Influence of Incorporating Shredded Corn Stover on some Physicochemical Properties of the Soil and Corn Crop Production

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Abstract: Proper management of corn stover could simultaneously affect the soil quality and crop productivity especially in new reclaimed areas. The purpose of this study was to investigate the effectiveness of incorporating dried and shredded corn stover directly in the soil during the preparatory tillage stage on some physicochemical properties of the soil (bulk density, infiltration rate, pH, electrical conductivity, available nitrogen (N), available phosphorus (P), and organic carbon) as well as on the crop yield in two successive cultivation seasons of corn (*Zea mays*, L.). A field experiment was conducted over two cropping seasons in the farm of Faculty of Agriculture, Suez Canal University, Ismailia, Egypt to evaluate the impact of incorporating different levels of corn stover accumulated from the previous season at rates of 0, 25, 50, 75 and 100% (equivalent to 0, 3.33, 6.67, 9.99 and 13.33 tons ha^{-1}). The obtained results revealed that incorporating 25% (3.33 tons ha^{-1}) of corn stover significantly improved the soil physicochemical properties accompanied with increasing the corn yield up to 19.00 tons ha^{-1} and the stover yield up to 11.5 tons ha^{-1}. However, incorporating greater amounts of corn stover up to 100% (13.33 tons ha^{-1}) in the soil decreased corn yield and stover yield to 9.68 and 8.11 tons ha^{-1}, respectively.

Keywords: Crop residues, corn stover, soil quality, soil chemical properties, soil physical properties

INTRODUCTION

Corn (*Zea mays*, L.) is a global field crop that produces enormous amounts of corn stover consisting of all leaves, stalks, sheaths, husks and tassels left in the field after harvest. Such stover can be utilized as a livestock feed, converted to biofuel or burned for generating heat or electricity and other competitive applications with various useful benefits (Kenney *et al*., 2015). Correct corn stover management will improve the dynamics and nutrient cycling of the soil's organic matter, creating a generally favorable environment for plant growth (Bahadur *et al*., 2015). One of the most effective ways to manage corn stover is to incorporate chopped corn stover into the soil using tillage equipment to bury plant residues in the soil (Liu *et al*., 2019) as it can increase or sustain soil quality and productivity owing to increasing organic materials and soil nutrients (Mulumba and Lal, 2008).

Mulching and crop residue incorporation are regarded as sustainable techniques of soil management which inhibit soil erosion, conserve water, tamp up soil temperatures, preserve ecosystems and enhance the structure of soil. All of these are key factors for improving plant development. In this regard, it is crucial to highlight the differences between the two uses of crop residues (mulching and incorporation) for enhancing soil quality. While residue incorporation is the application of tillage process to inhume crop residues or any organic materials such as straw, leaves and husks into soil (Mulumba and Lal, 2008; Liu *et al.*, 2019), mulching is the technique for covering the soil surface using different materials such as crop residues, plastic film and wood layer (Ibrahim *et al.,* 2020). Moreover, mulching is usually combined with reduced or no-tillage scenarios to preserve the mulching material itself (Erenstein, 2003). The combined effects of minimal interaction between soil and crop residues causes a slower rate of decomposition for mulches than for incorporated residues (Douglas *et al.,* 1980). Consequently, the advantages of mulching are often sluggish, even after six or longer growing seasons, without definite measurable improvements (Kihara *et al.,* 2012). Physically, mulching improves soil structure and causes aggregate stability (Gregorich *et al.,* 1997), while residue incorporation with the soil improves soil porosity (Mulumba and Lal, 2008). Hence, the incorporation of crop residues in the soil led to lower soil moisture contents than that in mulching on the soil surface (Souza *et al.,* 2016). However, the influence of crop residue incorporation in the soil on the greenhouse gas (GHG) emissions has to be also considered (Lehtinen *et al.,* 2014).

When biomass decomposes in the soil, the nutritive elements are released and uptake by the cultivated plants leading to minimizing chemical fertilization. Crop residues contribute to increase soil organic matter, nutrient and water retention (Kenney *et al*., 2015). These effects generally contribute to enhanced plant growth and productivity of soil and crops (Justes *et al*., 1999; Power *et al*., 1986). Because of the nutritive value of residue biomass, there is a tendency to incorporate it with the soil as a sustainable management technique to preserve the soil organic carbon, consequently, enhance soil fertility (Dhar *et al*., 2014; Lehtinen *et al*., 2014; Petersen *et al*., 2011; Shan and Yan, 2013). For sustainable agriculture to successfully address other major issues like reducing soil erosion, maintaining soil organic matter, and sustaining soil fertility, a sufficient amount of crop residues must be left on the farm (Jeschke *et al*., 2012).

In general, stover incorporation in the soil has a significant effect on soil physical properties including bulk density and infiltration rate. Stover incorporation with the soil leads to an increase in infiltration rate and reduces the soil bulk density (Lal, 2009). On the one hand, when the bulk density increased it could restrict the growth of the plant root that is why this property is often used as an indicator of soil quality. On the other hand, infiltration rate is also an indicator for soil quality, which controls runoff rates and soil erosion and helps in increasing crop yield. Additionally, the accumulation of available N, P and K may be promoted when crop residues are incorporated into the soil resulting in increased yield of cultivated crop (Shen *et al*., 2011). Moreover, availability of soil nutrients especially N, P, K and soil organic carbon increased after the stover incorporation. After incorporation of corn stover, soil pH immediately increased, and alkaline changes over time depending on the residue type (Butterly *et al*., 2013). Corn stover incorporation with the soil has also a positive effect on the crop yield on the long-term (Blanco-Canqui and Lal, 2007; Lehtinen *et al*., 2014). Although the stover incorporation in the soil has been widely employed as one of corn stover management techniques and in preventing erosion and maintaining or replenishing soil organic carbon, the percent and quantity of returning such residues to the soil required to sustain productivity, preserving the soil and recycling the nutrients should be clearly investigated. Therefore, the main aim of this study was to evaluate the effect of incorporating different quantities of dried and shredded corn stover on the physicochemical properties of the soil in terms of bulk density, infiltration rate, pH, electrical conductivity, available NP and soil organic carbon. Also, the influence of stover incorporation on corn yield and stover yield was targeted to identify the optimum amount of corn stover that should be incorporated in a virgin soil that has not been cultivated before.

