chemical analysis reported above. The 9 inch pots received 1.741 grams of commercial rock phosphate and 2.006 grams of coarse material. This gave 0.525 grams of P_2O_5 per pot. On a series of pots using big hop clover and Ladino clover superphosphate was applied at the rate of 300 pounds per acre. This required 1.115 grams of superphosphate for the 10 inch pots and 0.817 grams for the 9 inch pots.

Two methods of application were used: broadcast and row. In both cases about 2 inches of soil were removed from the pots, the fertilizer material spread evenly, either broadcast or in two bands about 1 inch wide and 5 inches

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[2] Note: Studies in which 1 gram of coarse rock phosphate was shaken with 450 ml. of distilled water saturated with carbon dioxide show that after 24 hours, 12 hours, 8 hours and 4 hours shaking and without shaking coarse rock phosphate has a solubility in saturated carbonic acid of 52, 40, 36, 30 and 20 parts per million, respectively. It was completely insoluble when 1 gram of coarse material was shaken for like periods of time in 450 ml. of distilled water boiled to free it of carbon dioxide.

apart, the ends of the rows were marked with small stakes, and the soil replaced. The seed were then planted in rows above the fertilizer material and water added to the soil to supply about 20 percent of capillary moisture. All treatments were replicated once.

The plants were harvested as they matured by cutting with a sharp knife about one half inch above the soil line. They were weighed to secure the green weight, placed in a drying oven at about 105°C for about 24 hours and weighed again to determine the dry weight. The plant material was then ground in a Wiley mill and analyzed for total nitrogen and phosphorus content.

The nitrogen determinations were made by the standard Kjeldahl method using a 0.5 gram sample for analysis. The phosphorus determinations were made on a 0.5 gram sample of plant material using a method recommended by Shelton and Harper (7).

CROP PRODUCTION AND CHEMICAL ANALYSIS

Alfalfa:

Data on the comparative yield and total nitrogen and total phosphorus content of two cuttings of alfalfa are shown in table II.

Table II Results of yield, phosphorus and nitrogen determinations of alfalfa. Average two replications.

First cutting: May 4, 1949

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	35.0	7.6	.3106	.155	2.733
Coarse, Broadcast	30.9	6.3	.3230	.161	2.639
Fine, Row Application	29.4	6.3	.3106	.155	2.781
Fine, Broadcast	27.3	6.1	.3354	.167	2.529
Check	9.0	1.9	.2114	.105	2.516

Second cutting: June 8, 1948

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	25.8	6.2	.2455	.128	2.377
Coarse, Broadcast	24.2	5.7	.2145	.107	2.299
Fine, Row Application	24.8	6.2	.2269	.113	2.279
Fine, Broadcast	22.1	5.9	.2501	.125	2.280
Check	7.0	1.1	.2176	.108	2.582

Figure 1 shows the comparative growth of the alfalfa on April 20 about two weeks before harvest.

Figure 1. The effect of coarse and finely ground rock phosphate on the growth of alfalfa. Seeded December 5, 1947. Photographed April 20, 1948.

It will be observed from the data (table 2) that the 100 to 200 mesh rock phosphate produced somewhat better average yields in both the first and second cuttings. In all cases except the check the phosphorus content was lower in the second cutting than in the first. There is not a sufficient difference in total phosphorus content of the alfalfa produced on the treated pots to make any distinction in the influence of degree of fineness of the rock phosphate on chemical composition. The total nitrogen content of the alfalfa from the fertilized pots was lower in the first cutting and higher in the second than the alfalfa produced on the fertilized pots.

Big Hop Clover:

Data on the yield and results of total nitrogen and phosphorus determinations of big hop clover are given in table III.

Table III Results of yield, phosphorus and nitrogen determinations of Big Hop Clover. Average two replications

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	28.0	6.6	.1990	.096	2.400
Coarse, Broadcast	19.35	4.9	.1633	.081	2.345
Fine, Row Application	20.1	3.9	.1866	.093	2.484
Fine, Broadcast	24.0	5.4	.1835	.091	2.309
Check	4.5	0.5	.1773	.088	2.794
S P. Row Application	64.0	14.3	.2749	.137	2.190
S P. Broadcast	59.3	12.8	.2734	.136	2.474

It will be observed from these data that superphosphate was more effective in promoting increased growth than either coarse or fine rock phosphate. The data further indicates that there is little difference in the effectiveness of the coarse and fine material in increasing growth, since both gave similar results when compared with the yields on the untreated pots. Little difference was observed in the total phosphorus content of the plant material harvested from the pots which were treated with rock phosphate and those which were not treated with phosphate fertilizer. Fertilization with superphosphate was much more effective in increasing the total phosphorus content of the crop than was either the coarse or fine rock phosphate. In all cases treatment tended to decrease the total nitrogen content of the plants.

