MANAGEMENT OF ORGANIC AND INORGANIC SOIL FERTILITY INPUTS IN INDIGENOUS AGRICULTURAL COMMUNITIES IN THE BOLIVIAN HIGHLANDS

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Introduction

The Bolivian highland plateau region (Altiplano) is a semi-arid region in the Andes Mountains that has a range in elevation of between 3600 and 4300 m above sea level. The region's climate is characterized by frost risks, low and irregular precipitation and high risks of drought during the growing season (Garcia et al., 2007). Recent research has indicated that the Andes region will experience temperature increases of up to 6°C by the end of the century (Bradley et al., 2006, IPCC, 2007). These climate changes may increase the risk of crop failure and food insecurity of local indigenous communities in the region. Agricultural practices in this region are primarily potato-based cropping systems and livestock rearing of cows, sheep and camelids (Valdivia et al., 2001).

One consequence of climatic and socioeconomic changes in the Altiplano has been increased soil degradation (Swinton and Quiroz, 2004; Motavalli et al., 2008). Soil organic matter (SOM) may assist in mitigating this soil degradation, improve soil quality and the long-term sustainability of agro ecosystems (Gupta et al., 1994). Improvements in existing soil management practices or the introduction of alternative practices that increase SOM may be needed for increased production and for reducing the negative consequences of climate change.

Objectives

1. To develop alternative fertilization practices that would improve long-term soil fertility and increase SOM.
2. To engage community members in ongoing evaluation of the practices and the potential for their adoption.

Figure 1. Semi-arid conditions of the landscape in Umala showing well-adapted rustic vegetation used for grazing.

Materials and Methods

- Field experiments planted to potato (*Solanum tuberosum ssp. andigena*) were established in 2006-07 and 2007-08 in three communities in Umala, a municipality in the central Bolivian Altiplano.
- Treatments (RCB design with 4 reps) included a control (no fertilizer), sheep and cow manures at 10 MT ha^{-1}, compost at 5 MT ha^{-1}, Biofert (a commercial microbial activator) at 0.2 MT ha^{-1}, urea and diammonium phosphate at 80-120-00 kg ha^{-1} of N-P-K, and combinations of these treatments.
- Soil samples were taken during the growing season to assess changes in soil properties (data not shown).
- Samples of the organic amendments were collected prior to the growing season and analyzed for total organic C and soil nutrient levels.
- Several plant measurements were taken including total N and Cardy Meter nitrate of leaf petioles.
- A panel of community members evaluated crop performance due to the treatments.

Figure 2 A-B. A) Indigenous Altiplano farmer showing some of his native potato varieties and B) collection of native potato varieties used in the region.

Figure 3. Photos illustrating field research activities carried out by farmers and undergraduate students in Umala communities.

Results and Discussion

- In both years and in all communities there was a low rainfall and occurrence of frost (Fig. 4) that reduced plant growth and consequently the potato tuber yield.
- In general, treatment combinations of animal manure and fertilizer significantly outyielded other treatments in all communities (Fig. 5). Farmer evaluations at flowering and harvesting time also indicated preferences for the combined treatments (Fig. 8).
- Farmers often indicated a preference for sheep manure over cow manure as a soil amendment, but very limited differences in nutrient composition were observed in the collected samples.
- Higher gravimetric soil water content were found when sheep manure alone or combined fertilizer plus manure were added (Table 2).
- Addition of manure significantly reduced the soil bulk density (Table 2).
- Soil organic matter content was significantly increased when cow manure and Biofert were added (Table 2).
- Cardy meter nitrate readings of leaf petioles significantly related to total leaf N, but variability among the communities was observed in this relationship (Fig. 7).

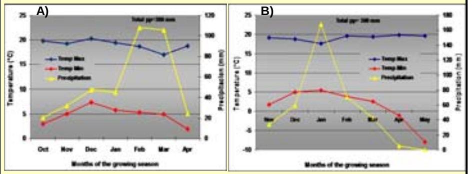

Figure 4 A-B. Monthly average of the maximum and minimum temperature and the rainfall in Umala communities during the growing season A) 2006-07 and B) 2007-08.

Table 1. Selected properties and application rate of organic sources used in the field trials.

