Egypt. J. Soil. Sci. Vol. **59**, No. 3, pp. 275- 284 (2019)

Egyptian Journal of Soil Science
http://ejss.journals.ekb.eg/

Economic Assessment of Sugarcane Pulp as Amelioration of Soil Hydro-physical Characteristics, Water Productivity, and Wheat Yield

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Sugarcane pulp as organic material offers many advantages compared to other crop residues. Application of organic materials is targeted to improve soil hydro-physical characteristics, saved-water, and increase crop productivity. However, the use of sugarcane pulp to achieve these targets and its economical assessment has not been tested so far.Therefore, a field experiment was conducted in the twosuccessive wheat-growing seasons 2015 and 2016 in a completely randomized design with four treatments and three replications.Thesugarcane pulp treatments were 2, 4, and 6 t ha^{-1}, plus to the control (0 t ha^{-1}).The soil hydro-physical characteristics were determined, i.e., bulk density, total porosity, moisture content at both field capacity and wilting point, available water content, drainable pores, holding pores, capillary pores, saturated hydraulic conductivity, aggregate mean weight diameter and water-stable aggregates. Also, water requirements, saved-water (WS), water productivity (WP), and grain yield (GY), as well as, benefit-cost ratio (BCR) were calculated.Both treatments 6 and 4 t ha^{-1} improved soil hydro-physical characteristics, and increased GY, WS, and WP to highest values; and there were no significant differences between them for several characteristics.However,both treatments 2 and 4 t ha^{-1} achieved highest and comparable BCR (0.97 and 0.95, respectively), whereas the treatment 6 t ha^{-1} achieved lowest BCR (0.85).Therefore, economically, the use of2 t ha^{-1} is preferred and recommended.

Keywords: Benefit-cost ratio, Saved-water, Water productivity, Water requirement, Waste recycling

Introduction

Recently, Egypt is facingan increasing population and water scarcity problems. Hence, increasing wheat production and its profitability with conserving soil hydro-physical properties from degradation, and saving irrigation water through increasing water unit productivity, are the most important techniques for facing such problems (El Afandi et al., 2010; El-Marsafawy et al., 2018; Harb et al., 2017 and Nassr, 2014).Application of manures, plant residues, and other waste materials as organic materials to soil amelioration is an important way to increase the soil moisture-holding capacity through improving hydro-physical characteristics, thus reducing irrigation frequency and delay the onset of plant wilting; the result is to save irrigation water and increase crop productivity (Abd El-Lattief, 2014; Nassr, 2014; Thangasamy et al., 2017 and Zhang et al., 2017).

Sugarcane pulp is considered as a by-product of the sugar industryand could be used as a low-cost soil amelioration material because it is available in large quantities either for no cost or little price. In addition, it offers many advantages compared to other crop residues, e.g., it can hold water by 20–30 times its own weight when fully saturated; this is because of its spongy texture with a large surface area and characteristics of moisture affinity (hygroscopic) (Rainey, 2012). Even though most recent studies have tested different organic materials as an amelioration of soil hydro-physical characteristics and the effects on increasing saved-water, water productivity and yield of wheat (Eldardiry et al., 2013; Mandal

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DOI: 10.21608/ejss.2019.15371.1293
Received 28/7/2019; Accepted 21/8/2019

et al., 2019;Phullan et al., 2017;Thangasamy et al., 2017 and Zhang et al., 2017), there are no studies about: (1) the use of sugarcane pulp on such subjects (2) the economic assessment for sugarcane pulp as soil amelioration; therefore, this study was initiated.

Materials and Methods

Experimental site and study soil

A field experiment was conducted in a private farm located in Kafr El-Zayat, El-Gharbeya governorate during successive seasons (2014/2015 and 2015/2016) with cultivated wheat.The studied soil texture is a clay loam. Some hydro-physical characteristics of the studied field up to 20 cm depth for both wheat-growing seasons are shown in Table 1.The daily air temperature (°C) and daily rainfall (mm) during the wheat-growing seasons showed that winter is cool with a mean air temperature around 19°C and about 50 mm rainfall. Summer is hot (no rains) with a mean air temperature of about 30°C. The mean relative humidity was about 70% during the daytime for summer months.

