Cana de açúcar: Indicadores de fertilidade física e vulnerabilidade do solo em Tucumán, Argentina

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ABSTRACT

In a sugarcane experimental site (Famaillá, Tucumán, Argentina) there were determined the load-strain ratio, the pre-compression stresses and the compression indexes of unaltered soil samples. Test procedure was based on the methodology described in ASTM D 2435 03. Soil samples were soaked for 48 hours in order to reach the saturation state before being subjected to vertical pressures from 6 to 1478 kPa. The time of application was the necessary one to allow the drainage of excess water from the soil sample. Deformation of the soil sample was plotted as a function of the logarithm of the time. Voids ratio were established as a function of the logarithm of the pressure and, from this function, the mentioned parameters were calculated. Results obtained from the consolidation tests seem to show the effect of the history of loads exerted on the soil. There is a high gradient of reduction of void ratio, which tends to compromise the future physical integrity of the soil.

KEYWORDS: Precompression stress, soil compaction, void ratio.

INTRODUCTION

Precompression stress is considered by numerous authors as the capacity of soils to support loads and consequently, as the risk of compaction of cultivated soils (IMHOFF et al., 2004; RUCKNAGEL et al., 2007). For other authors, it is an indicator of soil mechanical resistance and stability (BERLI, 2001). Various methods are used to determine precompression stress (ARVIDSSON and KELLER, 2004; IMHOFF et al., 2004), and it is noted that significant errors in the estimation can be made if the curve tends non-linear at high tensions. TERZAGUI (1936) uniaxial compression test, it is used to characterize soil compressibility (Figure 1).
Strictly, precompression tension represents the load history that soil has resisted in its geological development, while the angle of the segment called “virgin compression curve” would indicate and estimate the risk of compaction (TERZAGUI and PECK, 1976; JUÁREZ BADILLO and RODRÍGUEZ, 1972). Nevertheless, there is an almost unanimous opinion that if the applied loads are less than the preconsolidation tension, soils is deformed and recovers elastically. If, on the other hand, the loads exceed the preconsolidation stress, the deformation suffered in the soil is irreversible (LEBERT and HORN, 1991). The objective of this work is

to determine the efficiency of the cultural activities normally used in sugarcane crops using indicators of physical soil fertility and soil vulnerability, in particular, by the uniaxial compression test.

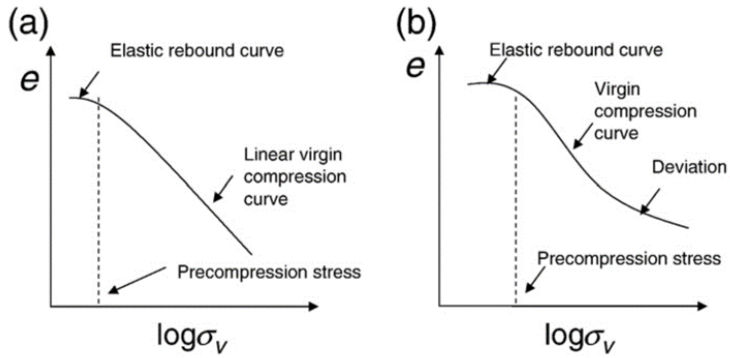

FIGURE 1: Principal shapes of strain-load curves: bi-linear (a) and S-shaped curves (b).

MATERIALS AND METHODS

Tests were realized using unaltered soil samples, extracted on June of 2013 using 110 mm stainless steel hoop cores (Figure 2a). Experimental site was conducted as a traditional long-term sugarcane monoculture (+20 years). Two years before the extraction of samples, the site was ploughed and a soybean crop was sowed. Soil profile and textural analysis of the experimental site are detailed in Table 1.

Soil samples were taken from *A* and *Bt1* horizons, as those are the densified layers in experimental site, and all sites evaluated at Tucumán province (TESOURO et al., 2012). Soil strain-load curves were obtained following a protocol based in the ASTM D 2435 03 methodology, using a uniaxial compression apparatus developed in the Laboratorio de Terramecánica e Implantación de Cultivos (IIR - CIA - INTA Castelar) (Figure 2b).

TABLE 1: Soil horizons sequence and textural classes of the experimental site.

Depth (cm)	0 - 5	5 - 25	25 - 40	40 - 62	62 - 85
	Ap	**A**	**Bt1**	**Bt2**	**BC**
Sand (%)	20,7	20,7	18,7	14,7	14,7
Silt (%)	46,0	46,0	42,0	46,0	70,0
Clay (%)	33,3	33,3	39,3	39,3	15,3
Texture	Clay Loam	Clay Loam	Silty Clay Loam	Clay Loam	Silty Loam

FIGURE 2: a) Soil sample after precompression test, stainless steel hoop cores, and a soil sample as brought from field test, before flushing. b) Uniaxial compression apparatus.

Soil samples were soaked for 48 hours in order to reach the saturation state before being subjected to vertical pressures of 6, 19, 34, 62, 113, 210, 400, 760 y 1478 kPa. More evaluation pressures points were added when it was considered needed. Application time was the necessary one to allow the drainage of excess water from the soil sample from both sides (up and down) of the core. Soil sample deformation was measured with a digital micrometer (minimum resolution of 0.01 mm) and then it was plotted as a function of time logarithm. Voids ratio was established as a function of pressure logarithm, from this function, it was determined the load-strain ratio, maximum curvature point, the soil precompression stress and the compression indexes of all unaltered soil samples.

