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Biochar Ash and Manure Mixture Impacts on some Soil Physical Properties and Landscape Quality

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ABSTRACT

Biochar ash is a waste product of traditional charcoal production process in the absence of oxygen and consists of cement-like organic matter dust collected from traditional kilns floor. This study tested the changes in some soil physical properties and the establishment of ryegrass cover area as a natural landscape resulting from the application of biochar ash mixed with organic waste in clay and sandy soil. Biochar ash (BA) collected from kiln dust waste was applied as an equal mixture with farmyard manure (BA/FM) and poultry manure (BA/PM) at dry weight basis to 10 kg soil pots in the greenhouse at different rates of 0, 2, 4, 6, 10%. Mixtures of BA/FM or BA/PM addition increased clay and sandy soils water holding and available water capacities at all application rates compared to control. Soil aggregate stability against water increased significantly as the mixture rate addition increased. Relative to the control, mixture of biochar ash and manure amendment decreased the dispersibility of soil aggregates and had significant effects on soil aggregate stability. Soil physical improvements were not significantly different when BA mixed with FM or PM. Incorporation of biochar ash mixture into sandy or clay soil has established sufficient landscape of ryegrass covering area to prevent erosion compared to control. Once the agronomic benefits and environmental impacts of using biochar ash as a soil amendment have been identified, an environmental and economic feasibility study should be conducted to determine whether landfilling biochar by-products is better or using them in sandy soil reclamation projects.

Keywords: Biochar Ash, Aggregate Stability, Soil Dispersibility.

INTRODUCTION

Productivity of clay and loamy soils in the Nile Valley has deteriorated due to intensive agriculture, mismanagement and the state of poverty experienced by small farmers in Egypt. In addition, soil productivity, crop yield and crop quality are limited in the newly reclaimed sandy soils in western of El-Minia Governorate due to low soil fertility, low moisture-holding capacities, and low organic matter contents of the sandy and sandy calcareous soils in that region. Accordingly, some physiochemical characteristics of these soils are not at optimum levels for high and sustained crop productivity. Specifically, these soils exhibit poor structure, which manifests increases in water erosion, especially under conventional tillage practices. The most common solutions for soil moisture stress and to overcome limited water retention is by improving the structure of these soils by organic waste additions (Sims et al., 1995b; Abd El-Azeim et al., 2021; Abbas et al., 2022; Chen et al., 2022).

In Egypt, traditional production of biochar using kilns in the absence of oxygen for domestic consumption such as hookah smoking, barbeque or even for generation of electricity in thermal power plants (Helwan steel power plant) results in huge amounts of dust waste in the kiln floor, which are commonly known as biochar ash (BA). Environmental pollution and the associated health problems due to the release of smoke, gases, effluents, and solid wastes from such activities is one of the major issues of concern. Landfilling is the traditional method of BA disposal, but the dual factors of increased cost and stricter legislation have prompted research into alternative methods of disposal or utilization of this waste material (Kriesel et al., 1994; Chen et al., 2022; Haddad et al., 2022).

Worldwide, over the last two decades numerous studies on the use of biochar and its derivatives (e.g. biochar ash (BA) and charcoal fly ash (CFA)) as a soil amendment have been conducted, and several reviews on this subject have been published (e.g., El-Mogazi et al., 1988; Carlson and Adriano, 1993; Tiwari et al., 2007, Abd El-Azeim et al., 2021; Abbas et al., 2022; Chen et al., 2022). In general, it appears that BA can have significant beneficial effects in addressing certain problems in soil quality, for instance, the predominantly negative functional groups on biochar particles surface as well as clay and silt-sized nature of BA has been used to improve soil physical properties (Liang et al., 2006; Lehmann, 2007; Tiwari et al., 2007; Mawof et al., 2021). Biochar ash is a cementitious material because of its high content of organic matter that makes it useful in soil application where cementing action is desirable especially in the case of sandy soils.