The comparative growth of big hop clover treated with coarse rock phosphate and superphosphate and without treatment is shown in figure 2.

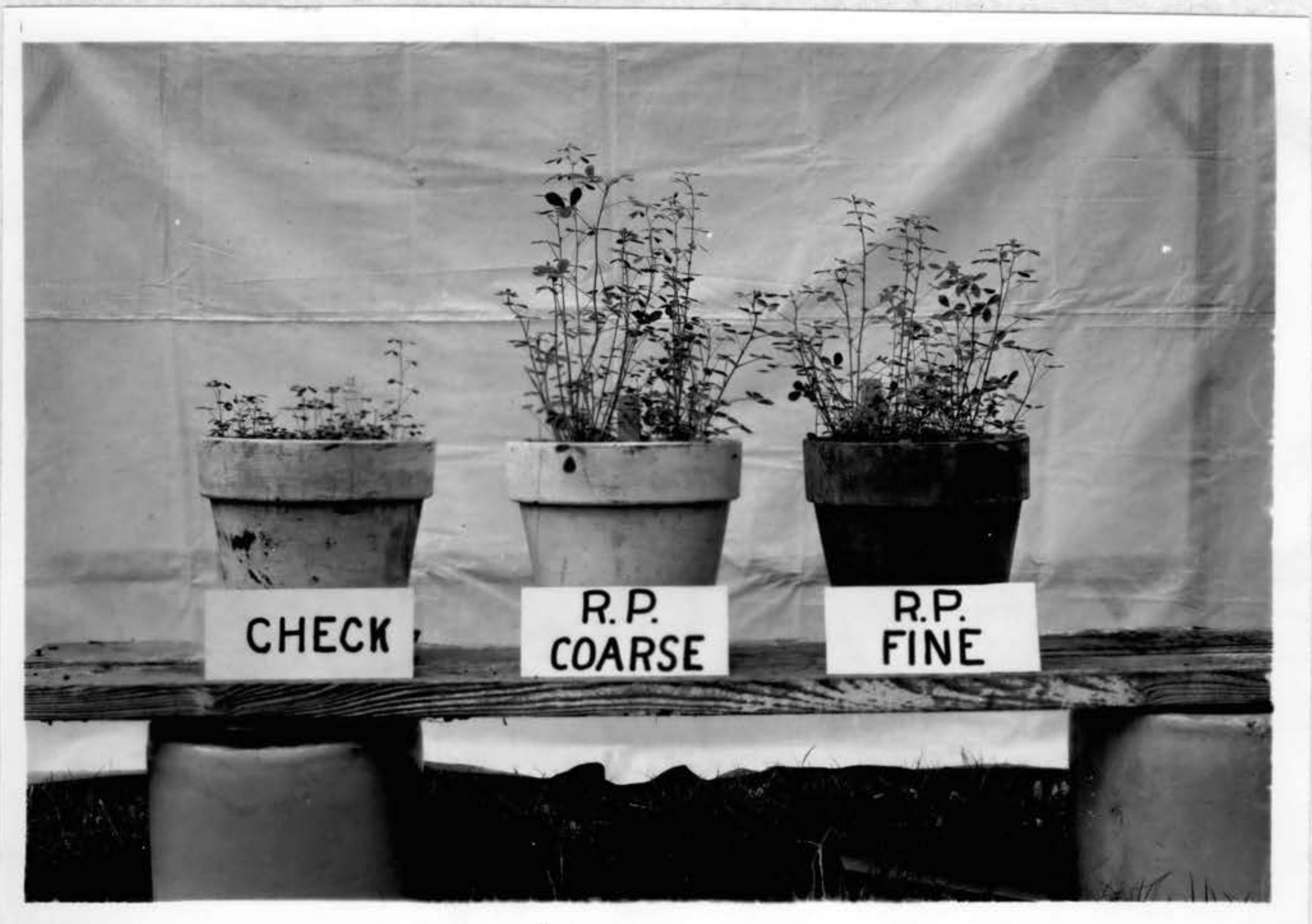

Figure 2. The effect of coarse rock phosphate and superphosphate on the growth of big hop clover. Seeded January 7, 1948. Photographed April 20, 1948.