Sugarcane pulp

Sugarcane pulp (SP; Fig. 1a) was obtained locally from sugarcane juice shops. After separating the outer rind, the pulp was air-dried, after that crushed with silage machine (Fig. 1b), and then with maize grain grinder (Fig. 1c) to obtain more surface area. The ground pulp was passed through a 2-mm sieve to ensure uniformity. Chemical analysis of SP is shown in Table 2.

Treatments and experimental design

Sugarcane pulp levels were: 2, 4, and 6 t ha^{-1}; in addition tothe control treatment (0 t ha^{-1}).There were 12 experimental plots, i.e., 4 treatments with 3 replications in a completely randomized design, and each experimental plot area was 12 m^2 (3 m width × 4 m long). The experimental plots were separated by the uncultivated area with 2 m long from each side. In the first season, the experiment was carried out in a part of the field covers about 340 m^2 (17 × 20 m), while in the second season it was shifted to another part (340 m^2 area; 17 × 20 m) to avoid the residual effect of the pulp.

Agronomic practices

At the time of land preparation, the pulp was applied to the soil and mixed thoroughly with the upper 0.20 m layer using rotary tiller (handheld plowing machine), and then the soil was leveled well. Wheat grains (Triticumaestivum, c.vGemiza 9) were sown on the 25th of November in both seasons. Sowing was done by broadcast using the seed rate of 145 kg ha^{-1}.

TABLE 1. Soil hydro-physical characteristics in the experimental field

Property	Unit	Wheat-growing season	
		2014/2015	2015/2016
Sand	%	44.20	45.00
Silt	%	20.30	18.50
Clay	%	35.50	36.50
Soil texture		Clay Loam	Clay Loam
Saturation capacity	(V/V) %	43.00	44.00
Field capacity	(V/V) %	32.00	33.00
Wilting point	(V/V) %	15.00	15.00
Bulk density	Mg m^{-3}	1.31	1.32
Real density	Mg m^{-3}	2.37	2.36
Hydraulic conductivity	m h^{-1}×10^{-2}	1.04	1.03
Organic matter	%	0.91	0.89
Mean weight diameter	mm	4.20	4.19
EC (soil paste)	dS m^{-1}	1.12	1.14
pH (1:2.5)		7.75	7.70

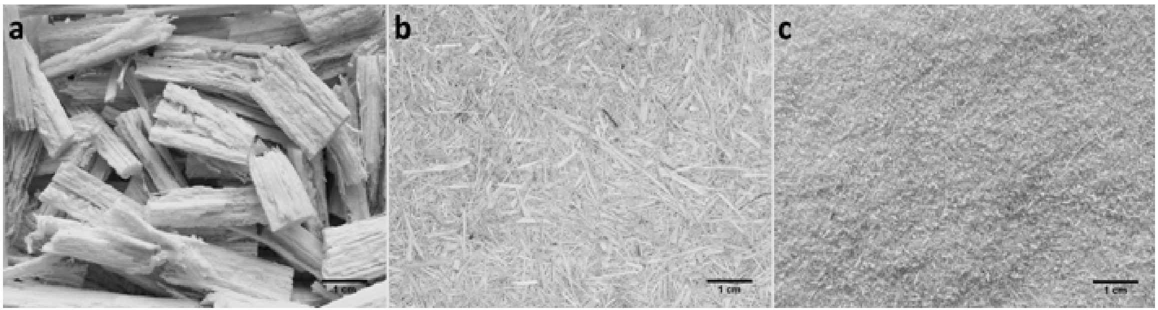

Fig. 1. Sugarcane pulp(a),after crushing with silage machine (b), and after crushing with maize grain grinderand sieving at 2-mm mesh size (c).

TABLE 2. Chemical properties of sugarcane pulp (SP)

Property	Unit	SP
Total content		
Nitrogen (N)	%	0.48
Phosphorus	%	0.31
Potassium	%	0.99
Calcium	%	1.05
Magnesium	%	0.98
Organic carbon (C)	%	56.55
C: N ratio		118.00
Bulk density	Mg m^{-3}	0.12
Particle size	mm	<2
Water holding capacity	% (V/V)	60
pH (pulp: water, 1:10)		6.64
Electrical conductivity (pulp: water, 1:10)	dS m^{-1}	1.54

The recommended NPK fertilizer dose was applied as follows: calcium superphosphate (15.5% P_2O_5) at rate of 55 kg ha^{-1} P_2O_5 and potassium sulfate (50% K_2O) at rate of 66 kg K_2O ha^{-1}were applied during soil preparation, whereas nitrogen at rate of 190 kg N ha^{-1}(urea, 46.5%) was applied in three equal doses; the 1stduring soil preparation, and the 2ndand the 3rdafter 4 and 10 weeks from sowing, respectively.The harvest was done manually in the last week of April and close to the ground (2-4 cm height).Wheat grain yield (GY) and straw yield (SY) was recorded andthen expressed in kg ha^{-1}.

