LONG TERM PHOSPHORUS RESEARCH ON CORN AND GRAIN SORGHUM

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ABSTRACT

Phosphorus fertilizer is needed for optimum production and economic returns from irrigated corn and grain sorghum in western Kansas. A long term study shows that the yield benefit from P increases over time from no yield difference initially to over 100 bu/acre higher corn yields after 30 years. Without fertilizer P, soil P levels declined from 17 ppm Bray-1 P to less than 10 ppm within five years, where they stabilized for both corn and sorghum. The addition of fertilizer P at 40 lb P_2O_5/acre is sufficient to maintain soil P levels for sorghum, but a higher rate is needed for corn. Application of P decreased nitrate accumulation from N fertilizer for both crops. However, nitrate accumulation was less with corn than sorghum, reflecting greater yields (approximately 25 %) and N removal by corn. Phosphorus increased N fertilizer demand by about 10 lb N/acre for corn and sorghum while increasing maximum yields by almost 60 bu/acre for corn and over 20 bu/acre for sorghum. Phosphorus increased the maximum net revenue over $130/acre for corn and almost $40/acre for sorghum while decreasing the minimum cost of production of corn $0.45/bu and over $0.15/bu for sorghum.

OBJECTIVES

Corn and grain sorghum are the predominant row crops grown under irrigation in western Kansas and the major user of phosphorus and nitrogen fertilizers. The objectives of this study were to evaluate the effects of long term P and N fertilization of irrigated continuous corn and grain sorghum on grain yield, residual soil P content, profile soil nitrate accumulation, and optimum economical levels of P and N.

METHODS

Phosphorus and nitrogen fertilizers were applied annually since 1961 to irrigated continuous corn and grain sorghum grown on a Ulysses silt loam under flood irrigation. Initial chemical properties of the surface soil (0-6 inch) were 17 pprn P (Bray-1), 1.4 % organic matter, and pH of 7.9. Fertilizer treatments included N rates ranging from 0 to 200 lb N/acre in 40 lb increments with and without P at 40 lb P_2O_5/acre. Grain yield was adjusted to 15.5 % moisture for corn and 12.5 % for grain sorghum. Periodically during the study, soil samples (0-6 inch) were collected and analyzed for Bray-1 P. After harvest in 1990, soil samples to a depth of 10 ft were collected and analyzed for NO_3-N.

Production functions were estimated with yield as a function of nitrogen at both 0 and 40 lb P_2O_5/acre for corn and grain sorghum. Corn yields increased approximately one bushel per year on average during the study. To account for this yield trend, a time variable was included in the estimated corn production functions. There was no significant trend in grain sorghum yields over time. The estimated production functions along with cost and price assumptions were used to determine the points of maximum net revenue and minimum cost per bushel. The cost and price assumptions used were: N cost of $0.15/lb, P_2O_5 cost of $0.25/lb, corn price of $2.50/bu, sorghum price of $2.25/bu, fixed cost for corn of $190/acre and fixed cost for sorghum of $120/acre. Fixed costs included all production expenses other than P and N costs.

RESULTS AND DISCUSSION

For the first five years, corn yields were not increased by P fertilizer. However, after five years, the yield benefit from P application has steadily increased. Phosphorus fertilizer, across all N rates, increased corn yields an average of 24 bu/acre over 31 years, 37 bu/acre over the past 10 years, and 73 bu/acre in 1991 (Table 1). With adequate N in 1991, corn yields were over 100 bu/acre greater with P than without P.

Similar to corn, sorghum yields were not affected by P for the first five years of the study, but have shown a positive yield response since. Phosphorus increased sorghum yields less than corn, partially because sorghum yields were about 25 % lower than corn yields. When averaged across N rates, P increased sorghum yields 12 bu/acre over 31 years, 18 bu/acre over the past 10 years, and 24 bu/acre in 1991 (Table 1). When P was applied without N, there was no yield increase with either corn or sorghum.

Soil P levels declined rapidly when no fertilizer P was applied from about 17 ppm Bray-1 P initially to less than 10 ppm after 5 years and then stabilized at this lower level for both corn and sorghum (Figs. 1 and 2). Soil P was increased by application of P on sorghum, although higher N rates tended to reduce the buildup. At low N rates on corn, soil P was increased by application of P fertilizer. However, at higher N rates, soil P levels tended to decline slightly indicating that P removal by corn exceeded that supplied by fertilizer P.

