is at a higher concentration than recommended for agricultural practices (7).

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Table IV. Summary of Gibberellic Acid Residues in Grapes

Sample	Days after Application	Bioassay, P.P.M.	Isotope Analysis, P.P.M.	Recovery, %
Thompson seedless, Indio				
Control	0	0.024[a]	..	....
Gibberellic acid	0	2.60	..	....
H^3-gibberellic acid	0	1.79	3.320	....
Control	34	0.00[b]	..	....
Gibberellic acid	34	0.021	..	....
H^3-gibberellic acid	34	0.025	0.086	....
Thompson seedless, Davis				
Gibberellic acid	62	0.024	..	....
H^3-gibberellic acid	62	0.008	0.032	....
Control	..	0.00[b]	..	....
Control + 0.1 p.p.m. GA	0	0.24	0.056	120% (bioassay)
Control + 0.1 p.p.m. H^3-GA				56% (isotope analysis)
Black Corinth, Davis				
Control	0	0.32[a]	..	....
Gibberellic acid	0	0.75	..	....
H^3-gibberellic acid	0	4.33	12.630	....
Control	78	0.00[b]	..	....
Gibberellic acid	78	0.019	..	....
H^3-gibberellic acid	78	0.008	0.028	....

[a] Not significant—Duncan's test (5% level). [b] Less than 0.002 p.p.m.

Table V. Gibberellic Acid Residue Analysis by Isotope Counting

Initial deposit, Thompson Seedless, April 30, 1958

Sample	Aliquot Counted, G.	Counts per Minute: Sample, net	Counts per Minute: Standard net	H^3-Gibberellic Acid Added, γ	Gibberellic Acid Found, P.P.M.
I A	0.029	2014	25,689	1.23	3.36
I B	0.029	2060	28,148	1.14	3.12
II A	1.00	569	203	1.14	3.23
II B	1.00	566	195	1.23	3.58

LEACHED ZONE PHOSPHATES

Initial and Residual Effectiveness of Two Leached Zone Phosphate Fertilizers

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Two NPK fertilizers prepared from Florida leached zone phosphate were compared with concentrated superphosphate for successive crops of Sudangrass, wheat, and Sudangrass in greenhouse and field experiments. The two leached zone fertilizers differed in the water solubility of their available phosphorus content, 4 and 32%. The available phosphorus was citrate-soluble. The initial effectiveness, as measured by the first-crop yields of Sudangrass, was related to water solubility; the 4% fertilizer was less effective than and the 32% fertilizer was comparable to concentrated superphosphate. No differences were found in residual effectiveness for the second or the third crop.

THE LEACHED ZONE ORES overlying the phosphate rock in the Florida deposits have been used by the Tennessee Valley Authority in the production of nitric phosphate fertilizers. The methods of fertilizer manufacture have been described in detail by Hignett *et al.* (2). The phosphate in the ores is present primarily as the minerals wavellite and pseudowavellite, although some ores contain varying amounts of apatite.

Starostka, Norland, and MacBride (4) reported that a leached zone fertilizer in which 6.7% of the available phosphorus was water-soluble was less effective than concentrated superphosphate, but one with 21% water-soluble phosphorus was comparable to concentrated superphosphate. DeMent and Seatz (1) concluded from the results of a number of field and greenhouse experiments that leached zone fertilizers were satisfactory sources of phosphorus for cotton, small grain, and corn, even though they were somewhat less effective than concentrated superphosphate.

The experiments reported were conducted to measure both the initial and residual effectiveness of the leached zone fertilizers as compared with concentrated superphosphate in greenhouse and field experiments.

Experimental Procedure

Similar field experiments were con-

Table I. Location and Some Chemical and Mineralogical Properties of Soils

Soil Type, Silt Loam	State	pH of Unlimed Soil	Soluble Phosphorus, P.P.M. 0.002N H_2SO_4 (Truog)	0.01N HCl: 0.03N NH_4F (Bray)	0.5N $NaHCO_3$ (Olsen)	Estimated Minerals in Clay Fraction,[a] % Vermiculite	Kaolinite	Illite	Quartz	V/M[b]
Tilsit	Kentucky	5.3	8.0	9.3	5.0	25–50	25–50	10–25	>10	10–25
Sequoia	Tennessee	5.2	0.7[c]	...	...	...	...	...	...	...
Nason	Virginia	5.1	5.0	5.0	5.0	45	25	15	15	...

[a] Clay mineral determination made by C. I. Rich, Agronomy Department, Virginia Polytechnic Institute.
[b] Interstratified vermiculite and montmorillinite.
[c] Extracted with 0.05N H_2SO_4, containing 1% $(NH_4)_2SO_4$, 1:4 soil-solution ratio.

