Does Balanced Fertilization Improve Soil Health?

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Crop fertilization not only improves crop yields but also generates positive changes in soil health, which contributes to cropping system sustainability. Balanced fertilization during 12 consecutive years improved soil organic matter, soil microbial population and enzyme activity, and soil aggregate stability in fields with long annual cropping history and coarse soil texture. Similar effects were not found in fields with shorter annual cropping history and finer soil texture.

KEYWORDS:
long-term experiments; Pampas; crop rotation; C sequestration; cropping history.

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; S = sulfur; C = carbon; ppm = parts per million.

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The Argentine Pampas is dominated by fertile Mollisol soils that are broadly characterized as having deep soil profiles high in organic matter and agricultural suitability. Yet inadequate soil management creates erosion and promotes soil degradation processes. A lack of crop rotation schemes under soybean monoculture, and negative soil nutrient balances have caused up to 50% reductions in soil organic matter (SOM) compared to original values, and have negatively affected crop yields (Álvarez, 2001; Sainz Rozas et al., 2011).

Sustainable agriculture should be based on getting better crop production efficiencies per resource unit. But strategies are needed to preserve the natural resources needed to meet global food demands (Masera et al., 2000). In order to generate information about crop nutrition management for the central Pampas, the Southern Santa Fe Region of CREA (*Consorcios Regionales de Experimentación Agrícola*), IPNI Latin America Southern Cone Program, and *Agroservicios Pampeanos* (ASP, Agrium Inc.) established an on-farm experimental network to evaluate the effects of long-term fertilization on crop yields, nutrient use efficiency, economics, and soil health (García et al., 2010). This CREA Southern Santa Fe Crop Nutrition Network (CSSFNN) is still active in five out of the initial eleven on-farm experiments that were initiated in 2000. This report provides an analysis of soil physical and biological properties after a 12-year period of contrasting crop nutrient management.

Five sites within the CSSFNN were included in this study (**Table 1**). Plot size was 25 to 30-m wide and 65 to 70-m long. Three treatments included: i) soils with no agricultural history (Reference) that were adjacent to the experimental plots, ii) agricultural soils that have not been fertilized (Unfertilized) between 2000 and 2012, and iii) agricultural soils that have been fertilized with N, P, and S (fertilized) during this same 12-year period. Nitrogen, P, and S are the most deficient nutrients for this region. Nitrogen was applied at optimum rates for high-yielding crops according to local research in maize and wheat, but N was not added to soybean crops. Phosphorus and S rates were decided each season before planting according to the expected crop yield and P and S removal. All nutrients were applied before or at planting using fertilizer blends. The sources of N, P, and S were urea (46-0-0), mono-ammonium phosphate (12-52-0), and calcium sulfate (0-0-0-19S), respectively. Each site included only one rotation at a time so not all of the crop phases were present every year.

In 2012, soil physical and biological properties were examined under each treatment. Soil variables included: soil organic carbon (SOC) due to its role on nutrient supply and soil structure; microbial biomass carbon (MBC) and total enzyme activity (FDA - fluorescein diacetate) due to their roles within soil organic matter (SOM) and nutrient release dynamics; soil bulk density (SBD) which is related to soil porosity; and lastly ag-

Table 1. Soil taxonomy, cropping history, and soil texture for the five study sites. Two sites has a corn-double-cropped wheat/soybean (C-W/S) rotation while three had a corn-soybean-double-cropped wheat/soybean (C-S-W/S) rotation.

	----- C-W/S Rotation -----		------------ C-S-W/S Rotation ------------		
Properties	Balducci	San Alfredo	La Blanca	La Hansa	Lambaré
Soil classification	Typic Hapludoll	Typic Argiudoll	Typic Hapludoll	Aquic Argiudoll	Typic Argiudoll
Years of continuous row cropping*	+60	8	6	+20	12
Textural class (surface layer)	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam
Clay, %	12	18	16	18	20
Silt, %	53	62	56	79	77
Sand, %	35	20	28	3	3

*years after the last pasture season.

gregate stability (AS) due to its relationship with SOC, soil water content, and soil aeration.

