IOWA STATE UNIVERSITY

AGRONOMY
• Crops
• Soils
• Climate

Fertilizer Phosphorus—Use It Efficiently

Applications of fertilizer phosphorus to Iowa soils deficient in phosphorus continue to give profitable crop yield increases. Economically optimum rates of fertilizer phosphorus—rates that give maximum net profit per acre—generally exceed crop removal of phosphorus on low testing soils. This results in a buildup of soil phosphorus which is reflected in higher soil test values.

As soil test values for phosphorus increase, available soil phosphorus increases and economic optimum rates of fertilizer phosphorus decrease. **Soil testing** is the best tool to detect these desirable changes. When fertilizer phosphorus is in short supply or the cost of fertilizer relative to the crop price increases, efficient use of fertilizer phosphorus is an advantage to all crop producers.

This publication discusses the effect of fertilizer phosphorus additions on soil test values, crop response to fertilizer phosphorus at different soil test values, and efficient use based on **soil testing.**

Fertilizer Phosphorus Use in Iowa

Fertilizer phosphorus was used rather sparingly in the 1940's and 1950's. Initial use was often on forage legumes that were grown in rotation with corn and oats. For a variety of reasons use increased dramatically during the 1960's and peaked in 1971 at more than 400,000 tons of P_2O_5. This level of use is being maintained as shown in table 1. The 1967 crop year was the first time that fertilizer phosphorus use exceeded the estimated removal of phosphorus in all harvested crops. Current use still exceeds estimated crop removal, but higher crop yields and increased row crop acreages in recent years are decreasing the net difference.

Phosphorus applied to the land in manure has not been considered here. It would make the net additions increase greatly because a gross estimate of the amount of phosphorus applied in manure in recent years is 40 percent of that applied annually as fertilizer phosphorus.

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Soil Phosphorus Buildup

As a consequence of applying more phosphorus to the land than is being removed, an increase in soil test values would be expected. Table 2 gives the percentage of soil samples sent to the Iowa State University Soil Testing Laboratory for testing in various categories for selected time periods.

These figures indicate some movement from the very low and low testing category to higher testing categories. However, over half of the samples still test low to very low, indicating that many Iowa fields will respond profitably to high rates of fertilizer phosphorus. These summary data also suggest that fields which test high to very high may still be receiving buildup rates of fertilizer phosphorus, although such rates are not profitable.

Table 3 shows the effect on soil test values of applying different rates of fertilizer phosphorus to continuous corn annually over an 8-year period. Although the 35-pound-per-acre rate of P_2O_5 was less than annual crop removal, a small increase in the soil test value for the plow layer resulted. At the 70-pound-per-acre rate of P_2O_5, which definitely exceeded annual crop removal, soil test values increased 24 pounds on the Galva silt loam soil and 42 pounds on the Nicollet silt loam soil. Adding these values to the beginning soil test values of 15 pounds per acre gives soil test classes of medium and high, respectively, for the two soil types (according to the interpretation given in table 4 for soil test values).

Note that essentially doubling the annual 70-pound rate of P_2O_5 per acre to near 140 pounds gave a threefold increase in soil test values, placing

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both soil types in the very high soil test category at the end of the 8-year period.

The effect of fertilizer phosphorus additions on soil test values was much greater on the Nicollet soil than on the Galva soil (table 3). This indicates the difficulty in predicting for all soils how much fertilizer phosphorus is needed to raise the soil test value a given amount. At the rate of 104 pounds P_2O_5 per acre applied annually over the 8-year period on the Galva silt loam soil, it required 18 pounds of P_2O_5 (8 pounds of P) to raise the soil test value an average of 1 pound of P. For the Nicollet silt loam, it required 10 pounds of P_2O_5 (4 pounds of P) to raise the soil test value by 1 pound of P. The difference between the two soils in these experiments is thought to be due in part to the slightly higher soil pH of 6.2 for the Nicollet silt loam compared to a soil pH of 5.8 for the Galva silt loam. At the higher soil pH, more soil phosphorus is made available as measured by the soil test.

