ECONOMICS OF A ONE-TIME PHOSPHORUS FERTILIZER APPLICATION[1]

Ardell D. Halvorson, Soil Scientist
USDA-ARS, Akron, Colorado

Alfred L. Black, Soil Scientist
USDA-ARS, Mandan, North Dakota

ABSTRACT

Grain yield and protein data from a soil fertility study initiated in 1967 and continued through 1983, on a Williams loam with a $NaHCO_3$ soil test P level of 6 ppm, was evaluated to determine the potential economic benefits of a one-time P fertilizer application under conditions of varying fertilizer N levels. Fertilizer N (0, 40, and 80 lb N/acre) was applied each crop year, except two, as main plots. Fertilizer P (0, 20, 40, 80, and 160 lb P/acre) was applied one time, at study initiation, as subplots in a split-plot design. Fertilization and interest costs, tax credit, and crop price were used to estimate the net dollar return from N and P fertilization. The most economical treatment was the one-time application of 80 lb P/acre plus 40 lb N/acre each crop year. This treatment returned a net of $18/acre per crop above that of the check plot when averaged over 11 crops and was profitable starting with the second crop. Generally, net returns increased as the level of initial P fertilizer application increased at all N rates. Premium payments for grain protein in hard red spring wheat in the northern Great Plains can potentially pay for 50 to 75% of the fertilizer N added.

OBJECTIVES

Wheat yields in the northern Great Plains are generally increased by P fertilization on soils testing "very low" and "low" in plant-available P, as has been demonstrated by numerous studies. Few of these studies have considered the economic benefits resulting from the positive effects of residual P fertilizer on crop yields. The current emphasis on the need for higher fertilizer rates to optimize grain yields necessitates that the short- and long-term economic impact of these fertilizer applications be evaluated. Recently, Halvorson and Black (1985a and 1985b) completed a long-term (17 years) residual P fertilizer study. Halvorson et al. (1986) also completed an economic analysis of this same P study. The objective of this paper is to present a brief summary of the yield and protein data and economic analysis presented in the above referenced studies.

MATERIALS AND METHODS

Grain yield and protein data were collected from 1967 to 1983 from 11 crops of a N and P fertilizer study conducted on a glacial till Williams loam

[1] Contribution from USDA, Agricultural Research Service. In Proceedings of 1986 Great Plains Soil Fertility Workshop, Denver, Colorado, March 4-5, 1986.

near Culbertson, MT. After the 6th crop in a crop-fallow sequence, the plots were annually cropped through 1983. Although safflower and barley were grown during the annual cropping phase of the study, they had yields in terms of pounds/acre equivalent to wheat. Therefore, to keep the analysis in wheat equivalents, the yields of safflower and barley were calculated based on 60 lb/bu grain test weight. However, only the protein data from the 8 wheat crops are included in this analysis.

Ammonium nitrate (0, 40, and 80 lb N/acre) was applied broadcast each crop year as main plots in a split-plot design, except to the 7th and 8th crops which were safflower and barley, respectively. By the end of the 6th crop-fallow cycle, residual NO_3-N had accumulated in the root zone of the 40 and 80 lb N/acre fertilizer treatments (Halvorson and Black, 1985c), and therefore, no additional N was applied to the 7th and 8th crops. Fertilizer P was applied only once, at initiation of each plot series in 1967 or 1968. The fertilizer P (0, 20, 40, 80, and 160 lb P/acre) was broadcast and incorporated with a disk to a depth of about 3 inches. All other tillage operations during the study were performed to a depth of 2 to 3 inches. This analysis represents the average results from these duplicate sets of plots.

The economic factors considered in this analysis included crop and fertilizer price, fertilizer application costs, protein premiums, federal income taxes, and real interest rates. A grain price of $3.30 was used because this is the average U.S. loan price for hard red spring wheat. A fertilizer cost of $0.47/lb P and $0.23/lb N with a broadcast application cost of $2.44/acre was used for the first year. All subsequent N fertilizer applications were assumed to be anhydrous ammonia ($0.16/lb N) with an application cost of $4.20/acre. A 6.25% real interest or discount rate was used, which is a 10.25% nominal interest rate minus a 4.00% inflation rate. A tax advantage was calculated assuming a 50% tax bracket for the 1st crop year and a zero percent tax bracket for crop-years 2 through 11. Protein premiums were calculated assuming a zero premium at 12% protein and a $0.46/bu premium at 17% protein with a linear relationship between this protein range, based on a 16-year average of protein premiums paid in North Dakota.

RESULTS

The average cumulative grain yield increase over that of the no fertilizer treatment for the 11 crops, used as the data base in this economic analysis, is shown in Table 1. The treatment with the greatest cumulative yield above that of the check was the single application of 160 lb P/acre plus the addition of 80 lb N/acre each crop year, except as noted. Following the 6th crop, the cumulative yields for the zero N plots showed little change and tended to decrease slightly during the annual cropping phase of this study.

