Response of Soybeans to Gypsum, Lime, and Fertilizer on Three Soils in Southeastern Virginia

D. L. Hallock
Department of Agronomy
Virginia Polytechnic Institute

Research Report No. 89 August 1964

Virginia Agricultural Experiment Station
Blacksburg, Virginia

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SUMMARY

Experiments with soybeans which included 4 rates of gypsum, 3 rates of fertilization, and 2 rates of lime were carried out on Craven fine sandy loam in 1959, Bladen fine sandy loam in 1960, and Sassafras loamy fine sand in 1961. A summary of the results follows:

1. Gypsum did not increase or decrease yield or any other crop variable measured.
2. Lime increased yields at both the Craven and Sassafras sites.
3. Lime increased seed size at the Craven site.
4. Lime increased the expression of purple seed stain disease in Hood soybeans grown in 1959 on Craven soil.
5. Lime increased the content of protein in seeds grown on Craven soil.
6. Lime reduced the percentage of oil in seeds grown on Sassafras soil.
7. Fertilizer reduced the percentage of protein in seeds grown on both Craven and Sassafras soils.
8. There was an interaction in the effect of lime and fertilizer on the percentage of protein in seeds grown on Sassafras soil.
9. There were no statistically significant differences among the plant data recorded for the Bladen site.
10. It is concluded that soybeans grown on well-limed southeastern Virginia soils, which by rapid chemical tests are still low in available calcium, generally do not respond to gypsum fertilization.

Response of Soybeans to Gypsum, Lime and Fertilizer on Three Soils in Southeastern Virginia

D. L. Hallock [1]

Approximately 40% of the soybeans produced in Virginia are grown in 12 southeastern Virginia counties. In 1959 the average yield for these counties was 22 bushels per acre. Such yields seem rather low, especially in view of the relatively good yields of other crops generally obtained on farms in this area.

In a soil test summary of these southeastern Virginia counties, 84% of the samples tested were low or medium in available calcium (less than 775 lbs. per acre CaO), but only 20% were strongly acid (below pH 5.5). Therefore, a possible need for supplemental fertilization with calcium on soils of this area was indicated. Gypsum is a soluble source of calcium which would not increase soil pH and thus decrease the availability of many essential minor elements.

This project was initiated in 1959 to investigate the feasibility of gypsum as a source of calcium and sulfur for soybeans. Also, the response of soybeans to lime and fertilizer was studied.

Considerable research work has demonstrated the value of calcium to soybeans, but only a small part of it involved the use of gypsum. Studies by Siegal, et al. (16), Hampton, et al. (5), and Scanlan (15) have indicated that calcium amendments have been especially beneficial to nitrogen fixation by soybeans. A few studies (18, 3) have indicated both favorable and unfavorable yield responses to gypsum. Volk, et al. (17) obtained the highest yields of soybeans when both gypsum and lime were applied in an investigation involving 3 Norfolk and 2 Orangeburg sandy soils. Recent soil fertility studies[2] with soybeans in eastern Virginia have shown some yield response to lime. In these latter studies the increased yield mainly resulted from a definite increase in seed size on the limed plots. Bertramson, et al. (2) obtained an increase of more than 1% in the oil content of the beans from the use of sulfur.

1/ Associate Professor of Agronomy, Virginia Agricultural Experiment Station, Holland.

2/ Unpublished data, H. M. Camper, Assistant Professor of Agronomy, Eastern Virginia Research Station, Virginia Agricultural Experiment Station, Warsaw.

METHODS AND MATERIALS

This experiment included 4 rates of gypsum, 3 rates of fertilizer, and 2 rates of lime:

Gypsum: 0, 400, 800, and 1,200 lbs. per acre.

Fertilizer: 0, 300, and 600 lbs. per acre of 0-10-20 commercial fertilizer.

Lime: 0 and 1 ton per acre of dolomitic limestone (75%, 100 mesh or finer; 25%, 20 mesh or finer).