Nitrate levels in the soil profile after 30 years of N and P applications were greater with higher N rates (Figs. 3 and 4). At higher N rates, nitrate accumulation was less with corn than sorghum, reflecting greater N removal (higher yields) by corn. The addition of P reduced nitrate accumulation throughout the profile, particularly for sorghum. Application of P with N reduced nitrate accumulation to about one-third of the nitrate level attained with higher rates of N alone. When high rates of N (160 or 200 lb/acre) without P were applied to sorghum, about 700 lb NO_3-N was accumulated in the top 10 ft of soil with over 400 lb NO_3-N below 5 ft. With reduced possibility of plant uptake at lower depths, this nitrate is more susceptible to further leaching and could potentially contaminate groundwater. This emphasizes the importance of applying P along with N in a balanced fertility program to reduce environmental risk.

Application of P affects the economics of irrigated corn and grain sorghum production including; net revenue, cost/bushel, and the optimal rate of N fertilizer. Phosphorus significantly increases corn and sorghum grain yield with only a small increase in N demand (Fig. 5). As yields increase with P application, maximum net revenue increases over $130/acre for corn and almost $40/acre for sorghum (Fig. 6). The N rate for corn to maximize net revenue is about 155 lb N/acre with the application of 40 lb P_2O_5/acre and 145 lb N/acre without P. In addition to P increasing net revenue, the cost of production per bushel decreases because of higher yields (Fig. 7). The minimum cost per bushel decreased by $0.45/bushel for corn and over $0.15/bu for sorghum with P application. The optimal N rate for corn and sorghum for maximum grain yield, maximum net revenue, or minimum cost per bushel was only slightly higher with P than without P, indicating fertilizer P allows the plant to more efficiently utilize available N rather than substantially increasing N demand.

Table 1. Effect of nitrogen and phosphorus on yield of irrigated grain sorghum and corn, Tribune, KS.

N rate	P_2O_5 rate	Sorghum 1991	Sorghum 1982-1991	Sorghum 1961-1991	Corn 1991	Corn 1982-1991	Corn 1961-1991
lb/acre		- - - - - - - - bu/acre - - - - - -- -					
0	0	67	72	72	64	82	70
	40	59	72	73	78	87	73
40	0	91	87	93	82	109	107
	40	121	109	107	119	131	119
80	0	100	95	105	82	115	121
	40	138	111	114	158	150	143
120	0	97	91	103	90	114	124
	40	135	115	118	180	166	159
160	0	109	93	103	89	120	131
	40	134	118	121	206	177	169
200	0	110	97	105	92	119	132
	40	134	117	121	196	173	166
MEANS							
Nitrogen							
0 lb/acre		66	73	73	73	86	73
40		112	101	102	106	124	115
80		125	107	112	129	139	136
120		123	107	114	156	151	148
160		125	108	114	166	155	155
200		130	111	116	164	155	155
	LSD .05	10	4	3	10	8	4
Phosphorus							
0 lb/acre		96	89	97	83	110	114
40		120	107	109	156	147	138
	LSD .05	7	3	2	8	5	3

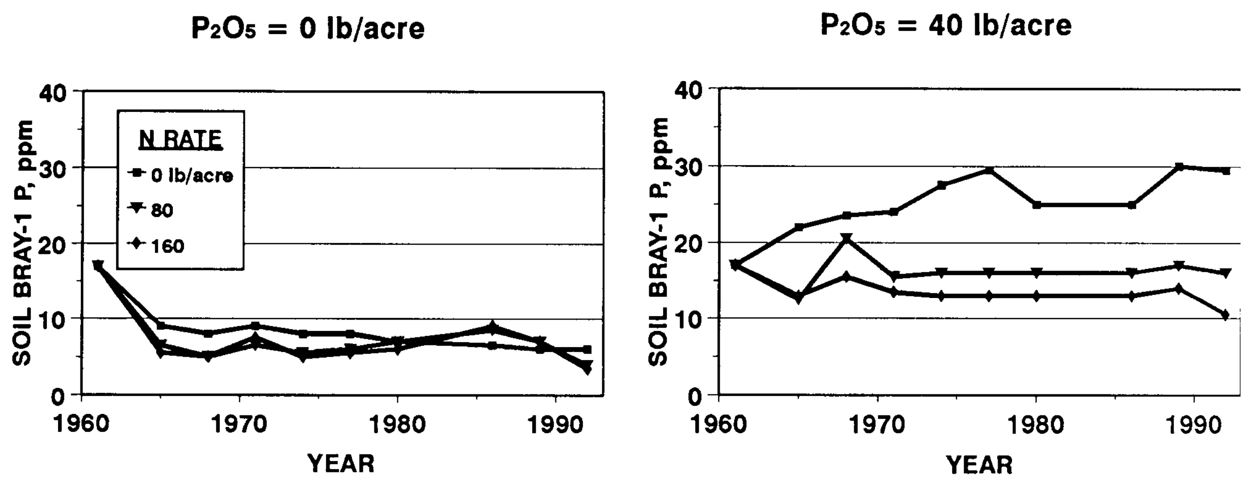


Figure 1. Effect of N Rate on Soil Bray-1 P on Corn.

