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Effect of Sugarcane Pulp Extract on Ameliorating Soil Structure Stability

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APPLICATION of organic materials is a common practice to increase soil aggregates and its stability, but the use of sugarcane pulp extract as a soil structural improvement, expressed in terms of mean weight diameter (MWD), has not been tested so far. Therefore, a laboratory experiment was conducted on intact soil core samples in a randomized complete design with two factors, i.e., two sources of extract (1) fresh sugarcane pulp (FSP) and (2) compost of sugarcane pulp (CSP), and seven drying and wetting cycles, plus the control (tap water only). Each soil core received an extracted volume of 175 cm^3 (equivalent to the addition of 10 t FSP or CSP ha^{-1}) on parts 25 cm^3 for each cycle. The effectiveness of CSP extract was 3-folds as that of FSP extract in improving MWD. The most pronounced effect was at the 4th cycle, suggesting that 100 $cm^3$of CSP extract (equivalent to the addition of 6 t CSP ha^{-1}) instead of 175 cm^3 appears to be sufficient for improving the soil structural stability. Overall, the extract derived from CSP could be a faster way in improving soil structure than FSP which takes time to decompose and shows its benefits.However, more future investigations should be expanded to other types of soil and field trials to obtain further information to be used in advising land managers, especially those who use a drip-irrigation system.

Keywords: Compost extract, Mean weight diameter; Drying and wetting cycles, Soil aggregates

Introduction

Soil structure is a major indicator of soil quality and the agricultural system. It's known that soil structure supports plants, provides them with adequate water, and affects aeration and release of ready-available nutrients (Alvares et al., 2012; Tagar et al., 2014 and Tagar et al., 2015). On the other hand, the particle size distribution of soil and the resistance of soil aggregates against disrupting by water are determining soil fertility and productivity.Therefore soil structural quality might be investigated by the percentageof water stable aggregates. Out of the various index of structure improvement,measurement Mean Weight Diameter (MWD) is an important index (Boogar et al., 2014; Tagar et al., 2015 and Tuo et al., 2017). The most recent studies confirmed that soil improvement by addition of the organic materials reduces-the deterioration of geometric arrangement of soil aggregates (Bashir et al., 2016; Vidal-Beaudet et al., 2018; Farid et al., 2014; Tuo et al., 2017; Gülser et al., 2015 and Zhang et al., 2014). An important positive relationship between soil organic carbon content and the increase of MWD was reported (Bashir et al., 2016; Gülser et al., 2015 and Zhang et al., 2014). Soil organic carbon as a major binding agent is one of the important drivers of soil structure and stabilization process of their aggregates, hence improves the relative abundance of macroaggregates at the expense of other aggregates (Das et al., 2014; Kashif et al., 2015 and Zhang et al., 2014).

Sugarcane pulp is the inner part of the sugarcane stalks, which is made up of a soft fibrous substance with a spongy structure (Wirawan et al., 2010). In the sugar industry, the pulp is regarded as a by-product, and in most cases is used for steam generation or producing paper or fiber boards. Instead of burning the pulp, it could be used as a low-cost soil improvement material, because it is available in large quantities either for no cost or for a small price (Rainey, 2012 and Cifuentes et al., 2013).

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Addition of organic compost and other solid manures have beneficial and great effects on plant and soil, but they take time to decompose andshow benefits (Ryan et al., 2005). Therefore, the use of compost extract maybe the solution, where it is claimed the positive effects on plant and soil to appear quickly after the addition of compost extract than the addition of compost material itself (Khaled & Fawy, 2011 and Pant et al., 2009). Thus, the use of compost extract became increasingly popular in organic agriculture as liquid fertilizer, especially with drip irrigation systems (Pibars et al., 2015). Compost extract is a liquid phase of compost preparations produced by steeping of compost in water and brewed for a defined period. Addition of compost extract to soils could be a source of organic acids, fine particulate of organic matter, and soluble mineral nutrients, as well as, microbial biomass (Edwards et al., 2013; Kim et al., 2015; Pane et al., 2016 and Sujesh et al., 2017). Even though many studies have tested organic materials as soil improvements, there is no information about the effect of both extracts derived from fresh sugarcane pulp (FSP) and compost of sugarcane pulp (CSP) on the soil structural stability expressed in terms of MWD. Therefore, this study was initiated.

