RESIDUAL VALUE of PHOSPHATES

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E. V. Smith, *Director* Auburn, Alabama

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ACKNOWLEDGEMENT

Field experiments to study the residual value of applied phosphates have been in progress for nearly 30 years. In preparing this bulletin, the author summarized results of many workers.

Studies on the Experiment Fields were conducted by J. T. Cope, Jr., F. E. Bertram, Fred Glaze, J. W. Richardson, J. F. Segrest, Jr.,[1] J. T. Williamson,[2] J. R. Taylor,[1] and R. W. Taylor.[1]

Studies on the Substations were conducted by John Boseck, R. C. Christopher,[1] S. E. Gissendanner, Fred Stewart,[3] and J. P. Wilson.[2]

[1] Resigned
[2] Deceased
[3] Retired

COVER PHOTO. These plots at the Sand Mountain Substation in 1957 show effects of residual phosphorus on growth of cotton. Plot at left had received no phosphorus since 1930. One at right got applications of superphosphate from 1930 until 1955.

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RESIDUAL VALUE of PHOSPHATES

L. E. ENSMINGER, *Soil Chemist*

ADDED PHOSPHORUS accumulates to some extent in soils. This occurs because only a small percentage of phosphorus applied in fertilizers is removed in the harvested portion of crops or lost by leaching. Extent of accumulation depends on such factors as amount of phosphorus added, amount lost by erosion, crop grown, and how much of the crop is removed from the land.

Loss of phosphorus by erosion and runoff has been recognized as an important factor in reducing the accumulation of applied phosphates *(1, 2, 6, 10)*. In a study of nutrient losses from a 3-year rotation on Dunmore silt loam, Rogers *(6)* found that the eroded material from corn land was richer in nitrogen and phosphorus than the original soil.

Removal of large tonnages of hay or silage may result in the removal of as much as 50 or more pounds of P_2O_5 per acre per season. The amount of P_2O_5 removed depends on the crop and the amount of growth removed, as shown by the following examples:

Crop	*P_2O_5 removed, pounds per acre*
Cotton (1,500 pounds seed cotton)	18
Corn (60 bushels grain)	23
Alfalfa (4 tons hay)	46
Coastal Bermudagrass (6 tons hay)	54

The residual value of applied phosphates has been studied by a number of investigators *(5, 10, 12, 13)*. Volk *(10)* found that cotton yields declined on a Hartsells fine sandy loam when phosphorus fertilization was discontinued after various rates had been applied over a 5-year period. However, there was a residual effect that was in proportion to the amount that had been added.

Data reported by Weeks and Miller *(13)* showed that crop yields declined with time on plots that had formerly received superphosphate, whereas there was no decline on plots that had previously received 4 times as much phosphorus from rock phosphate.

The availability of accumulated phosphorus for succeeding crops is of practical importance. Soil tests can be used to determine the amount of residual phosphorus in soils and from these tests phosphorus needs can be predicted. Since available phosphorus levels of soils vary a great deal because of past management, a soil test is the only practical method of evaluating residual phosphorus present in soil of a particular field. Now that many soils have accumulated rather large quantities of residual phosphorus, phosphorus fertilization should be based on this fact.

Chemical fixation of phosphorus by soils has been credited with the low-efficiency often obtained *(7, 9)*. Fixation, which is the reversion to a less soluble form, is undoubtedly responsible for some loss in availability of phosphorus. However, yield data and radiophosphorus uptake have shown that fixed phosphorus is fairly available to plants *(3)*.

This bulletin summarizes pertinent data obtained in Alabama showing residual effects of applied phosphorus.

RESULTS OF EXPERIMENTS

Residual Effects of Superphosphate on Hartsells Fine Sandy Loam

FIRST PERIOD (1930-55). This experiment was started in 1930 at the Sand Mountain Substation to determine residual effect of rates of superphosphate as measured by yields of cotton in continuous culture. The experiment is still in progress in revised form and is perhaps the oldest residual phosphorus test in existence.

Rates of P_2O_5 of 0, 30, 60, 90, and 120 pounds per acre were applied annually to certain plots during 1930-34 and none thereafter. Figure 1 shows the residual effects of these rates as measured by yields of seed cotton. Yields gradually declined after phosphorus was discontinued in 1934, but residual effects were evident for 21 years and were in proportion to the amount of phosphorus that had been applied. For the last 6-year period (1950-55) the treatment that received 120 pounds of P_2O_5 annually during 1930-34 and none thereafter averaged 640 pounds of seed cotton more than the treatment that had not received any phosphorus. However, yields from the 120-pound residual treatment averaged 320 pounds less than the one that received 60 pounds of P_2O_5 annually.

