Crop Responses to Fertilization in the Eastern Plains of Bolivia

By Jorge Terrazas, Grover Guaygua, Estanislao Juárez, Mauricio Crespo, and Fernando García

The eastern plains of Bolivia is an important area of grain crop production. A network of exploratory experiments conducted from 2005 to 2008 focused on crop nutrient deficiencies and responses to applied P, K, S, micronutrients, and N. Results of these experiments are presented in this article. A high probability of grain yield response to P was measured when Olsen P tested less than 6 mg/kg. Potassium, S, and micronutrients might be deficient under certain conditions.

Bolivia is one of the main grain (i.e. cereal and oil crop) producing countries of South America with an estimated total production in 2008 of 3.65 million (M) t within an area of 2 M ha (INE, 2010). Soybean is the most important grain crop with a production in 2008 of 1.2 M t on 835,000 ha—an average yield of 1,468 kg/ha. Grain production is largely carried out in the eastern plains in the Department of Santa Cruz **(Figure 1)**. The northern and eastern regions of the plains have distinct soil characteristics, soil fertility, and weather conditions which transition towards its central regions.

Poor native soil fertility in some areas, generally low fertilizer use, and continuously high nutrient removal brought about by 30 years of intensified cropping have made the appearance of nutrient deficiencies commonplace. However, most of the research has been limited to a few annual experiments that examine specific nutrients and areas.

In the winter of 2005, the farmers' organization Fundacruz (the Foundation for the Agricultural Development of Santa Cruz), started a network of exploratory field experiments with the collaboration of IPNI to evaluate deficiencies and responses to P, K, S, and micronutrients (i.e. B, Cu, Zn) in the northern, central, and eastern regions of Santa Cruz de la Sierra. Evaluation of N responses were carried out when maize and wheat crops were included in the rotation.

A total of seven field experiments were established: four in the northern region at Mónica Norte, Nuevo Horizonte, El Porvenir, and Cauce Viejo farms, two in the central region at CAICO, and El Paraíso farms, and one in the eastern region at Curichi farm. Soil analyses at the beginning of the experiments are shown in **Table 1**.

Treatments evaluated included: 1) Check; 2) PK (20 kg/ha P + 50 kg/ha K); 3) PS (20 kg/ha P + 10 kg/ha S); 4) KS (50 kg/ha K + 10 kg/ha S); 5) PKS (20 kg/ha P + 50 kg/ha K + 10 kg/ha S); and 6) PKS+Micros (20 kg/ha P + 50 kg/ha K + 10 kg/ha S + 0.2, 0.1, and 0.3 kg/ha of B, Cu, and Zn, respectively). Fertilization rates were repeated every season in the same plots to allow for the evaluation of direct and residual fertilization effects. Nitrogen fertilization was evaluated in the maize and wheat