Materials and Methods

Soil studied

A private field was selected to obtain 42 intact soil core samples (15-cm long, 10-cm inner diameter) from a depth of 0–10 cm after maize harvest. A 5 cm height free space was left at the top of the column. A disturbed soil sample was also collected from the 0–10 cm soil layer, then transported to the laboratory, air-dried, passed through a 2-mm sieve and physical and chemical soil properties were measured. The physical properties; soil texture, bulk density, total porosity, mean weight diameter (as an index of soil aggregates), water content at field capacity and at the wilting point were determined as described by Klute et al. (1986). The chemical soil properties; soil reaction (pH), electrical conductivity in the soil paste extract (EC_e) and organic matter content were determined according to the methods described by Page et al. (1982). The soil texture is clay loam with low organic matter (0.85%) and low EC_e (1.90dSm^{-1}), basic pH (7.8), and MWD is 3.8 mm (Table 1).

Sugarcane pulp

Fresh sugarcane pulp (FSP; Fig. 1a) was obtained locally from sugarcane juice shops. After separating the outer rind, the pulp was air-dried, gently crushed and passed through a 1-mm sieve (Fig. 1b) to ensure uniformity, more surface area formicrobial to attack the pulp and rapid decomposition. Chemical composition of FSP is shown in Table 2.

Composting the sugarcane pulp and its extract

A heap (5 kg) of FSP (particles size <1mm) was prepared. The heap was covered with a plastic sheet andwas turned from top to bottom every week and wetted by tap water at the rate of 50% of solid mass water holding capacityuntil maturity. Chemical composition of the tap water is shown in Table 3. The heap allowed maturing for two

TABLE 1. Physical and chemical properties of the investigated soil

Property	Unit	Mean value
Sand	%	14.41
Silt	%	42.16
Clay	%	43.43
Texture		Clay Loam
Bulk density	Mg m^{-3}	1.41
Particle density	Mg m^{-3}	2.58
Organic matter	%	0.85
Water content at field capacity	%	38.12
Water content at wilting point	%	16.20
Total porosity	%	45.35
Mean weight diameter of aggregates	mm	3.80
pH (1:2.5 H_2O)		7.60
EC_e(Electrical conductivity; saturated soil paste extract)	dS m^{-1}	1.90

months using a windrow composting system. The maturity was ensured when the temperature of the reaction inside the heap wasreduced from 65 °C to 35 °C. Chemical composition of the CSP is shown in Table 2. The obtained composted material CSP after two-months was used for the producingof aerated extract using the bucket-bubbler technique (Ingham, 2005) by soaking an amount from the CSP or FSP that equivalent to addition 10 t ha^{-1}(Abd El-Halim and Lennartz, 2017), one kilogram of dry CSP with 20 liters of tap water in handmade compost extract brewer. Actively aerated CSP extract was allowed to brew at room temperature for four days of incubation in handmade compost extract brewer with an air pump. Following the incubation period, actively aerated CSP was filtered through two-layer cheesecloth before application. The same previous procedures were done to the FSP and tap water to obtain the FSP extract and aerated water. Chemical composition of the extract derived from FSP and CSP is shown in Table 4.