Lime and fertilizer were broadcast with a small fertilizer spreader and disked into the freshly plowed soil prior to planting. Gypsum was top-dressed by hand on the rows shortly after the soybean plants had emerged. Mixing gypsum and soil occurred when the soybeans were cultivated a few days after application, and during additional cultivations for weed control. All land preparation, planting, and cultivation operations were performed by the farmer.

This experiment was located on a different farm field each year. All locations were on Coastal Plain soils with a pH of 5.5 or below. The first experiment, in 1959, was placed on moderately well-drained Craven fine sandy loam which has a pale yellow or light brownish-yellow to gray friable surface soil. Craven subsoil is a rather plastic clay or silty clay in the upper part, grading into mottled heavy clay or silty clay in the lower part. The 1960 test was located on a poorly drained Bladen fine sandy loam. This soil has a dark gray to grayish-brown friable surface and a mottled plastic silty clay or clay subsoil. The third experiment (1961) was on well-drained Sassafras loamy fine sand. This soil is much lighter than either of the others, both in the surface and subsoil which are very sandy.

Lime and fertilizer treatments were arranged according to a factorial in the main plots of a split-plot design. The gypsum treatments were the sub-plots. All treatments were replicated 3 times. The sub-plots were 20' long and 3 rows wide. A 16' segment of the center row in each plot was used for the crop data obtained. The soybeans were threshed with a rasping bar plot thresher. Hood soybeans were planted in 1959 and Lee in 1960 and 1961.

Soil samples (plow layer) were taken from each plot after the crop was mature and analyzed for pH, contents of organic matter, and available phosphorus, potassium, calcium, and magnesium by rapid soil testing procedures (14). Soluble sulfate content of the soil was determined by the method of Bardsley and Lancaster (1).

Information was obtained on a number of plant and seed characteristics, including:

Seed size is expressed as weight in grams per 100 seeds.

Lodging is rated at maturity on a scale of 1 to 5: 1 = most plants erect; 5 = all plants lodged severely.

Plant height is the average distance from ground level to the top of the main stem at maturity.

Seed quality is rated on a scale of 1 to 5: 1 = very good; 5 = very poor. Factors considered are seed development, wrinkling, seed coat cracking, and brightness of seed.

Purple seed stain is rated as percentage of seeds visibly infected. The disease is caused by *Cercospora kikuchii*.

Oil and protein contents of the seed are reported on a dry weight basis [3].

RESULTS

1959 Experiment on Craven Fine Sandy Loam

The site of the initial experiment was on a farm 1/2 mile south of Franklin, Va. Hood soybeans were planted in 36" rows during the last week in May and harvested during the second week of November. Temperature conditions were about normal during the growing season. Precipitation was erratic, with excessive amounts in July and October and dry periods in August and September, but the plants appeared to obtain sufficient moisture. Temperature and precipitation data during the 1959 growing season at Holland, which is about 8 miles from the site of this study, are given in Table 7.

The yield, seed size, percentage of purple seed stain, and protein and oil in the seeds grown on the Craven plots are presented in Table 1. Soil pH, contents of organic matter, and available calcium, magnesium, phosphorus, potassium, and sulfur in the plow layer (determined when the crop matured) are given in Table 2.

Lime significantly (1% level) increased the average yield of seed by approximately 3 bushels per acre. Gypsum and/or fertilizer at the rates applied did not influence yields appreciably, although fertilization (0-10-20) increased average yields 1 bushel per acre.

Lime significantly (1% level) increased soybean seed size. The average weight of 100 seeds was 16.7 and 15.6 grams from the limed and unlimed plots, respectively. The average seed size was slightly higher (0.4 grams per 100 seeds) at the 1,200 lb. rate of gypsum than when none was applied. Similarly, seed size increased slightly as the rate of fertilization increased, but neither of these relationships were significant (5% level).