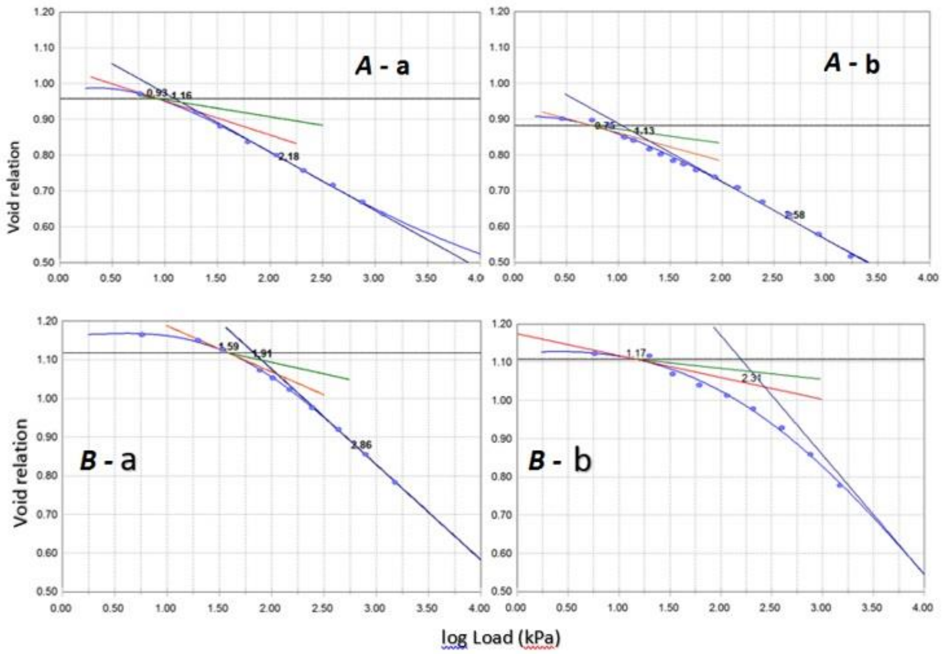

FIGURE 3: Strain-load curve, expressed as void relation, A) obtained on *A* horizon (a) soil sample 1, (b) soil sample 2; B) obtained on *Bt1* horizon (a) soil sample 1, (b) soil sample 2.

RESULTS AND DISCUSSION

Strain-load relations observed in Figures 3A shown that precompression stress was of minimum magnitude and practically identical, between 13.5 y 14.5 kPa. This values implies a brief range of tensions in which soil reacts elastically, over this threshold values soils deformation are irreversible. Horizon *A* performance when superficial loads are applied, obey to its historical management as seen by LEBERT and HORN (1991): it can be observed remains of artificial porosity created by 2011 shallow tillage before the implantation of this treatments, tillage also made that layer more susceptible to plastic deformation.

A complete different situation stands on *Bt1* horizon, with historical less disturbance than *A* horizon. In this case, preconsolidation stresses fluctuated on a range from 80 to 200 kPa, situation that can be appreciated on Figures 3B. These values should reflect the load of *A* horizon layer, drying and wetting cycles and anthropic effect. The 4 kPa pressure exerted by the superior actual layer (*Ap* and *A* soil layers summed) was estimated using its thickness (300 mm) and its bulk density (TESOURO et al., 2016). Soil mechanics adhere to the teory that capilar tensions developed during drying cycles generates the major force involved in soil contraction and provokes an irreversible compression of susceptible soils (TERZAGUI, 1936). Neutral load at the beginning of the air inlet (37.2% of gravimetrical humidity) was estimated in 30 kPa. At the end of residual contraction, neutral tension arrived to 140 kPa. Precompression strain-load of one of the *Bt1* samples exceed widely that value (Table 2).

TABLE 2: Principal parameters obtained of strain-load deformation relation of soil samples

Sample	Void relation (origin)	Maximum curvature point	Preconsolidation load (Pc)	Void relation at Pc point		Compression index (Cc)	
	(cm^3/ $cm^{3)}$	(log kPa)	(log kPa)	(kPa)	(cm^3/$cm^{3)}$	($\Delta y/\Delta x$)	(degree)
A - 1	0.99	0.93	1.16	14.5	0.93	-0.1638	-9.30
A - 2	0.91	0.75	1.13	13.5	0.85	-0.1617	-9.18
Bt1 – 1	1.17	1.59	1.91	81.3	1.07	-0.2466	-13.85
Bt1 - 2	1.13	1.17	2.31	204.2	0.98	-0.3127	-17.36

CONCLUSIONS

With this approach, it is possible to determine the maximum loads that can be applied to a sugarcane soil before plastical deformation. *A* Horizon had a behaviour similar to a refurbished sample, presumably because of its historical heavy tillage action. On those samples it cannot be estimated its load history, and the virgin compression load initiates almost on the origin of its strain-load function. Instead, *Bt1* horizon showed precisely its process of consolidation, reducing consequently its stage of elastical deformation.

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