Table II. Chemical Composition of Fertilizers

Fertilizer	Symbol	Nominal Grade	N, %	P_2O_5, % Total	Available[a]	Water-soluble, % of available	K_2O, %
Leached zone							
Low water-soluble	LZ-LWS	15-15-15	15.1	15.1	14.8	4.1	15.0
High water-soluble	LZ-HWS	13-16-14	13.2	16.9	16.6	31.9	14.3
Concentrated superphosphate	CSP	0-47-0	...	48.7	47.3	92.4	...

[a] Soluble in neutral ammonium citrate.

Table III. Yields of No-Phosphorus Treatment

Soil	Yield[a] 1st crop (Sundangrass)	2nd crop (wheat)[b]	3rd crop (Sudangrass)	Total
	Field Experiments			
Sequoia	5.2	16.6	6.9	28.7
Tilsit	26.9	7.9	28.8	63.6
	Greenhouse Experiments			
Nason	15.4	19.9	30.3	65.6
Sequoia	13.3	5.0	5.7	24.0
Tilsit	4.4	4.8	7.2	16.4

[a] Cwt. per acre in field, grams per pot in greenhouse.
[b] Grain in field, forage in greenhouse.

ducted in Kentucky and Tennessee and similar greenhouse experiments in Kentucky, Tennessee, and Virginia. The analyses of the soils used are given in Table I.

Two leached zone fertilizers were used —one in which approximately 4% of the available phosphorus was in water-soluble form (LZ-LWS) and the other in which approximately 32% was in water-soluble form (LZ-HWS). Concentrated superphosphate (CSP) was included as a standard source of phosphorus. The analyses of the fertilizers are given in Table II.

The field plots were arranged in a randomized block design, with four replications of each treatment. There were three replicates in the greenhouse pot experiments. In the field experiments, Sudangrass was seeded in spring of 1955, wheat in fall of 1955, and Sudangrass again following wheat harvest in 1956. The same cropping sequence was followed in the greenhouse. All of the phosphorus was applied to the first Sudangrass crop and no additional phosphorus was applied to the succeeding crops. Phosphorus was applied as concentrated superphosphate at rates of 20, 40, 80, and 120 pounds of phosphate (P_2O_5) per acre in all experiments, except in the greenhouse experiment in Kentucky, where 80, 160, 320, and 480 pounds of phosphate per acre were applied. Leached zone fertilizers were applied at rates to supply 20 and 40 pounds of phosphate per acre except in the greenhouse experiment in Kentucky, where 80 and 160 pounds were applied. In a check treatment, no phosphorus was applied. Nitrogen and potash were applied at rates of 100 pounds of nitrogen (N) and 100 pounds of potash (K_2O) per acre to the first Sudangrass crop, 45 pounds of nitrogen and 60 pounds of potash to wheat, and 100 pounds of nitrogen and 60 pounds of potash to the second Sundangrass crop. Ammonium nitrate and potassium chloride were used to supply all the nitrogen and potassium in the concentrated superphosphate and no-phosphorus treatments and to supplement the leached zone fertilizers so that equal amounts of nitrogen and potassium were applied to all plots.

The soils were limed as follows: 3 tons of limestone per acre in Kentucky, 2 tons in Tennessee, and 10 tons in Virginia. All fertilizers and lime were broadcast and disked into the surface soil in the field and were mixed thoroughly with the soil in the greenhouse.

The data from the different experiments were analyzed by means of the analysis of variance, and comparisons between means calculated as described by Snedecor (*3*). The yield curves for the various rates of concentrated superphosphate are presented to show the type of response obtained for phosphorus. The combined statistical analyses showed no interactions between source and rate of the leached zone fertilizers, and indicated that they behaved similarly on the different soils. Therefore, the yields for each leached zone fertilizer are presented as the average relative yield of the two rates (calculated as per cent of concentrated superphosphate) for each location and as the average relative yield of each fertilizer at all locations.

Experimental Results and Discussion

Field Experiments. The actual yields obtained on the no-phosphorus treatments are given in Table III. Average yield increases obtained with phosphate on Tilsit and Sequoia soils (Figure 1, left) indicate a response to each increment of applied concentrated superphosphate. The total yield of the three crops is the sum of the Sudangrass yields of the first and third crops plus the yield of wheat grain (in hundredweights per acre). For each soil, comparison of the response curves for the yield of the first crop with that for the total yields of the three crops indicates that initial applications of concentrated superphosphate increased yield in the second and third crops.

As shown in Table IV, yields of the first Sudangrass crop were consistently lower with the leached zone fertilizer than with concentrated superphosphate.

Greater differences were obtained on Sequoia than on Tilsit soil. Lower yields were obtained with leached zone fertilizer of 4% water solubility than with that of 32% solubility. No significant differences between sources of phosphorus were obtained for wheat or for the second Sudangrass crop, nor were any consistent trends evident.

The phosphorus content of the first Sudangrass crop was determined, but the percentage of phosphorus in the plant was not affected by the source of phosphorus at either location. Because the total uptake of phosphorus was closely correlated with yields, the results of the chemical analyses are not given.

