Sugarcane Production and Changes in Soil Phosphorus Forms after Organic and Inorganic Fertilization

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Where adequate organic sources exist, high yield sugarcane production systems should integrate their use with inorganic fertilizers. Both have a role in providing nutrients to crops and improving the physical microbiological properties of soil. An integrated strategy promotes agro-ecosystem diversity and maximum economic yield (MEY) agriculture.

Adopting appropriate soil and crop management practices positively affects chemical, physical, and biological conditions of soil. Addition of phosphorus (P) may impact soil P forms and thus the timing and intensity of P availability. Both organic and inorganic sources enhance soil P availability and crop yields. In tropical soils, the effectiveness of either is often site-specific (Ball-Coelho et al., 1993; Reddy et al., 1999; Sui et al., 1999). Overall, research results suggest the need for more investigation regarding the impact of fertilization on P cycling in tropical agro-ecosystems.

Sugarcane production in Costa Rica is mainly located on high organic matter soils derived from volcanic ash (Andisols). Andisols are strongly P-fixing due to adsorption at the active surfaces of allophane and imogolite minerals and also by aluminum (Al)-humus complexes through ligand-exchange reactions (Sanchez and Uehara, 1980; Molina et al., 1991; Espinosa, 1992). High organic matter contents imply that the organic P fraction plays an important role in satisfying the crop's demand. Conditions typical of the soil and region combine to complicate the estimation of soil P status and challenge the ability of soil testing to adequately predict soil P availability (Beck and Sanchez, 1994; Espinosa, 1992).

This experiment studied soil P forms resulting from application of organic and inorganic fertilizers on an Andisol. Yield response data for the nutrient sources applied to sugar cane was also evaluated. A sugarcane (*Sacharum* sp. var H-611721) field experiment conducted from 1997 to 2002 on a Typic Hapludand at Juan Viñas, Costa Rica (1,000 meters above sea level and 2,000 mm of rain per year) was harvested twice during this period. Yield of cane and sugar were measured along with total P uptake. Treatments consisted of 0, 50, and 100% of the inorganic fertilizer recommendation in combination with compost at either 0 or 8 t/ha (**Table 1**).

Sugarcane production without added fertilizer can seriously deplete all forms of soil P on soils derived from volcanic ash.

Table 1. Estimated amounts of nutrients (N, P, and K) applied as fertilizer on sugarcane over 4 years on a Typic Hapludand at Juan Viñas, Costa Rica.

Treatments		Nitrogen			Phosphorus			Potassium		
Compost	Fertilization	Organic	Mineral	Total	Organic	Mineral	Total	Organic	Mineral	Total
		kg/ha								
0	0	0	0	0	0	0	0	0	0	0
0	50%	0	245	245	0	59	59	0	162	162
0	100%	0	490	490	0	118	118	0	323	323
8 t/ha	50%	46	245	291	10	59	69	26	162	188
8 t/ha	100%	46	490	536	10	118	128	26	323	359

Nutrients were applied at the beginning of each growing cycle.

Soil samples were collected, ground (<100 mesh), and analyzed using a modified Hedley P fractionation scheme (Hedley et al., 1982). This technique is a sequential extraction procedure that removes labile inorganic P (Pi) and organic P (Po) followed by the more stable P forms. Inorganic P is first extracted by anion exchange membranes (AEM-P) followed by sodium bicarbonate ($NaHCO_3$), sodium hydroxide (NaOH), and hydrochloric acid (HCl). The sample is then digested in sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2). These inorganic fractions are related to soluble/labile-Pi, labile-Pi, iron (Fe) and Al phosphates, calcium phosphates, and residual P. Extractable organic P was determined by the difference of total P (coming in digested aliquots of $NaHCO_3$ and NaOH) and the Pi initially determined from these extracts. AEM-P and $NaHCO_3$-Pi were summed and expressed as labile-Pi. $NaHCO_3$-Po and NaOH-Po were summed and expressed as extractable-Po. Routine soil analyses were conducted before the beginning of the experiment and at the beginning of the 2001 season (**Table 2**).

Yield Response and P Uptake by Sugarcane

The two yield variables responded differently to nutrient application (**Table 3**). Fresh cane yield was consistently higher for all treatments supplying nutrients compared to the control. Yields ranged from 106 to 145 t/ha in the first harvest (1999) and from 163 to 258 t/ha in the ratoon season (2001). Accumulated yield was nearly 50% higher than the control when inorganic and organic sources were co-applied at their higher levels. Despite these yield responses, variability prevented any statistical differences among treatments supplying nutrients. Nutrient application over this time frame did not seem to affect the amount of sugar produced per tonne of fresh cane.

Table 2. Selected properties of the soil used in the study, Juan Viñas, Costa Rica.