MATERIALS AND METHODS

Experimental site:

The experimental work of this study was conducted in the experimental farm (30° $37^{\prime}$ N, 32° $15^{\prime}$ E) of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt (Fig. 1) during two consecutive seasons (2017 and 2018). The experimental site is virgin and has not been cultivated before and it was a sandy soil in texture. Soil samples were collected from the site (5 replicates), air-dried, crushed, sieved through a 2 mm sieve, and analyzed for some major properties. The initial determined properties of the soil in terms of sand %, silt %, clay %, pH, EC were shown in Table (1).

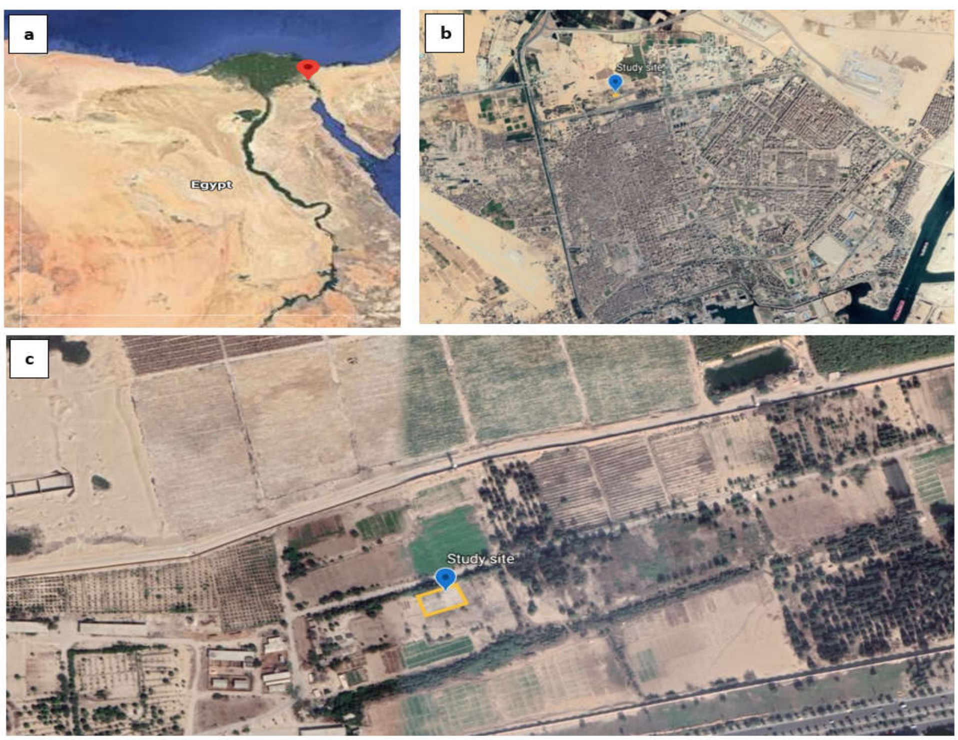


Fig. (1): Location of the study site in Egypt (a) located in Ismailia Governorate (b) at the experimental farm of Faculty of Agriculture, Suez Canal University (c)

Corn stover and experimental design:

Five different quantities of corn stover of 0, 3.33, 6.67, 9.99 and 13.33 tons ha^{-1} were prepared to be incorporated in the soil during the primary tillage stage before planting. These amounts of corn stover treatments were obtained from the previous harvest year (2016) representing 0, 25, 50, 75 and 100% from the corn stover biomass. The corn stover from aboveground corn biomass excluding ears (stems, stalks and leaves without corncob and roots cutted 5 cm above the ground) was naturally dried to a stable weight (*i.e.* moisture content of 12%) and then chopped to particle size approximately less than 2 mm using a local chopping machine (Model 250794, Ruston & Hornsby Ltd., UK).

Table (1): Some physical and chemical properties of the soil used in this study

Characteristics	Unit	Soil
Particle size distribution:	%	
Sand		94.0
Silt		4.00
Clay		2.00
Textural class		Sand
pH†		7.73
ECe‡	$dS\ m^{-1}$	0.55
Soluble cations:	$meq\ l^{-1}$	
Ca^{+2}		1.25
Mg^{+2}		1.22
Na^{+}		0.80
K^{+}		0.06
Soluble anions:	$meq\ l^{-1}$	
HCO_3^{-}		1.25
Cl^{-}		1.79
SO_4^{-2}		0.29
Organic C	$g\ kg^{-1}$	4.20
Total N	$g\ kg^{-1}$	0.13
Available N	$mg\ kg^{-1}$	10.48
Available P	$mg\ kg^{-1}$	9.59

The average weight of the naturally dried stover was 200 g plant^{-1} and the number of plants ha^{-1} was 70000 plants ha^{-1} yielding 13.33 tons ha^{-1} (100%) of corn stover. The dried, chopped stover was then stored in a dry, ventilated place for subsequent experimental use. The experiment was conducted for two cultivation seasons during 2017 & 2018 in a completely randomized design with five treatments (0, 3.33, 6.67, 9.99 and 13.33 tons ha^{-1}) in three replicates laid out in 6 m^2 plots for each replicate and each plot had three lines.