Greenhouse Experiments. Phosphorus was applied at the same rate in the greenhouse as in the field, except on Tilsit soil, where four times as much phosphorus was applied as in the field. Yields obtained on the no-phosphorus treatments are also given in Table III. Phosphorus applications tended to increase yields on all soils throughout the experiment (Figure 1, right). As in the field experiments, the second and third crops showed a residual response to the initial phosphate applications.

Table IV. Relative Yields Obtained with Leached Zone Fertilizers

Source of Phosphorus	Soil	Average Relative Yield, % CSP: 1st crop (Sudangrass)	2nd crop (wheat)	3rd crop (Sundangrass)	Total of 3 crops
		Field Experiments			
LZ-LWS	Sequoia	62[a]	113	91	84
	Tilsit	95	97	102	98
	Av.	79[a]	105	97	91
LZ-HWS	Sequoia	81[a]	117	90	93
	Tilsit	96	98	103	100
	Av.	89[b]	108	97	97
		Greenhouse Experiments			
LZ-LWS	Nason	88	106	107	98
	Sequoia	88[a]	92	101	90[a]
	Tilsit	64[a]	88	85	79[a]
	Av.	80[a]	95	98	89
LZ-HWS	Nason	97	96	108	99
	Sequoia	110[a]	83[b]	90	102
	Tilsit	82[a]	96	104	94
	Av.	96	92	101	98

[a] Differed significantly from CSP at 1% level.
[b] Differed significantly from CSP at 5% level.

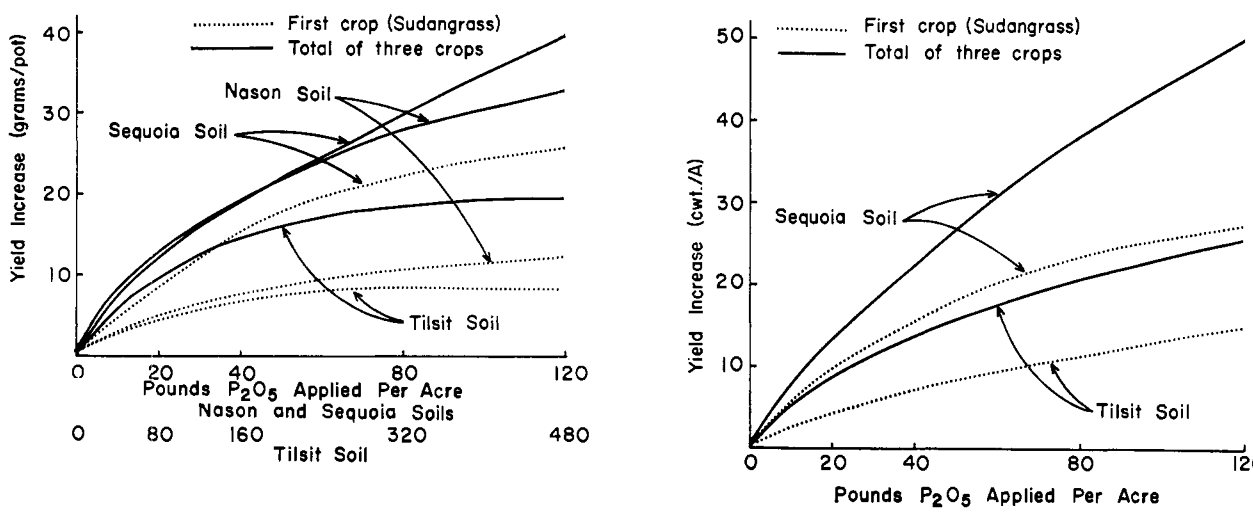

Figure 1. Effect of increasing rates of concentrated superphosphate on increases in yield over no-phosphorus treatments
Left: Field experiments Right: Greenhouse experiments

The relative yields obtained with the leached zone fertilizers in the greenhouse are also given in Table IV. Yields of the first crop tended to be lower on all soils with the fertilizer of 4% solubility than with one of 32% solubility or with concentrated superphosphate. No consistent trends were apparent between concentrated superphosphate and the fertilizer of 32% solubility. No significant differences in wheat yields were noted on Nason and Tilsit soils, but concentrated superphosphate appeared to be superior to the leached zone fertilizer of 32% solubility on Sequoia soil. For the second Sudangrass crop, no significant differences between sources of phosphorus were obtained, although yields tended to be lower with the fertilizer of 4% solubility than with that of 32% solubility on concentrated superphosphate on Tilsit soil. The total yields with the leached zone fertilizer of 4% solubility on Sequoia and Tilsit soils were significantly lower than those with concentrated superphosphate. As no differences between these two sources were obtained for the second and third crops, this difference in total yield must be due to the lower yields of the first crop. The phosphorus content of the first Sudangrass crop in the greenhouse was also determined but, as in the field plots, no additional useful information was obtained.

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