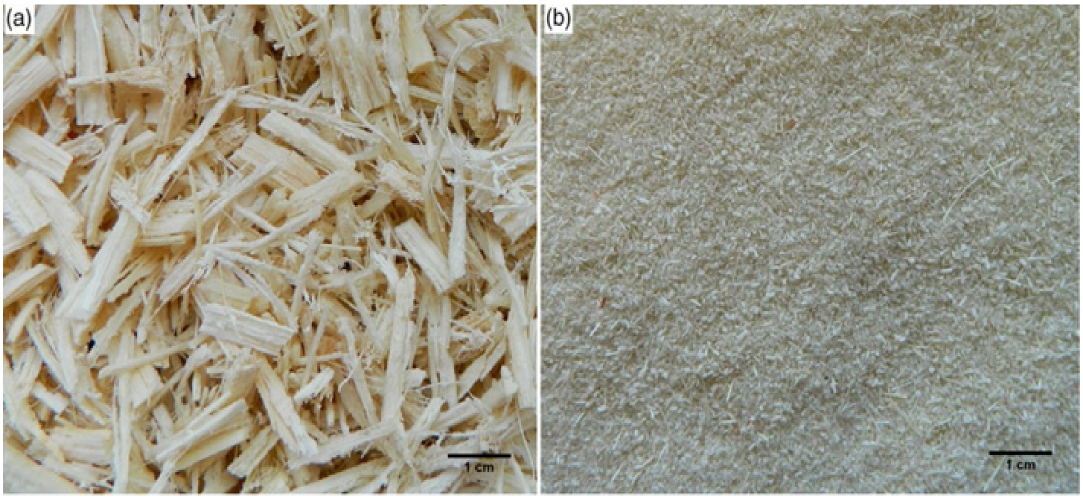

Fig. 1. Fresh sugarcane pulp: (a) before crushing and (b) after crushing and sieving with1mm mesh size

TABLE 2. Chemical properties of fresh sugarcane pulp (FSP) and compostedsugarcane pulp (CSP)

Property	Unit	FSP	CSP
Nitrogen (N)	meq l^{-1}	266.67	694.44
Phosphorus	meq l^{-1}	200.00	354.84
Potassium	meq l^{-1}	253.85	320.512
Calcium	meq l^{-1}	525.00	980.00
Magnesium	meq l^{-1}	806.58	1111.11
Organic carbon (C)	%	56.55	20.18
C: N ratio		118.00	16.14
Bulk density	Mg m^{-3}	0.45	0.43
Particle size	mm	<1	<1
Water holding capacity	%	60	65
$pH_{1:20}$		6.64	5.71
$EC_{1:20}$	dS m^{-1}	1.54	2.57

TABLE 3. Chemical properties of tap water used in the extraction process and during the drying and wetting cycles

Property	Unit	Mean value
EC_w(dS m^{-1})	dS m^{-1}	0.52
pH (H_2O)		7.16
Soluble cations		
Sodium	meq l^{-1}	1.76
Potassium	meq l^{-1}	0.21
Calcium	meq l^{-1}	2.22
Magnesium	meq l^{-1}	1.18
Soluble anions		
Sulphate	meq l^{-1}	0.67
Bicarbonate	meq l^{-1}	0.33
Chloride	meq l^{-1}	1.35

The experimental procedure

A laboratory experiment was conducted in a randomized complete design with two factors. The first factor was two sources of extract (1) fresh sugarcane pulp (FSP) and (2) compost of sugarcane pulp (CSP), in addition to control (aerated water only). The second factor was seven drying and wetting cycles through 35 days with five days intervals. Each soil core received an extracted volume of 175 cm^3, through 7 drying and wetting cycles (25 cm^3 for each drying and wetting cycle), which equivalent to the addition of 10 t FSP or CSP ha^{-1}, giving 3 treatments × 7 drying and wetting cycles × 3 replications = 63 columns. Each soil core sample was closed at the bottom with a PVC lid and a 5 cm height free space was left at the top of the core to facilitate the addition of extract and/or aerated water. The treated cores received the same volume of extract at each wetting and drying period (25 cm^3) and then aerated water was added to reach a soil moisture content at field capacity. The same was done with the untreated cores, but with only usingaerated water. Treated and untreated cores were left on a laboratory table at approximately constant temperature (29 ± 2 ºC, the relative humidity of 60 ± 4%, RH) for 35 days. A new drying and wetting cycle is starting when the soil moisture content of each core reach to approximately 50 % of field capacity by weighing. Three intact soil core samples from treated and untreated treatments were taken after each drying and wetting cycle to determine the MWD of aggregates.