Another factor significantly (5% level) higher on the limed plots was the percentage of seeds showing purple stain - 7.8% versus 6.1%. A definite explanation for these results cannot be offered. Since the actual difference

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[3] Courtesy of J. L. Cartter, U. S. Regional Soybean Laboratory, Urbana, Ill.

Table 1. Effect of gypsum, fertilizer, and lime on yield, seed size, percentage of purple stain, and protein and oil in Hood soybeans grown on Craven fine sandy loam, 1959.

Treatment: Main: Lime lb./A.	Treatment: Main: 0-10-20 lb./A.	Treatment: Sub-plots: Gypsum lb./A.	Yield bu./A.	Purple stain %	Weight per 100 seeds gm.	Seed protein %	Seed oil %
		0	34	5.3	16.2	42.9	21.9
		400	29	5.0	15.6	42.4	20.8
0	0	800	29	5.7	15.5	43.0	21.3
		1200	30	6.7	15.7	42.3	21.5
		Average	30 b*	5.7	15.7 bc	42.6 a	21.4
		0	32	8.7	16.2	43.9	21.9
		400	33	8.0	16.5	43.4	21.5
2000	0	800	32	7.3	16.5	41.7	21.3
		1200	34	7.7	16.8	42.4	21.5
		Average	33 ab	7.9	16.5 ab	42.8 a	21.6
		0	30	8.0	15.4	40.4	22.4
		400	32	5.7	15.7	41.3	22.0
0	300	800	34	7.0	15.5	42.5	21.7
		1200	32	9.3	16.0	40.7	22.3
		Average	32 ab	7.5	15.7 bc	41.2 b	22.1
		0	33	6.0	16.2	42.4	21.4
		400	34	11.7	16.7	41.4	21.7
2000	300	800	35	7.7	16.4	42.3	22.0
		1200	36	7.3	17.3	41.8	21.9
		Average	34 a	8.2	16.7 a	42.0 ab	21.8
		0	32	5.0	15.3	41.6	21.7
		400	31	4.3	15.6	41.5	21.5
0	600	800	33	5.3	15.4	41.1	21.7
		1200	29	5.7	15.8	41.0	22.0
		Average	31 b	5.1	15.5 c	41.3 b	21.7
		0	35	6.7	17.1	41.3	22.1
		400	34	7.3	17.0	42.3	21.5
2000	600	800	34	8.0	16.9	42.1	22.1
		1200	35	7.0	17.2	42.7	22.3
		Average	34 a	7.3	17.0 a	42.1 ab	22.0

* Means followed by unlike letters are significantly (5% level) different according to Duncan's Multiple Range Test. Single degree of freedom contrasts showed lime significantly (5% level or higher) increased yield, percent purple stain, seed size, and percent seed protein.

Table 2. Soil pH, percentage organic matter, and contents of available calcium, magnesium, phosphorus, potassium, and sulfur in a Craven fine sandy loam *, 1959.

Treatments			Soil	Organic	Available nutrients in the soil				
Lime lb./A.	0-10-20 lb./A.	Gypsum lb./A.	pH	matter %	CaO lb./A.	MgO lb./A.	P_2O_5 lb./A.	K_2O lb./A.	S lb./A.
0	0	0	5.2	1.4	390	90	195	135	8
		400	5.1	1.4	525	60	175	135	18
		800	5.1	1.4	470	60	170	120	16
		1200	5.0	1.4	720	65	175	125	91
		Average	5.1	1.4	526	69	179	129	33
2000	0	0	6.1	1.4	735	320	180	115	13
		400	6.0	1.3	595	295	200	110	18
		800	6.0	1.4	705	270	190	110	22
		1200	6.0	1.5	710	280	125	100	44
		Average	6.0	1.4	686	291	174	109	24
0	300	0	5.0	1.2	400	35	210	140	19
		400	5.1	1.4	540	45	195	130	15
		800	5.1	1.3	610	45	180	125	26
		1200	4.9	1.3	535	40	185	130	44
		Average	5.0	1.3	521	46	193	131	26
2000	300	0	6.0	1.4	575	310	195	150	8
		400	6.1	1.5	580	260	180	135	10
		800	5.9	1.4	720	285	210	135	17
		1200	5.7	1.4	615	230	220	135	84
		Average	5.9	1.4	623	271	201	139	30
0	600	0	5.0	1.5	490	45	235	185	16
		400	5.1	1.4	460	50	205	170	13
		800	5.1	1.5	515	45	180	175	16
		1200	5.0	1.5	605	40	185	160	66
		Average	5.1	1.5	517	45	201	173	28
2000	600	0	6.1	1.4	710	315	270	180	8
		400	5.9	1.3	620	285	220	170	16
		800	6.0	1.5	625	295	230	190	32
		1200	5.9	1.4	745	265	215	165	28
		Average	6.0	1.4	675	290	234	176	21