Sandy soil stabilization and clay soil aeration can be accomplished by the addition of materials like biochar ash. Biochar ash is well suited for soil stabilization by improving its ability to withstand saturated conditions and generally more economical productivity (Lee et al., 2006; Mukherjee, and Lal, 2013; Mawof et al., 2021). Because biochar ash is relatively enriched in trace elements, it has been successfully applied to alleviate micronutrient deficiencies (El-Mogazi et al., 1988; Abbas et al., 2022; Haddad et al., 2022). Past studies have also revealed several shortcomings to the use of BA as a soil amendment. The most cited deficit is that Fly ash alone is a poor source of the macronutrients N and P (Carlson and Adriano, 1993 and Keefer, 1995; Lehmann, 2007). Nitrogen

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is volatilized during the process of pyrolysis, while most phosphorus of BA is relatively unavailable (Bradshaw and Chadwick, 1980; Khadem et al., 2021).

Adding animal manure to soils is a recognized method for boosting aggregate stability, organic matter levels, water-holding capacity, minimizing erosion, and improving soil fertility (Six, et al., 2000; Whalen and Chang, 2002; Zornoza, et al., 2016; Yin et al., 2022). By using agricultural waste, sewage sludge, and farmyard manures, numerous attempts have been undertaken to raise the low levels of soil organic matter in Egypt (Mekail et al., 2006). High rates of aerobically digested sewage sludge application have also been shown to alter the aggregate stability and porosity of soils (Abdel-Sabour and Mohamed, 1994). In addition, ryegrass as turfgrass is used in the landscape and occupies a large area of any park and is used nowadays to establish locations for recreations and different kinds of sports activity. Several studies had indicated the positive effects of different organic fertilization programs on the visual and quality of turfgrasses in some soccer and golf fields (Abdel Kader, et al., 2018).

Soil application of biochar ash alone as a soil amendment is a poor source of macronutrients such as nitrogen, phosphorous and potassium. Whereas, by mixing biochar ash with organic manures, macronutrients can be increased while refining handling and decreasing odor. Therefore, the current research is used on mixing BA with farmyard manure (BA/FM) or poultry manure (BA/PM) is superior soil amendment. The use of organic waste addresses the deficiency of macronutrients in BA, while BA can act as a bulking agent for the organic wastes and a stabilizing agent for the investigated soil. The objectives of this study were to identify some types of Nile valley soil and newly reclaimed sandy soils in west El-Minia Governorate that could benefit from incorporating biochar ash mixed with manures of farmyard (BA/FM) or poultry (BA/PM) in terms of improving soil aggregates, organic carbon content, stability to water, available water capacities and the establishment of a grassy cover area as a natural landscape.

MATERIALS AND METHODS

Materials collection and characterization of samples:

Investigated soils were collected from the top 0-30 cm layer at village 7, village 8 and the Nile valley in the Samallute district of Northwest El-Minia Governorate. They constitute important agricultural soils and represent a wide range of soil characteristics in this region. Soil was air-dried at room temperature and sieved through a 2 mm sieve. Free biochar ash made from waste of fig trees pruning was obtained from a local kiln located in the Nile riverbank of El-Minia Governorate after collecting solid biochar, then air-dried at room temperature and finely ground to pass through a 2 mm sieve. In village 8, mature poultry and farmyard manures were gathered from feedlots and air-dried at room temperature before being ground to a fine enough consistency to pass through a 2 mm sieve. Tables (1 and 2) list some significant traits of the examined soils, charcoal ash, and manure. The pipette method was used to measure particle size (Day, 1965), and sodium acetate was used to measure cation-exchange capacity. The chemical properties of biochar ash and manures were examined using the techniques described by Black (1965), Page et al. (1982), and Avery and Bascomb (1982).

Table 1. Some physicochemical characteristics of the investigated soils.