Determination of the mean weight diameter (MWD)

The wet sieving method was usedas proposed by Kemper and Rosenau (1986) and described in Nimmo and Perkins (2002) with a wet sieving apparatus (Yoder, 1936). Soil samples were wetted by capillary and left overnight to weight equilibrates. After this pre-treatment, each sample was wet sieved for 5min in an analytic sieve shaker machine with the following aperture sizes 4, 2, 1, 0.5, and 0.25 mm; by the wet sieving procedure six classes were separated (>4; 4-2; 2-1; 1-0.5;0.5-0.25 and <0.25 mm). Each of the fractions retained in each sieve was collected, dried at 105ºC for 24 hours, finally weighted and the aggregate percentof various sizes was calculated. The mean diameter of any particular size range of aggregates (Xi) separated by sieving is multiplied by the weight of the aggregates in that sizes range as a fraction of the total dry weight of the analyzedsample (Wi). The sum of the products gives the in mm (Van-Bavel, 1950).

$$MWD\ (mm)=\sum X_i \times W_i \quad (1)$$

Chemical analysis

Chemical analyses of the tap water used in the extraction process; pH, EC, soluble cations, were determined according to the methods described by Page et al. (1982). The pH and EC of the FSP, CSP and their extracts were measured using conductivity/pH meter. Organic carbon was determined using the Walkley-Black titration method as outlined by Page et al. (1982).Portions of FSP, CSP were ground and wet digested with the di-acid mixture (H_2SO_4 + $HCLO_4$) as described by Cottenie et al.(1982) and some macro elements in the FSP,CSP and their extracts, (total N, P, K, Ca and Mg), were measured. Nitrogen was determined by the micro-Kjeldahl method. Phosphorus was determined spectrophotometrically using ammonium molybdate and stannous chloride reagents.

Potassium was measured by the flame photometer. Calcium and Magnesium were determined separately by Ethylene Diamine Tetra Acetic acid (EDTA) titration method.

Statistical analysis

Two-way analysis of variance (ANOVA) was used to analyze the effect of both extracts derived from FSP and CSP on the MWD. The difference at $p< 0.05$ level was considered as statistically significant.The Tukey's honestly significant difference (HSD) test at α =0.05 was used to indicate when arithmetic means of MWD differed significantly between the treated and untreated treatments at the different drying and wetting cycles.

Results

Irrespective to the drying and wetting cycles, both extracts derived from FSP and CSP showeda positive effect on the MWD. The application of both extracts significantly increased the MWD ($p< 0.001$) as in Table 5. Irrespective to the source of the extract, the Tukey's honestly significant difference (HSD) between the grand means of MWD showed that the most pronounced effect was at the 4th drying and wetting cycle (after 20 days; Table 5) with the value of 4.31 mm. However, the closer inspection of the calculated differences for the 4th, 5th, 6th, and 7th drying and wetting cycle (the 20, 25, 30 and 35 days from the beginning) shows that the additional increase from both extracts after the 4th drying and wetting cycle is not well justified, because the differences calculated between the means were at par (Table 5). Accordingly, a new volume of 100 cm^3 from both extracts that approximately equal to the addition of 6 t FSP or CSP ha^{-1} appeared tobe sufficient forimproving the stability of soil structure.