Soil Organic Carbon

At all sites, lower SOC was observed for both unfertilized and fertilized treatments when compared with adjacent reference soils (**Figure 1**). The Balducci and La Hansa sites

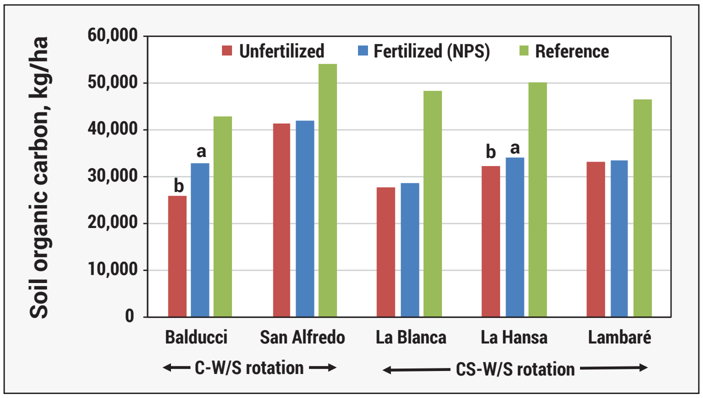

Figure 1. Soil organic carbon (0 to 15 cm) for unfertilized, fertilized, and reference plots. Different letters indicate significant differences between treatments after 12 years of study ($p \leq 0.05$).

had the longest annual cropping histories and showed significant differences in SOC between fertilized and unfertilized plots (i.e., 7,010 and 1,782 kg SOC/ha, respectively). Balanced NPS fertilization increased both crop biomass and grain yield, which produced large inputs of C for the soil.

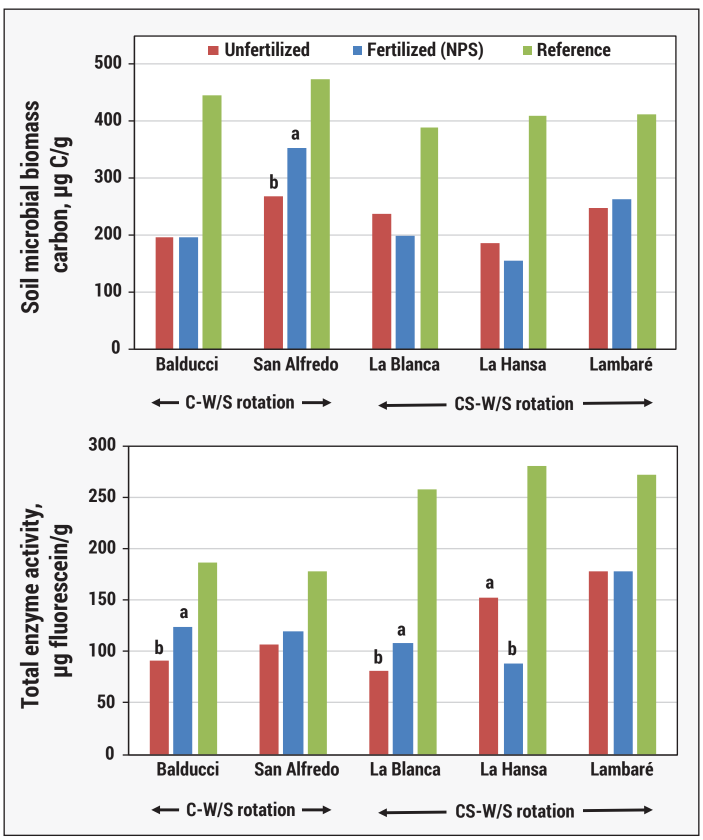

Figure 2. Soil microbial biomass carbon (top) and total enzyme activity (FDA; Bottom) for unfertilized, fertilized, and reference plots. Different letters indicate significant differences between treatments after 12 years of study ($p \leq 0.05$).

Soil cover under fertilized (top) and unfertilized (bottom) plots at the La Hansa site during the 2012-13 cropping season.

The sites at La Blanca, San Alfredo, and Lambaré all had shorter cropping histories and showed no significant differences in SOC amongst treatments.

Microbial Biomass and Enzyme Activity

Reference soils always had the highest MBC and FDA indices. Soil MBC was higher in the fertilized plots compared to the unfertilized plots in San Alfredo, but no other sites showed this difference (**Figure 2a**). The FDA indicator revealed higher enzyme activity with fertilization at La Blanca and Balducci; however, lower enzyme activity was also detected within fertilized plots at La Hansa (**Figure 2b**).

Enzymes determined by FDA hydrolysis are estearases, proteases, and lipases, which are involved in the decomposition of different types of residues. Normally they are exocellular and exist in a free-form in soil. Input of residues and increased SOC might promote soil microbial populations and enzymatic activity. Long-term building of SOM under balanced fertilization may contribute to the retention and