As a rule of thumb, annual additions exceeding 45 pounds of P_2O_5 per acre to continuous corn or other Iowa crops will measurably increase the soil test level. Additions of fertilizer phosphorus once in a crop sequence will have to average 45 or more pounds of P_2O_5 per crop year to have a similar effect.

Response to Fertilizer Phosphorus

As soil test values increase, the yield response to additions of a given rate of fertilizer phosphorus decreases. As the data in table 5 show, the corn yield response to additions of fertilizer phosphorus was small or nil on high testing soils. As soil test values reach the high range, rates of fertilizer phosphorus can profitably be reduced.

Crop yields do increase as soil test phosphorus increases from very low and low to the high range. The important decision is how to most profitably increase the soil test level and then maintain it at the medium to high level over time. Annual economic optimum rates will increase soil test phosphorus on low and very low testing soils. Maintenance rates, essentially equal to crop removal, are designed to maintain a given soil test level. Suggested maintenance rates are given in table 6 for yield increments of the major Iowa crops.

Crop Production Practices

Two production practices, which can easily be done by crop producers, can help attain efficient utilization of phosphorus.

Liming acid soils will increase availability of soil phosphorus. Data shown in table 7 from a long-term rock-superphosphate experiment with two soil pH levels indicate that raising the soil pH increases the availability of soil phosphorus, thus increasing crop yields. Yield responses to fertilizer phosphorus have tended to be smaller on the limed plots, also suggesting increased availability of soil phosphorus from liming.

A row or starter application of fertilizer phosphorus on corn can be an efficient use of small amounts, particularly on poorly drained soils. Corn yield increases above the check yield given in table 8 for three locations show for two of the locations an advantage for row placement of a portion of the fertilizer phosphorus. On a well-drained soil on the Galva-Primghar Experimental Farm the row placement performed similar to the broadcast placement, that is, a smooth yield response curve to fertilizer rates was obtained. On poorly drained soils on the Clarion-Webster and Carrington-Clyde Experimental Farms, however, responses to a small amount of P_2O_5 applied as a row placement in addition to the broadcast treatment were greater than responses obtained from a larger additional amount broadcast.

Row placement, particularly on poorly drained soils that tend to remain cool in the spring, can be an efficient method for small amounts of fertilizer phosphorus on low testing soils or for maintenance amounts on higher testing soils.

Efficient Use

Efficient use of fertilizer phosphorus can only be done on the basis of need. **Soil testing** is the best tool for determining that need. Whether the consideration is allocation of limited amounts of fertilizer phosphorus, concern about crop production costs, or concern about the fertilizer-crop price ratio, **soil testing** is the fairest method to determine the amount of fertilizer phosphorus for any given field.

From fertilizer use and soil test summary data, it appears that either soil test levels are increasing in the same fields or more fields are testing higher. Crop response data from field experiments show little or no yield response to broadcast fertilizer phosphorus additions on soils testing high or very high. On the high testing fields, fertilizer phosphorus additions should not exceed maintenance levels. Application of fertilizer phosphorus which exceeds maintenance rates on high testing soils is an inefficient use and only increases the cost of production. **Soil testing** is the only method to determine the current level of available soil phosphorus.

Steps to consider for efficient use of fertilizer phosphorus:

— Test soil.

— Lime acid soils.

— Apply available fertilizer phosphorus to very low and low testing fields first.

— Use row application for small amounts, particularly on poorly drained soils.

— Use no more than maintenance amounts on high testing soils.

— Apply none, except possibly a small amoun in a row fertilizer, on very high testing soils.

Table 1. Fertilizer phosphorus use and estimated crop removal in Iowa for selected years. All figures are in terms of P_2O_5 for direct comparisons.

Year	Fertilizer used, tons P_2O_5	Phosphorus removed in crops expressed as tons P_2O_5	Use minus removal, tons P_2O_5
1940	2,720	150,437	-147,717
1950	52,996	168,869	-115,873
1960	115,070	236,472	-121,402
1970	411,261	287,244	124,017
1971	422,566	334,629	87,937
1972	402,108	355,344	46,764
1973*	407,800	384,514	23,286

*Preliminary.

