Long-term Effects of Phosphorus Fertilization on Wheat Yields, Efficiency and Soil Test Levels

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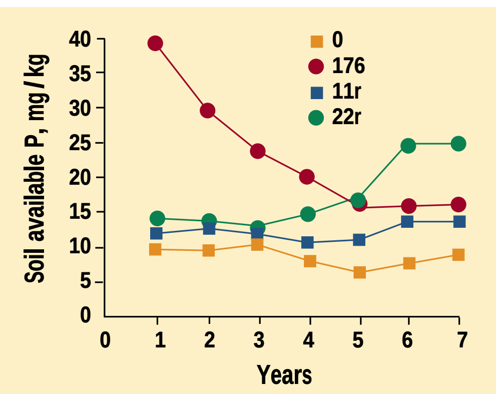
Several years of phosphorus (P) fertilization studies are now providing a basis to evaluate long-term effects on wheat yields, nutrient efficiency and soil test levels in the Pampas of Argentina.

The Pampas region of east central Argentina has extensive plains, mainly dedicated to grain and beef cattle production. Soils under cereal crop production are Mollisols, generally Argiudolls. The surface horizon is usually moderately acid with organic matter levels from 2 percent in the west to 6 percent in the east. Annual precipitation ranges from 1,100 mm in the northeast to 500 mm in the southwest.

Soil P levels are usually deficient for grain production in the central and east area of the Pampas. Several field experiments in the last 30 years have shown the need for P fertilization for maximum economic yield (MEY). Many farmers have adopted P fertilization as a regular practice for wheat, corn and forage production. Annual P fertilization has resulted in the buildup of soil P levels in several cases, but the agronomic value of this increased soil P has not been evaluated for annual crops. Residual P is especially important for cropping systems in which the cost of fertilizer is high, because it might allow adjustments in the rate of fertilizer, improving the economic results.

Figure 1. Evolution of soil available P (Ps) with P application only in the initial year (Pi) and with two annual rates of P (Pr) in the CW rotation.



The objective of this research was to evaluate the long-term effects of P fertilization on wheat yields, P recovery in grain, and soil P levels (Bray P-1).

Materials and Methods

Two field experiments were begun in 1988 at the Balcarce Agricultural Experimental Station, Buenos Aires Province, Argentina (37° 45' S, 58° 18' W; altitude 130 m). The soil is a loamy, illitic, thermic, typic Argiudoll. Soil organic matter was 6.2 percent, pH 5.8, and soil P 10.2 mg/kg at the initial soil sampling of the surface horizon (0 to 18 cm) in the experimental areas.

The effects of residual P were evaluated on a continuous wheat (CW) rotation (Experiment 1), and in a wheat-sunflower (WS) rotation (Experiment 2). A randomized complete block design with three replications was used for each experiment. Treatments included six rates (0, 11, 22, 44, 88, and 176 kg/ha) of P applied only in the first year (1988), and two rates (11 and 22 kg/ha) P annually applied.

Fertilizer was applied annually in the CW rotation, but only to wheat in the WS rotation. Phosphorus fertilizer was applied with the seed at the 11 and 22 kg/ha rates. The remainder was broadcast and incorporated with a disk before planting. Urea was applied annually at a rate of 120 kg N/A to all treatments to avoid N deficiencies.

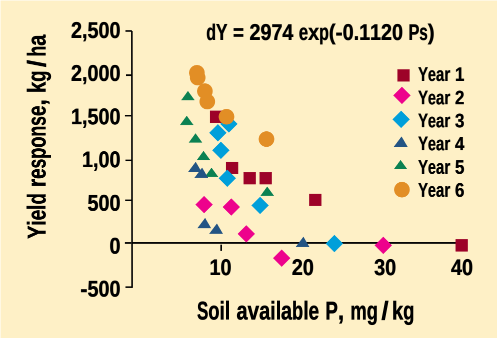


Figure 2. Relationship between soil available P (Ps) and yield response (dY), for the CW rotation.

Sixty subsamples at 0 to 18 cm depth were taken from each plot before wheat planting to determine soil P levels. Aboveground biomass at physiological maturity of wheat, grain yield and recovery of P in grain were determined. Data from seven years (1988-1994) for the CW rotation, and from four years (1988, 1990, 1992, and 1994) for the WS rotation were analyzed.