SECOND PERIOD (1956-57). The experiment was revised in 1956 so that residual effects of rates of superphosphate applied an-

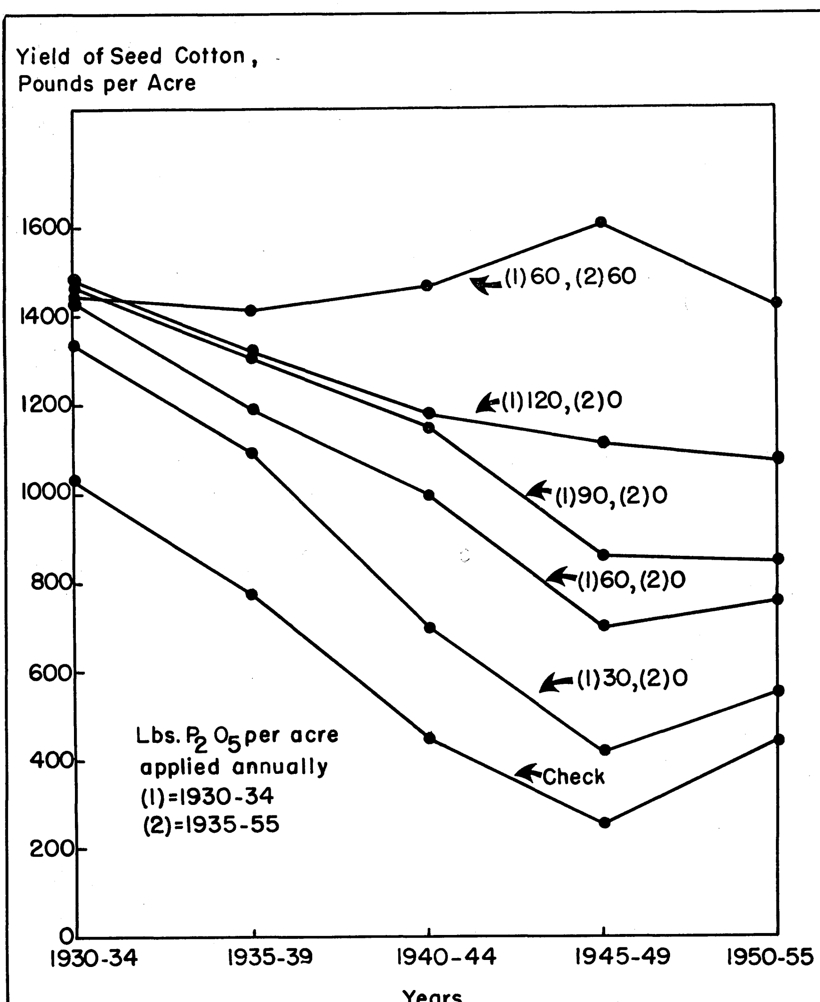

FIGURE 1. Response of cotton to residual phosphorus on Hartsells fine sandy loam is shown above by yields of seed cotton.

TABLE 1. RESIDUAL EFFECTS OF SUPERPHOSPHATE AS MEASURED BY YIELDS OF SEED COTTON AND EXTRACTABLE PHOSPHORUS, HARTSELLS VERY FINE SANDY LOAM

P_2O_5 per acre applied as superphosphate			Seed cotton yields	P_2O_5 extracted from soil samples collected in 1956			
1930-34	1935-55	1956-57	1956-57	Dilute acid	Neutral NH_4F	HCl—NH_4F	Resin exchange-able
Lb.	*Lb.*	*Lb.*	*Lb.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
0	0	0	1,081	11	21	65	6
0	30	0	1,555	38	66	174	17
0	60	0	1,710	76	120	264	34
0	90	0	1,850	126	258	454	68
0	120	0	1,845	193	378	605	96
30	30	30	1,668	37	63	169	17
60	60	60	1,770	77	135	280	38
90	90	90	1,812	132	280	451	65
120	120	120	1,802	224	429	662	102

nually for as long as 21 years could be studied. Yield data for the first 2 years after revision are given in Table 1. Plots that received as much as 60 pounds of P_2O_5 annually for 21 years and none thereafter produced as much cotton as plots that continued to receive 60 pounds annually.

The soluble phosphorus content of soil samples collected at beginning of the second phase of the residual study in 1956 was determined by four methods of extraction, Table 1 and Figure 2. Although the amount extracted by the various solutions varied considerably, any one of them could be used as a measure of available soil phosphorus if calibrated in terms of yield response to residual phosphorus.