* Samples obtained in early November when the crop matured.

in the apparent content of the disease is rather small, it may be only an unequal expression of the disease pigment. More detailed or refined observations were probably needed for much importance to be placed on this relationship. However, Murakiski (11) showed that pH of the culture medium will influence development of the pigment by this organism. Furthermore, Kulik (9) reported that seed lots showing large amounts of stained seed invariably contained many infected but non-stained seed.

Lime significantly (1% level) increased protein content of the seeds by approximately 0.6%. On the other hand, average oil content of the beans was not influenced appreciably by liming. Normally, the oil and the protein contents of beans tend to vary inversely (6).

On this soil, application of 0-10-20 fertilizer significantly (1% level) reduced the percentage of protein in the beans from 42.8% to 41.7%. Nelson, et al. (12) reported a 2% increase in oil content and a 5% reduction in protein content with potassium fertilization of a particular soil low in this nutrient. In this study on Craven soil, the average oil content of the beans was increasesd slightly, although not significantly, by fertilization. Therefore, it is possible that the depressional effect of fertilization on the percent protein in this case also may have been a response to potassium, and to the negative relationship between oil and protein contents mentioned previously.

The percentage of oil was not influenced significantly by any of the treatments. For the test as a whole, the beans averaged approximately 21.8% oil. Similarly, plant height, lodging, and seed quality were not differentially affected by the various treatments and were not included in Table 1. The plants grew uniformly throughout the season, attaining an average height of 37". In general, lodging and seed quality were rated 3 and 2.5, respectively. No significant or appreciable effect of gypsum on any of these variables was noted.

Liming increased the soil pH from 5.0 to approximately 6.0 during the growing season (Table 2). It also increased available calcium and magnesium contents of the soil. Approximately 700 lbs. per acre of calcium and 300 lbs. of magnesium oxides were applied in the lime. However, according to the soil test, available magnesium levels of the limed plots relative to the check plots were increased considerably more than calcium levels. In fact, the increase in available magnesium was about double that of calcium. Increases in available calcium as the rate of gypsum increased were somewhat erratic. Perhaps this resulted from leaching during periods of heavy precipitation in July and October (table 7).

Application of 300 and 600 lbs. per acre 0-10-20 increased the contents of both available phosphate and potash by about 20 to 50 lbs. per acre for the 2 rates, respectively. According to the results in Table 2, this soil rated high in phosphate and medium in potash (14) which is considered to be about the optimum nutrient level for efficient crop production in this soil.

The contents of soluble sulfates were increased somewhat by the application of gypsum. Generally, appreciable quantities were found only when the high rate of gypsum had been applied. Probably most of the applied sulfates had leached below the sampling zone by November because of excessive rainfall during July and October.

1960 Experiment on Bladen Fine Sandy Loam

The 1960 experiment was on a farm in Chesapeake, (formerly Norfolk County) Va. near the Dismal Swamp. Lee soybeans were planted in 42" rows early in June and harvested in the middle of November. Mean daily temperatures were slightly higher than normal. Rainfall also was somewhat higher than normal, except during June and the first 3 weeks in July (Table 7) when the area was somewhat deficient in moisture.