Treatments			P	Ca	Mg	K	Acidity	O.M.
Compost	Fertilizer	pH H_2O	mg/kg	cmol$_{(+)}$/kg				g/kg
1997 †		5.0	3.0	2.19	0.19	0.11	1.1	-
2001 ‡								
0	0	5.2	4.6	4.65	0.30	0.09	0.17	160
0	50%	4.9	4.8	5.85	0.33	0.10	0.20	140
0	100%	4.8	5.5	3.49	0.23	0.10	0.27	151
8 t/ha	50%	4.8	5.5	4.49	0.28	0.09	0.17	158
8 t/ha	100%	4.9	5.8	3.91	0.11	0.11	0.22	172
Critical level		5.5	10.0	4.00	1.00	0.20	<0.5	-

† Initial soil sampling before beginning the experiment
‡ 1.5 t/ha of dolomite was applied in 1998

Table 3. Sugarcane yields obtained after two growth cycles during 4 years on a Typic Hapludand, Juan Viñas, Costa Rica.

Treatments		1999 yield		2001 yield		Accumulated
Compost	Fertilizer	kg sugar/t	t/ha	kg sugar/t	t/ha	yield, t/ha
0	0	112	106 b	101	163 b	269 b
0	50%	111	134 a	98	218 a	352 a
0	100%	113	142 a	103	239 a	381 a
8 t/ha	50%	115	139 a	108	224 a	363 a
8 t/ha	100%	119	145 a	96	258 a	403 a
Significance		ns	**	ns	*	**

ns Not significant at p=0.05
* Significance at p=0.01 to 0.05
** Significance at p=0.01
Means within the same column followed by the same letter are not significantly different (p=0.05) by LSD test.

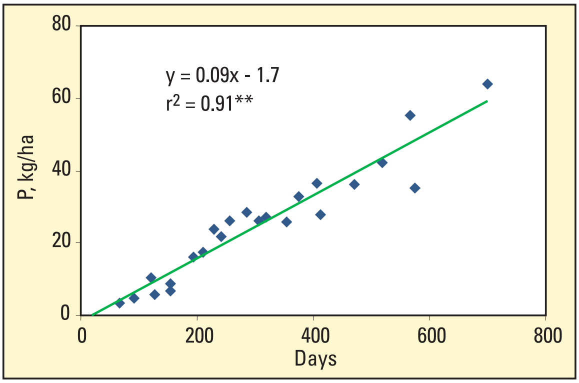

Figure 1. Total P uptake of sugarcane on a Typic Hapu-land, Juan Viñas, Costa Rica.

Phosphorus uptake by sugar cane is shown (**Figure 1**). Total uptake by sugar cane yielding 180 t/ha in 700 days (2-year growth cycle) was approximately 60 kg/ha.

Soil P Forms

According to the fractionation scheme applied, the proportions of soil P forms in the fertilizer plus compost treatments averaged: 0.4% labile-P, 6.4% NaOH extractable-Pi, 9.2% HCl extractable-Pi, 32.5% extractable-Po, and 51.4% residual-P. Soil P forms that were most correlated with yield and applied P were labile-P and NaOH-Pi (**Figure 2**). The NaOH-Pi fraction represents P held by chemisorption to Fe and Al components of soil surfaces. This fraction is thought to act as a sink for inorganic fertilizer applied and labile-Pi. Little relation was found between cane yield and organic-, residual-, or total-P.

Summary

Applied P was mainly correlated with labile-Pi and NaOH-Pi, but results suggest active participation from nearly all soil P fractions in maintaining labile-Pi levels in this soil. Adsorption-desorption processes act intensively in this soil and it was possible to see the effect of fertilizer in desorbing P for a long time after its application. Crop production without added fertilizer will seriously deplete all forms of soil P. BC

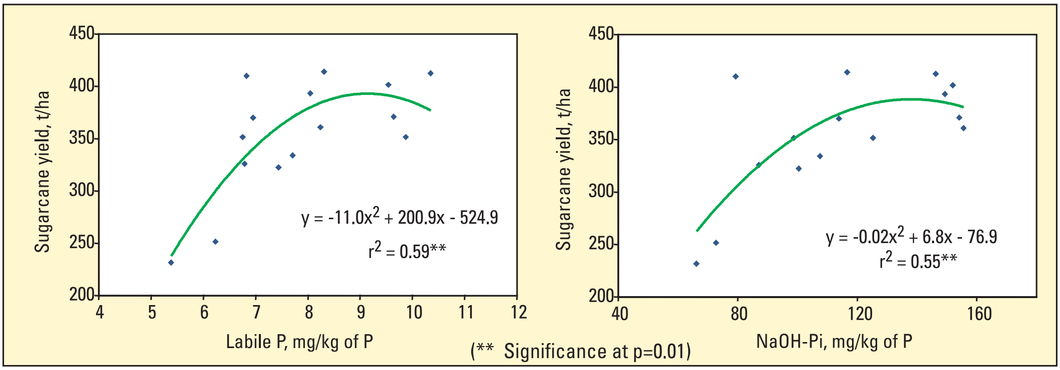

Figure 2. Relation between accumulated sugarcane yields and labile-Pi and NaOH-Pi on an Andisol. Juan Viñas, Costa Rica.

More study is needed regarding impact of P fertilization on P cycling in tropical agro-ecosystems.

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