Corn stover incorporation:

In essence, pre-cultivation standard soil services were typically followed by plowing the soil with a chisel plow in two perpendicular directions. Corn stover was evenly incorporated in the soil at the predefined quantities and the corn seeds (*Zea mays*, L) (yellow variety of Three Way Cross 356) were then sowed after plowing the soil in the same day. The seeding rate was 15.5 kg fed^{-1} where two seeds were sowed in every seedbed, and then thinned to one seedling after 21 days from planting. Cattle manure was added at a rate of 20.0 m^3 fed^{-1} before sowing as an organic fertilizer. The recommended levels of fertilizer for corn in Ismailia, Egypt were followed in the forms of ammonium sulfate (20.6%) and ordinary superphosphate (15.5% P_2O_5). Ammonium sulfate was applied at a rate of 105 Kg fed^{-1} at three doses of 20, 30 and 50% of the total amounts after 21, 30 and 60 days from sowing. The potassium fertilizer was applied at a rate of 50 Kg K_2O fed^{-1} in the form of potassium sulfate (50% K_2O) at two equal doses after 30 and 60 days from sowing. Superphosphate was mixed with the soil in each plot before sowing. All plots were then irrigated twice a week. At the ripeness stage, samples of corncobs were taken after 95 days from sowing to record their essential measurements such as corncob length, maximum diameter, weight and weight of 100 grains. After 95 days, soil samples were also collected to measure the levels of pH, EC, available NP and organic carbon.

Soil analyses:

To determine some physical and chemical properties, three soil samples from each plot were collected directly before harvesting. The bulk density of undisturbed sample from 0-5 cm soil depth was determined by the core method (Carter, 1990) and the infiltration rate was measured by the single ring method (Bagarello *et al.,* 2009). To determine the soil chemical properties, soil samples were first air dried, sieved by 2 mm sieve and the available NP, organic carbon, pH and electrical conductivity (EC) were measured. The pH value was measured in soil-water suspensions (1:2.5) using pH meter (Jenway 3510, Bibby Scientific Ltd., UK). Soil EC was measured in saturated soil paste using EC meter (Jenway 4510, Barloworld Scientific Ltd., EU). Available N was extracted using 2.0 M potassium chloride and determined using Kjeldahl method (Bremner, 2018). Available P was determined spectrophotometrically (Specrto 22, Laborned Inc., USA) in 0.5 M ($NaHCO_3$) according to the Olsen method in which 2 ml of sample solution added to 5 ml Ammonium Heptamolybdate $(NH_4)_6 Mo_7 O_{24}$ with 0.25 ml stannous chloride $SnCl_2$ and continued to 50 ml with distilled water. After giving the blue color, the spectrophotometer used on 660 nanometer.

Crop yield:

At the maturity stage after 95 days from cultivation, the corn cobs and stover from each of the 15 plots (5 treatments × 3 replicates) were harvested separately. The morphological characteristics such as plant length, stem diameter and number of leaves of mature plants were recorded and the weight, length and maximum diameter of corncobs were also measured.

Cost analysis:

The economic feasibility study was performed in compliance with the respective treatments. The total cost of cultivation (TC) includes all inputs and related costs (field, labor, fertilizers, shredding, transportation, service operations, etc.) that were involved in crop production from sowing to harvesting. Gross returns (GR) were calculated based on the crop yield and the local market price in Egypt. The net return (NR) was calculated by subtracting the total cost from the gross returns ($NR = GR - TC$).

Statistical analysis:

Analysis of variance (ANOVA) was performed using a general linear model by using SPSS 25.0 software (Version 25.0, IBM Inc., USA) to realize the significant difference among the five levels of corn stover on the soil physicochemical properties and on crop yield in two different planting seasons. Post hoc comparisons were also performed using the least significant difference (LSD) post hoc test at a statistical level of probability of $P \leq 0.05$.

RESULTS AND DISCUSSION

Soil physical properties:

Generally, the effect of adding corn stover is comprehensively discussed from its effect on soil fertility in terms of several soil physical and chemical properties. According to Table (2), which illustrates the field experiment results, adding various amounts of corn stover between the two seasons had a significant ($P \leq 0.003$) impact on the soil's physical properties, including its bulk density and infiltration rate. These findings are consistent with those made by (Carter and Stewart, 1996; Carter, 2002; Wilhelm *et al.,* 2004; Lal, 2005). By the way, adding corn stover increased the infiltration rate of the soil compared to the control. In the first season, the infiltration rate of the soil reached its highest value of 0.46 mm sec^{-1} after incorporating 50% of corn stover. The infiltration rate of the soil continues its increasing trend in the second season reaching its maximum at control treatment (0%) of corn stover followed by 25% Table (2). In regard to infiltration rate values in the second season, significant difference was observed between control treatment (0% corn stover) and the other levels of crop residues incorporated in the soil (25, 50, 75 and 100%) ($P \leq 0.039$) as agreed with those results reported by Haynes and Naidu (1998) and Alvarez (2006). This may be due to the accumulation of substantial quantities of organic carbon from crop residues resulting in soil water repellence that affects soil infiltration rate as indicated by Harper *et al.* (2000). While Hamblin & Davies (1977) attribute the cause to crop residues increasing the amount of humified organic matter and water-holding properties in the soil. The behavior of adding crop residues to the soil is explained by Carter and Stewart (1996) as a reason for better levels of plant nutrients NPK , ease of soil penetration and seedbed preparation, greater aggregate stability, reduced bulk density, improved water holding capacity at lower infiltration rate, enhanced porosity and soil warming.

On the one hand, contrary to what Zeleke *et al.* (2004) found, the data provided in Table (2) showed that there was no significant difference ($p \geq 0.802$) in bulk density between the control treatment (0% corn stover) and the other crop stover treatments (25, 50, 75, and 100%) in the first season.

