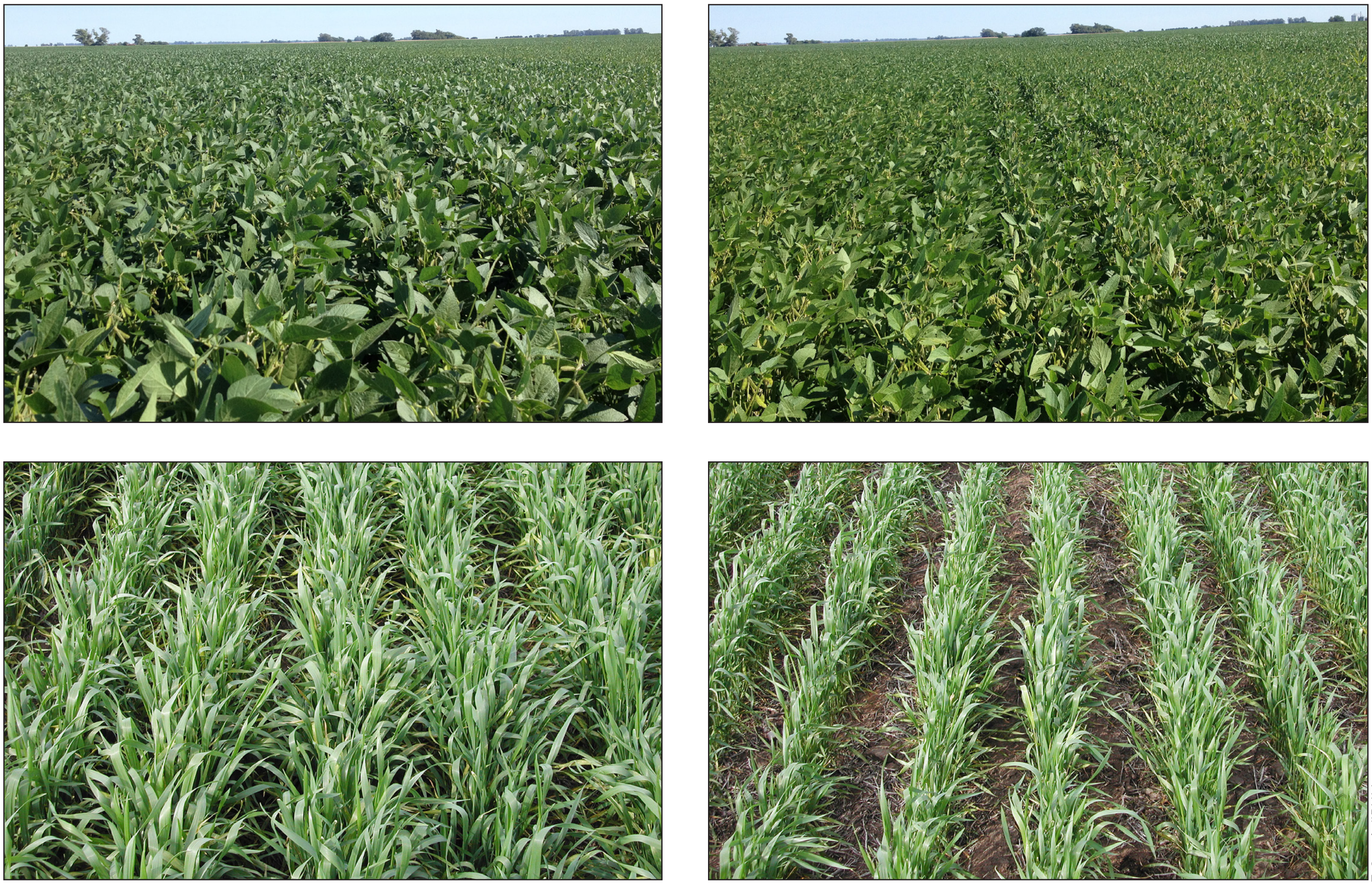
How Can Soil P Balance Influence Soil Test P? A case study from the Argentinian Pampas

By Florencia A. Sucunza, Flavio H. Gutiérrez Boem, Fernando O. García, Miguel Boxler, and Gerardo Rubio



F. García/IPNI Images

Visual responses to fertilizer P in soybean (Balducchi site) and wheat (La Blanca site). Plots on the left received N+P+S; plots on the right received N+S.