Table 1. Wheat grain yield of the check treatment each crop year and cumulative yield above check with each additional crop year for the various N and P treatments.

Treatment N	Treatment P	Crop year 1	2	3	4	5	6	7	8	9	10	11
lb/acre		Check yield, bu/acre										
0	0	31	18	35	23	32	20	17	32	24	18	15
		Cumulative yield above check, bu/acre										
0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	6	7	8	9	14	16	17	16	17	16	14
0	40	7	12	16	18	25	27	31	30	30	29	28
0	80	8	13	19	22	32	38	42	40	41	39	38
0	160	10	18	27	31	41	48	52	51	53	49	50
40	0	-2	-1	1	1	6	4	10	7	12	23	28
40	20	7	14	15	15	23	23	33	34	40	52	56
40	40	12	20	26	30	44	50	59	59	65	78	86
40	80	12	24	36	45	65	79	88	91	98	112	119
40	160	13	27	39	48	70	87	96	100	110	125	133
80	0	-2	-0	1	0	8	7	17	17	21	33	42
80	20	7	11	15	15	26	28	38	38	43	55	61
80	40	10	18	28	31	46	53	63	65	70	84	93
80	80	11	25	38	45	64	77	86	86	93	109	118
80	160	12	27	42	50	69	89	100	103	114	132	142

The cumulative net returns above fertilizer costs, discounted at a rate of 6.25% but without any tax credits, are shown in Table 2. Without N fertilization, the 20 and 40 lb P/acre treatments were profitable in crop-yr 1, 80 lb P/acre in crop-yr 2, and 160 lb P/acre in crop-yr 3. The 40 lb N/acre treatment without fertilizer P was not profitable. With 40 lb N/acre each crop year, the 20 and 40 lb P/acre treatments were profitable in crop-yr 1, and the 80 and 160 lb P/acre treatments in crop-yrs 2 and 3, respectively. The 80 lb N/acre treatment without fertilizer P was not profitable. With 80 lb N/acre each crop year, the 40 and 80 lb P/acre treatments were profitable in crop-yr 2 and the 160 lb P/acre treatment in crop-yr 3. The 20 lb P/acre treatment did not become profitable until crop-yr 7 at the 80 lb/acre N rate. These data show that a good balance in both N and P is needed to achieve optimum economic returns. The one-time application of 80 lb P/acre plus 40 lb N/acre each crop year resulted in the highest average estimated net income, $18/acre per crop year above that of the check treatment.

On the assumption that a farmer had a high income situation in one year that extended him into the 50% tax bracket, we calculated an estimated net return with the tax savings. Without N fertilization, all P treatments were profitable the first year except 160 lb P/acre, which became profitable in crop-yr 2. The 40 and 80 lb N/acre treatments without P fertilization did not show a profit at any time. All treatments receiving fertilizer P showed a net profit in crop-yr 1 when 40 or 80 lb N/acre were added each crop year, except for the 160 lb P/acre plus 80 lb N/acre treatment which showed a profit in crop-yr 2. When considering the tax benefit, the 160 lb P/acre plus 40 lb N/acre treatment had the greatest long-term net profit above that of the check plot with an average net profit of $21/acre per crop year. Using this scenario, the tax savings could contribute greatly to the long-term net profits and make the economic returns to N and P fertilization even more profitable.

Table 2. Cumulative net dollar return above check plot for the various N and P treatments with each additional crop year with a 6.25% discount rate but without tax considerations.

Treatment		Crop year										
N	P	1	2	3	4	5	6	7	8	9	10	11
lb/acre		$/acre										
0	0	0	0	0	0	0	0	0	0	0	0	0
0	20	8	10	12	17	29	34	36	35	36	34	32
0	40	2	18	30	33	53	58	67	65	65	62	60
0	80	-14	1	20	27	53	68	76	73	75	71	69
0	160	-46	-20	7	17	42	60	69	67	71	65	66
40	0	-17	-23	-30	-39	-32	-45	-31	-37	-34	-17	-14
40	20	4	12	8	-0	12	3	27	29	37	54	54
40	40	8	25	33	34	63	69	88	90	98	116	124
40	80	-9	18	45	59	103	129	149	156	166	187	194
40	160	-43	-11	15	32	80	115	133	142	158	181	189
80	0	-28	-38	-49	-66	-60	-73	-51	-52	-51	-36	-30
80	20	- 9	-10	-16	-29	-14	-22	1	2	4	18	21
80	40	- 7	3	15	10	37	40	63	67	70	87	95
80	80	-23	4	27	34	68	89	108	109	117	137	144
80	160	-57	-25	3	10	47	83	107	115	131	155	164