Crimson Clover:

Comparative yield data and results of total phosphorus and nitrogen determinations for crimson clover are shown in table IV.

Table IV Results of yield, phosphorus and nitrogen determinations of crimson clover. Average two replications.

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	39.4	8.6	.1571	.078	2.182
Coarse, Broadcast	47.1	9.7	.1897	.094	1.969
Fine, Row Application	77.0	18.2	.1974	.093	2.035
Fine, Broadcast	59.3	13.4	.2145	.107	1.979
Check	37.7	8.6	.1494	.074	1.636

These data show that treatment with fine rock phosphate increased the yield of this crop to a greater extent than treatment with coarse rock phosphate. The coarse material produced only a slightly higher yield than that received from the unfertilized pots. Treatment also tended to increase the total phosphorus content, especially in those pots which received the fine material. There is only a slight difference in total nitrogen content between the coarse and fine rock phosphate treatments. Both were higher than the check.

Ladino Clover:

Data on the yield and total phosphorus and nitrogen content of Ladino clover is given in table V.

Table V Results of yield, phosphorus and nitrogen determinations on Ladino clover. Average two replications.

First Cutting: May 4, 1948

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	43.3	7.7	.2408	.120	2.813
Coarse, Broadcast	49.5	8.3	.2579	.129	2.510
Fine, Row Application	65.6	11.8	.2223	.111	2.499
Fine, Broadcast	89.5	16.0	.2582	.126	2.733
Check	16.4	2.8	.1680	.084	2.764
SP. Row Application	92.3	19.5	.2021	.102	2.473
SP. Broadcast	102.0	21.3	.1850	.092	2.367

Second Cutting: June 8, 1948

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	31.3	6.2	.2408	.120	2.640
Coarse, Broadcast	30.0	5.1	.2517	.126	2.490
Fine, Row Application	31.5	6.1	.2579	.128	2.630
Fine, Broadcast	41.8	8.0	.2749	.138	2.601
Check	20.9	3.0	.2098	.105	2.725
SP. Row Application	47.0	8.4	.2408	.120	2.600
SP. Broadcast	20.7	5.3	.2610	.130	2.582

The data shows that superphosphate was the most efficient fertilizer material in promoting highest average yields in the first cutting; however, in the second cutting one superphosphate series was less efficient than no treatment in promoting growth. It is possible that the increased growth from the superphosphate may be due in part to the sulfur which is contained in the superphosphate in the form of calcium sulfate. This is further indicated by the fact that both superphosphate series of the first cutting contain less total phosphorus than the rock phosphate series, while in the second cutting the total phosphorus content of all treated pots is comparable. Comparison of yield data for coarse and fine treatments show that the fine material produced the highest average yield in both the first and second cuttings.

The total phosphorus content of the coarse and fine treatments is comparable in both cuttings except for one series in which Ladino clover on a fine rock phosphate pot fell below the average of the other rock phosphate treatments but all were higher than the untreated pots. As previously stated both superphosphate series contained less total phosphorus than either the coarse or fine rock phosphate but were higher than the untreated pots.

All phosphate fertilizer decreased the total nitrogen content in all cases except in one coarse series and that is only 0.04 percent higher than the untreated series. This is due, in all probability, to the fact that those pots which produced the greatest growth contained a considerable quantity of stems and leaves which had died because of shading in the heavy growth and to the higher ratio of stems to leaves in those pots which produced the greatest amount of growth.

The comparative growth of Ladino clover in pots treated with coarse and finely ground rock phosphate and superphosphate is shown in figure 3.

Figure 3. The effect of coarse and finely ground rock phosphate and superphosphate on the growth of Ladino clover. Seeded December 5, 1947. Photographed April 20, 1948.

Korean Lespedeza:

Data on the yield and total nitrogen and phosphorus content of Korean lespedeza are given in table VI.

Table VI Results of yield, phosphorus and nitrogen determinations of Korean Lespedeza. Average two replications.