SUMMARY

Data from long-term crop rotation study sites were combined to evaluate the effect of long-term application (and omission) of P fertilizers. The impact of maintaining either a negative or positive P balances on soil test P at five distinct sites was described by single response functions despite a range of differences in soil properties.

KEYWORDS:

Bray P; double-cropping; critical values; depletion; on-farm experiments.

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus; K = potassium; S = sulfur.

IPNI Project ARG-12

http://doi.org/10.24047/BC102411

Knowing how soil test P varies with the P balance within a cropping system is a key part of planning P management strategies. Models that predict how soil test P declines once P applications stop, provide useful information about the dynamics of plant-available P, and help determine when to apply more. Models that are conversely able to predict the increase in soil test P under a positive P balance, allow for the identification of maximum P rates, and lessen the risk for environmental pollution.

Most fertilizer P is retained by the soil matrix and only a fraction is absorbed by the target crop. Phosphorus retained in the soil matrix will eventually be available for subsequent crops. The P balance is generally calculated by subtracting the main output (P removed in harvested products: grain, forage) from the main input (fertilizer P or manure P). Due to the strong interaction of phosphates with the soil, the relationship between P balance and soil test P is often not straightforward (Ciampitti et al., 2011). Some reports suggest that the net balance of P in the system is the key factor regulating the dynamics of soil test P. Long-term field ex-

Table 1. Soil classification, location and properties (0 to 20 cm depth) at the beginning of the experimental period (September, 2000) for the five experimental sites.

Site	Balducchi	San Alfredo	La Blanca	La Hansa	Lambare
Soil	Typic Hapludoll	Typic Argiudoll	Typic Hapludoll	Aquic Argiudoll	Typic Argiudoll
Location	34º09.461`S; 61º36.465`W	33°51'35.57"S; 61°28'7.84"W	33º29.923`S; 62º37.958`W	32º38.405`S; 61º19.967`W	32º 10.236`S; 61º 48.674`W
Bray P, mg/kg	11	12	16	18	68
Organic C, %	1.4	2.0	1.3	1.2	1.9
pH	5.9	6.0	6.6	5.5	5.6
Ca, cmol/kg	8.1	11	7.2	7.6	9.9
Mg, cmol/kg	2.0	2.1	2.0	1.6	3.0
K, cmol/kg	1.4	1.7	1.9	1.7	2.6
Clay, %	12	18	16	18	21
Silt, %	53	62	56	79	76
Sand, %	35	20	28	3	3
Rotation	Bi-annual: maize-wheat/soybean		Tri-annual: maize-soybean-wheat/soybean		

periments arise as the best tool for quantifying the impact of P balance and P fertilization practices on the dynamics of soil test P. This article evaluates the effect of long-term applications of P fertilizers on soil P balance and soil test P.

Study Description

The Pampean region occupies more than 500,000 km^2 in the east central part of Argentina. Around half of the Pampas is dedicated to cereal or oil crops (mainly maize, wheat, and soybean; Rubio et al., 2019). The climate is temperate and the rainfall regime is humid in the east and semi-arid in the west. In 2000, a long-term fertilization study was established by the Southern Santa Fe Regional Consortium of Agricultural Experimentation (CREA), which is comprised of groups of 10 to 15 farmers, located in the southern sector of Santa Fe, southeastern Cordoba, and northern Buenos Aires Provinces in the northern Pampas of Argentina. The experimental sites showed a variation in soil types (Typic Argiudolls or Typic Hapludolls), soil test P (Bray P), and soil management history (**Table 1**). Each site followed one of the following two crop rotations: 1) bi-annual rotation: maize (first year) and double-cropped wheat/soybean (second year); 2) tri-annual rotation: maize (first year); full season soybean (second year), and double-cropped wheat/soybean (third year).