The protein concentration in the grain generally decreased with increasing level of P fertilization for all N treatments. However, grain protein was increased significantly by N fertilization. The average (16 wheat crops) value of the protein per crop year above that of the check treatment is shown in Table 3. Without N fertilization, increasing the rate of P fertilization resulted in a greater net loss per acre because of the lower protein concentration in the grain than that of the check treatment. With N fertilization, the average value of protein per acre increased with increasing rate of P fertilization as a result of an increase in grain yield above that of the check. The 80 lb P/acre plus 80 lb N/acre treatment had the greatest estimated average return per wheat crop ($7.43/acre) due to protein premium. This increase in grain value due to N fertilization can potentially pay for 50 to 75% of the N applied.

Table 3. Average value of the grain protein above that of the check plot per wheat crop for the various N and P treatments.

N Rate	Fertilizer P Added, lb P/acre				
	0	20	40	80	160
lb/acre	$/acre				
0	0.00	-0.36	-0.27	-0.51	-1.38
40	3.51	4.06	4.24	4.67	4.96
80	4.70	5.29	6.48	7.43	7.43

REFERENCES

Halvorson, A. D., and A. L. Black. 1985a. Long-term dryland crop response to residual phosphorus fertilizer. Soil Sci. Soc. Am. J. 49:928-933.

Halvorson, A. D., and A. L. Black. 1985b. Fertilizer phosphorus recovery after seventeen years of dryland cropping. Soil Sci. Soc. Am. J. 49:933-937.

Halvorson, A. D., and A. L. Black. 1985c. Safflower helps recover residual nitrogen fertilizer. Mont. AgResearch 2:19-22.

Halvorson, A. D., A. L. Black, D. L. Watt, and A. G. Leholm. 1986. Economics of a one-time phosphorus application in the northern Great Plains. Applied Agricultural Research (In review).

USDA-ARS SOIL FERTILITY RESEARCH AT AKRON, COLORADO

The purpose here is to briefly outline the soil fertility research projects being conducted by USDA-ARS and cooperators at the Central Great Plains Research Station at Akron, Colorado.

PROJECT TITLE: Effect of N and P fertilization on water-use efficiency by winter wheat, barley, and corn in the Central Great Plains.
Objective: Determine the effects of N and P fertilization on crop yield, quality, and water-use efficiency using reduced tillage under irrigated and dryland conditions.
Personnel: Ardell D. Halvorson and C. A. Reule.
Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Effect of N source, placement, and rate on dryland winter wheat yields in a no-till system.
Objective: Determine the effectiveness of several N sources for use in no-till production systems and the best method of managing these N sources to obtain optimum economic returns.
Personnel: Ardell Halvorson, USDA-ARS, and Hunter Follett, CSU.
Location: Northeast of Platner, CO.

PROJECT TITLE: Management of N fertilizer for dryland winter wheat in reduced tillage systems.
Objective: Determine the N needs of crops grown in an annual cropping reduced-tillage system and the best placement method for N fertilizer in this system.
Personnel: Ardell Halvorson and C. A. Reule.
Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Effect of time and rate of N fertilizer application on soil profile NO_3-N distribution and crop yield and quality.

Objective: Determine the best time to apply fertilizer N for optimum winter wheat production and quality. Nitrogen is applied at 4 rates in early November, mid-May, mid-July, and mid-September during the fallow period, and top dressed to the wheat in mid-March.

Personnel: Ardell Halvorson and C. A. Reule.

Location: Northwest of Otis, CO.

PROJECT TITLE: Management of P fertilizer for dryland winter wheat in reduced tillage systems.

Objective: Determine the most efficient method of P placement for optimum economic yields and the value of residual fertilizer P for future wheat production.

Personnel: Ardell Halvorson, USDA-ARS, Akron, CO and John Havlin, Kansas State University, Manhattan, KS.

Location: Peetz, CO, and Scottsbluff, NE.

PROJECT TITLE: Crop rotation and N fertilization for efficient water use.

Objective: Determine the potential of producing economical dryland corn or sorghum yields following winter wheat in a wheat-corn-fallow rotation using reduced tillage systems. The N fertilizer requirements for optimum crop production and efficient water use are being evaluated.

Personnel: Ardell Halvorson, USDA-ARS, and John Shanahan, CSU.

Location: Central Great Plains Research Station, Akron, CO.

PROJECT TITLE: Reduced tillage/nutrient management for winter wheat production on eroded soils.

Objective: Nitrogen and P rate and application method for winter wheat production on soils where up to 46 cm of top soil has been removed in relation to the use of no-till, reduced-till and conventional stubble mulch tillage systems is being studied.

Personnel: Darryl E. Smika, USDA-ARS, Akron, CO.

Location: Central Great Plains Research Station, Akron, CO.