Table (2): Some physical properties of soil after two growing seasons at the addition of different percentages of corn stover

Treatment (%) †	Bulk density, g cm^{-3}		Infiltration rate, ml sec^{-1}	
	Season I (2017) ^{B**}	Season II (2018) ^{A}	Season I (2017) ^{B}	Season II (2018) ^{A}
0	$1.27^{a*} \pm 0.02^{††}$	$1.41^{a} \pm 0.02$	$0.39^{bc} \pm 0.01$	$0.76^{a} \pm 0.01$
25	$1.25^{a} \pm 0.01$	$1.33^{ab} \pm 0.04$	$0.46^{ab} \pm 0.01$	$0.69^{b} \pm 0.01$
50	$1.26^{a} \pm 0.01$	$1.31^{ab} \pm 0.04$	$0.46^{a} \pm 0.01$	$0.67^{b} \pm 0.01$
75	$1.25^{a} \pm 0.01$	$1.27^{b} \pm 0.03$	$0.34^{c} \pm 0.03$	$0.57^{c} \pm 0.02$
100	$1.25^{a} \pm 0.02$	$1.21^{b} \pm 0.03$	$0.37^{c} \pm 0.02$	$0.44^{d} \pm 0.01$

[†] Treatments refer to the added percentages (0, 25, 50, 75 and 100%) of corn stover corresponding to 0, 3.33, 6.67, 9.99 and 13.33 tons of corn stover per hectare

[††] Mean ± Standard Error

[*] Different small superscripted letters in the same column indicate significant difference among treatments in one season at a significance level of $p \leq 0.05$

[**] Different capital superscripted letters indicate significant difference between the two seasons at a significance level of $p \leq 0.05$

On the other hand, the results shown in Table (2) indicated that there was a significant difference ($p \leq 0.043$) in bulk density between the control treatment (0% corn stover) and the treatments of crop stover (75 and 100%) in the second season indicating a substantial reduction in bulk density of the soil when tremendous amounts of corn stover were added to the soil , which is in agreement with Zeleke *et al.* (2004).

Moreover, the results shown in Table (2) revealed that there was a significant difference ($P \leq 0.003$) in soil bulk density between the first and second season. In general, the addition of crop residues to the soil resulted in increased organic materials (Loveland, 2003), porosity (Rose, 2003), micro aggregate proportions and aggregate stability (Puget *et al.,* 1998), but reduced the overall bulking density of the soil as explained by Cannell and Hawes (1994); Carter and Stewart (1996) and Chan *et al.* (2003). When the bulk density increased, an excessive soil strength occurs and restricted root growth and insufficient aeration are expected especially in dry conditions (Cogger, 2005). With higher bulk densities, restrict root penetration and elongation in the soil is substantially reduced, which affects the absorption of water and essential nutrients and negatively affects the overall growth of plants (Kranz *et al.,* 2020). The results also showed that the interaction between corn stover treatments and seasons had no significant effect on bulk density ($P \geq 0.059$).

Soil chemical properties:

The results and statistical analyses shown in Table (3) revealed that soil chemical characteristics in terms of pH, available nitrogen and phosphorus were significantly affected ($P \leq 0.000$) by adding different levels of corn stover to the soil (Burgess *et al.,* 2002; Govaerts *et al.,* 2007). However, the electrical conductivity (EC) and organic carbon (OC) were not significantly affected ($P \geq 0.532$) by corn stover addition to the soil (Lenka *et al.,* 2019).

As a general trend for both cultivated seasons, the pH values of the soil were substantially decreased with crop residues incorporation despite the amount of corn stover added to the soil, which is in agreement with Stewart (1991). The difference was not significant ($P \geq 0.502$) and ($P \geq 0.304$) between the rate of 25% (3.13 ton ha^{-1}) and 50% (6.67 ton ha^{-1}) when compared with the control treatment (0%) in the first season.

Table (3): Effect of incorporating different quantities of corm stover on the soil chemical properties in two successive cultivation seasons (2017 & 2018)

Treat. †	pH	EC dS m^{-1}	N mg kg^{-1}	P mg kg^{-1}	O.C g kg^{-1}
Season I (2017)	A**	B	B	B	B
0	7.89^{a*} ± 0.05††	0.35^{b} ± 0.04	12.76^{d}±1.15	11.69^{b} ±0.38	4.91^{a} ± 0.13
25	7.80^{ab} ± 0.06	0.55^{a}± 0.04	18.36^{cd}±0.82	22.86^{a} ± 1.93	4.55^{a} ± 0.34
50	7.75^{ab} ± 0.08	0.45^{ab}± 0.02	26.13^{ab}±1.95	22.57^{a} ±1.43	4.72^{a}± 0.16
75	7.57^{bc} ± 0.08	0.45^{ab}± 0.03	28.62^{a}±2.87	21.91^{a} ± 1.82	4.70^{a} ± 0.14
100	7.39^{c} ± 0.09	0.48^{a}± 0.04	21.47^{bc}± 2.03	17.71^{a} ±0.90	5.01^{a} ± 0.21
Season II (2018)	B**	A	A	A	A
0	7.50^{a} ± 0.02	0.72^{a} ± 0.02	14.00^{c} ± 1.75	15.99^{b} ±1.11	5.71^{a} ± 0.36
25	7.38^{ab} ± 0.08	0.73^{a} ± 0.04	24.64^{b} ±3.54	33.60^{a} ±3.35	6.45^{a} ± 0.17
50	7.35^{ab} ± 0.06	0.69^{a} ± 0.08	38.34^{a} ± 3.99	30.61^{a} ±1.73	6.55^{a} ± 0.38
75	7.34^{ab}± 0.08	0.72^{a} ± 0.08	41.92^{a} ± 2.90	29.86^{a} ±1.80	6.56^{a} ± 0.20
100	7.22^{b}± 0.03	0.70^{a} ± 0.05	33.60^{ab} ± 2.97	29.64^{a} ±1.72	6.93^{a} ± 0.34

† Treatments refer to the added percentages (0, 25, 50, 75 and 100%) of corn stover corresponding to 0, 3.33, 6.67, 9.99 and 13.33 tons of corn stover per hectare

†† Mean ± Standard Error

* Different small superscripted letters in the same column indicate significant difference among treatments in one season at a significance level of $p \leq 0.05$

** Different capital superscripted letters indicate significant difference between the two seasons at a significance level of $p \leq 0.05$

However, the difference was significant ($P \leq 0.034$) and ($P \leq 0.003$) when corn stover was added at a rate of 75% (9.99 ton ha^{-1}) and 100% (13.33 ton ha^{-1}), respectively. The pH values continued to decrease in the second season, and they differed significantly from those observed in the first season ($P \leq 0.000$). The addition of crop residues to the soil usually results in increasing of organic materials accumulation in soil (Ye *et al*., 2019) leading to improving the soil pH status by increasing the soil buffer capacity (Bot and Benites, 2005) which consequently affects nitrogen (N) and phosphorous (P) absorbing by plants leading to growth enhancement (Abbasi *et al.,* 2017). However, the interaction between corn stover treatments and seasons on soil pH value was not significant ($P \geq 0.432$).