The yields, seed size, and percentage of seed protein and oil produced on this Bladen soil are given in Table 3. There were no statistically significant (5% level) differences among the plant data recorded, since none of the treatments appeared to have any appreciable, consistent effect on the soybeans. The content of purple stain was low - less than 1%. The Lee variety is resistant to this disease. Other observations were similar, regardless of treatment. The average plant height was 37" with considerable lodging. Seed quality rating was 2 in each case.

The soil pH, percentage of organic matter, and contents of available calcium, magnesium, phosphorus, potassium, and sulfur in the November sampling of this soil are given in Table 4. These data indicate this soil was quite fertile, except that phosphate level was only medium (14). It is somewhat unusual for farm soils of this area to be low or even medium in phosphorus. However, it apparently was sufficient since no response to phosphate was obtained at this site. Soil calcium and magnesium levels were very high, even in the plots not limed or without gypsum. Soil pH levels were increased only about 0.3 to 0.4 units by 1 ton of lime, but the content of organic matter was quite high. The application of gypsum generally increased both the soil calcium and sulfur contents considerably.

1961 Experiment on Sassafras Loamy Fine Sand

This experiment was on a farm located on the "Pungo Ridge" section of Virginia Beach (formerly Princess Anne County). Lee soybeans were planted in 40" rows early in June and harvested early in November. Temperature and moisture (Table 7) conditions were reasonably good throughout this growing season, except for a couple of short drouth periods in July and early September.

Average yields, seed size, and percentage of seed protein and oil for each level of the various treatments are given in Table 5. Yields were rather low in 1961. Also, the seeds were very small. The average weight per 100 seeds was less than 10 grams, or nearly 5 grams lower than in the 1960 test with the same variety. This small seed size was undoubtedly an important factor causing reduced yields (6). Perhaps the dry period during the first half of September, when the seeds were developing, was largely responsible for the small seed size and lower yields.

These data show a rather consistent, significant (1% level) yield response to lime of about 3 bushels per acre. Protein content in the beans

Table 3. Effect of gypsum, fertilizer, and lime on yield, seed size, and percentage of protein and oil in Lee soybeans grown on Bladen fine sandy loam, 1960.

Treatment: Main: Lime lb./A.	Treatment: Main: 0-10-20 lb./A.	Treatment: Sub-plots: Gypsum lb./A.	Yield bu./A.	Weight per 100 seeds gm.	Seed protein %	Seed oil %
0	0	0	40	14.0	43.8	21.4
		400	33	14.3	43.1	20.4
		800	36	13.7	43.1	19.7
		1200	36	13.7	42.8	20.2
		Average	36	13.9	43.2	20.4
2000	0	0	35	14.0	43.1	20.4
		400	36	14.7	43.3	20.4
		800	25	13.3	43.0	20.6
		1200	30	14.7	42.8	20.2
		Average	32	14.2	43.1	20.4
0	300	0	32	14.2	43.3	20.2
		400	30	14.2	43.6	19.6
		800	32	14.0	43.7	20.1
		1200	27	13.3	42.9	20.2
		Average	30	13.9	43.4	20.0
2000	300	0	34	15.0	43.0	20.2
		400	30	14.0	42.9	19.9
		800	33	13.7	43.6	20.5
		1200	30	14.7	42.9	19.7
		Average	32	14.4	43.1	20.1
0	600	0	27	14.7	42.3	20.7
		400	28	13.7	42.9	20.5
		800	30	14.3	42.7	20.6
		1200	30	14.3	42.1	20.7
		Average	29	14.3	42.5	20.6
2000	600	0	36	14.0	42.8	20.4
		400	33	14.3	42.7	20.0
		800	36	14.3	41.8	20.5
		1200	31	14.7	43.1	20.3
		Average	34	14.3	42.6	20.3

* Lime, fertilizer, and gypsum did not significantly (5% level) effect these variables on this soil type.