Soil property	Soils		
	Village 7	Village 8	Nile valley
Coarse sand (%)	48.20	55.60	15.10
Fine sand (%)	41.80	34.50	13.10
Silt (%)	6.30	3.10	22.90
Clay (%)	3.70	6.80	48.90
Texture	Sand	Sand	Clay
pH (1:2.5 H_2O)	8.34	8.23	7.54
CEC ($cmol_c$/kg soil)	6.64	5.84	28.76
EC (dS m^{-1})	3.27	3.67	1.64
O.M (g/kg)	2.25	4.31	26.03
O.C (g/kg)	1.30	2.50	15.10
Total N (g kg^{-1})	0.11	0.22	1.3
C/N Ratio	11.82	11.36	11.62
$CaCO_3$ (g/kg)	69	109	21
WHC (%)	19.5	21.1	31.6
Water-stability of aggregates (%)	9.80	15.30	37.90

Table 2. Characteristics of biochar ash, farmyard, and poultry manures.

Property	Biochar ash (BA)	Farmyard manure (FM)	Poultry manure (PM)
pH (l:10 H_20)	8.32	8.24	7.75
EC (dS m^{-1})	3.25	2.19	2.89
CEC (Cmolc/kg soil)	51.36	42.88	45.77
Organic Matter (%)	28.57	32.20	41.56
Organic Carbon (%)	16.57	18.68	24.11
Total N (%)	1.43	1.61	2.08
Total P (%)	0.06	1.28	1.46
C:N ratio	11.59	11.60	11.59
Available K (mg/kg)	14.19	15.66	13.19
Available Ca (mg/kg)	13.28	8.9	11.38
Available Mg (mg/kg)	12.56	1.55	11.66
Water holding capacity (%)	53%	42%	43%

Experimental procedures:

This trial was conducted following a randomized complete block design with three replicates consisting of 90 pots. Each pot was filled with biochar ash and manure mixtures of 0.0, 200, 400, 600 and 1000 g mixed thoroughly with 10 kg of the < 2 mm soil fraction and incubated under greenhouse conditions at field capacity for 15 days before grass cultivation. Mixture combinations were mixed by hand prior to soil application at the dry weight ratios of 1:1 for BA/FM and BA/PM. The entire experiment was maintained under controlled greenhouse conditions with a day and night temperature of 30 ± 10ºC. Ryegrass was sown after 15 days to study the effectiveness of the organic waste mixture to promote a grass-covering area as a natural landscape, which in turn encourages a positive control of the soil erosion in the case of newly reclaimed sandy soil The soil-manure combination pots were weighed daily, and any moisture lost due to evaporation was quantitatively compensated to maintain optimal growth. 75 days after seeding, grass was trimmed in preparation for digital photography.

A digital camera was used to take digital photographs of the grass experimental pots after each harvest and average grass coverage was obtained. The relative position, altitude and inclination angle was kept constant during the acquisition of the photographs for all pots. The digital photographs were then downloaded and imported for processing using EASI/PACE image processing software. Simple density slicing was used to determine the percentage cover (PCI, 1997).

After grass harvest, pots were left for 2 months in an incubator under 25 ºC, covered with black polyethylene and watered once a week for grass roots to decompose before the soil physical analyses. For laboratory experiments with this kind of organic mixture, a 60-day incubation period has been determined to be sufficient (Chandra and De, 1982). The soil-manure and biochar ash mixtures were incubated, and then their aggregate stability, dispersion ratio, aggregate density, moisture retention capability, and residual organic-carbon content were assessed. This process took ten days.

Dry aggregates, which were obtained by sieving, were in the following size ranges: 2-4, 1-2, 0.5-1, 0.25-0.5, 0.125-0.25, 0.05-0.125 and <0.05 mm. Soil moisture constants were determined using undisturbed soil samples. The completely saturated soil core samples were exposed to constant levels of pressure using the pressure Cooker and Membrane by the method of **(**Klute, 1986**).** The single-sieve water stability technique was used to assess aggregate stability (De Boodt, 1967). In this approach, 10 g of the soil or soil-organic combination were helicoidally oscillated 20 times at a rate of one oscillation per second along a stroke of 4 cm after being presoaked on a 0.2 mm sieve for 10 min. The resistant aggregates were weighed after being oven-dried at 105°C for 24 hours, corrected for the sand percentage, and then measured to determine the mass of the real aggregates (Kember and Rosenau, 1986).$AS = [(M_{ra} + {}_{sf} - M_s)/(TM_s - M_s)]\ 100$. Where, AS is the aggregate stability (%), $M_{ra}+_{sf}$ is the mass of the resistant aggregates plus sand fraction (g), M_s is the mass of the sand fraction (g) and TM_s, is the total mass of soil used (g).