Irrigation management and water calculations

Soil samples were taken before and two days after each irrigation event from the most favorable layer for root development (the 0-0.20 m layer; Atta et al., 2013) to measure volumetric soil water content. The irrigation is applied when the volumetric soil water content reached 50% of the field capacity.The depth of applied irrigation water (WA; m) was calculated using the following equation (James, 1988):

$$WA=(\theta_2-\theta_1)\times D_{rz} \quad (1)$$

where θ_2 and θ_1 arethe volumetric soil water content after irrigation and before the subsequent irrigation, and is the effective root zone (0.20-m soil depth). Irrigation water delivered to each plot was measured by awatermeter.The water requirement (WR)ofthe wheatcrop was computed by summing the applied irrigation water and effective rainfall during the growing season. Effective rainfall has been measured directly with rain gauge that has been installed in the experimental field. The saved-water (WS) is the volume of water saved per treatment (m^3 ha^{-1}) and obtained from the difference between the WR of pulp treatments and the control treatment. Water productivity (WP, kg m^{-3}) was calculated as following (Molden1997):

$$\text{WP}= \text{GY/WR} \quad (2)$$

where GY is the wheat grain yield (kg ha^{-1}), and WR is the wheat water requirement (m^3 ha^{-1}).

Soil sampling and hydro-physical analysis

After the wheat harvest, in the middle part of each plot, triplicate undisturbed soil cores samples (0.15-m high and 0.076-m diameter) were taken at 0-0.20 m depth.The moisture content at saturation (that represents the total porosity of the soil, TP), field capacity (FC), and wilting point (WP) were determined using a pressure plate apparatus at a suction level of 0 kPa, 10 kPa, and 1500 kPa, respectively (Richards, 1943).Available water content (AWC) was calculated from the difference between FC and WP. The percent of volumetric moisture content of soil samples at equilibrium with the different pressures represent two limits of each pore size class as follows: water-draining pores (WDP; 0-10 kPa), water-holding pores (WHP; 10-1500 kPa), and fine-capillary pores (FCP; > 1500 kPa).Bulk density (BD) was determined by core sampler (BashourandSayegh, 2007). The saturated hydraulic conductivity (K_{sat}, m h^{-1}) was measured by the constant-head permeability test using the same undisturbed soil cores with the following equation (Reynolds, 2008):

$$K_{sat}=\text{QL/HAT} \quad (3)$$

where Q (m^{-3}) is the volume of the percolating water, L (m) is the height of the soil column, H (m) is the total head, A (m^2) is the cross-sectional area of the soil column, and T (h) is the time of collecting percolates.Large clods were broken into smaller clods prior to their air drying, after that, they sieved through an 8-mm and 5-mm sieve. The aggregates that retained on the last sieve were exposed to the wet sieving technique as proposed by Kemper and Rosenau (1986) and described in Nimmo and Perkins (2002) with a wet sieving apparatus (Yoder, 1936). After wet sieving, aggregates from each sieve were oven-dried at 150 °C and weighed.The mean weight diameter (MWD, mm) was computed as following (Van-Bavel, 1950):

$$\text{MWD (mm)}=\sum X_i \times W_i \quad (4)$$

where is the mean diameter of any particular size range of aggregates separated by sieving and is the weight of aggregates in that size range as a fraction of the total dry weight of soil used. Water stable aggregates (WSA) were computed by summing of different size fractions and expressing them as a percentage of dry soil.