Table 4. Soil pH, percentage organic matter, and contents of available calcium, magnesium, phosphorus, potassium, and sulfur in Bladen fine sandy loam, 1960*.

Treatments			Soil	Organic matter	Available nutrients in the soil				
Lime lb./A.	0-10-20 lb./A.	Gypsum lb./A.	pH	%	CaO lb./A.	MgO lb./A.	P_2O_5 lb./A.	K_2O lb./A.	S lb./A.
		0	5.1	8	3500	740	55	210	50
		400	5.1	10	3500	790	55	220	65
0	0	800	5.0	11	6300	765	45	225	150
		1200	5.0	10	5600	800	55	210	250
		Average	5.1	10	4725	774	53	216	129
		0	5.4	10	4760	1000	45	195	45
		400	5.4	11	6300	790	35	210	90
2000	0	800	5.4	9	5320	835	35	245	170
		1200	5.2	11	6300	790	45	210	300
		Average	5.4	10	5670	854	40	215	151
		0	4.9	11	2100	760	55	225	65
		400	5.2	11	3360	750	70	195	70
0	300	800	5.1	11	4200	785	90	175	100
		1200	4.9	11	4900	740	55	185	250
		Average	5.0	11	3640	759	68	195	121
		0	5.5	12	4900	875	45	185	50
		400	5.6	9	5320	875	80	210	65
2000	300	800	5.4	10	6300	875	70	250	120
		1200	5.3	11	6300	790	45	280	260
		Average	5.5	11	5705	854	60	231	124
		0	5.2	11	3500	875	55	390	55
		400	4.9	13	3640	790	45	315	125
0	600	800	5.1	10	4900	790	55	315	150
		1200	4.9	12	4200	765	70	310	150
		Average	5.0	12	4060	805	56	333	120
		0	5.5	12	6300	950	55	280	50
		400	5.5	9	6300	835	100	270	60
2000	600	800	5.3	11	6300	875	80	270	155
		1200	5.4	10	5320	850	70	240	200
		Average	5.4	11	6055	878	76	265	116

* Samples obtained in early November when the crop matured.

from the non-fertilized, limed plots versus the unlimed plots is approximately 1.5 to 2% higher; the opposite was noted for the fertilized plots. Thus, it appears that fertilizer caused a reversal in response over and above the lime effect. This interaction was statistically significant at the 5% level. Also, lime was significantly (5% level) related in a inverse manner to the percent oil in the seeds.

No differential effects were noted in other crop variables among the various treatments. The infestation of purple seed stain disease was very low. The soybean plants grew uniformly to a height of about 36" with only a small amount of lodging (category2). Seed quality was quite good (category 1.5).

For the third straight year, the soybeans did not respond significantly to rates up to 1,200 lbs. per acre of gypsum. However, the average yields of beans were about one bushel per acre higher on the plots which received gypsum, but this is probably a chance variation.

Soil analysis data for Sassafras fine sandy loam are given in Table 6. The general fertility level of this soil was very high, particularly with respect to phosphorus. Until a few years prior to this test, the area was used principally for truck crops which were fertilized heavily. Noteworthy is the general depression in amount of available magnesium, particularly in the limed plots, and also potash as the rate of gypsum application increased. The contents of magnesium and calcium were increased by liming. Both calcium and sulfur contents were increased by gypsum applications.

Soil pH of the plots where no gypsum was applied was increased from about 5.2 to 6.0 by liming at 1 ton per acre. On the other hand, pH levels were apparently decreased appreciably as the rate of gypsum increased. Generally, gypsum does not affect soil reaction particularly, but in this case there was a rather marked effect.

DISCUSSION

Lime obtained principal response by soybeans to any of the treatments in this series of experiments. Since the main objective was to ascertain whether soybeans on Coastal Plain soils need supplemental calcium, no studies were carried out to elucidate the causes of other responses. The reason for this lime response can be only one of supposition. However, the lack of response to gypsum indicates rather definitely that it is not a calcium response. The level of calcium in these soils was apparently sufficient for good yields, even though soil test results for the Sassafras site indicated low calcium in the unlimed, no-gypsum plots.

