Aggregate breakdown and dispersion of Brazilian soil samples amended with sugarcane vinasse by ultrasonic energy

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Abstract
Aggregate stability is very complex and related to important soil attributes. This work aimed to evaluate the aggregate stability by ultrasonic energy of Brazilian soil samples amended with sugarcane vinasse – an important byproduct from ethanol and brandy production in Brazil. Two Oxisols and one Ultisol were used in this study. Aggregates 1-2 mm size, previously treated with sugarcane vinasse under lab conditions were submitted to different levels of ultrasonic energy and the particle size distribution (53-2000 µm, 2-53 µm and <2 µm fractions) was quantified. The mass of aggregates in each of these fractions was modelled as function of applied ultrasonic energy and some parameters that describe the aggregate stability were obtained based on work of Field and Minasny (1999). The methodology was sensitive to detect differences in the aggregate stability of all three soils. The Oxisols showed more aggregate stability than Ultisol. Vinasse enhanced the aggregate stability, mainly in the Oxisols.

Key Words
Soil aggregation, ultrasonic energy, tropical soils.

Introduction
Formation and stabilization of soil aggregates are highly complex (Six *et al.* 2004). The aggregate stability is related to important soil parameters, such as: soil porosity, hydraulic conductivity, sealing, compressibility, soil erodibility and carbon stabilization (Gregorich *et al.* 1989; Raine and So 1993). The most traditional and widely used method to measure aggregate stability is the wet-sieving method, proposed by Yoder (1936) – a simple technique whose results are well reproducible and correlated with soil attributes. However, in this method, the energy which is responsible for breaking and dispersing the aggregates is unknown. North (1976) proposed the use of ultrasonic energy, so that the dispersive energy which is responsible by the aggregate breakdown could be known. Latter, Raine and So (1993, 1994) proposed a method to measure the released energy by the ultrasonic probe, based on calorimetric techniques. By this method, the results are normally expressed through soil dispersion curves. For example, the <2 µm fraction released (dispersed) at different levels of ultrasonic energy represents the soil dispersion characteristic curve (SDCC) (Raine and So 1993). From this curve the required energy to complete soil dispersion can be estimated. The rate of aggregate breakdown can also be evaluated by the aggregate disruption characteristic curve (ADCC) (Tippkötter 1994), which is represented, for example, by reduction of 53 – 2000 µm fraction aggregates. The occurrence of a soil-aggregate hierarchy results in an aggregation liberation and dispersion curve (ALDC) (Field and Minasny 1999), for example, the stepwise breakdown of 2-53µm fraction aggregates, plotted against energy. This stepwise is a consequence of linkages within and between aggregates. Field and Minasny (1999) proposed some models to describe the results and showed some parameters related to the shape of ALDC curve (k_1, k_2 and E_{crit}), where k_1 represents the rate of aggregates liberation (e.g., 2-53 µm) and k_2 represents their subsequente dispersion. The E_{crit} represents the total applied energy that is required to initiate the dispersion of particles.

The sugarcane vinasse is the main byproduct of ethanol and brandy production. It is produced in large amounts, approximately 13 liters per liter of ethanol or brandy. Considering that the 2009 ethanol production in Brazil was estimated in 27 billion liters, 354 billion liters of vinasse was produced. Disposal in soils as liquid fertilizer is an alternative use for this product, mainly as a source of K. This practice avoids dupping vinasse into the water courses and lakes, which was common in the past (Günkel *et al.* 2007).
This work aimed to assess the aggregate breakdown and dispersion by ultrasonic energy of two Oxisols and one Ultisol from Brazil amended with sugarcane vinasse, based on work of Field and Minasny (1999).

Methods

Topsoil samples (0-10 cm layer) from a Red Latosol (LV), Red Yellow Latosol (LVA), and Red Yellow Argisol (PVA), according to Brazilian System of Soil Classification, two Oxisols and Ultisol (U.S Taxonomy), respectively, were collected for this study. The samples were air-dried and carefully ground and sieved in order to obtain 1-2 mm aggregates. Soil columns made of PVC tubes (6.0 cm high and 4 cm internal diameter) containing 200 g of aggregates (density 1.00 ±0.04 g/cm^3 and total porosity 0.59 cm^3/cm^3) were used to perform the incubation with sugarcane vinasse. The vinasse (from brandy production) was applied at the following rates: 0 (control), 150 and 300 m^3 ha^{-1}; then, the samples were kept at the field capacity (~0.30 cm^3/cm^3 for all soils) for 1, 30, and 60 days. After each incubation time, the aggregates were carefully removed from columns and air-dried for 48 hours; 5g of aggregates (oven-dried basis) were placed into 250-mL beaker and pre-moisture by slow dropping of distilled water in the walls of the beaker (inclined approximately 30 degrees) using a burette. After all the aggregates were immersed in water, the volume was completed to 200 mL (soil: water ratio 1:40). The soil suspension was submitted to increasing levels of ultrasonic energy: 210, 420, 840, 1680, 3360, 6720, and 13440 J/g, based on calorimetric techniques described by Raine and So (1993, 1994) and summarized in Brazil by Sá *et al.* (2000). The equipment used was a probe-type Misonix, XL 2020 model, with an output power of 70 W and immersed 2.5 cm into soil suspension. After each level of applied ultrasonic energy, the 53-2000 µm fraction was gently separate by wet-sieving. The aggregates and soil suspension that passed through the sieve was transferred to measuring cylinders. After adequate settling-times, the <2 µm fraction was determined using the pipette method. The 53-2000 µm, 2-53 µm and <2 µm fractions was adjusted to the models proposed by Field and Minasny (1999) and calculated the energy required to aggregate breakdown and dispersion (E_{crit}) and the constants k_1 and k_2.