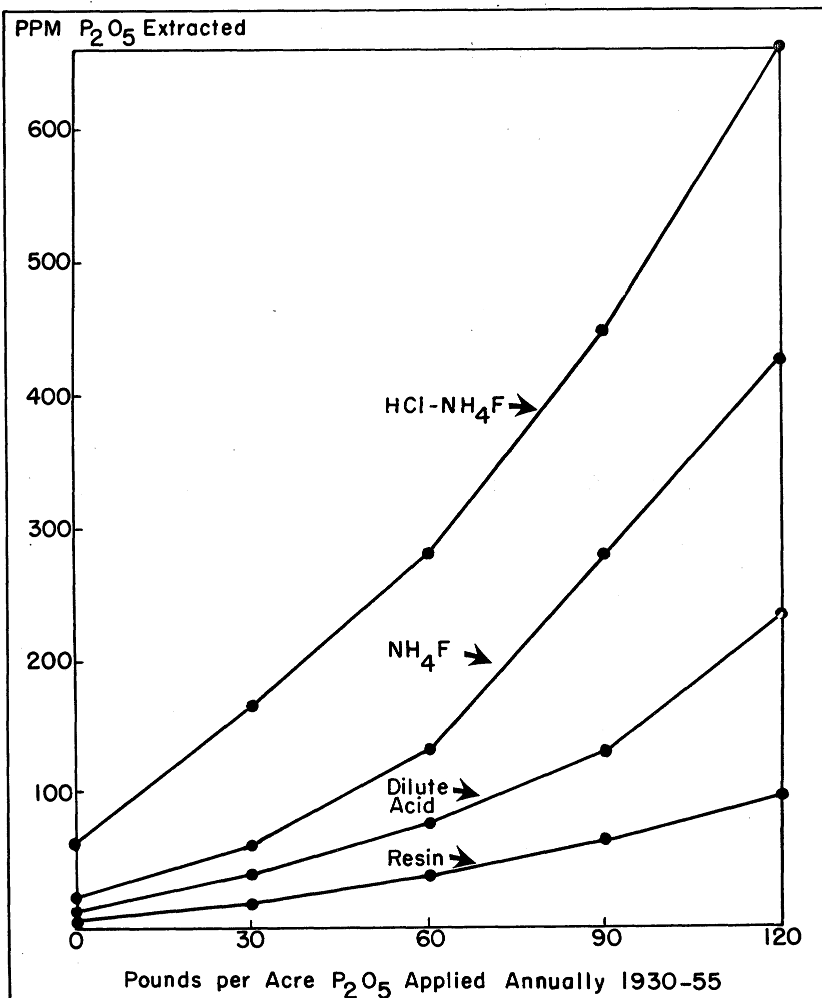

FIGURE 2. Shown is extractable phosphorus content of Hartsells fine sandy loam at Sand Mountain Substation when treated with varying amounts of superphosphate.

Residual Effects of Various Sources

CORN-COTTON ROTATION WITHOUT WINTER LEGUMES. A sources-of-phosphorus test was conducted at four locations from 1930 to 1945. Sources of phosphorus along with rates applied and locations are given in Table 2. Phosphorus treatments were discontinued after 1945 to study residual effects. Yield data are presented for the last 4 years of the period during which phos-

TABLE 2. INCREASED YIELDS OF SEED COTTON FROM VARIOUS PHOSPHATES FOR THE LAST 4 YEARS OF THE PHOSPHATING PERIOD AND FOR THE 4-YEAR RESIDUAL PERIOD IN A ROTATION OF COTTON AND CORN

Source of phosphorus	P_2O_5 per acre applied to cotton	Increased yield of seed cotton									
		Norfolk sl, Wiregrass Substation		Magnolia fsl, Monroeville Expt. Field		Decatur sl, Tennessee Valley Substation		Decatur cl, Alexandria Expt. Field		Average of 4 locations	
	1930-45	1942-45	1946-49	1942-45	1946-49	1942-45	1946-49	1942-45	1946-49	1942-45	1946-49
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Superphosphate	24	199	104	499	378	367	174	520	360	396	254
Superphosphate	48	216	174	480	461	360	265	652	427	427	332
Conc. superphosphate	48	205	29	363	171	346	196	----	----	----	----
Basic slag	48	157	249	420	571	437	372	624	438	409	407
Ppt. trical. phos.	48	173	169	411	312	345	219	----	----	----	----
Ammo-phos. A.	48	—471	—223	—225	—102	210	266	399	417	—22	89
Colloid. phos.	48	134	99	348	155	252	209	----	----	----	----
Rock phosphate	48	42	58	358	284	170	119	486	281	264	185
Rock phosphate	96	107	133	338	285	314	230	679	418	359	266
Superphosphate[1]	24	233	136	432	261	327	224	662	435	413	264
Superphosphate[2]	24	243	256	504	518	439	332	626	474	453	395
Average yield of checks	0	1,029	503	849	870	890	1,011	777	727	886	778

[1] In addition to superphosphate, rock phosphate applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.
[2] In addition to superphosphate, basic slag applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.