Economic analysis

The total cost basically includes both operating and variable costs. Operating costs (labor, land preparation, seeds, fertilizers, and chemicals) of pulp treatments and control treatment were equal and totaled 8000 Egyptian pounds (EGP) per hectare (Exchange rate: 1 EGP ≈ US$0.12 in 2016).Variable costs depended on the cost of the total amount of irrigation water required and the cost of sugarcane pulp. The cost of sugarcane pulp mainly includes the cost of transporting, milling, and labors (estimated to be 300 EGP per ton). Farmers in the study area do not pay for irrigation water, but they only bear the costs of labor to irrigate (estimated 280 EGP ha^{-1} per irrigation), plus the price of fuel to run a pump to withdraw water from irrigation canals (1 hr costs 25 EGP). Accordingly, 1 m^3 water price was estimated to be ≈ 0.50 EGP. Seasonal water cost (total water cost) was calculated by multiplying the 1 m^3 water price by seasonal WR (total WR) of wheat crop.Gross revenue was calculated by summing of the total cost of grain yield (GY in kg ha^{-1} × GY market price kg^{-1}) and the total cost of straw yield (SY in kg ha^{-1} × SY market price kg^{-1}).The market price (local price) was 2.2 EGP kg^{-1}grains and 0.45 EGP kg^{-1} straws. Net return (NR) and benefit-cost ratio (BCR) was calculated as follows:

$$\text{NR} = \text{Gross revenue-Total costs} \quad (5)$$

$$\text{BCR} = \text{NR} / (\text{Total costs}) \quad (6)$$

Statistical analysis

Statistical analyses were carried out with the MSTAT-C™ version 2.0. A one-way analysis of variance (ANOVA) was used to verify the changes in the soil hydro-physical characteristics, water relations parameters, and yield of wheat across the two growing-seasons. The changes were evaluated by comparing the mean values obtained from the Tukey's honestly significant difference (HSD) test at α =0.05.Since data followed the homogeneity test, mean data over the two growing-seasons were used.

Results

Soil hydro-physical characteristics

Average data over the two wheat-growing seasons showed that soil hydro-physical characteristics have been affected significantly ($P<0.001$) by the different pulp rates with the exception of FCP (Table 3).Tukey'sHSD showed that both rates of 2 and 4 t ha^{-1}were at par and did not differ significantly for several characteristics. The same was forboth rates of 4 and 6 t ha^{-1} (Table 3).

Compared to the control (0 t ha^{-1}), application the pulp at the rates of 2, 4, and 6 t ha^{-1} decreased the BD by about 4.1%, 9.1%, and 11.4%, respectively; vice versa, they increased the MWD by about 23.4%, 31.8%, and 34.8% and the WSA by about 15.5%, 17.3%, and 19%, respectively (Table 3), resulted in an increase of TP by about 8.9%, 15.5%, and 21%, respectively (Table 3), along with this, there was a systematic increase in both FC and WP (both increased in the same magnitude), which led to increasing the AWC by about 27.2%, 32.8%, and 40.7%, respectively (Table 3); however, WDP was decreased by about 30.8%, 51%, and 41.3% and WHP was increased by about 19.7%, 20.3%, and 24.8%, respectively (Table 3), which led to decrease the K_{sat} by about 8.6%, 10.5%, and 11.4%, respectively (Table 3).

Water requirement(WR) and water productivity (WP)

Average data over the two wheat-growing seasons showed that WR and WP were affected significantly ($P<0.001$) by the different pulp rates (Table 4).

Compared to the control (0 t ha^{-1}), application the pulp at the rates of 2, 4, and 6 t ha^{-1} reduced the number of irrigation events by about 1, 2, and 3 events and increased irrigation intervals by about 3, 7, and 12 days, thus the WR lowered by about 16.7%, 23.5%, and 30.3%, leading to saving irrigation water by about 899, 1264, and 1628 m^3 ha^{-1}, respectively (Table 4).With respect to WP, 6 t ha^{-1} gave highest WP (2.06 kg m^{-3}) compared to 4 t ha^{-1} (1.84 kg m^{-3}) and 2 t ha^{-1} (1.66 kg m^{-3}), whereas, the control gave lowest WP (1.22 kg m^{-3}) (Table 4).

Grain and straw yield (GY and SY)

The mean of the two seasons of the experimental study showed that the GY and SY have been significantly ($P<0.001$) affected by the different pulp rates (Table 4). Tukey'sHSD showed that GY of both rates 2 and 4 t ha^{-1} were at par and no significant differences between them. The same was forboth rates 4 and 6 t ha^{-1} (Table 4).