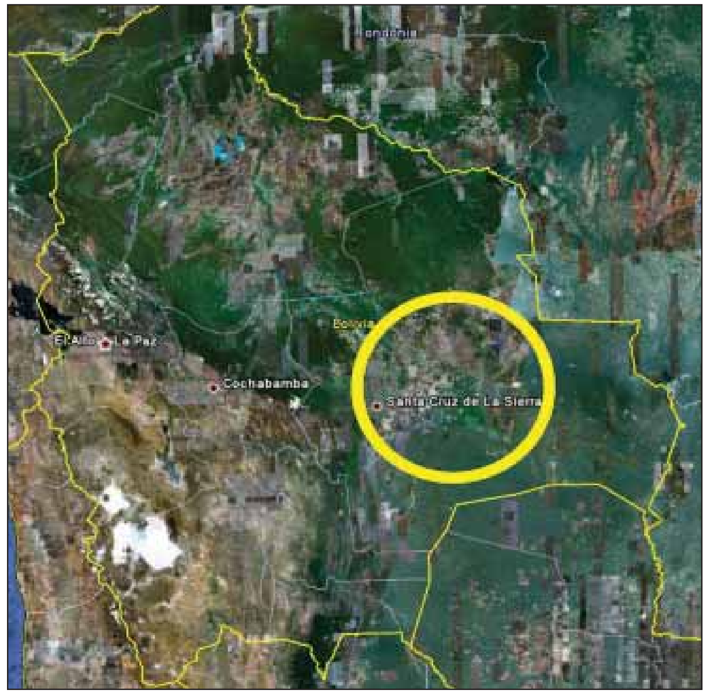

Figure 1. Map of Bolivia showing the Department of Santa Cruz de la Sierra*. Source: Google Earth ©2010. *The yellow circle includes most of the agricultural region of the department.

Common abbreviations and notes: N = nitrogen; P = phosphorus; S = sulfur; K = potassium; B = boron; Cu = copper; Zn = zinc.

Table 1. Soil chemical properties of the A horizon (0 to 20 cm) at the establishment of the field experiments.

	Northern region				Central region		Eastern region
Property	Monica Norte	Nuevo Horizonte	El Porvenir	Cauce Viejo	Paraiso	CAICO	Curichi
pH	8.0	7.7	6.5	6.8	7.0	7.2	7.0
EC, dS/cm	226	86	105	59	20	75	93
Clay, %	14	9	11	10	9	17	29
Silt, %	85	75	87	82	51	80	68
Sand, %	1	16	2	8	40	3	3
Organic matter, %	1.7	1.1	2.0	1.4	1.2	2.5	2.9
Total N, %	0.13	0.08	0.15	0.12	0.17	0.27	0.23
Olsen P, mg/kg	1.8	3.1	7.8	5.5	5.3	2.2	37
Sulfate-S, mg/kg	10	4	4	7	3	33	48
Exchangeable K, $cmol_+$/kg	0.15	0.32	0.34	0.35	0.18	0.72	0.73

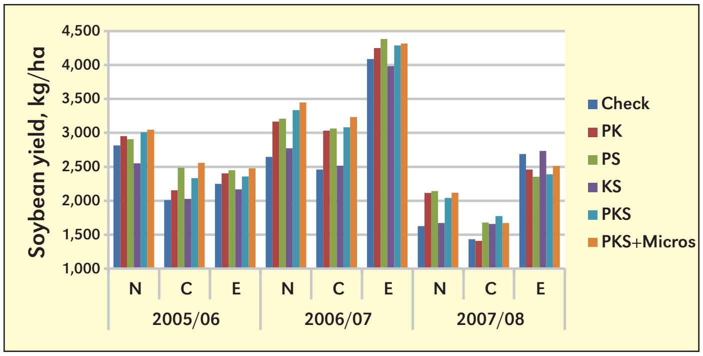

Figure 2. Soybean grain yield, averages of the sites of each region, for the six treatments evaluated in the summer seasons 2005/06, 2006/07, and 2007/08. N, C, and E stand for northern, central, and eastern regions, respectively.

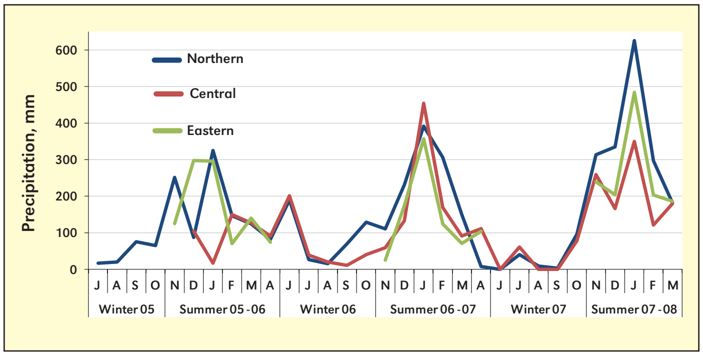

Figure 3. Monthly precipitation in the three regions from July 2005 through March 2008.