Organic amendment*	C:N ratio	Total organic C	Total N	Total P	Total K	Total Zn	Total Fe	Total Mn	Total Cu
		%				mg kg^{-1}			
Cow manure	18	26.6	1.4	0.31	2.1	35.3	3397	156	7.4
Sheep manure	18	29.4	1.7	0.34	2.2	37.7	2798	165	7.6
Compost**	11	13.0	1.2	0.34	0.7	74.8	5992	302	13.1
Biofert***	4	37.6	10.1	0.22	0.4	63.9	2934	119	6.2

* Manure samples collected from composted piles and averaged over all communities
** Composted rural waste
*** Biofert is a commercial microbial activator soil amendment

Table 2. Changes in A) gravimetric soil water content, B) bulk density and C) organic matter content in 2007 due to organic and inorganic soil amendments in Umala.

A)

Amendment	At harvesting (%)	Duncan (α = 0.01)
SM	11.62	a
SM+Biofert	11.29	a
SM+DAP+Urea	11.27	a
CM+SM	10.39	ab
Compost	10.19	ab
CM+DAP+Urea	10.09	ab
CM+SM+Biofert	10.02	ab
CM+Biofert	10.00	ab
CM	9.32	ab
CM+SM+DAP+Urea	9.29	ab
DAP+Urea	8.29	ab
Control	7.75	b

B)

Amendment	At harvesting (g/cm^3)	Duncan α = 0.01
Control	1.30	a
SM	1.26	ab
SM+DAP+Urea	1.26	ab
DAP+Urea	1.22	ab
CM+SM+DAP+Urea	1.22	ab
CM	1.22	ab
CM+SM	1.22	ab
SM+Biofert	1.22	ab
Compost	1.20	b
CM+Biofert	1.19	b
CM+SM+Biofert	1.18	b
CM+DAP+Urea	1.18	b

C)

Amendment	At harvesting (%)	Duncan α = 0.01
CM+Biofert	1.42	a
CM+SM+Biofert	1.38	ab
CM	1.36	ab
SM+Biofert	1.35	ab
CM+DAP+Urea	1.34	ab
CM+SM	1.28	abc
Compost	1.28	abc
SM+DAP+Urea	1.25	abc
CM+SM+DAP+Urea	1.23	bc
SM	1.22	bc
DAP+Urea	1.19	c
Blank	1.15	c

CM = Cow Manure; SM = Sheep Manure; DAP = Diammonium Phosphate
SOM before planting = 1.11 %

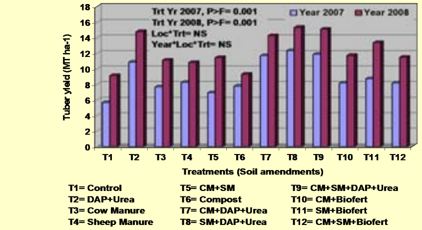

Figure 5. 2007 and 2008 potato tuber yield averaged over all trials in Umala.

Figure 6. Farmers evaluation of the effect of the soil amendments on potato plant growth at blooming time in the field trials.

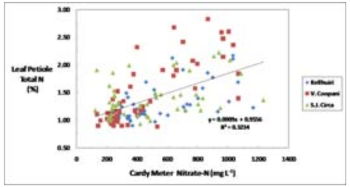

Figure 7. Relationship between Cardy Meter nitrate readings and total N in leaf petioles in Umala 2007.

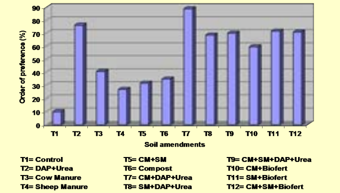

Figure 8. Farmers preference for the soil amendments based on the effect on plant growth and tuber yield in Umala 2007.

Conclusions

- Application of cow manure alone or combined with Biofert increased soil organic matter which may improve long-term soil fertility.
- Use of all the soil amendments for potato crop production significantly improved crop performance, but addition of organic amendments also had benefits for improved soil organic matter, water retention and bulk density reduction.
- Based on farmers' perception, the combination of manure and Biofert might be an alternative option for improving potato plant growth and tuber yield.
- The Cardy nitrate meter may assist in N fertilizer management of potato in this region where soil and plant testing resources are limited, but more testing of this method may be needed to determine factors that affect measurements.
- The relative residual effects of the organic and inorganic soil amendments on subsequent crops (e.g., quinoa) are currently being evaluated.