TABLE 3. Some soil hydro-physical properties for the different pulp rates after wheat harvesting in the 0-0.20 m soil depth (values are the mean of the two seasons of the experimental study)

	Soil hydro-physical properties†										
Pulp rate (t ha^{-1})	BD	TP	FC	PWP	AWC	WDP	WHP	FCP	K_{sat}	MWD	WSA
	Mg m^{-3}	---------------% (V/V)-------- -------		mm		--------------------%-------------------			m h^{-1} ×10^{-2}	mm	%
0	1.32^a	42.60^d	31.70^d	15.60^c	32.10^c	25.60^a	37.78^b	36.62	1.05^a	4.25^b	52.06^c
2	1.26^b	46.78^c	38.50^c	16.47^c	44.07^b	17.71^b	47.07^a	35.22	0.96^b	5.55^{ab}	61.64^b
4	1.20^c	50.40^b	41.50^b	17.61^b	47.77^b	17.65^b	47.40^a	34.95	0.94^c	6.23^a	62.97^{ab}
6	1.17^c	53.90^a	45.80^a	18.72^a	54.16^a	15.03^c	50.23^a	34.74	0.93^c	6.52^a	64.24^a
	Analysis of Variance (ANOVA) and Honestly Significant Differences (HSD)‡										
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	<0.001	<0.01	<0.001
SEM	0.008	0.577	0.577	0.236	1.234	0.570	0.883		0.006	0.368	0.552
HSD	0.038	2.615	2.615	1.068	5.588	2.581	4.000		0.026	1.667	2.501

† BD: bulk density; TP: total porosity; FC: moisture content at field capacity; PWP: moisture content at permanent wilting point; AWC: available water content; WDP: water drainable pores; WHP: water-holding pores; FCP: fine capillary pores; K_{sat}: saturated hydraulic conductivity; MWD: mean weight diameter; WSA: water-stable aggregates; Means of 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 the mean; $p <0.001$ means strongly significant.

Compared to the control, the rate of 6 t pulp ha^{-1} increased GY and SY (1160 kg ha^{-1} and 710 kg ha^{-1}), followed by 4 t ha^{-1} (1030 kg ha^{-1} and 673 kg ha^{-1}) and 2 t ha^{-1} (910 kg ha^{-1} and 186 kg ha^{-1}), respectively (Table 4).

Benefit-cost ratio (BCR)

Compared to the control (0 t ha^{-1}), the results of the two years of the experiment indicated that the differences in the total cost for the rates of 2, 4, and 6 t ha^{-1} were 9.24%, 11.46%, and 13.72%, respectively (Table 5).The rate of 4 t ha^{-1}achieved a net return higher than both rates of 2 and 6 t ha^{-1} by about 1.33% and 3.66%, respectively. However, the rate of 2 t ha^{-1} achieved highest BCR (0.97), followed by the rate of 4 t ha^{-1} (0.95) and the control treatment (0.92), while the rate of 6 t ha^{-1} achieved lowest BCR (0.85). This is indicating that the BCR of both rates of 2 and 4 t ha^{-1} were almost equal.

TABLE 4. Irrigation events, irrigation intervals, water requirement (WR), saved-water (WS), water productivity (WP), wheat grain yield (GY), and wheat straw yield (SY) for the different sugarcane pulp rates (values are the mean of the two seasons of the experimental study)

Pulp rate (t ha^{-1})	Irrig. events	Irrig. Intervals (days)	WR (m^3 ha^{-1})	WS (m^3 ha^{-1})	GY (kg ha^{-1})	SY (kg ha^{-1})	WP (kg m^{-3})
0	7	20	5369^{a}	-	6530^{c}	13610^{c}	1.22^{d}
2	6	23	4470^{b}	899	7440^{b}	13796^{c}	1.66^{c}
4	5	27	4105^{c}	1264	7560^{ab}	14469^{b}	1.84^{b}
6	4	32	3741^{d}	1628	7690^{a}	15179^{a}	2.06^{a}
Analysis of Variance (ANOVA) and Honestly Significant Differences (HSD) †							
P-value			<0.001		<0.001	<0.001	<0.001
SEM			42.17		34.40	41.15	0.010
HSD			191.00		155.80	186.36	0.047

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

TABLE 5. Benefit-cost ratio (BCR) of the different sugarcane pulp rates (values are the mean over the two seasons of the experimental study).

Pulp rate (t ha^{-1})	Variable costs	Operating costs	Total costs	Gross revenue	Net return	BCR
	-------------------Egyptian pound (EGP; LE) † --------------------					
0	2685	8000	10685	20491	9806	0.92
2	3435	8000	11435	22576	11141	0.97
4	3853	8000	11853	23143	11291	0.95
6	4871	8000	12871	23749	10878	0.85

† Exchange rate: 1 EGP ≈ US$0.12 in 2016.