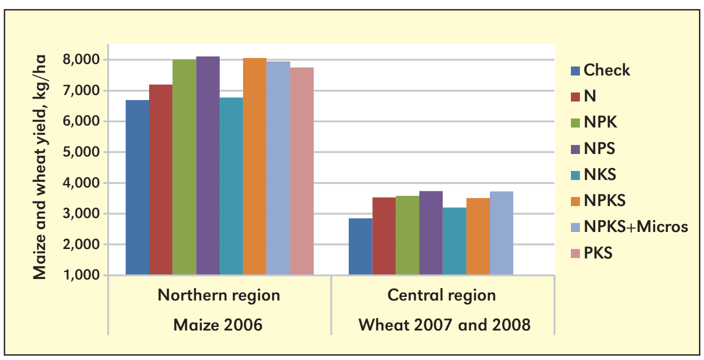

Figure 4. Grain yields of maize in the 2006 winter season, averages of four sites, and of wheat in the 2007 and 2008 winter seasons, averages of two sites, for eight fertilization treatments.

crops by introducing additional treatments with (60 kg N/ha) and without N in some experiments according to field rotation.

In the northern region, two crops are planted every year: winter and summer cropping seasons. In the central and eastern regions, the main season is the summer and planting in the winter season depends on soil water availability at planting. Crop management (i.e. varieties/hybrids, planting dates, pest management, etc.) was optimized and carried out by the farmers according to best management practices (BMPs) known for the region. All sites were managed under no-tillage. Soybean seeds were inoculated with *Bradyrhizobium* strains adapted to the region. Fertilizers were applied at planting, 3 to 4 cm below and to the side of seeds.

Phosphorus deficiency in a maize crop at Monica Norte, Winter 2006.

Results

Soybean grain yields were affected by flooding and soybean Asian rust in the 2007/08 summer season and by a dry period in the 2007 winter **(Figure 2)**. Differences in soybean grain yield among regions were related to disease pressure, soil conditions, and crop management. In the northern region, soybean yields performed similarly in the winter and summer seasons, despite the difference in precipitation between seasons **(Figure 3)**. Adequate weather conditions contributed to excellent grain yields of maize in the 2006 winter season, and wheat in the 2007 winter season **(Figure 4)**.

Phosphorus was the main nutrient deficiency with significant responses in 24 of a total of 32 site/years. These responses are attributed to the low Olsen P levels of most of the sites **(Figure 2 and 4)**. No responses were observed at Curichi, the only site with high soil Olsen P availability.

Relating relative yields (i.e. grain yield of the KS treatment/grain yield of the PKS treatment) and soil Olsen P, allowed estimation of a critical Olsen P level of 5 to 6 mg P/kg **(Figure 5)**. This critical level would be an initial tool for the region on deciding BMPs for P fertilization. The average response for 20 site/years of soybean below 6 mg P/kg was 268 kg/ha. For maize (4 site/years), the average response was 1,542 kg/ha. The estimated agronomic efficiencies (AE) were 13.4 kg soybean and 77.1 kg maize per kg P, which compare to fertilizer/grain price ratios of 8.3 and 15.9 kg soybean and maize, respectively, per kg P (considering prices of USD 3.5/kg P, USD 0.42/kg soybean, and USD 0.22/kg maize). Thus, the net return for P fertilization under soil Olsen P below 6 mg/kg would be USD 1.6/USD and USD 4.8/USD for soybean and maize, respectively.

The statistical analyses also showed significant responses to micronutrients at one site in the 2005 winter season soybean and to S at one site in the 2007/08 summer season soybean. These responses could not be confirmed in other seasons at the same sites. The low exchangeable K levels of Monica Norte and Paraiso **(Table 1)** would suggest a high probability of response to K fertilization, however no responses were observed at either of these two sites.

Nitrogen fertilization significantly increased grain yields in the 2006 winter maize at two sites, and in the 2007 winter wheat at one site **(Figure 3)**. Nitrogen fertilization produced no significant differences at the other sites.