Available magnesium levels in the unlimed plots on the Craven and Sassafras soils averaged about 40 lbs. per acre, which is on the upper limit of the low category (475). Application of lime increased by 7 to 8 times the amount of available magnesium in these 2 soils. Key and Kurtz (8) increased soybean yields 4 to 5 bushels per acre by applying 150 lbs. per acre of magnesium sulfate or 2 tons per acre of dolomite on a sandy soil.

Table 5. Effect of gypsum, fertilizer, and lime on yield, seed size, and percentage of protein and oil in Lee soybeans grown on Sassafras loamy fine sand, 1961.

Treatment: Main: Lime lb./A.	Treatment: Main: 0-10-20 lb./A.	Treatment: Sub-plots: gypsum lb./A.	Yield bu./A.	Weight per 100 seeds gm.	Seed protein %	Seed oil %
0	0	0	25	9.7	40.9	20.7
		400	25	9.3	41.1	21.0
		800	24	8.7	41.4	20.8
		1200	26	9.7	40.5	20.8
		Average	25 c*	9.4	41.0	20.8
2000	0	0	26	10.0	42.5	21.6
		400	26	10.0	42.9	20.0
		800	30	9.7	43.0	19.9
		1200	29	10.0	42.8	20.0
		Average	28 c	9.9	42.8	20.4
0	300	0	26	9.7	39.8	21.4
		400	25	9.3	41.5	20.6
		800	24	9.0	42.3	20.0
		1200	23	8.7	42.0	20.7
		Average	25 bc	9.2	41.4	20.7
2000	300	0	25	9.0	43.3	19.2
		400	29	10.0	40.0	19.5
		800	30	9.7	39.7	20.3
		1200	27	10.0	38.9	19.9
		Average	28 ab	9.7	40.5	19.7
0	600	0	26	9.0	43.2	19.2
		400	25	9.0	42.7	20.6
		800	24	9.3	42.3	20.4
		1200	28	10.0	41.1	21.4
		Average	26 ab	9.3	42.3	20.4
2000	600	0	28	9.7	41.6	19.6
		400	29	9.7	40.6	19.7
		800	30	9.3	39.6	19.9
		1200	27	9.3	39.9	20.0
		Average	29 a	9.5	40.4	19.8

* Means followed by unlike letters are significantly (5% level) different according to Duncan's Multiple Range Test. Single degree of freedom contrasts showed lime significantly (5% level or higher) increased yield and decreased percent seed oil. Also, there was a significant (5% level) interaction between lime and fertilizer on their effect on percent seed protein.

In this case the soil contained 60 to 75 lbs. per acre of exchangeable magnesium before treatment. They concluded that a level of 150 lbs. per acre appeared to be adequate for field crops on soils of moderate or low exchange capacity. Key and Kurtz observed no magnesium deficiencies on the untreated soybean plants; likewise, there were none observed in these studies. The level of available magnesium and calcium in the Bladen soil was very high before liming and no yield increase from liming was obtained. It appears that the yield increases with liming on the Craven and Sassafras soils may have been in part, at least, a response to magnesium supplied in the dolomitic lime.

Recently, soybean yield responses to liming have been linked to increased soil molybdenum availability. Parker and Harris (13) reported yield increases of 30% to 55% from 0.2 lbs. per acre of molybdenum applied on loam soils of pH 5.5. These workers obtained similar yield increases from the application of 2 tons per acre of dolomitic limestone. A high correlation ($r = 0.996$) existed between soybean yields and soil pH without molybdenum fertilization, but this relationship was completely eliminated by application of molybdenum ($r = 0.032$). Lavy and Barber (10) also related molybdenum yield response of soybeans to soil pH levels up to about 6.0. Presumably, the higher pH levels in soils examined by these workers was caused by higher rates of liming prior to sampling for their study. Hence, the responses reported in this paper also may have resulted from increased molybdenum availibility in those 2 soils.