TABLE 4. Chemical properties of the extracts derived from fresh(FSP) and composted sugarcane pulp (CSP) at 1:20 (w/v)

Property	Unit	Source of extract	
		FSP	CSP
Nitrogen	meq l^{-1}	0.68	1.76
Phosphorus	meq l^{-1}	1.94	2.74
Potassium	meq l^{-1}	2.76	3.48
Calcium	meq l^{-1}	4.28	41.93
Magnesium	meq l^{-1}	0.83	13.88
Carbon	%	0.60	2.92
pH		6.64	5.71
EC	dS m^{-1}	1.54	2.57

TABLE 5. Effect of the extract derived from both fresh sugarcane pulp (FSP) and from the compost of sugarcane pulp (CSP) on the mean weight diameter (MWD) under different drying and wetting cycles

Source of extract (F1)	Drying and wetting cycle (F2)							
	1st	2nd	3rd	4th	5th	6th	7th	Grandmean
	MWD (mm)							
Control	3.81^{f}	3.57^{g}	3.50^{gh}	3.50^{gh}	3.45^{hi}	3.40^{i}	3.39^{i}	3.52^{c}
FSP	3.88^{ef}	3.89^{ef}	3.90^{e}	3.92^{e}	3.93^{e}	3.95^{e}	3.95^{e}	3.92^{b}
CSP	4.73^{d}	4.85^{c}	5.00^{b}	5.50^{a}	5.52^{a}	5.52^{a}	5.73^{a}	5.24^{a}
Grand mean	4.14^{b}	4.11^{b}	4.14^{b}	4.31^{a}	4.30^{a}	4.29^{a}	4.29^{a}	
Analysis of Variance (ANOVA) and Honest Significant Difference (HSD)								
	P			SEM			HSD	
F1	<0.001			0.006			0.019	
F2	<0.001			0.008			0.037	
F1×F2	<0.001			0.015			0.083	

Means of row or column under each subheading followed by a different letter are significantly different by Tukey's HSD test (p = 0.05; otherwise statistically at par); SEM is the standard error of mean; p <0.001 means strongly significant.

MWD values resulted in applying both extracts showed a systematic positive response to the increase in drying and wetting cycles compared to the control. The grand mean of MWD across the drying and wetting cycles showed a more stable soil structure with both extracts compared to the control. However, the grand mean values of MWD resulted in applying the CSP extract were higher than the FSP extract (Table 5). Accordingly, the highest MWD values were recorded withthe extract derived from CSP (5.24 mm), followed by the extract derived fromFSP (3.92 mm), whereas, the lowest MWD values were recorded with the control (3.52 mm). Thus, there was an increase in MWD with both extracts derived from CSPand FSP by about 33 and 11% compared to the control, respectively. This means that the effectiveness of the extract derived from CSP in improving soil structure was superior three times to the extract derived from FSP.

Discussion

It is worthy to mention that aggregate stability expressed in terms of MWD was positively affected by both extracts derived from FSP and CSP. However, the extract derived from CSP was superior to the extract derived from FSP in increasing the MWD. The decomposition process of FSP during the composting process is accompanied by a release of positively charged ions (i.e. Ca^{2+}, Mg^{2+}, and K^{+}) in large amounts and in more available forms (Table 2), which transfer with the extract (Table 4). It could be due to the decrease ofswelling and dispersion of clays, which is considered a prerequisite for the formation of soil aggregates (Abd El-Halim and Lennartz, 2017; Chouhan et al., 2018 and Diacono & Montemurro, 2015). Electrolytes with Ca^{2+}, in particular in the extract derived from CSP (Table 4), can attract soil particles and form very stable soil structural units by the coalescence of micro-aggregates (Hughes andGirdlestone, 2001); consequentlyaggregate stability increases. This is supported by the low pH of the extract derived from CSP (Table 4), which helps to promote soil aggregation. On the other hand, the process of aggregation is supported by binding substances such as organic materials in general and organic acids in particular. Accordingly, various organic compounds and soil agglutinants, i.e., organic carbon (Table 4) and polysaccharides, are released in large amounts with the disintegration of FSP during the composting process, which transfer with the extract and facilitates aggregates formation and increases their stability (Annabiet al., 2011; Abd El-Halim and Lennartz, 2017; Bashir et al., 2016; Gülser et al., 2015; Sanjuán et al., 2001 and Zhang et al., 2014). In addition, some organic matter sources are hydrophobic substances, which may also have increased the resistance of aggregates to slaking in water (Piccolo andMbagwu, 1999), the result is to increase the aggregate stability.