Dr. Garcia (right) visiting one of the seven field experiments established within the Fundacruz network. This site (El Porvenir) was located in the northern region of eastern plains of Bolivia.

Summary and Conclusions

The Fundacruz network of exploratory experiments allowed determination of P deficiencies and a high probability of grain yield response in soils with Olsen P below 6 mg P/kg, contributing to the development of BMPs for fertilizer use in the region. Research also showed that K, S, and micronutrients might be deficient under certain soils and management conditions.

Further research will address the determination of right rate, source, time, and place of P fertilization under responsive situations. Also, exploration of K, S, and micronutrient deficiencies and responses should be continued. Fertility management should be integrated with soil management practices, and overall crop management to develop sustainable cropping systems in the eastern plains of Bolivia.

More information on this research project (Bol-01) is available from the IPNI Research Database found at www.ipni.net/research BC

Mr. Jorge Terrazas, Grover Guaygua, Mauricio Crespo, and Estanislao Juarez are former research staff members with Fundacruz (Foundation for the Agricultural Development of Santa Cruz), website: www.fundacruz.org.bo/. Dr. Garcia is Director, IPNI Latin America-Southern Cone, e-mail: fgarcia@ipni.net

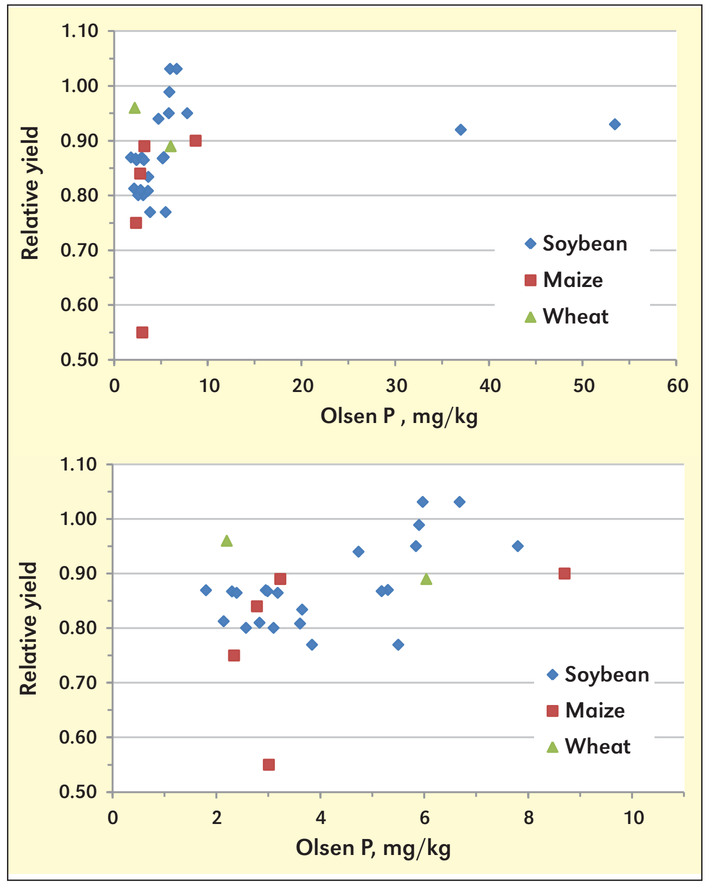

Figure 5. Relationship of relative yield of soybean, maize, and wheat with soil Olsen for 32 site-years of the Fundacruz network. Top figure shows the relationship for all site/years, and lower figure shows the relationship for sites with Olsen P below 10 mg P/kg.

References

INE. 2010. http://www.ine.gob.bo/indice/general.aspx?codigo=40104. Accessed September 2011.

Acknowledgements

We greatly acknowledge the help and collaboration of all the farmers and farm's staff who made possible this study, and the support of Corporacion Misti, Fino, Facer Trading, ADM-SAO, Monica Semillas, Agrosem, Cereales del Este S.A., and Stoller.