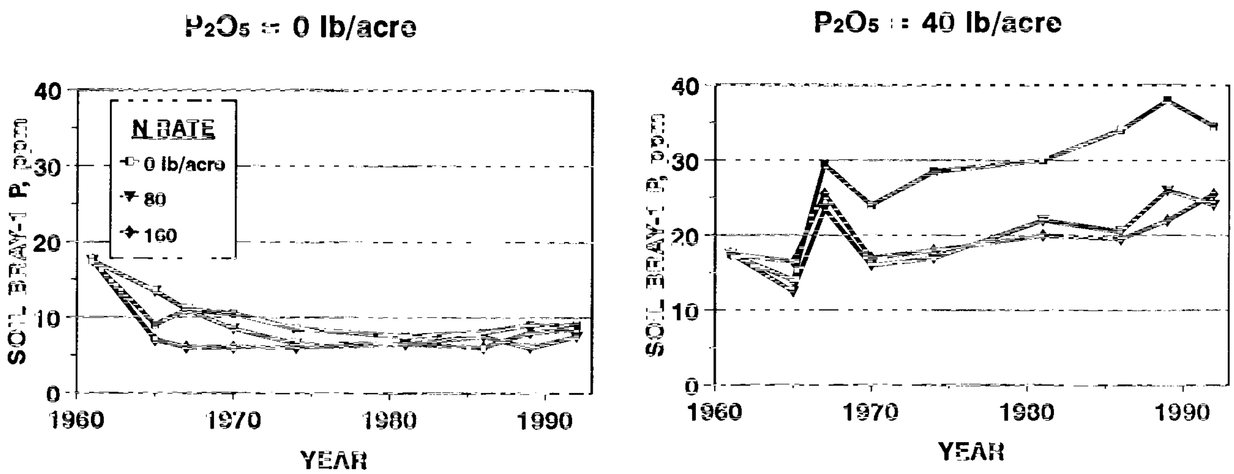


Figure 2. Effect of N Rate on Soil Bray-1 P on Sorghum.

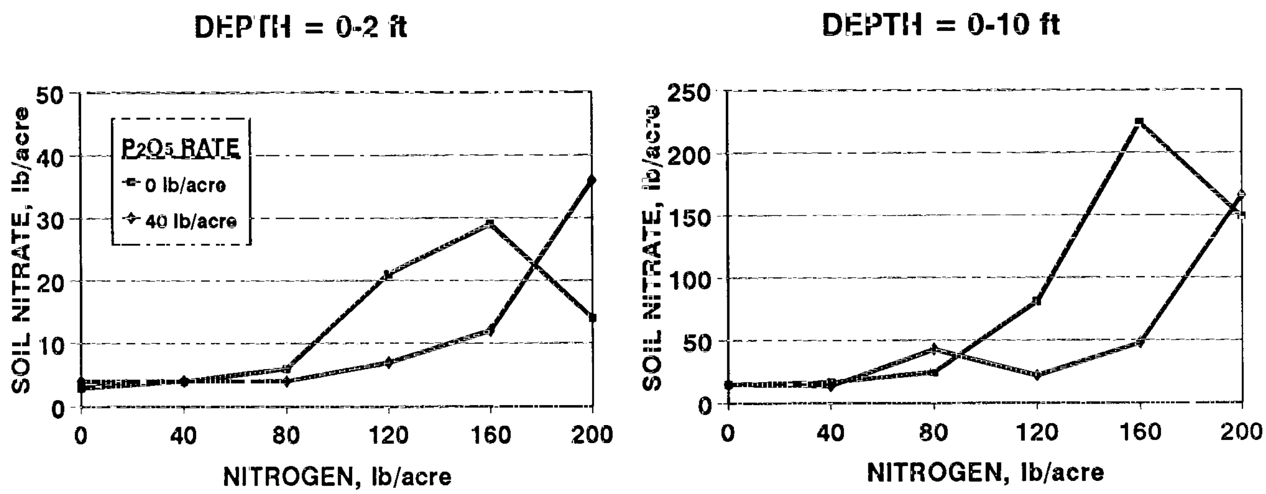


Figure 3. Effect of 30 Years of N and P Application to Corn on Soil NO_3-N Content.