TABLE 3. INCREASED YIELDS OF SEED COTTON FROM VARIOUS PHOSPHATES FOR THE LAST 4 YEARS OF THE PHOSPHATING PERIOD AND FOR THE 4-YEAR RESIDUAL PERIOD IN A ROTATION OF COTTON AND CORN WITH WINTER LEGUMES

Source of phosphorus	P_2O_5 per acre to cotton and to winter legumes	Increased yield of seed cotton per acre							
		Norfolk sl, Wiregrass Substation		Greenville fsl, Prattville Experiment Field		Decatur sl, Tennessee Valley Substation		Average of 3 locations	
	1930-45	1942-45	1946-49	1942-45	1946-49	1942-45	1946-49	1942-45	1946-49
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Superphosphate	24	302	183	157	60	405	255	288	166
Superphosphate	48	376	179	161	78	429	283	322	180
Conc. superphosphate	48	238	95	209	67	328	188	258	117
Basic slag	48	304	382	155	180	582	457	347	340
Ppt. trical. phos.	48	273	220	228	160	332	201	278	194
Ammo-phos. A	48	–329	–56	–416	–370	331	265	–138	–161
Colloid. phosphate	48	254	160	98	172	270	145	207	159
Rock phosphate	48	112	124	62	54	219	128	131	102
Rock phosphate	96	188	215	151	96	341	249	227	187
Superphosphate[1]	24	430	206	206	82	384	244	340	177
Superphosphate[2]	24	416	352	227	109	506	329	383	263
Average yield of checks	0	927	519	1,632	1,192	1,026	973	1,195	895

[1] In addition to superphosphate, rock phosphate applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.
[2] In addition to superphosphate, basic slag applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.

phates were applied as well as for the residual period, Table 2. Average yields for the four locations show a response to only 24 pounds of P_2O_5 from superphosphate for the last 4 years of the phosphating period. Rock phosphate did not produce as much cotton as did 24 pounds of P_2O_5 from superphosphate even when applied at the rate of 96 pounds of P_2O_5 per acre.

During the residual period, increased yields of cotton were less in most cases than during the phosphating period, but basic slag showed the greatest residual effect. In the residual period 24 pounds of P_2O_5 from superphosphate produced about the same amount of cotton as 24 pounds of P_2O_5 from superphosphate plus periodic applications of rock phosphate.

CORN-COTTON ROTATION WITH WINTER LEGUMES. A sources-of-phosphorus experiment similar to the preceding one was conducted at three locations from 1930 to 1945. In this experiment winter legumes were grown after cotton as a green manure crop for corn. Phosphorus was applied to winter legumes as well as to cotton. The phosphorus treatments were discontinued after 1945 and residual effects of sources were studied. Since corn did not respond much to phosphorus, corn yields are not given.

Increased cotton yields for the last 4 years of the phosphating period show that basic slag produced the highest yields, superphosphate the next highest, and raw phosphates considerably less that the other two sources, Table 3. Yields declined during the residual period, but slag showed the greatest residual effect of any of the sources, Figure 3.

Blue lupine was used as the winter legume on the Norfolk sandy loam soil at the Wiregrass Substation. Since it did not respond to phosphorus, yields of winter legumes from this location are not presented. Yields of vetch are given for the other two locations in Table 4. Yields for the last 4 years when phosphate was being applied show that 24 pounds of P_2O_5 from superphosphate produced more vetch than 96 pounds of P_2O_5 from rock phosphate. Also 24 pounds of P_2O_5 from superphosphate produced more vetch than 48 pounds from basic slag, tricalcium phosphate, or colloidal phosphate on Greenville fine sandy loam. On Decatur silt loam, basic slag and tricalcium phosphate produced about the same amount of vetch as an equivalent amount of phosphorus from superphosphate. However, basic slag showed a greater residual effect than other sources. On the Greenville sandy loam, some of the other less soluble sources,

FIGURE 3. Response of vetch to residual phosphorus on Greenville fine sandy loam at Prattville Experiment Field is shown in the photos made March 21, 1950. Plot at top had received no phosphate since 1930. One at bottom got 48 pounds P_2O_5 per acre annually from basic slag during 1930-45 and none thereafter.

such as tricalcium phosphate and colloidal phosphate, produced more vetch than an equivalent amount of phosphorus from superphosphate. Treatments of 24 pounds of P_2O_5 from superphosphate plus periodic applications of basic slag or rock phosphate showed rather high residual effects on both soils.