The dispersion ratio was calculated using the method outlined by Archer and Marks (1978). The ability of the individual aggregates to withstand breakdown when in contact with water molecules is gauged by the dispersion ratio (DR%). Lower resistance is indicated by higher values. After being immersed in either distilled water or sodium hexametaphosphate (5% calgon), the sample aggregates of a known weight were shaken end over end. The dispersion ratio is then computed as (L/H) 100 by comparing the percentage of silt and clay in samples that were dispersed in water (L) and sodium (H).

Statistical Analyses

Three replicates were used in the randomized complete block design of the experiment, and all data were subjected to regression coefficient and analysis of variance tests, as well as LSD procedures to assess mean differences.

RESULTS AND DISCUSSION

Soil aggregate stability and dispersion ratio

Village 7 was the least stable of the control treatment's soil aggregates to water, followed by Village 8 and then the Nile Valley (Table 3). This might be caused mostly by the Nile valley soil's elevated clay content and the soil in village 8's CaCO3 content. As shown by increasing the BA/FM or BA/PM rate, the total aggregate stability% improved, adding biochar ash/manure mixtures to these soils resulted in distinct responses with respect to aggregate stability (Table 3).

Table 3. Influence of BA/FM and BA/PM Amendment on Water-Stable Aggregates (%).

Soil locations	Addition rate (%)	BA/FM Water-stable aggregates (%)	BA/PM Water-stable aggregates (%)
Village 7	0	9.8	9.8
	2	10.5	11.6
	4	17.7	19.0
	6	19.6	21.3
	10	20.5	22.2
Means		15.62	16.78
Village 8	0	15.3	15.3
	2	20.4	22.1
	4	22.2	25.1
	6	25.8	28.3
	10	28.3	29.1
Means		22.4	23.98
Nile valley	0	30.9	30.9
	2	32.6	33.6
	4	34.6	35.6
	6	33.4	35.5
	10	32.2	34.4
Means		32.74	34
$LSD_{0.05}$	Soils type	0.84	0.87
	Mixture Rate	1.07	1.06
	Type of Mixture	2.13	

Aggregate stability of village 7 sandy soil increased significantly with increasing mixtures of BA/FM or BA/PM addition rate. In structurally intermediate calcareous soils (village 7 and 8 soils), the overall aggregate stability was a parabolic function of addition rate, with a slight aggregate stability and insignificant increase beyond the 6% addition rate. However, in structurally strong clay Nile valley soil, the overall aggregate stability decreased with increasing addition rates beyond the 6% addition. In both sandy and sandy calcareous soils, the relative improvement in overall stability may be mainly due to the application of the increased organic matter function of these soils with the stabilization effect of biochar ash. In clay soil of the Nile Valley, the improvement in aggregate stability at low addition rates was a function of the inherited stability of the soil. The disaggregating effect of organic mixtures on this clay soil was also observed by Mbagwu & Bazzoffi, (1988); Rautaray *et al*., (2003); Lee *et al*., (2006) and Tiwari *et al*., (2007).

When they introduced pure humic acids directly to clay-rich soils in several alluvial soils in India, Chandra & De (1982) also noted this behavior. Organic matter can aggregate or disaggregate in soils, depending on the proportional contributions of the other components affecting aggregate stability, according to Emerson (1983) and Oades (1984). The polyvalent cations that operate as bridges in the inter-crystalline domains of moderately high-clay soils, such this alluvial clay soil, are bonded to the clay surfaces by coulombic attraction.

The humic substances of the organic matter constituent of the investigated organic mixtures can penetrate the clay domain, especially at high additions, and form stronger complexes with the polyvalent cations, thereby displacing the less strongly bound clay particles. Such a break in the clay-polyvalent metal-humus complexes invariably result in reduced aggregate stability, as observed on the Nile valley soil at high BA/FM or BA/PM mixture rates. In general, BA/FM and BA/PM additions increased aggregate stability through the addition of small sized fractions of the biochar ash, fats, waxes, oils (ether-soluble), resins (alcohol-soluble), and water-soluble polysaccharides (Clapp *et al*., 1986; Lindsay and Logan, 1998; Khadem *et al*., 2021).