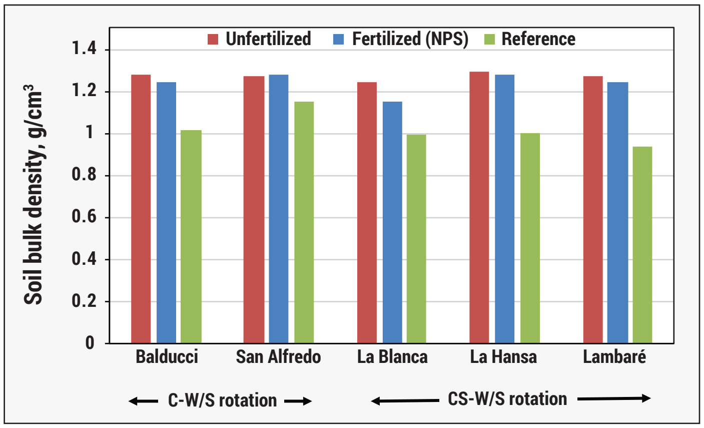

Figure 3. Soil bulk density (SBD) at the soil surface for unfertilized, fertilized, and reference plots after 12 years of study.

protection of these exocellular enzymes.

Bulk Density

Soil bulk density measurements produced no significant differences between unfertilized and fertilized plots (**Figure 3**). The lowest bulk densities were consistently observed in the reference soils due to their lack of disturbance. Root growth tends to be restricted in soils with bulk densities of 1.6 g/cm^3 or higher.

Aggregate Stability

High SOM and clay content allows for greater soil cohesion and AS. Good AS is critical for the storage and transmission of water, nutrients, and air, which in turn promote the growth and development of crops and soil organisms. Reference soils always had higher AS compared to unfertilized or fertilized plots. The Hapludoll sites (Balducci and La Blanca) had the lowest AS due to lower clay and SOC at the soil surface (**Figure 4**). Argiudolls (San Alfredo, La Hansa and Lambaré) showed higher levels of AS. After 12 years, fertilized plots showed higher AS compared to unfertilized plots at the sites with coarser-textured soils (Balducci and La Blanca) while no differences were detected among the sites with finer-textured soils.

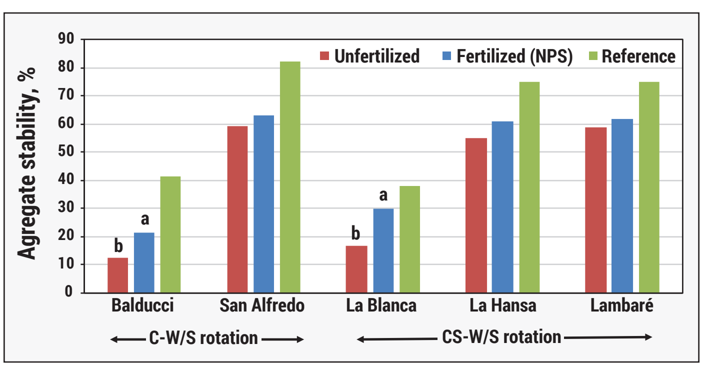

Figure 4. Soil aggregates stability at the soil surface (0 to 20 cm) for unfertilized, fertilized, and reference plots. Different letters indicate significant differences between fertilization management situations after 12 years of study ($p \leq 0.05$).

Summary

The five study sites showed different responses to balanced NPS fertilization, which were dependent on crop rotation, cropping history, and soil texture. For the short crop rotation (C-W/S), with larger C inputs from residues, fertilization resulted in higher SOC, FDA, and AS in the site with coarser soil texture and longer cropping history (i.e., Balducci). Fertilization only increased MBC at the finer-textured site with shorter cropping history (i.e., San Alfredo). In the long crop rotation (C-S-W/S), the most significant changes were observed in the site with the coarser texture (La Blanca) where there were increases in FDA and AS. At La Hansa (finer texture but longer cropping history), there were only changes in SOC and FDA. The Lambare site, with the shortest cropping history and fine soil texture, did not show any impact of fertilization on the selected soil properties after 12 years.

There are important long-term effects of balanced crop nutrition management on soil health. The improvement of soil health is one of the most relevant issues that agronomists face in order to get the best performance from farming systems within the Pampas. Better crop nutrition translated into higher yields in these experiments (+27% to +120% depending on the site). Directly or indirectly, and through a positive feedback process that supports soil C sequestration, soil improvement, and crop growth, balanced fertilization can improve soil structure, soil water dynamics, soil biological activity, as well as soil nutrient supply.

Conditions and results of this study would replicate in many areas of the central Pampas of Argentina. The Southern Santa Fe Region of CREA includes 160 farmers who crop approximately half a million ha under similar cropping systems found in this study. **BC**

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References

Alvarez, R. 2001. Soil Use and Management 17:62-66.
García, F.O. et al. 2010. AACREA (ed.), 64pp.
Masera, O. et al. 2000. El marco de evaluación MESMIS. pp.109.
Sainz Rozas, H.R. et al. 2011. Ciencia del Suelo 29:29-37.