Radiophosphorus uptake by cotton plants and extractable phosphorus content of soil samples were used to measure the extent and availability of accumulated phosphorus. The radiophosphorus uptake data were used to calculate A values *(4)*. Since "tagged" superphosphate was used as the standard, A values indicate the amount of soil phosphorus that was as available as superphosphate. Based on these values, Table 5, all rates and sources

TABLE 4. INCREASED YIELDS OF VETCH FROM VARIOUS PHOSPHATES FOR THE LAST 4 YEARS OF THE PHOSPHATING PERIOD AND FOR 4-YEAR RESIDUAL PERIODS IN A ROTATION OF COTTON AND CORN WITH WINTER LEGUMES

Source of phosphorus	P_2O_5 per acre to cotton and winter legumes	Green weight of vetch, per acre				
		Greenville fsl, Prattville Experiment Field			Decatur sl., Tenn. Valley Substation	
	1930-45	1943-46	1947-50	1951-54	1943-46	1947-50
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Superphosphate	24	5,307	4,073	3,981	5,626	2,117
Superphosphate	48	6,118	5,666	6,024	7,768	4,665
Conc. superphosphate	48	4,997	4,703	4,809	7,065	3,018
Basic slag	48	3,431	7,284	9,232	8,050	7,628
Ppt. trical. phos.	48	4,845	8,133	8,019	7,042	3,644
Ammo-phos. A.	48	4,200	1,331	1,629	7,396	3,287
Colloidal phosphate	48	4,597	7,384	8,834	4,847	3,179
Rock phosphate	48	3,943	4,541	5,528	2,696	2,578
Rock phosphate	96	5,067	7,361	7,931	5,155	3,496
Superphosphate[1]	24	6,078	6,278	8,846	7,865	6,224
Superphosphate[2]	24	5,000	8,766	10,168	10,073	6,235
Average yield of checks	0	4,444	7,432	8,211	1,735	3,518

[1] In addition to superphosphate, rock phosphate applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.

[2] In addition to superphosphate, basic slag applied at rate of 2,000 pounds per acre in 1930, 1936, and 1942.

resulted in an increase in available phosphorus for both soils. In case of the Greenville soil, A values showed that superphosphate had a greater residual availability than rock or colloidal phosphate applied at same rate of P_2O_5 but not as great as basic slag. A values for the Decatur soil indicate that superphosphate had about the same residual availability as tricalcium phosphate and rock phosphate at same rate but less than basic slag. Residual availability of rock phosphate as measured by A values increased with increasing rates applied.

The extractable phosphorus data on samples collected at end of the residual period, Table 5, show that all sources applied at 48 pounds of P_2O_5 or more per acre annually from 1930 to 1945 resulted in some accumulation over unphosphated plots. Even the 24-pound rate of superphosphate resulted in some accumulation in the Greenville soil. Amount of phosphorus extracted by the three solutions varied with source. For example, neutral NH_4F solution extracted more phosphorus from the soil that had previously received 48 pounds of P_2O_5 from superphosphate than did dilute acid solution. However, the reverse was true for soils that had previously received an equivalent amount of P_2O_5 from

TABLE 5. RESIDUAL EFFECTS OF PHOSPHORUS SOURCES AS MEASURED BY A VALUES FOR COTTON IN 1950 AND 1951 AND ANALYSIS OF SOIL SAMPLES COLLECTED IN 1950

Source of phosphorus	P_2O_5 per acre applied annually 1930-45	Greenville fine sandy loam, Prattville Experiment Field				Decatur silt loam, Tennessee Valley Substation			
		Average A values, P_2O_5/acre 1950-51	P_2O_5 per acre extracted from samples collected in 1950			Average A values P_2O_5/acre 1950-51	P_2O_5 per acre extracted from samples collected in 1950		
			Dilute acid	Neutral NH_4F	HCl-NH_4F		Dilute acid	Neutral NH_4F	HCl-NH_4F
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Superphosphate	24	110	124	412	1,108	76	38	108	348
Superphosphate	48	213	210	590	1,362	176	100	220	626
Conc. superphosphate	48	118	160	522	1,184	175	70	208	528
Basic slag	48	400	274	494	1,432	229	94	212	624
Ppt. trical. phos.	48	207	190	360	1,170	159	62	128	438
Ammo.-phos. A	48	139	274	672	1,402	259	108	256	685
Colloid. phosphate	48	137	356	320	1,324	194	136	176	600
Rock phosphate	48	132	384	228	1,336	161	112	170	626
Rock phosphate	96	176	888	288	2,002	253	340	190	924
Superphosphate[1]	24	261	1,008	504	2,274	313	244	208	748
Superphosphate[2]	24	306	236	538	1,472	179	62	168	472
Average of check plots	0	79	70	230	930	58	40	114	342

[1] In addition to superphosphate, rock phosphate applied at rate of 2,000 pounds in 1930, 1936, and 1942.
[2] In addition to superphosphate, basic slag applied at rate of 2,000 pounds in 1930, 1936, and 1942.