Discussion

Soil hydro-physical characteristics

Several hydro-physical characteristics showed a remarkable improvement by sugarcane pulp application compared to the control treatment. In this research, we observed that MWD and WSA were positively affected by the application of sugarcane pulp. This is attributed to the decomposition of sugarcane pulp during the wheat-growing season, especially during the first 2 months, and completely within 120 days (Cifuentes et al., 2013), leading to release (1) various binding substances such as organic materials in general and organic acids in particular, which increases MWD (Abd El-Halim and Lennartz, 2017; Wong et al., 2010 and Zhong et al., 2017) and (2) various agglutinants such as polysaccharides, which increases WSA (Abd El-Halim & Lennartz, 2017; Ghosh et al., 2018; Khotabaei et al., 2013 and Six & Paustian, 2014). However, the effect of pulp on soil hydro-physical characteristics, particularly the MWD and WSA, depends on its decomposition rate, amounts of binding and agglutinants substances, and the amount applied (Trivedi et al., 2015).The increase in MWD and WSA can explain the observed decrease in BD and the simultaneous increase in TP (Abd El-Halim and Lennartz, 2017; Phullan et al., 2017 and Thangasamy et al., 2017). Although, both MWD and WSA increased, WDP, FCP, and K_{sat} were decreased and WHP was increased. This can be explained by increased the solid phase and decreased the air phase due to the change of phase composition of the soil matrix because of the addition of sugarcane pulp, the result is an increase in the micro-pore space, which is responsible for an increase in WHP; moreover, K_{sat} has a strong positive correlation with the BD (Eldardiry et al., 2013 and Nassr, 2014). The increase in WHP was probably responsible for the increase in volumetric water content at FC and WP, and also its related properties of AWC (AbdEl-Halim and Lennartz, 2017; Khotabaei et al., 2013). However, the difference between the relative increases in FC and PWP, the AWC, was less strongly affected because of a similar increase in FC and PWP with increasing pulp application. This is because increased MWD led to an increase in TP, and as a result to a decrease in BD, a change in pore-size distribution and an increase in the relative number of micropores (Eldardiry et al., 2013 and Nassr, 2014).

Water requirement (WR) and saved-water (WS)

Incorporation of sugarcane pulp in the soil reduced WR of the wheat crop, saving irrigation water, and increased WP, compared to the control. Improvement in WHP due to the reduction of the BD and increased of the TP, and specific surface area of soil particles is, in fact, a significant advantage of the incorporation of sugarcane pulp. This is because of its spongy texture with a large surface area and characteristics of moisture affinity (hygroscopic) (Rainey, 2012). Moreover, increased WHP and decreased K_{sat} can potentially increase soil water conservation ability and reduce the amount of water lost by evaporation and deep percolation.Accordingly, sugarcane pulp could introduce a significant reservoir of soil water to plants on-demand in the upper 20 cm soil layer where the root systems normally develop. This is probably responsible for decreasing the number of irrigation events and increase irrigation duration for the pulp-treated soil in comparison to the non-pulp-treated soil (Table 4). The decrease in the number of irrigation events and increase irrigation duration can explain the observed decrease in WR and the simultaneous increase in WS (Nassr, 2014).

Wheat grain yield (GY) and water productivity (WP)

The increase of GY was due to the incorporation of sugarcane pulp that led to improvingthe soil hydro-physical characteristics that provide a better environment for root development, consequently more plant growth, as well as, the increase of soil AWC that enhance the availability of nutrients to wheat plants (Mandal et al., 2019 and Nassr, 2014). Interestingly, the decrease in WR between the pulp-treated soil treatments was large, whereas the increase between GY was small; indicating the water loss through soil evaporation was inhibited after pulp application. This could be attributed to the moisture affinity (hygroscopic) of pulp, where it can hold water by 20–30 times its own weight when fully saturated (Rainey, 2012). The decreased WR and increased GY is probably the responsible for increasing WP in the pulp-treated soil treatments compared with the pulp-untreated soil treatments(Eldardiry et al., 2013; Zhang et al., 2017).