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	15.4	5.2	.1587	.079	2.047
Coarse, Broadcast	9.7	2.9	.1634	.082	2.201
Fine, Row Application	15.5	5.0	.1695	.085	2.270
Fine, Broadcast	14.7	4.2	.1773	.089	2.157
Check	5.2	1.3	.1804	.090	2.154

The greatest average yield of Korean lespedeza was secured from the fine rock phosphate although the yield on one of the coarse rock phosphate pots was higher than on the two pots receiving the fine rock phosphate. The chemical analyses indicate that treatment had little effect on the total nitrogen and phosphorus content. It would appear from the data that in the coarse series which produced the highest average yield the total phosphorus and nitrogen were depressed by treatment.

Figure 4 shows the comparative growth produced by different treatments of Korean lespedeza about 2 weeks before harvest.

Figure 4. The effect of coarse and finely ground rock phosphate on the growth of lespedeza. Seeded January 7, 1948. Photographed April 20, 1948.

Sweet Clover:

Data on the comparative yield and total nitrogen and phosphorus content of sweet clover are given in table VII.

Table VII Results of yield, phosphorus and nitrogen determinations of Sweet Clover. Average two replications

Treatment	Green Wt. (grams)	Dry Wt. (grams)	Mg. P	% P	% N
Coarse, Row Application	95.9	20.7	.3121	.156	2.882
Coarse, Broadcast	117.1	27.3	.2889	.144	2.452
Fine, Row Application	75.4	15.6	.3137	.157	2.651
Fine, Broadcast	108.4	25.7	.3106	.155	2.529
Check	24.7	2.1	.2579	.128	2.542

These data indicate that coarse rock phosphate is more effective than fine rock phosphate in increasing yields of sweet clover. The data further indicates that treatment with rock phosphate increases the total phosphorus content of this crop although it has little effect on the total nitrogen content.

Comparative growth of sweet clover under different treatments is shown in figure 5.

Figure 5. The effect of coarse and finely ground rock phosphate on the growth of sweet clover. Seeded December 5, 1947. Photographed May 20, 1948.

No attempt was made to discuss the influence of method of application on the yield or chemical composition of the crops tested for the reason that observations during the course of the experiment indicated that pot tests were not a satisfactory method of studying fertilizer application methods. It can readily be seen that the row application method used in the experiment does not give the same width of rows as that given by a standard grain drill with fertilizer attachment. Neither does the broadcast method as used in the experiment give the same distribution of fertilizer material as the commonly used method of broadcasting the fertilizer material on top of the soil and mixing it with the soil by use of a disk harrow.

SUMMARY

This experiment was conducted in an effort to secure more information on the response, under greenhouse conditions, of various legumes to coarse and finely ground rock phosphate and to different methods of application. The results secured indicate:

1. That the six legume crops tested respond in different ways to treatment with coarse and finely ground rock phosphate.

2. That alfalfa is able to feed on rock phosphate which is held on a 200 mesh seive as efficiently as it does on the commercial product, and that one material is as effective as the other in increasing the total nitrogen and phosphorus content of the plant when grown on a phosphorus deficient low nitrogen soil.

3. That there is little difference in the effectiveness of the coarse and finely ground rock phosphate in promoting increased growth of big hop clover. Both are considerably less efficient than superphosphate in promoting increased growth and increased phosphorus content of this crop. All phosphate material used seemed to depress the total nitrogen content of big hop clover. This was probably due to a decrease in the leaf-stem ratio of plants grown on the fertilized pots.

4. That fine rock phosphate is more efficient than coarse phosphate in increasing yield and total phosphorus content of crimson clover. Both grades of rock phosphate seemed to be equally efficient in increasing the total nitrogen content of this crop.

5. That of the phosphate material used on Ladino clover, superphosphate was the most effective material in increasing yields, although in the first cutting it depressed total phosphorus content. Finely ground rock phosphate was more effective than coarse rock phosphate in increasing the yield of this crop. Both materials were equally effective in increasing the total phosphorus content. The general tendency was for all phosphate material to depress the total nitrogen content of Ladino clover. The stem-leaf ratio was probably responsible for this variation in chemical composition.

6. That coarse rock phosphate was as effective as finely ground rock phosphate in promoting growth of Korean lespedeza. Application of the two materials had little effect on the total phosphorus and nitrogen in this crop.

7. That sweet clover produced higher average yields on coarse rock phosphate than on finely ground rock phosphate. Both materials seemed to be equally effective in increasing total phosphorus and nitrogen in sweet clover.

8. That further investigation should be made to determine the effect of degree of fineness of rock phosphate on other legumes.

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