Treatments compared in this research were: 1) a control without P, and 2) continuous P fertilization. The plots were 25 to 30 m wide and 65 to 70 m long. The P rate was decided annually according to the expected crop removal plus 5 to 10% in order to maintain a slightly positive P balance. On average, the annual P rate was 37 kg P/ha. Monoammonium phosphate was the P source and was incorporated at a 5-cm depth before sowing. Nutritional limitations for crop yield other than P were avoided through N and S applications.

Soil P balances were calculated as the difference between P inputs and outputs. Inputs were calculated using the P rate and concentration of the fertilizer applied. Outputs were calculated using crop yields and measured grain P concentrations.

Phosphorus Effects on Crop Yields

Crop yields ranged from adequate to high compared to local standards. Yield (t/ha) for non-fertilized crops ranged between 7.3 to 16 (maize), 3.1 to 6 (full season soybean), 1.7 to 5.2 (double-cropped soybean), and 1.5 to 5.1 (double-cropped wheat). Yields for these fertilized crops ranged between 8.5 to 16, 3.8 to 6, 1.7 to 5.3, and 1.7 to 5.8 t/ha. Wheat was the crop most responsive to P, and P responses for maize and soybean were smaller and somewhat equivalent. As expected, the site with the lowest initial Bray P (Balducchi) had the highest responses to P whereas the site with the highest initial concentration (Lambare) had the lowest P response.

What Happens if P Fertilization is Interrupted?

Differences among soil properties (**Table 1**) were not large enough to affect the dynamics of Bray P in the non-fertilized treatments. In these plots, the rate of Bray P decline was best described by exponential decay functions (**Figure 1**) rather than by linear functions. The equation obtained is

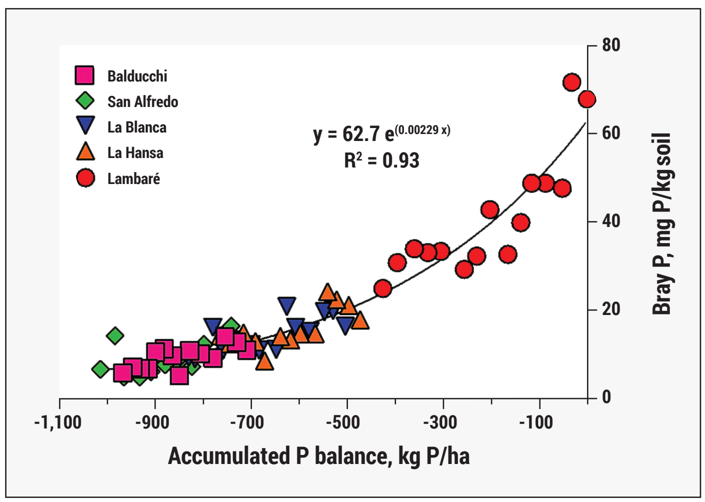


Figure 1. Relationship between Bray P and accumulated P balance for the treatment without P fertilization (control treatment) at five locations of the Northern Pampean Region. The five sites had a common relative rate of decay. In this figure each site was horizontally shifted in order to bring the individual curves into coincidence in a combined curve of Bray P as a function of a modified x-axis (i.e., an extended negative P balance).

appropriate to predict the decline in soil test P after stopping P fertilization. A net extraction of 327 kg P/ha was needed to reduce the initial soil test P values by half regardless of the initial Bray P value of the soil. The ratio of change in Bray P to P removed by the crop increased as initial Bray P values increased, which indicates that soil P pools other than Bray P would have exerted a greater contribution to crop P nutrition in the P-poor soils. This means that a greater proportion of the P taken by the crop came from the soil P reserves (i.e., soil P not recovered by the Bray extractant) at low P concentrations than at high P concentrations. As observed in U.S. soils by Dodd and Mallarino (2005), the decline in Bray P was steeper in P-rich soils and tended to stabilize as the soil became impoverished in P, whereas P-poor soils had slower and somewhat steady declines. The curvilinear decline of extractable P would be associated with the increase in the diffusive flux towards this fraction from other less labile P fractions as the size of the extractable-P pool diminishes.

What Happens if P Fertilizer Rates are Higher than P Exported by Harvested Products?