rock phosphate. Evidently, much of the rock phosphate remained in the soil in unreacted form and was easily acid-soluble. Thus, values based on acid extractants are likely to be high in terms of residual availability where rock phosphate has been used. Soil samples were analyzed for HCl-NH_4F-soluble phosphorus, since previous data *(1)* showed that such an extraction gave a good measure of the quantity of phosphorus that had accumulated in sandy soils. This extraction indicates that only 56 per cent of the phosphorus from the 48-pound rate of superphosphate applied to Greenville soil had accumulated. Loss of phosphorus by erosion *(1)* is undoubtedly a big factor in lowering the efficiency of applied phosphorus.

Residual Effects of Superphosphate Applied to Soils in Cement Bins

Surface soil from Norfolk sandy loam, Eutaw clay, and Cecil sandy loam was brought to Auburn in 1934 and placed in 11- × 6-foot cement bins to a depth of 8 inches. From 1934 to 1947 the bins were used for rates of phosphorus and residual studies with vegetable crops *(12)*. This was followed by a study of residual value of phosphorus for cotton from 1948 to 1950. During 1954 and 1955 the bins were used to study the relationship between

TABLE 6. RESIDUAL EFFECTS OF SUPERPHOSPHATE AS INDICATED BY YIELDS OF SEED COTTON GROWN IN CEMENT BINS, 1948-50

P_2O_5 per acre applied annually[1]			Average per acre yields of seed cotton			Dilute acid-soluble P_2O_5 per acre		
1934-42	1943-47	1948-50	Norfolk sandy loam	Eutaw clay	Cecil clay loam	Norfolk sandy loam	Eutaw clay	Cecil clay loam
Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
0	0	0	353	1,318	326	42	32	18
80	40	20	653	1,869	1,058	67	76	53
160	80	40	871	1,975	1,433	96	214	116
240	120	60	1,109	2,055	1,583	148	360	221
320	160	80	1,219	2,172	1,642	176	502	337
320[2]	160	80	1,508	2,125	1,659	304	548	478
80	0	0	473	1,829	810	62	29	34
160	0	0	605	1,935	1,275	82	62	79
240	0	0	766	2,019	1,425	102	114	141
320	0	0	832	1,870	1,351	152	188	208
320[2]	0	0	1,378	2,155	1,685	254	309	296
L. S. D.	0.01		358	269	475			
	0.05		254	191	336			

[1] Norfolk soil received only half as much P_2O_5 for the first 2 periods.
[2] Limed in 1934 and in 1939. Norfolk received 2,995 pounds of lime, Eutaw 5,580, and Cecil 2,617.

soluble phosphorus as determined by soil test methods and Ladino clover yields *(14)*.

COTTON YIELDS. Average yields of seed cotton for the three soil types are given in Table 6. All three soils showed an appreciable response to applied phosphorus. Residual effects from superphosphate applied from 1934 to 1942 were also appreciable and were in proportion to the amounts that had been applied. The highest residual phosphorus treatments produced 68, 82, and 86 per cent as much cotton as an 80-pound annual P_2O_5 treatment for Norfolk, Cecil, and Eutaw, respectively. Where lime had been applied, yields from residual phosphorus were 91, 100, and 100 per cent for Norfolk, Cecil, and Eutaw, respectively. It should be pointed out that the Norfolk received only half as much phosphorus as the other two soils before phosphorus was discontinued.

LADINO CLOVER YIELDS. In the fall of 1953, 1 ton of lime per acre was applied to the Cecil and Norfolk bins and 2 tons to the Eutaw bins. Four bins of each soil that had received the highest rate of superphosphate during the period 1934 to 1950 received 160 pounds per acre P_2O_5 annually from superphosphate in 1953 and 1954. Yields from the phosphated bins represent 100 per cent yields and all other yields are relative to those from the phosphated bins. Ladino clover was seeded in October 1953 and clippings were made for 2 years.

Relative yields of Ladino clover, Table 7, showed appreciable

TABLE 7. RESIDUAL EFFECTS OF SUPERPHOSPHATE AS INDICATED BY RELATIVE YIELDS OF LADINO CLOVER GROWN IN CEMENT BINS, 1954-55

P_2O_5 per acre applied annually[1]			Relative yields (phosphated bins = 100)[2]			P_2O_5 per acre by soil test		
1934-42	1943-47	1948-50	Norfolk sandy loam	Eutaw clay	Cecil clay loam	Norfolk sandy loam	Eutaw clay	Cecil clay loam
Lb.	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*
0	0	0	46	18	4	64	18	17
80	40	20	65	63	40	104	43	44
160	80	40	86	79	68	183	138	98
240	120	60	97	88	78	258	260	229
80	0	0	54	44	25	77	33	29
160	0	0	54	75	52	121	64	57
240	0	0	76	78	69	190	131	115
320	0	0	80	84	74	248	203	191
320	0	0	95	95	88	287	153	229