Benefit-cost ratio (BCR)

Both rates 2 and 4 t ha^{-1} of sugarcane pulp gave the highest BCR; this may be due to the low costs and high net return.The highest net return and the lowest total costs obtained with both rates can be attributed to the decrease in costs of sugarcane pulp because of small amounts are used. On the other hand, both rates 2 and 4 t ha^{-1} of sugarcane pulp had a comparable BCR, indicating that 2 t ha^{-1} is the lower limit to the addition of sugarcane pulp, whereas the upper limit is 4 t ha^{-1}. These results are partially in agreement with those indicated that integrated use of chemical fertilizers (NPK) and farmyard manure (FYM) at (50% NPK + 4 tons FYM) gave the highest BCR and were, then, recommended for profitable wheat grain yield. (Abd El-Lattief, 2014).However, the results of this research indicate that economically, the use 2 t ha^{-1} is preferred and recommended.

Conclusion

Soil water–plant relationships and their nutritional status are mainly controlled by their content of organic materials. Accordingly, sugarcane pulp could introduce a significant reservoir of soil water to plants on-demand in the upper 0.20 m soil layer where the root systems normally develop. This is because it has the ability to improve soil hydro-physical properties (BD, TP, FC, WP, AWC, WDP, WHP, K_{sat}, MWD, and WSA), consequentlyincreased WS and WP, as well as, GY with increased application rate from 2 to 6 t ha^{-1}. However, the application of 2and 4 t ha^{-1} achieved highestand a comparableBCR (0.97 and 0.95, respectively), whereas the application of 6 t ha^{-1} achieved lowest BCR (0.85), compared to the control (0.92). Therefore, economically, the use of 2 t ha^{-1} is preferred and recommended.

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التقييم الاقتصادي للب قصب السكر كمحسن للخصائص المائية الفيزيائية للتربة وإنتاجية المياه وإنتاجية القمح

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يوفر لب قصب السكر كمادة عضوية العديد من المزايا مقارنة ببقايا المحاصيل الأخرى. يستهدف تطبيق المواد العضوية تحسين الخصائص الفيزيائية المائية للتربة وتوفير المياه وزيادة إنتاجية المحاصيل. ومع ذلك ، فإن استخدام لب قصب السكر لتحقيق هذه الأهداف وتقييمه اقتصاديًا لم يتم اختباره حتى الآن. لذلك ، أجريت تجربة حقلية في موسمي زراعة القمح ٢٠١٥ و ٢٠١٦ في تصميم عشوائي كامل مع أربعة معاملاتفي ثلاث مكررات. كانت معاملات لب قصب السكر هي ٢ و ٤ و ٦ طن للهكتار ، بالإضافة إلى معاملة المقارنه (الكنترول، بدون استخدام لب قصب السكر). تم تقدير الخصائص المائية الفيزيائية للتربة ، أي الكثافة الظاهرية ، المسامية الكلية ، محتوى الرطوبة عند السعة الحقلية ، محتوى الرطوبة عند نقطة الذبول الدائمة ، المحتوى المائي الكلي المتاح ، المسام الصرفيه ، المسام التي تحتفظ بالماء ، المسام الشعرية الدقيقة ، التوصيل الهيدروليكي المشبع ، متوسط القطر الموزون للمجمعات الارضيه ، المجمعات الارضيه الثابته ضد الماء. أيضاً ، تم احتساب الاحتياجات المائيه للقمح ، الماء المتوفر (WS) ، إنتاجية المياه (WP) ، وانتاجية الحبوب (GY) ، كذلك ، نسبه الفائدة / التكلفة (BCR). كلاالمعاملتين ٦ و ٤ طن للهكتار حسنوا الخصائص الفيزيائية المائية للتربة ، وزادواGY و WS و WP إلى أعلى القيم؛ ولم تكن هناك اختلافات ذات دلاله احصائيه بينهما لمعظم الخصائص.ومع ذلك ،كلا المعاملتين ٢ و ٤ طن للهكتار حققوا أعلى BCR و كانت قيمهم متقاربه (٠,٩٧ و ٠,٩٥ ، على التوالي) ، في حين حققت المعامله ٦ طن للهكتار أدنى القيم (٠,٨٥). لذلك ، يفضل استخدام ٤ طن للهكتار ويوصي به ، لأنه مبرر اقتصاديًا من حيث زيادة WS (٤٠,٦ ٪) و WP (١٠,٨ ٪)، وكذلكGY (١,٦ ٪)، مقارنة بـ ٢ طن للهكتار.