After 14 years of continuous P fertilization, the progressive accumulation of positive P balances increased Bray P following straight line functions in all sites. No significant differences were found between the fitted slopes for each site, suggesting that the increase in Bray P did not depend on initial Bray-P but on the magnitude of the accumulated positive P balance. The relationship between Bray P and P balance could be described by a simple linear regression model (**Figure 2**). The combined function was plotted on an extended x-axis ranging between 0 to 240 kg of positive P balance and indicated that a positive balance of 3.2 kg P/ha was necessary to increase Bray P by 1 mg/kg. At the end of the experiment, the five sites reached Bray P values above the critical values (12 to 19 mg/kg). This means that fertilization is no longer required to increase profitable yields on these plots. However even in these cases, farmers should not abandon soil testing because it provides key information for soil P fertility and environmental management.

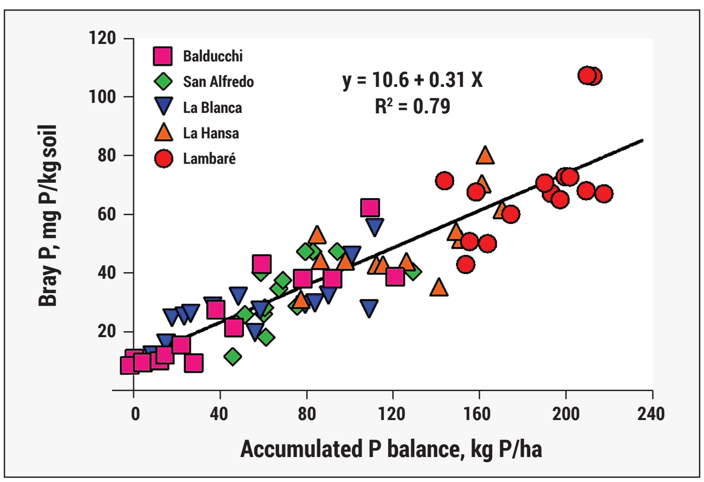


Figure 2. Relationship between Bray P and accumulated P balance for the fertilized treatments at five locations of the Northern Pampean Region. The five sites had a common slope. Each site was horizontally shifted in order to bring the individual lines into coincidence in a combined line of Bray P as a function of the modified x-axis (i.e., an extended positive P balance).

TAKE IT TO THE FIELD

Continued draw-down of soil available P leads to the depletion of more slowly available pools not accounted for by routine soil testing. Even slightly positive P balances maintained over a relatively short time frame can raise soil test P beyond critical values.

Conclusion

The data obtained on rates at which soil P test decreases or increases according to the P balance constitute a useful tool to monitor future changes of soil P concentrations and to estimate the P demand of croplands in Mollisols, and related soil types. It also helps in the planning of strategies that ensure that yields are not constrained by a lack of plant-available P, and the risk of P loss to the environment is minimized. **BC**

Acknowledgments

Financial support was provided by CONICET, University of Buenos Aires, and ANPCYT. We are grateful to the Southern Santa Fe CREA Region, IPNI Southern Cone, and Nutrien Ag Solutions for carrying out and supporting these experiments, and to the CREA farmers for their valuable help.

These results were published in Sucunza, F.A., F.H. Gutierrez Boem, F.O. García, M. Boxler, and G. Rubio. 2018. Long-term phosphorus fertilization of wheat, soybean and maize on Mollisols: Soil test trends, critical levels and balances. European J. Ag. 96: 87-95.

Ms. Sucunza, Dr. Gutierrez Boem and Dr. Rubio (e-mail: rubio@agro.uba.ar) are with INBA (CONICET UBA) and Soil Fertility and Fertilizers, School of Agriculture, University of Buenos Aires, Buenos Aires, Argentina; Dr. García is Director of the IPNI Latin America-Southern Cone Program; Mr. Boxler is a private consultant in Cordoba, Argentina.

References

Ciampitti, I.A. et al. 2011. Soil Sci. Soc. Am. J. 75, 131-142.

Dodd, J.R. and A.P. Mallarino. 2005. Soil Sci. Soc. Am. J. 69, 1118-1128.

Rubio, G. et al. 2019. *In*: Rubio, G. et al. (eds.) The Soils of Argentina. World Soils Book Series. Springer Int. Publ. ISBN 978-3-319-76851.