Results

The energy required to complete dispersion (plateau of the SDCC - Figure 1A) decrease as follows: LVA > LV > PVA. The stepwise of aggregate breakdown was observed indicating the aggregate hierarchy for all soils (Figure 1C). As mentioned by Field and Minasny (1999), the shape of the ALDC is described by constants k_1 and k_2 showed in Figure 2. The LVA showed the lowest k_1 and k_2. This indicates more resistance to aggregate liberation and subsequente dispersion. Moreover, the LVA needed more energy (> E_{crit}) to initiate the dispersion of liberated aggregates. Based on E_{crit}, constants k_1 and k_2 (Figure 2), the aggregate stability decrease as follows: LVA > LV > PVA.

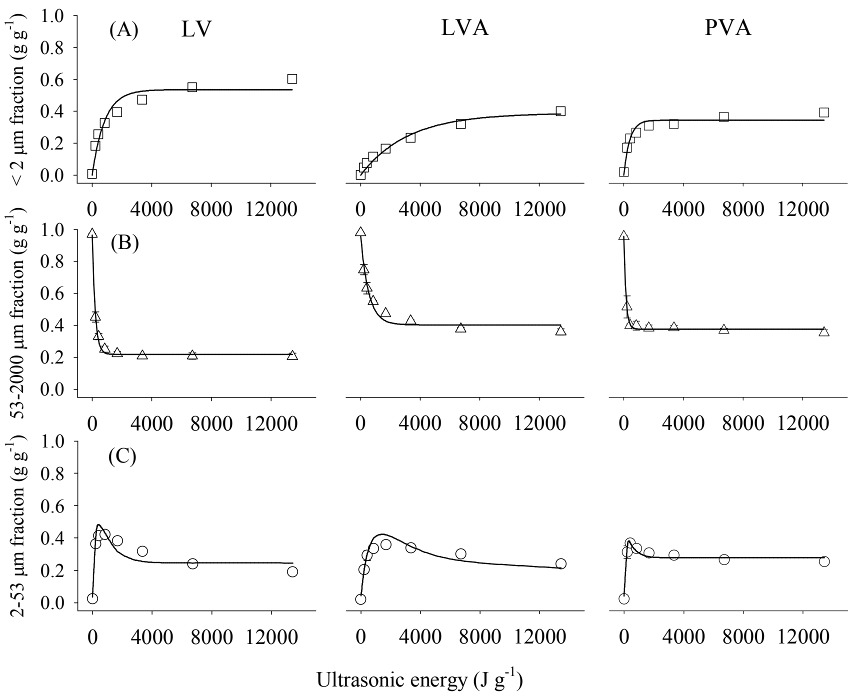

Figure 1. Soil dispersion characteristic curve – SDCC (A), aggregate disruption characteristic curve – ADCC (B) and aggregate liberation and dispersion curve – ALDC (C) to Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). The data were adjusted to models proposed by Field and Minasny (1999). Error bars indicate the average standard deviation (n = 3).

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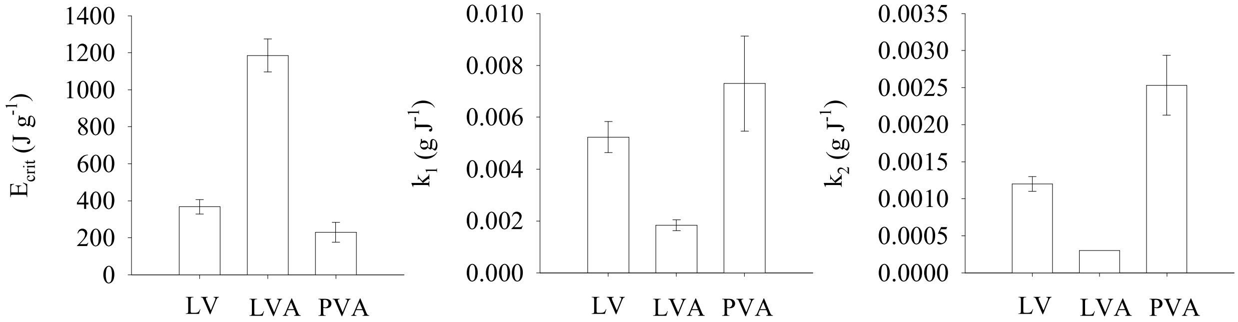

Figure 2. E_{crit} and constants k_1 (rate of aggregate liberation) and k_2 (rate of dispersion of liberated aggregates) of Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). Error bars indicate the average standard deviation (n = 3).