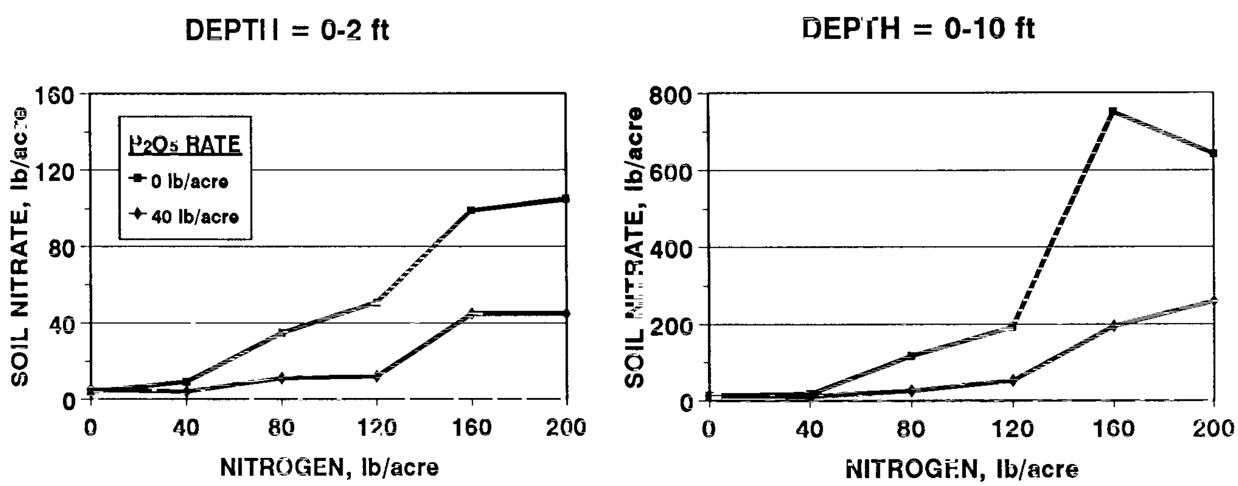


Figure 4. Effect of 30 Years of N and P Application to Sorghum on Soil NO_3-N Content.