[1] Norfolk soil received only half as much P_2O_5 for first 2 periods.
[2] 100 per cent yields are: Norfolk = 9,954, Eutaw = 10,691, and Cecil = 9,394 pounds of dry matter for the 2-year period.

residual effects of past applications of superphosphate. In general, residual effects as measured by clover yields were greater for the Norfolk and Eutaw soils than for the Cecil. On the Norfolk soil almost as much clover was produced by the high residual phosphorus treatment as by the treatment that received 160 pounds P_2O_5 from superphosphate.

SOIL TEST VALUES. For residual phosphorus to be used efficiently, it is necessary to have a rapid chemical method of assaying availability of accumulated phosphorus. If chemical extraction data are to have any value in this regard, they must be correlated with yield response. The extractable phosphorus data presented in Tables 6 and 7 show that past phosphorus treatments are reflected by the amount of phosphorus extracted and yields of cotton and clover are related to past applications of phosphorus and to extractable phosphorus.

Soil samples from the clover experiment were analyzed for extractable phosphorus by three different solutions. The results were related to relative yields of clover as shown in Table 8. The amounts of soil test P_2O_5 required to give specified relative yields were calculated for five classes. The 0.03N NH_4F + 0.1N HCl solution extracted much more phosphorus than either of the other two solutions. However, the degree of correlation between

TABLE 8. DIVISION OF SOIL TEST VALUES FOR PHOSPHORUS INTO CLASSES ON THE BASIS OF SOIL TEST REQUIRED TO GIVE SPECIFIED RELATIVE YIELDS OF LADINO CLOVER

Soil type	Relative yield[1]	Amount of P_2O_5/A. required as determined by:		
		$NaHCO_3$	$HCl + H_2SO_4$	$NH_4F + HCl$
	$\leq$ 25	$\leq$ 32	$\leq$ 29	144
Cecil	26-50	33- 77	30- 69	145- 312
	51-75	78-189	70-167	313- 678
	76-90	190-317	168-282	679-1081
	$>$ 90	$>$ 317	$>$ 282	$>$ 1081
Eutaw	$\leq$ 25	$\leq$ 15	$\leq$ 16	$\leq$ 80
	26-50	16- 41	17- 43	81- 198
	51-75	42-112	44-116	199- 491
	76-90	113-203	117-210	492- 846
	90	203	210	846
	$\leq$ 25	$\leq$ 32	$\leq$ 36	$\leq$ 190
Norfolk	26-50	33- 65	37- 75	191- 365
	51-75	65-128	76-157	366- 701
	76-90	129-193	158-246	702-1037
	$>$ 90	$>$ 193	$>$ 246	$>$ 1037

[1] For Cecil, Eutaw, and Norfolk, 100 per cent yields were 9,394, 10,691, and 9,954 pounds of dry matter per acre for the 2-year period, respectively.