Results and Discussion

Table 1 shows grain yields, grain yield responses and P fertilizer efficiency in the CW and WS rotations, from 1988 to 1994. Average yield for the highest rate of P applied in 1988 (176 kg/ha) was 4,321 kg/ha for the CW and 5,076 kg/ha for the WS rotations, respectively. Yield response for the same treatment was 1,090 and 968 kg/ha, or 34 percent and 24 percent above check yields for the CW and WS rotations, respectively.

Residual P effect for the rate of 176 kg/ha P was significant in the seven years, but it was not enough to reach maximum yields in the last two years. There were significant residual effects through the fourth and seventh year for the rates of 11 and 22 kg/ha P, respectively (data not shown).

Phosphorus fertilizer efficiency for the CW rotation, considering the accumulated yield response for the seven years, was approximately 160 kg of grain per kg of P for rates of 11 and 22 kg/ha P. Phosphorus fertilizer efficiency decreased to 44 kg of grain per kg of P for higher rate of initial P fertilization. The same trend was observed for the WS rotation, but with lower efficiency because of the lower number of years (four) under wheat.

Table 1. Accumulated grain yield (Yac), accumulated grain yield response (dYac), accumulated P fertilizer efficiency (dYac/P), and accumulated grain P (Pgac) for the seven years (1988-1994) of the CW and WS rotations.

Treatment	Continuous Wheat				Wheat – Sunflower			
P, kg/ha	Yac kg/ha	dYac kg/ha	dYac/P kg/kg P	Pgac P, kg/ha	Yac kg/ha	dYac kg/ha	dYac/P kg/kg P	Pgac P, kg/ha
0	22,605	–	–	57	16,435	–	–	43
11	24,333	1,728	159	66	17,070	635	58	47
22	26,188	3,583	164	73	18,249	1,814	83	51
44	27,492	4,887	112	78	19,032	2,597	59	55
88	28,685	6,080	70	82	19,347	2,912	33	58
176	30,249	7,644	44	98	20,305	3,870	22	68
11r	28,065	5,460	72	84	19,142	2,707	35	57
22r	31,822	9,217	60	98	20,521	4,086	27	65

r = annually fertilized

Annual fertilization with 22 kg/ha P resulted in the highest accumulated grain yield for the seven years in both rotations, although it did not result in maximum yields in the first years. Average annual response and P fertilizer efficiency for this rate were 1,317 and 1,021 kg/ha and 60 and 27 kg grain per kg P for the CW and WS rotations, respectively.

Average annual grain P removal was 14 to 17 kg/ha for the initial rate of 176 kg/ha P and the annual rate of 22 kg/ha P, depending upon rotation. Grain P removal averaged 8 to 11 kg/ha for the check treatments (data not shown).

Figure 1 shows the dynamics of soil P over years for some of the treatments of the CW rotation. For the P rate of 176 kg/ha, there was a progressive decline in soil P until it reached 16 mg/kg in the fifth year. Annual fertilization with 22 kg/ha increased soil P up to 25 mg/kg in the sixth year. Soil P variations for the check and the annual rate of 11 kg/ha were much lower.

It has been estimated that to increase soil P by 1 mg/kg in the CW rotation, it was necessary to apply 6 kg P/ha in the previous year or 20.8 kg P/ha seven years before.

Figure 2 shows the relationship between grain yield response and soil P for the CW rotation. The adjusted equation estimates grain yield responses of 1,700, 1,000, 550 and 300 kg/ha for the soil P of 5, 10, 15 and 20 mg/kg, respectively. Soil P for the 90 percent maximum yield was estimated at 17.2 mg/kg. Variations among years are mainly attributed to water availability.

Conclusions

Residual P in Typic Argiudolls of southeastern Buenos Aires Province (Argentina) was high considering the effects on wheat yield and soil P.

Phosphorus use efficiencies for initial rates of 22 and 44 kg P/ha were 164 to 112 kg grain per kg P for the seven years under consideration.

The changes in soil P through the years were highly associated with the initial P rates and yield responses, indicating that the extraction method is accurate enough to evaluate residual P under the conditions of the experiments.

Applications of 6 kg P/ha in the previous year or 20.8 kg P/ha seven years before increased soil P by 1 mg/kg. BCI

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