The ability of the individual aggregates to withstand breakdown when in contact with water molecules is measured by the dispersion ratio (DR) (Mbagwu, 1990). Table (4) shows the variations in the dispersion ratio between the treated and control soils. At various application rates, aggregate stability rose by 8 to 22%. The dispersion ratio was only slightly and insignificantly affected by increasing the rate of both mixtures. Data in Table (4) clearly demonstrate that applying BA/FM and BA/PM was successful in enhancing aggregate stability. Significant and superior to control treatments were the decreases in the dispersion ratio and, as a result, the increases in aggregate stability in treated pots. This could be attributed to the organic matter stabilizing effect of biochar ash with both organic manures. Also, as evidenced by the biochar scanned images at different magnification levels indicative of the morphological features of the biochar cavity (Fig. 1),

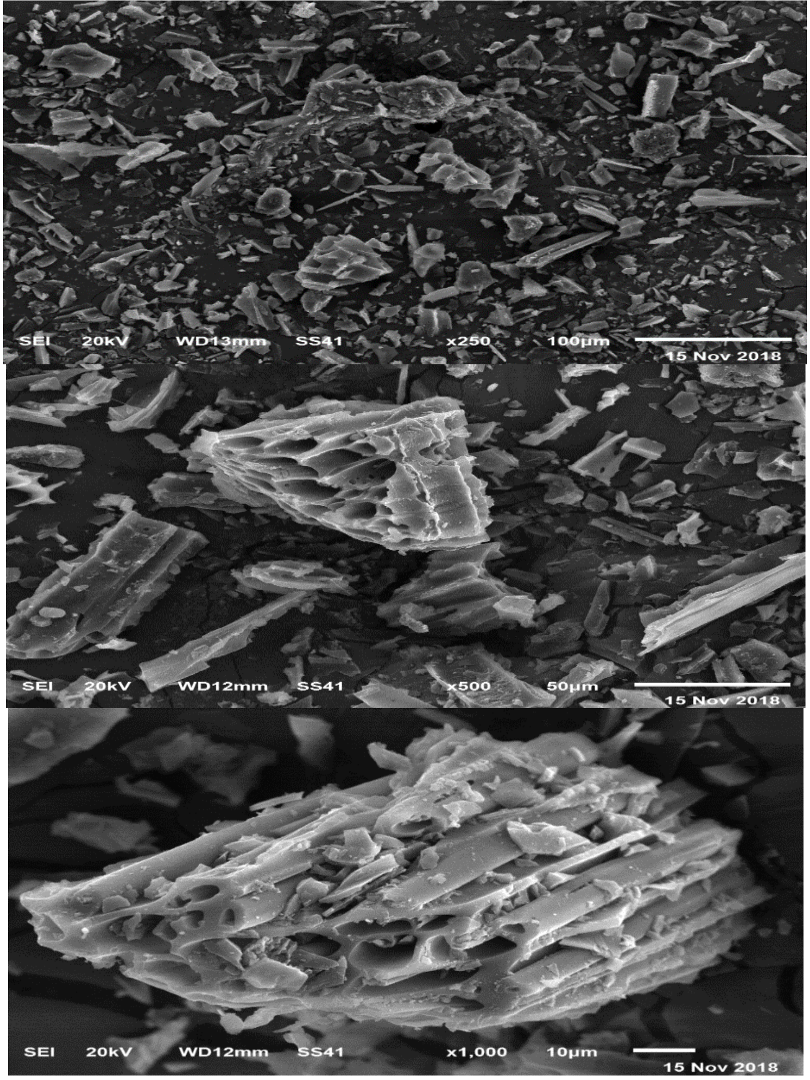

Figure 1. Biochar scanned images by Scanning Electron Microscope at different magnification levels.

Table 4. Dispersion ratio (DR%) and degree of aggregation (DA%) of the investigated soils as affected by different application rates of BA/FM and BA/PM.