As the soil of the experimental area has not been cultivated before, the electrical conductivity (EC) increased significantly in the first season ($P \leq 0.036$) by increasing the amount of corn stover added to the soil. This is ascribed to the fact that the decomposition of the added crop residues induces the release of crop residue components (low-molecular and macro-molecular organic matter, inorganic matter, cellulose, hemicelluloses and lignin) which increase the amount of soil solvent ions and consequently increase the soil EC (Loveland, 2003; Singh and Rengel, 2007). Thus, in the second season, the EC reached its highest value of 0.73 dS m^{-1} after adding 25% of corn stover (1.40 tons fed^{-1}) to the soil. Furthermore, the results shown in Table (3) indicated that there was a highly significant difference ($P \leq 0.000$) in EC of the soil between the first and second season for all levels of stover added to the soil. More interestingly, the results revealed that the interaction between corn stover treatments and seasons had no significant effect on the soil EC ($P \geq 0.559$).

In general, the addition of corn stover to the soil at a certain level increased the available nitrogen and phosphorus significantly ($P \leq 0.005$) compared with the control soil. However, increasing the amount of corn stover incorporated in the soil beyond this level negatively affects the available nitrogen and phosphorus Table (3). Also, the results shown in Table (3) indicated that there was a highly significant difference ($P \leq 0.000$) in the available nitrogen concentrations in the soil between the first and second season for all levels of corn stover added to the soil (Graham *et al.,* 2002).

Additionally, the results revealed that the interaction between corn stover treatments and seasons had no significant effect ($P \leq 0.123$ and $P \leq 0.472$) on the available nitrogen and phosphorus in the soil, respectively. Generally, the increase in the available N and P may be attributed to the decomposition of crop residue biomass resulting in releasing the nutrients in the soil in available forms (Wilhelm *et al.,* 2004).

The results showed also that the highest available nitrogen concentration of 28.62 and 41.92 mg kg^{-1} was recorded after adding 75% of corn stover in the first and second season, respectively. All other levels (25, 50 and 100%) of corn stover addition were not significantly different ($P \geq 0.424$). The highest available phosphorous of 22.86 and of 33.60 mg kg^{-1} were recorded at 25% corn stover in the first and the second season, respectively. However, there was no significant difference ($P \geq 0.426$) between the effect of 50, 75 and 100% of corn stover added to the soil on the available phosphorous as those amounts of corn stover are all outperformed over the control treatment.

As the retention of crop residues is the key to increase or maintaining organic carbon level in the soil (Govaerts *et al.,* 2009), addition of corn stover slightly affected the overall content of organic carbon in the soil. However, this effect was not clear in the first season of corn stover applications at all levels. In the second season, incorporating corn stover in the soil increased its content of organic carbon up to about 17.39% at 100% of corn stover added to the soil. The results shown in Table (3) indicated that there was no significant difference ($P \geq 0.513$) in organic carbon between the control treatment (0%) and the other levels of corn stover (25, 50 and 75%) in the first season, which is in agreement with the results reported by (Heenan *et al.,* 2004), (Bi *et al.,* 2009) and (Alberto *et al.,* 2015) who reported that a significant gain in soil organic carbon was observed over the years as an accumulative effect of continuous residue incorporation. This result was in disagreement with (Iqbal *et al.,* 2009) who explained that adding crop residues to the soil stimulates the SOC mineralization process efflux CO_2 to the atmosphere and lowered the SOC content in soil. The CO_2 fluxes from the soil to the environment are primarily caused by an easily mineralizable reservoir of organic carbon. As a consequence, crop rotations, manure application, conservation tillage, managing higher quality crop residue, proper water management, and soil erosion control are all necessary to maintain a balance between soil carbon decomposition and sequestration (Frasier *et al.,* 2016). Also, the behavior of the microbial pool and the C:N ratio of the substrate have a significant correlation with carbon mineralization in soil. The SOC status and the soil's ability to supply nitrogen have a clear positive relationship (Benbi and Chand, 2007).

However, due to the accumulating of crop residues in the soil for two consecutive seasons, the results shown in Table (3) indicated that there was a highly significant difference ($P \leq 0.0001$) in organic carbon percentage between the first and second season for all levels of corn stover added to the soil. Therefore, the results revealed that the interaction between corn stover treatments and seasons had no significant effect ($P \leq 0.380$) on soil organic carbon.

Effect of corn stover on plant and corncob morphological features

The second aim of this work was to investigate the influence of adding different percentages of corn stover on the morphological features of the grown corn plants as well as the final harvested corncob characteristics in two successive seasons. The results showed that all morphological features (plant length, stem diameter and number of leaves on the plant) of the grown corn plants were increased significantly by incorporating 25% (3.33 ton ha^{-1}) of corn stover in the soil during the preparatory stage of the soil before sowing. For instance, the highest plant length of 194 cm was recorded in the first season when 25% of corn stover was incorporated in the soil and increased by 4.90% (*i.e.* 204 cm) in the second season. This was accompanied with increasing the average number of leaves on the corn plant from 13-14 leaves per plant in the first season to 14-15 leaves per plant in the second season Table (4). In general, there was a significant difference in all morphological features (plant length, stem diameter and the number of leaves per plant) between control treatment (0%) and those ones received different quantities of corn stover (25, 50, 75 and 100%). Moreover, the results shown in Table (4) indicated that there was a highly significant difference ($P \leq 0.000$) between the two growing seasons regarding these features. This may result from the decomposition of crop residues that leads to increase the available nutrients and consequently improves plant growth (Lal, 2005).