The vinasse enhanced the aggregate stability of soils (Figure 3). For LV and LVA the vinasse increased the E_{crit} and reduced the constants k_1 and k_2 in all incubation times. For PVA this was observed only at 60 days incubation time. In summary, the effect of vinasse on aggregate stability can be explained as follows: organic compounds presents in the vinasse and incorporated into soil protected the aggregates against the cavitation; the vinasse contributed to flocculation and binding of soil particles; the vinasse enhanced the growth and microbial activity.

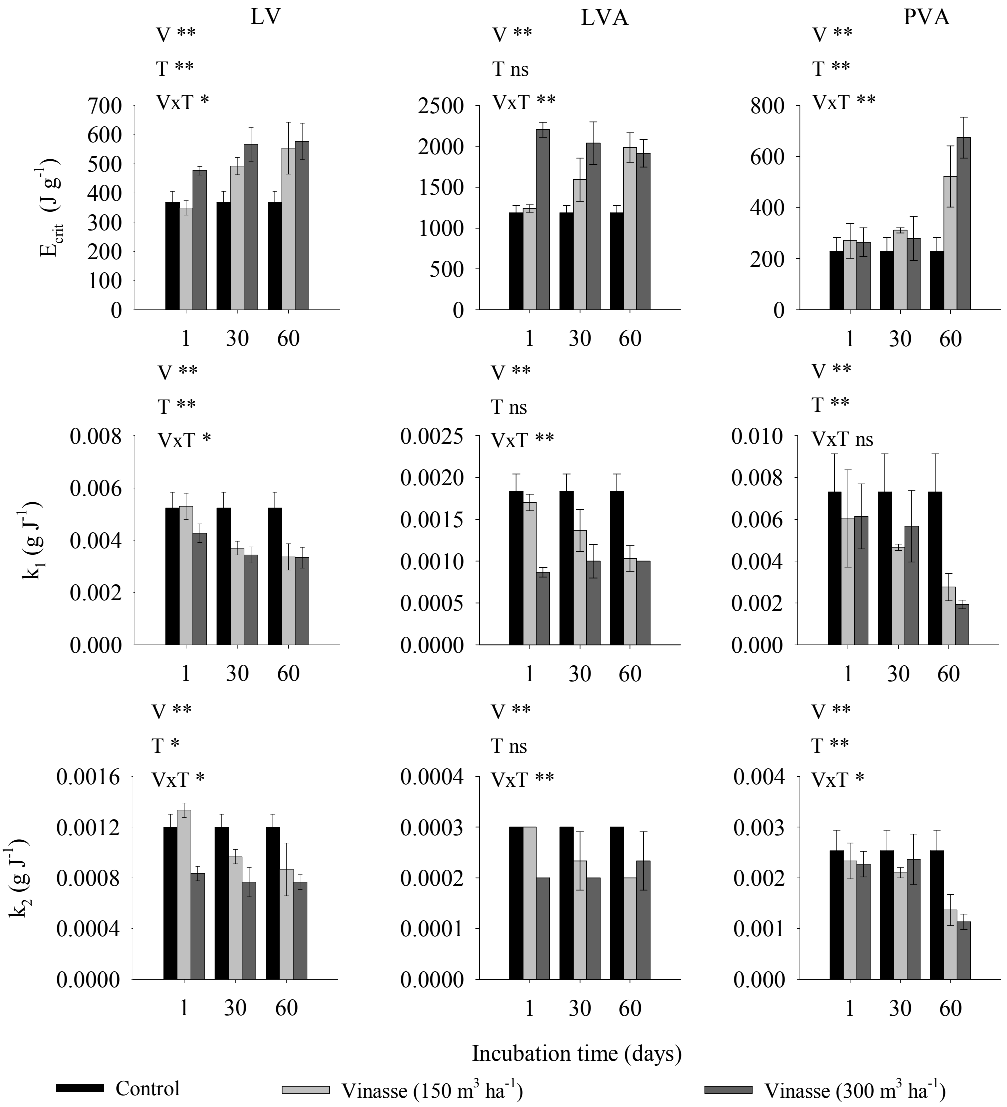

Figure 3. Effect of sugarcane vinasse and incubation time on E_{crit}, k_1 and k_2 of Red Latosol (LV) (Oxisol), Red Yellow Latosol (LVA) (Oxisol) and Red Yellow Argisol (PVA) (Ultisol). Error bars indicate the average standard deviation (n = 3). *, ** p<0.05 and 0.01, respectively (F Test).

Conclusion

The methodology used was sensitive to detect differences in the aggregate stability of the soils. The aggregate stability of the soils decreased as follows: LVA > LV > PVA. In other words, Oxisols > Ultisol. The vinasse increased the aggregate stability of all soils, mainly in the LVA and LV (Oxisols).

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