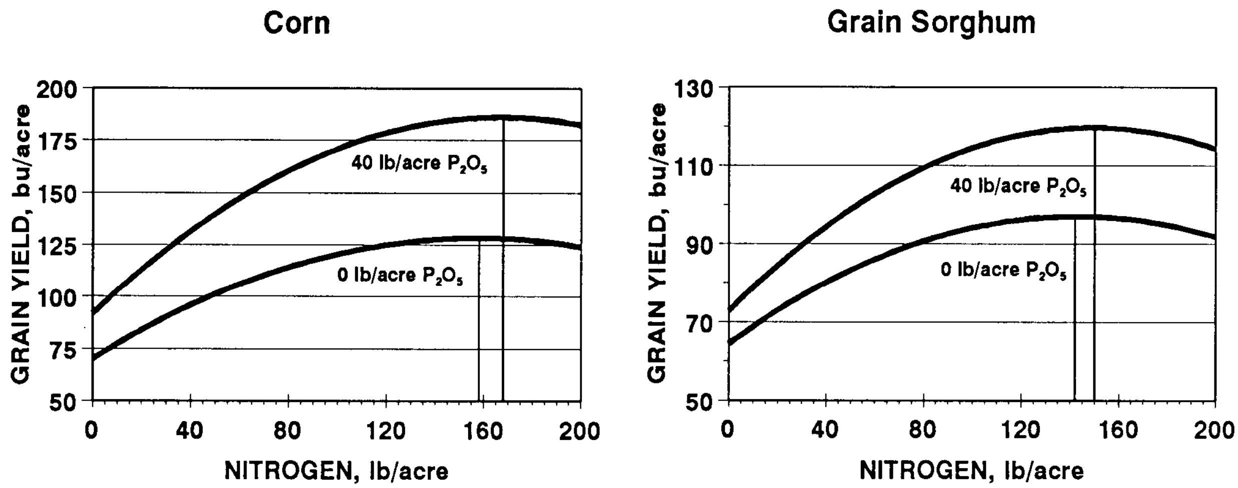
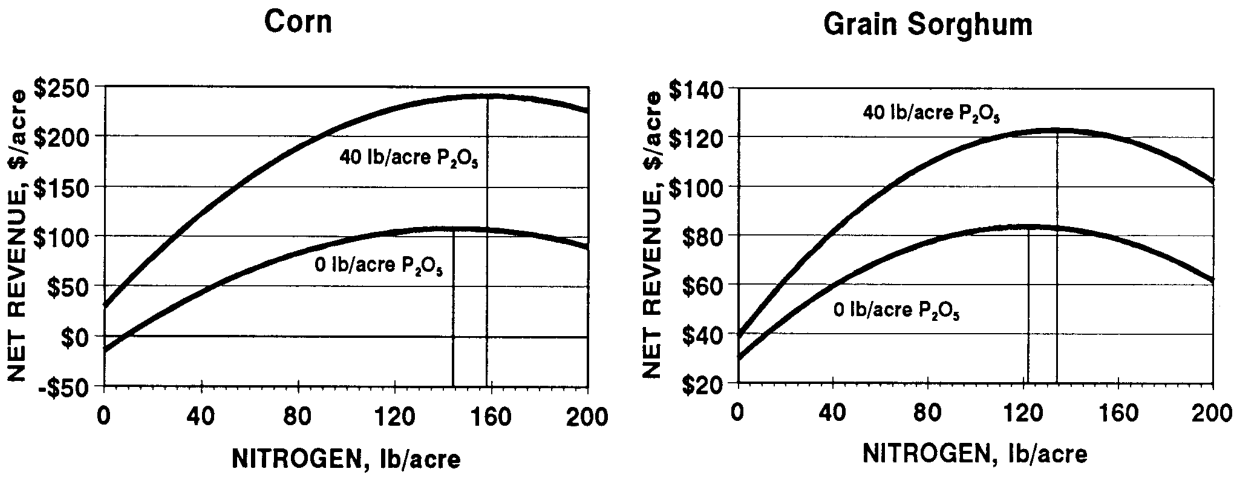


Figure 5. Effect of P on Grain Yield.



Pc=$2.50/bu, Pn=$0.15/lb, Pp=$0.25/lb, FC=$190/ac

Ps=$2.25/bu, Pn=$0.15/lb, Pp=$0.25/lb, FC=$115/ac

Figure 6. Effect of P on Net Revenue.

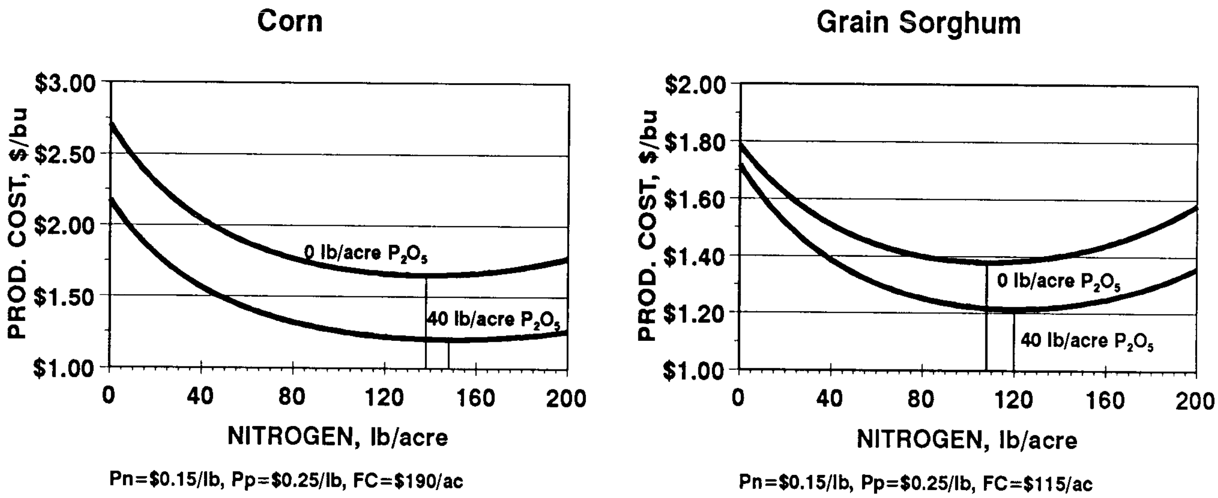


Figure 7. Effect of P on Cost of Production.