Table (4): Effect of incorporating different quantities of corm stover on some morphological features of corn plants in two successive cultivation seasons (2017 & 2018)

Treatment (%) †	Plant length, cm		Stem diameter, mm		Number of leaves	
	Season I (2017) ^{B}	Season II (2018) ^{A}	Season I (2017) ^{B}	Season II (2018) ^{A}	Season I (2017) ^{B}	Season II (2018) ^{A}
0	$185^{ab} \pm 2.33$ ††	$195^{ab} \pm 1.42$	$21.4^{a} \pm 0.28$	$23.5^{a} \pm 0.12$	$14.0^{a} \pm 0.19$	$15.0^{a} \pm 0.08$
25	$194^{a} \pm 2.64$	$204^{a} \pm 1.29$	$21.2^{ac} \pm 0.35$	$24.8^{a} \pm 0.18$	$14.0^{a} \pm 0.19$	$15.0^{a} \pm 0.10$
50	$174^{bc} \pm 2.19$	$187^{bc} \pm 0.86$	$20.9^{ac} \pm 0.28$	$23.9^{a} \pm 0.15$	$13.0^{a} \pm 0.16$	$15.0^{a} \pm 0.09$
75	$169^{bc} \pm 2.13$	$172^{c} \pm 0.79$	$21.7^{b} \pm 0.36$	$21.7^{b} \pm 0.19$	$13.0^{a} \pm 0.15$	$14.0^{b} \pm 0.10$
100	$156^{c} \pm 2.76$	$158^{d} \pm 2.56$	$20.2^{c} \pm 0.36$	$20.3^{b} \pm 0.29$	$14.0^{a} \pm 0.17$	$14.0^{b} \pm 0.10$

† Treatments refer to the added percentages (0, 25, 50, 75 and 100%) of corn stover corresponding to 0, 3.33, 6.67, 9.99 and 13.33 tons of corn stover per hectare.

†† Mean ± Standard Error

* Different small superscripted letters in the same column indicate significant difference among treatments in one season at a significance level of p≤ 0.05

** Different capital superscripted letters indicate significant difference between the two seasons at a significance level of p ≤ 0.05

Results obtained from field experiments revealed that corncob characteristics (length, maximum diameter and weight) were significantly affected ($P \leq 0.000$) by incorporating different percentages of corn stover to the soil as presented in Table (5). In specific, incorporating 25% (3.33 ton ha^{-1}) of corn stover provided the highest increase of corncob length, maximum diameter and weight of 298 mm, 54.8 mm and 276 g in the first season and 312 mm, 57.7 mm and 297 g in the second season, respectively. However, incorporating more amount of corn stover above 25% (3.33 ton ha^{-1}) negatively affected the corncob characteristics for all higher quantities of corn stover (6.67, 9.99 and 13.33 ton ha^{-1}) in both seasons.

Table (5): Effect of incorporating different quantities of corm stover on some morphological features of corncobs in two successive cultivation seasons (2017 & 2018)

Treatment (%) †	Corncob length, mm		Maximum diameter, mm.		Corncob weight, g	
	Season I (2017) ^{A}	Season II (2018) ^{A}	Season I (2017) ^{B}	Season II (2018) ^{A}	Season I (2017) ^{B}	Season II (2018) ^{A}
0	$237^{c} \pm 4.14$	$263^{b} \pm 6.09$	$48.6^{b} \pm 0.73$	$51.7^{ab} \pm 0.77$	$183^{b} \pm 9.28$	$230^{b} \pm 9.03$
25	$298^{a} \pm 7.28$	$312^{a} \pm 6.02$	$54.8^{a} \pm 0.80$	$57.4^{a} \pm 0.79$	$276^{a} \pm 9.98$	$297^{a} \pm 9.71$
50	$241^{b} \pm 5.25$	$242^{bc} \pm 5.22$	$46.3^{bc} \pm 0.69$	$47.0^{bc} \pm 0.84$	$142^{c} \pm 7.45$	$168^{c} \pm 7.75$
75	$238^{b} \pm 8.15$	$223^{cd} \pm 3.73$	$44.7^{c} \pm 0.67$	$45.7^{b} \pm 0.81$	$124^{c} \pm 5.86$	$124^{c} \pm 3.92$
100	$205^{d} \pm 7.63$	$203^{d} \pm 3.60$	$39.4^{d} \pm 0.82$	$41.4^{c} \pm 1.15$	$79.3^{d} \pm 4.06$	$98.7^{d} \pm 2.61$

† Treatments refer to the added percentages (0, 25, 50, 75 and 100%) of corn stover corresponding to 0, 3.33, 6.67, 9.99 and 13.33 tons of corn stover per hectare

†† Mean ± Standard Error

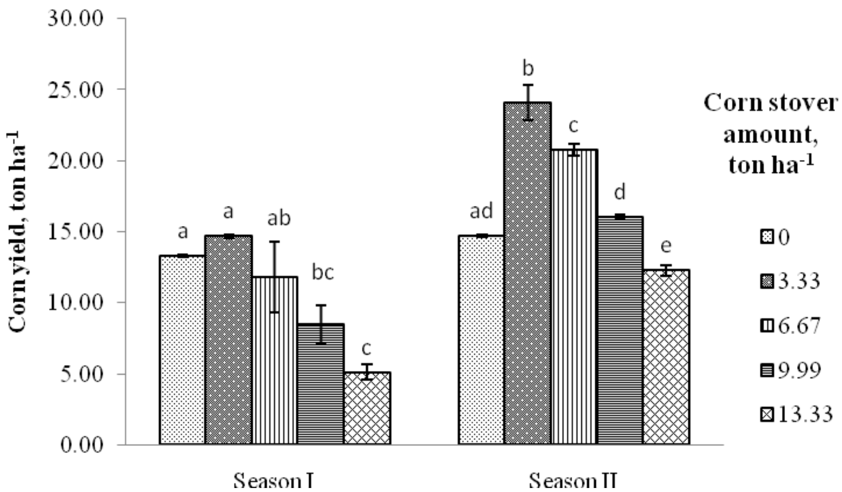
* Different small superscripted letters in the same column indicate significant difference among treatments in one season at a significance level of p≤ 0.05