Aggregation index %	Soils	Control	BA/FM				BA/PM			
		0.0 %	2 %	4 %	6 %	10 %	2 %	4 %	6 %	10 %
DR	Village 7	92	80	75	72	72	78	74	74	73
	Village 8	90	77	74	71	70	76	72	68	68
	Nile Valley	65	58	54	52	52	57	54	52	51
DA	Village 7	8	20	25	28	28	22	26	26	27
	Village 8	10	23	26	29	30	24	28	32	32
	Nile Valley	35	42	46	48	48	43	46	48	49

NB. Degree of aggregation = (100 – Dispersion ratio).

L.S.D P ≤ P 0.05 (Soils, 1.3) (Application rates, 2.2) (Mixtures, 5.14).

These caverns resulted in more aggregate stability and lower dispersal ratio of the examined soils. Results of the dispersion ratio clearly demonstrate that the BA/PM amendment, when applied at all application rates, promoted the stability of aggregates slightly differently than when applied at BA/FM's equal application rates. The significant superiority of the aggregate stability and dispersion ratio indices was mainly due to the stabilizing effects of application organic manures and biochar ash.

It is important to note that the aggregate stability in both combinations rose dramatically with rising addition rate, seemingly peaking at both the 6 and 10% application rates. This maximal impact is a reflection of these soils' limited ability to aggregate in response to the addition of organic matter. The superiority of treated soil to control on the measured physical properties was due to the stabilizing effects of biochar ash and the increases in the residual organic carbon contents of the investigated soil.

Changes in soil moisture contents

Generally, soil moisture contents in the treated soils were significantly higher than the control. The highest moisture differences existed between the treated soil at 10 % of BA/PM rate and the control in the clay soil. Intermediate significant values were obtained for the other treatments. The influence of BA/FM was insignificant upon moisture content compared with BA/PM at all application rates. Increasing amendment rate additives led to significant improvements in water retention and accessible water capacity of the three soils tested compared to control for all three soil moisture constants measured (Table 5).

Table 5. Effect of BA/FM and BA/PM on water retentions of the investigated soils.

Soil		Mixture rates%	Moisture retention contents (%)							
			0.01 (MPa)		0.03 (MPa)		1.5 (MPa)		AWC*	
			BA/FM	BA/PM	BA/FM	BA/PM	BA/FM	BA/PM	BA/FM	BA/PM
Village 7 (Sandy soil)		0	20.4	20.8	24.1	24.4	5.7	5.9	14.7	14.9
		2	28.3	28.9	27.1	28.2	6.1	6.3	22.2	22.6
		4	29.3	30.1	28.3	29.1	6.3	6.3	23.0	23.8
		6	33.2	34.2	29.5	30.1	6.9	6.6	26.3	27.6
		10	34.5	35.0	29.9	30.5	7.1	6.7	27.4	28.3
Means			29.14	29.8	27.78	28.46	6.42	6.36	22.72	23.44
Village 8 (Sandy cal. soil)		0	24.2	24.6	27.5	27.5	7.1	7.4	24.1	24.2
		2	32.4	33.1	27.0	28.2	8.6	7.2	23.8	25.9
		4	35.1	36.3	28.6	28.9	8.5	7.3	26.6	29.0
		6	38.3	38.6	30.9	31.7	9.1	7.5	29.2	31.1
		10	39.2	39.1	33.5	34.6	8.7	8.1	30.5	31.0
Means			33.84	34.34	29.5	30.18	8.4	7.5	26.84	28.24
Nile valley (Clay soil)		0	35.2	35.2	28.5	28.5	8.2	8.2	27.0	27.0
		2	38.2	39.5	29.7	30.2	8.9	9.3	29.3	30.2
		4	39.9	40.1	31.8	32.6	9.5	9.5	30.4	30.6
		6	41.6	41.9	30.6	31.2	9.6	10.0	32.0	31.9
		10	41.6	43.2	32.6	33.3	10.1	9.9	32.5	33.3
Means			39.3	39.98	30.64	31.16	9.26	9.38	30.24	30.6
LSD $_{0.05}$	Soils (S)		1.20		1.37		0.34		1.50	
	Mixtures (M)		1.91		1.93		1.55		1.93	
	Rates (Rates)		0.6		1.23		0.66		1.1	