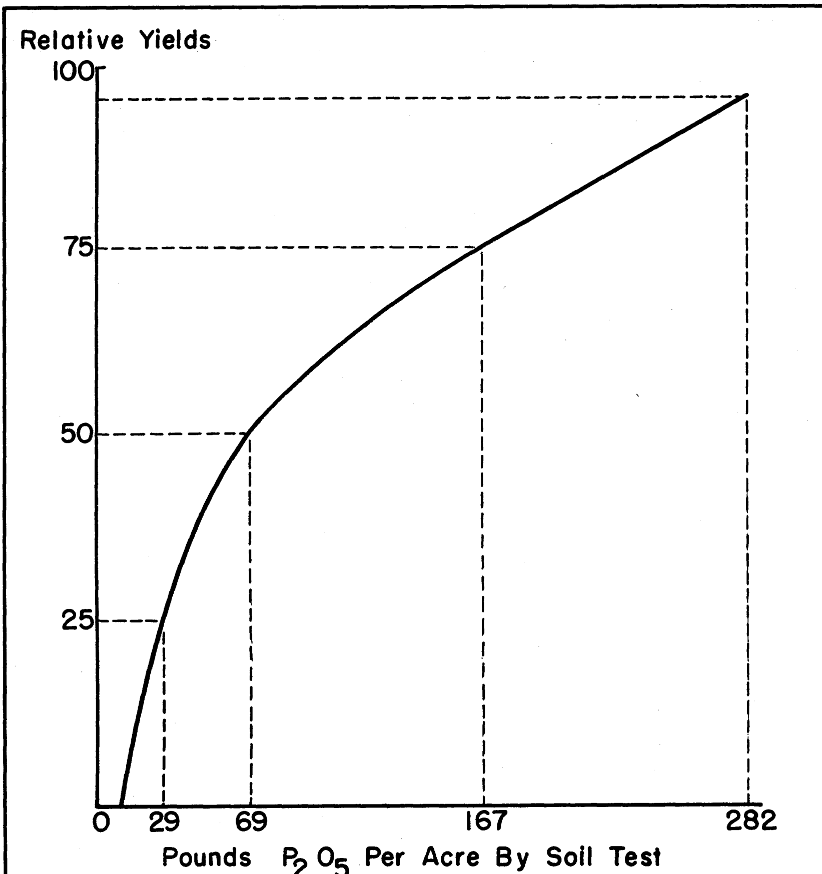

FIGURE 4. Division of soil test values into classes on basis of values required to give specific relative yields of Ladino clover is presented in the graph. Data are from Table 8 for Cecil clay loam and 0.05N HCl + 0.025N H_2SO_4 solution.

amounts extracted and relative yields is the important thing. All three solutions gave a high degree of correlation with relative yields. This points out the necessity of correlating chemical soil test values with yields if chemical tests are to have value in making fertilizer recommendations.

A graphical presentation of the classes for the 0.05N HCl + 0.025N H_2SO_4 extraction for the Cecil soil, taken from data in Table 8, is given in Figure 4. These data show that residual phosphorus influences clover yields and that yields are related to chemical soil tests. However, for a complete evaluation of soil test data, response of clover to rates of phosphorus on soils with various residual phosphorus levels should also be known. With this information at hand, it would be possible to predict the amount of phosphorus that should be added to raise relative yields to the desired level.

GENERAL DISCUSSION

The phosphorus status of Alabama soils has changed considerably as a result of past fertilization. Most soils of the State were deficient in available phosphorus when first cleared and as a result phosphorus fertilization was generally needed. Now the soils range from low to very high in available phosphorus, depending on past treatment. This means that a general recommendation will not fit as many of the soils now as it did earlier.

Even though processed phosphates become chemically fixed when applied to soils, yield data have shown that the accumulated phosphorus is of considerable value and that it should be considered in making fertilizer recommendations. Since it is impractical to determine crop response on every field, soil testing appears to be the most practical way of making best use of residual phosphorus. Numerous extraction methods can be used to give an index of available phosphorus if properly calibrated against yield response in the field.

Soil testing should be considered as a means of extending the usefulness of field data. It is doubtful if any soil testing method will give an exact measure of available phosphorus in a soil. However, to know that a soil is either low, medium, or high in available phosphorus is helpful in making fertilizer recommendations. It is emphasized that it is seldom advisable to discontinue phosphorus fertilization for most crops even though the soil test for phosphorus is high.

It is often suggested that raw phosphates may have a greater cumulative or residual effect than processed phosphates. Results from experiments conducted for a period of 16 years do not indicate any appreciable cumulative effect for raw phosphates. Results for a 4-year residual period varied with location. In the case of a Greenville fine sandy loam, the residual effects of raw phosphates in some instances exceeded those of an equal amount of P_2O_5 from superphosphate. On a Decatur silt loam, superphosphate was superior to raw phosphates during the phosphating period as well as during the residual period. The residual effect of basic slag was high on both Greenville and Decatur soils. Since basic slag is also a liming material, it is difficult to determine how much of the residual effect resulted from phosphorus and how much from lime.

SUMMARY

Numerous field tests have been conducted since 1930 to determine the residual value of phosphorus in terms of crop yields. In many cases extractable phosphorus was correlated with yields for calibrating soil test methods. Radiophosphorus has also been used to evaluate the availability of accumulated phosphorus in soils.

Results of residual phosphorus studies to date are summarized as follows:

1. Soil analysis data showed that applied phosphorus accumulated in soils and the extent of accumulation was in proportion to the amount applied.

2. Yields of cotton, vetch, and Ladino clover showed residual effects that were directly related to past phosphate fertilization. Where moderate amounts of phosphorus had been applied, crop yields usually decreased when application was discontinued. Where high amounts of phosphorus had accumulated, yields were not reduced much when phosphorus was discontinued.

3. Considerable residual effects were obtained from all sources studied as measured by crop yields. For any particular source, the residual effect was directly related to the amounts that had been added. Basic slag gave the greatest residual effect of any of the sources.

4. Even though accumulated phosphorus is chemically fixed by soils, yield data show that it is of considerable value in crop production and should be considered in making fertilizer recommendations.

5. Extractable phosphorus content of soils was directly related to yield response to residual phosphorus. This relationship is the basis for making phosphorus fertilizer recommendations by soil test.

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