A third factor should be considered when seeking possible causes for increased soybean yields from liming. Acid soils contain certain elements, such as aluminum, which may decrease the growth of soybeans if they are present in toxic quantities (7). Proper liming eliminates this toxic effect.

In a small survey experiment, gypsum was applied at rates of 400 and 800 lbs. per acre on soybeans planted immediately after harvesting wheat in late June of 1963. The soil type was Goldsboro loamy fine sand with only 80 lbs. per acre of available calcium in the plow layer. Average yields of soybeans were similar although rather low (18 bushels), at all rates of gypsum. These results agree with the 3 larger experiments, which indicated that even at relatively low levels of available soil calcium, soybeans did not respond to gypsum applications. Therefore, it is concluded that soybeans grown on properly limed southeastern Virginia soils, which are still relatively low in available calcium, generally do not respond to supplemental calcium fertilization.

Table 7. Mean daily maximum and minimum temperatures and precipitation, May through November, at stations near experiment sites.

Month	Mean temperatures °F Maximum	Mean temperatures °F Minimum	Precipitation inches
Holland, Va., Craven Site, 1959			
May	80	57	1.16
June	86	62	3.62
July	87	69	10.55
August	89	68	1.64
September	83	61	1.92
October	73	54	12.72
Airport, Norfolk, Va., Bladen Site, 1960			
May	77	59	4.43
June	84	66	2.57
July	87	69	4.78
August	88	73	6.49
September	80	65	5.88
October	70	53	2.76
Back Bay Wildlife Refuge, Va. Beach, Va., Sassafras Site, 1961			
May	-	-	4.65
June	81	62	5.15
July	89	70	4.62
August	90	66	5.19
September	84	65	3.52
October	70	-	6.23

Table 6. Soil pH, percentage of organic matter, and contents of available calcium, magnesium, phosphorus, potassium, and sulfur in Sassafras loamy fine sand, 1961 *.

Treatments			Soil	Organic	Available nutrients in the soil				
Lime lb./A.	0-10-20 lb./A.	Gypsum lb./A.	pH	matter %	CaO lb./A.	MgO lb./A.	P_2O_5 lb./A.	K_2O lb./A.	S lb./A.
		0	5.3	1.8	145	70	520	225	20
		400	5.2	1.8	205	15	455	185	130
0	0	800	5.2	1.4	240	45	510	165	180
		1200	4.9	1.6	700	15	560	165	230
		Average	5.2	1.7	323	36	511	185	140
		0	6.1	1.6	680	485	520	235	30
		400	5.4	1.6	325	285	610	170	110
2000	0	800	5.7	1.4	540	282	515	155	95
		1200	5.4	1.7	985	290	615	165	245
		Average	5.7	1.6	633	336	565	181	120
		0	5.2	1.8	95	35	600	240	20
		400	5.2	1.6	205	120	620	235	55
0	300	800	4.7	1.4	475	15	620	220	260
		1200	4.8	1.7	920	15	600	210	265
		Average	5.0	1.6	424	46	610	226	150
		0	6.0	1.5	250	405	600	250	50
		400	5.7	1.5	475	300	725	235	65
2000	300	800	5.7	1.7	320	275	755	220	95
		1200	5.5	1.6	765	290	680	220	220
		Average	5.7	1.6	453	318	690	231	108
		0	5.2	1.5	50	40	565	280	35
		400	5.2	1.6	215	30	545	250	55
0	600	800	4.9	1.7	165	15	675	245	120
		1200	4.8	1.6	1385	45	614	185	275
		Average	5.0	1.6	454	33	600	240	121
		0	6.0	1.6	555	565	625	270	25
		400	5.9	1.7	620	385	710	230	45
2000	600	800	5.4	1.6	1035	240	680	215	235
		1200	5.5	1.4	1440	270	650	220	225
		Average	5.7	1.6	913	365	666	234	133

* Samples obtained in early November when the crop matured.

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