** Different capital superscripted letters indicate significant difference between the two seasons at a significance level of p ≤ 0.05

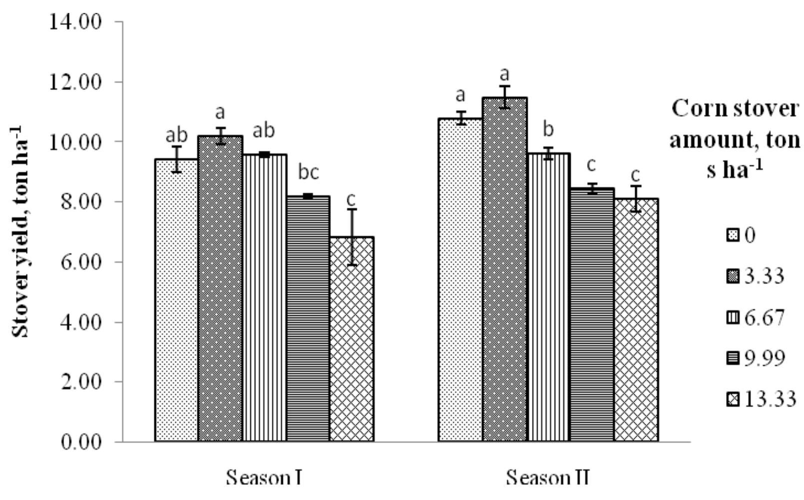
The statistical analyses indicted that this reduction in the average length, maximum diameter and weight of the harvested corncobs at 50, 75 and 100% (*i.e.* 6.67, 9.99 and 13.33 ton ha^{-1}) were significantly ($P \leq 0.000$) lower than that of 25% level. Furthermore, the results indicated that the interaction between the corn stover treatments and the seasons had a significant effect ($P \leq 0.038$) as well on the length, maximum diameter and weight of the final harvested corncobs.

Effect of corn stover on corn yield and stover yield:

Any effective agricultural services and/or field practices experienced during soil preparation and/or after sowing should be reflected in the final yield because maximizing this yield is usually the ultimate aim to increase profit. In this regard, the effect of incorporating different percentages of corn stover to the corn field on the corn yield (included the overall corncob with grains, kernel and outer shelters) was investigated. Moreover, the influence of corn stover incorporation on the stover yield should be also considered in evaluating such treatments. In general, the amount of stover produced each season depends basically on different factors such as weather, soil and management practices like fertilization and pest control applications. When all of these factors are constant and without weather stresses, the corn stover incorporation practices act as a critical factor affecting the final stover yield. The findings demonstrated that the incorporation of various amounts of corn stover into the soil resulted in a significant difference in corn yield and stover yield ($P \leq 0.000$). The highest corn yield and stover yield values of 11.63 ton ha^{-1} and 10.2 ton ha^{-1} were obtained for the first season when 25% of corn stover was added to the soil, and increased up to 19.00 and 11.5 ton ha^{-1} in the second season, as shown in Figure (2).This is attributed to the remedy effects of crop resides added to the soil that were responsible for enhancing physical, chemical, and biological properties of the soil (Zhukov *et al.,* 1993; Wilhelm *et al.,* 2007). However, increasing the amount of stover incorporated in the soil above 25% (3.33 ton ha^{-1}) had a negative effect on both corn yield and stover yield. For instance, the results indicated that the lowest values of corn yield and stover yield of 4.04 ton ha^{-1} and 6.82 ton ha^{-1} (in the first season) and 9.68 ton ha^{-1} and 8.11 ton ha^{-1} (in the second season) were recorded when 100% of corn stover (13.33 ton^{-1}) were incorporated in the soil as shown in Figure (2). As the organic matter is the limiting factor that affects complex soil exchange and retention of nutrient cations (Johnston, 1991), addition of organic matter can immobilize metals through the creation of strong organo-metal complexes. This process can minimize or improve the solubility of certain soil metals leading to improving plant growth and increasing the corn yield.



(a)



(b)

Fig. (2): The effect of crop residues incorporation on (a) corn yield and (b) stover yield

Moreover, the results shown in Figure (2) showed that there was no significant difference ($P \leq 0.210$) between the effects of adding (50%), (75%) and (100%) of corn stover addition to the soil. However, there was a highly significant difference ($P \leq 0.000$) in corn stover yield between the control treatment (0%) and the other treatments (25, 50, 75 and 100%).

Similarly, the results illustrated in Figure (2) indicated that there was a highly significant difference ($P \leq 0.000$) in stover yield between the first and second season under the effect of incorporating different levels of corn stover to the soil and this result is in agreement with that reported by (Singh *et al.,* 1990). Similar to corn yield, the stover yield decreased significantly at higher levels of corn stover. The decreasing of corn yield and stover yield by incorporation 100% of corn stover to the soil is thought to be attributed to the allelopathic effect of crop residues as described by (Zheng *et al.,* 2015) because certain chemicals retained in crop residues have been shown to be inhibitory and influence plant growth. For instance, nitrogen deficiency in plants may occur when organic matter with high carbon content (from corn stover) is added to soil. In such situation, the soil organisms utilize the nitrogen to break down this carbon, making nitrogen unavailable to the plants and affect their growth.

As illustrated in Table (6), the total cost of cultivation (Seeds, fertilizers, pesticide, labor, irrigation, shredding and transportation, rent and grain separation) were 10000 L.E. for control and 13000 for cultivating season. While the first season's gross return was 17900, equation (1) says that the net returns were just 4900. Additionally, according to equation (1), the second season's net returns were 16222 while the season's gross return was 29222.