Conclusion

Both extracts that derived from FSP and CSP resulted in a significant increase in the MWD of soil aggregates. The extract derived from CSP was superior three timesto the extract derived from FSP in increasing the MWD. Improvements in the MWD is most probably related to the particular characteristics of the extract derived from CSP, where it contains a high content of organic carbon and a high content of soil agglutinants, i.e., the positively charged ion, Ca^{2+}, Mg^{2+}, and K^{+}, as well as, polysaccharides. The results indicated that the additional increase from both extracts after the 4th drying and wetting cycle (after 20 days from the beginning) is not well justified, because the differences calculated between the means of MWD were at par. This research suggests that the addition of CSP extract at a volume equallingto that extracted by soakingan amount of CSP that equivalent to addition of 6 t ha^{-1} (extraction ratio, 1: 20, w/v), markedly improves the MWD, and could play an important role in soil structural stability, especially after about four drying and wetting cycles.Overall, the extract derived from CSP could be a faster way in improving soil structure than FSP itself that takes a while to decomposition and appears its benefits.However, the future investigation should be expanded to other types of soil and field trials to obtain further information to be used in advising land managers, especially those used drip-irrigation system.

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تأثير مستخلص لب قصب السكر على تحسين ثبات بناء التربة

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يعد استخدام المواد العضوية ممارسة شائعة لزيادة مجاميع التربة واستقرارها ، لكن استخدام مستخلص لب قصب السكر كمحسن لبناء التربة ، معبّر عنه بمتوسط وزن القطر (MWD) ، لم يتم اختباره حتى الآن. لذلك ، أجريت تجربة معملية على عينات تربة غير مثاره مأخوده باستخدام اعمده اسطوانية الشكل في تصميم كامل العشوائيه مع عاملين ، هما: مصدران للمستخلص المستخدم (١) لب قصب السكر الطازج (FSP) و (٢) سماد او كمبوست لب قصب السكر (CSP) ، وسبع دورات تجفيف وترطيب ، بالإضافة إلى معاملة الكنترول باستخدام ماء الصنبور فقط. اضيف لكل عمود تربه حجمًا من المستخلص يبلغ ١٧٥ سم ٣ (أي ما يعادل إضافة ١٠ طن منFSP أو CSP للهكتار) على أجزاء 25 سم 3 لكل دورة. كانت فعالية مستخلص CSP أعلى ٣ مرات من مستخلص FSP في تحسين MWD. كان التأثير الأكثر وضوحًا في الدورة الرابعة ، مما يشير إلى أن اضافة ١٠٠ سم ٣ من مستخلصCSP (أي ما يعادل إضافة ٦ طن من CSP للهكتار) بدلاً من ١٧٥ سم ٣ تبدو كافية لتحسين ثبات بناء التربة. بشكل عام ، يمكن أن يكون المستخلص المشتق من CSP طريقة أسرع في تحسين بنية التربة من FSP نفسه الذي يستغرق بعض الوقت للتحلل ويظهر فوائده.ومع ذلك ، ينبغي توسيع نطاق البحث المستقبلي ليشمل تجارب حقلية علي أنواعًا أخرى من الأراضي للحصول على مزيد من المعلومات لاستخدامها في تقديم المشورة لمديري الأراضي ، وخاصة أولئك الذين يستخدمون نظام الري بالتنقيط.