Table 2. Percentage of soil samples analyzed by the Iowa State University Soil Testing Laboratory testing in various categories for phosphorus in different time periods.

Soil test categories	1950's	1964-67	1968-73
Very low to low	67	60	52
Low medium to medium	24	20	25
High to very high	9	20	22

Table 3. Effect of annual fertilizer phosphorus additions on soil test values for continuous corn on two soil types over an 8-year period. The Galva silt loam is on the Galva-Primghar Experimental Farm, O'Brien County, and the Nicollet silt loam is on the Clarion-Webster Experimental Farm, Hancock County.

Annual additions of P (P_2O_5) lb./A	Total P (P_2O_5) applied over the 8-year period lb./A	Change in soil test phosphorus level, lb. P/A*	Annual change in soil test phosphorus values lb. P/A
Galva Silt Loam			
0	0	-2.2	-0.3
15 (35)	120 (275)	8.3	1.0
30 (69)	240 (550)	24.5	3.1
45 (104)	360 (825)	46.3	5.8
60 (138)	480 (1100)	73.7	9.2
Nicollet Silt Loam			
0	0	-3.5	0.4
15 (35)	120 (275)	14.9	1.9
30 (69)	240 (550)	42.4	5.3
45 (104)	360 (825)	80.6	10.1
60 (138)	480 (1100)	129.0	16.1

*Both soil types tested 15 lb. P per acre at the beginning of the experiments.

Table 4. Interpretation of soil test values into soil test classes.

Soil test value, lb. per acre or parts per 2 million	Soil test class
Less than 15	Very low
16-25	Low
26-35	Low-medium
36-45	Medium
46-75	High
More than 75	Very high

Table 5. Yield response of corn to 184 pounds of P_2O_5 at different soil test levels for phosphorus in 37 field experiments conducted on Iowa loess soils.*

	VL-L	L-M	M-H
Number of experiments	22	7	8
Number of positive yield responses	18	6	2
Number of negative yield responses	4	1	5
Average response, bu/A	13	5	-2
Average yield, bu/A—with P	121	131	134
Average yield, bu/A—without P	108	126	136

*160 pounds of N and 96 pounds of K_2O were also applied with and without the fertilizer phosphorus.

Table 6. Estimated maintenance amounts of fertilizer phosphorus for yield increments of Iowa crops.

Yield increment	Pounds of P_2O_5
20 bu. corn grain	7.5
20 bu. corn grain equivalent in silage	11
10 bu. soybeans	8
1 ton alfalfa	14
20 bu. oats + straw	8

Table 7. Average crop yields of a corn-oat-hay rotation for 1962-72 as influenced by broadcast applications of superphosphate and lime taken from a rock- and superphosphate experiment, Carrington-Clyde Experimental Farm, Buchanan County.

Additions of P (P_2O_5) per acre*	Soil pH	Corn bu/A	Oats bu/A	Hay tons/A
0	5.8	90	56	2.1
	6.5	110	60	2.6
20 (46)	5.8	116	62	2.9
	6.5	125	65	3.2
40 (92)	5.8	116	71	3.3
	6.5	126	67	3.3

*Applications of superphosphate are broadcast and made only to corn.

Table 8. Yield response of corn to row-applied phosphorus in addition to broadcast and plowed-under phosphorus fertilizer. Experiments are on the Clarion-Webster Experimental Farm, Hancock County, Galva-Primghar Experimental Farm, O'Brien County, and Carrington-Clyde Experimental Farm, Buchanan County.

Treatment (lb. P_2O_5 per acre)		Average yield increase, bu/A*		
Plowed-under	Row	C-W Farm 1957-72	G-P Farm 1957-73	C-C Farm 1962-72
0	23	20	11	15
46	0	33	16	26
46	23	40	19	31
92	0	37	22	26
92	23	41	23	33
138	0	35	20	29
138	23	43	21	34

*The difference between the pairs (0 and 23) is the effect due to row-applied fertilizer.

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