Cost analysis

According to Table (6), it is clear that the best productivity and economic return acquired at 25% incorporation percentage for the corn residues with the soil, so that it was the value of calculating the economic aspects. Consequently, productivity of the first season at 25% incorporation percentage for the corn residues with the soil was 19.00 tons/hrctare, with an economic return of 72178 L.E./hectare, which was less than the control by up to 27%. Therefore, it is likely that the producer did not make a sizable profit during the first season. In the second season, this profit jumped and doubled to reach 40068 L.E., with an increase of 231% and 107% compared to the first season and the control, respectively.

In light of this, we may draw the conclusion that the 25% absorption rate of crop residues into the soil will have a positive impact on the soil's ability to retain nutrients throughout the course of successive agricultural seasons.

Table (6): Economical analysis for corn stover incorporation with the soil for two seasons

Economic Items*	First season		Second season	
	Control	25%	Control	25%
Total Cultivation Cost (TC) £:	24700	32110	24700	32110
• Seeds	1976	1976	1976	1976
• Fertilizers	4940	4940	4940	4940
• Pesticides	494	494	494	494
• Ploughing & Levelling	1235	1235	1235	1235
• Irrigation	3458	3458	3458	3458
• Labor	3705	3705	3705	3705
• Rent	7410	7410	7410	7410
• Shredding & transport.	-	7410	-	7410
• Grains separation	1482	1482	1482	1482
Returns:				
• Corn yield, ton/ha	10.54	11.63	11.58	19.00
• Gross return (GR), £	40078	44213	44020	72178
The net returns (NR), £**	15378	12103	19320	40068
• $\mathrm{NR} = \mathrm{GR} - \mathrm{TC}$				

** all economic was calculated in Egyptian pound L.E. (£)*

*** all values were calculated according to 2022 stock exchange price which was 3800 L.E. (£) / ton.*

CONCLUSIONS

Recycling crop residues via soil incorporation or surface mulching has various beneficial impacts not only on the characteristics of soil quality but also on crop yield. In reality, farm residues can be a viable way to increase soil productivity through improving some essential soil properties. Besides being an effective way for stabilization of agricultural ecosystems, recycling plant residues is one alternative used for improving soil nutrient content and maintaining soil quality. Therefore, the principal objective of this study was to assess the impact of recycling corn stover by incorporation into new-reclaimed soil. The study showed that incorporating the whole yield of dried and shredded corn stover in the soil with a quantity of 13.33 ton ha^{-1} (100%) has a negative effect on soil physiochemical properties and yield productivity. Meanwhile, incorporating the quarter of corn stover yield with a quantity of 3.33 ton ha^{-1} (25%) provided reasonable results in terms of enhancing physiochemical properties and increasing corn yield in the next season. In conclusion, the results obtained from this study revealed that incorporating 25% (3.33 ton ha^{-1}) of corn stover in the soil significantly improved the soil physicochemical properties accompanied with increasing the corn yield up to 19.00 ton ha^{-1} and the stover yield up to 11.5 tons ha^{-1}. However, incorporating greater amount of corn stover up to 100% (13.33 ton ha^{-1}) in the soil decreased corn yield and stover yield to 9.68 and 8.11 ton ha^{-1}, respectively. This indicated that increasing the amount of the recycled corn stover in the soil may cause deterioration in soil quality, stunting phenomenon in plants, decreasing in yield productivity. This is thought to be due to the allelopathic effect of dry shredded corn stover. These findings also include a knowledge and comprehension gap about the nature of the allelopathy phenomena. Future studies should look into how unique treatments applied to maize stover before it is recycled in the soil can reduce the allelopathic effect. Future studies could also look into the long-term effects of adding maize stover to the soil.

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تأثير إضافة حطب الذرة على بعض الخواص الفيزيائية والكيميائية للتربة و على إنتاج محصول الذرة

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[١]قسم الهندسة الزراعية كلية الزراعة جامعة قناة السويس الإسماعيلية

[٢]قسم الأراضي والمياه كلية الزراعة جامعة قناة السويس الإسماعيلية

تعد عملية إعادة استخدام حطب الذرة من العمليات المؤثرة على جودة وخواص التربة وبالتالي إنتاج المحاصيل وخاصة فى المناطق حديثة الاستصلاح. لذلك كان الغرض من هذه الدراسة هو التحقق من فعالية خلط حطب الذرة المجفف والمقطع مباشرة في التربة أثناء مرحلة تجهيز الأرض للزراعة ودراسة أثر ذلك على الخواص الطبيعية والفيزيائية للتربة (الكثافة الظاهرية، معدل رشح التربة، درجة الحموضة، التوصيل الكهربي، النيتروجين الميسر، الفوسفور الميسر، الكربون العضوي) وكذلك تأثيرها على خواص محصول الذرة الشامية الصفراء خلال موسمين زراعيين متتاليين. وقد أجريت التجارب الحقلية لهذه الدراسة في مزرعة كلية الزراعة، جامعة قناة السويس، بمحافظة الإسماعيلية لتقييم أثر خلط مستويات مختلفة (٠، ٢٥، ٥٠، ٧٥ و ١٠٠ %) من حطب الذرة المتحصل عليها من محصول العام السابق، والتي تكافئ كميات الإضافة (٠، ٣.٣٣، ٦.٦٧، ١٣.٣٣,٩.٩٩ طن للفدان). وقد أشارت النتائج المتحصل عليها من هذه الدراسة أن خلط ٢٥% (٣.٣٣ طن للهكتار) من حطب الذرة فى التربة كان له الأثر الأكبر في تحسين خواص التربة الفيزيائية والكيميائية إضافة إلى زيادة إنتاجية محصول الذرة إلى ١٩.٠٠ طن للهكتار وزيادة حطب الذرة إلى ١١.٥ طن للهكتار. فيما وجد أن خلط نسبة أكبر من حطب الذرة في التربة ١٠٠% (١٣.٣٣ طن للهكتار) أدى إلى تدهور خواص التربة الفيزيائية والكيميائية فضلا عن تناقص في إنتاج محصول الذرة وإنتاج حطب الذرة إلى ٩.٦٨ و ٨.١١ طن للهكتار على التوالي.