*** AWC = 0.01 (MPa) minus 1.5 MPa moisture content.**

Concerning field capacity and permanent wilting point, addition of BA/FM or BA/PM improved moisture content at all application rates with significant differences in the three soils, relative to control. The trend for increasing available water-holding capacity was similar to that at field capacity. Similar increases in soils' ability to hold water have been noted by Lee *et al*., 2006 and Abd El-Azeim et al., 2021. Since the water-holding capacity of both mixtures is much higher than that of the control treatment. In other words, the proportional improvement in water retention at the permanent wilting point lessened the higher the soil's clay content (Whalen and Chang, 2002). According to Gupta et al. (1977), at high stress, soils' capacity to hold water is more strongly influenced by the surface area of their soil particles, which is a function of the quantity of clay fractions present. In addition, surface functional groups and porous structures are some of the inherent assets of biochar ash making it an option as a soil conditioner and a probable applicant for long-term carbon storage and sequestration in soils (Abd El-Azeim et al., 2021; Abbas et al., 2022; Haddad et al., 2022).

The BA/FM and BA/PM mixes that were utilized were extremely hydrophilic, holding up to 4.00 times their own weight of water at a stress of 0.01 MPa (Table 2). This study discovered that the increasing moisture content brought on by the application of organic waste amendments was larger for coarse-textured soils than for fine-textured soils. This finding has also been documented by Gupta et al. (1977) and Unger & Stewart (1974). The increased latitude for cultivation is the practical result of the increases in soil moisture contents brought on by the addition of amendments. This is crucial for clay soil, which under natural circumstances presents significant workability issues even at very low moisture concentrations. The amount of moisture at which plowing may be done without creating smearing is enhanced with the addition of amendments (Lee et al., 2006; Tiwari et al., 2007).

Sandy soils in the north-west of El-Minia Governorate cannot hold enough water in the profile to meet the needs of most crops during the hot summers. This is sometimes linked to their naturally low levels of organic matter. The volume and frequency of irrigation required in this area during dry spells should be anticipated to decrease because to improvements in the soils' capacity to hold onto water brought about by the application of high rates of biochar ash mixed with organic wastes.

The central quality of biochar as a soil conditioner is its highly porous structure, which improves water retention and increases soil surface area (Abd El-Azeim et al., 2021; Nguyen et al., 2022). Study by Liang et al. (2006) on sandy soil biochar inclusion demonstrated specific surface area and soil CEC increase relative to untreated soil, since the retention of nutrients in soils often depends on the ability of biochar to adsorb or transport nutrients (Khadem et al., 2021; Haddad et al., 2022)). Biochar has a better capacity to absorb water and cations than other soil organic matter because it has a larger surface area, more negative surface charge, and a higher charge density. The direct contribution of biochar to soil water availability has also been demonstrated to increase the efficiency of fertilizer usage with greater yield output (Mawof et al., 2021; Liu et al., 2022).

For all of the examined soils, the percentage of residual organic carbon rose as the rate of amendment was applied, as indicated in (Table 6). The treated soil has considerably more organic carbon than the untreated soil. The proportional increases in organic carbon for the village 7, village 8, and Nile valley soils at the 10% addition rate of BA/FM were 307, 168, and 36%, respectively. The 10% addition rate of BA/PM caused the higher levels of residual organic carbon; the improvements over the control were 400, 212, and 56% for the three soils, respectively. This pattern demonstrates that the proportional improvement in residual organic carbon is larger the lower the intrinsic organic carbon content of the soil is.

Results of the organic carbon contents show that application both BA/FM and BA/PM amendment at all application rates caused slight insignificant differences in promoting the increase of organic carbon. The relationships between the organic mixtures rates (R) and residual organic carbon (OC %) were simply linear with the following regression equations:

Village 7: OC (%) = 0.59 + 0.23 *(R)* (R^2 = 0.845) (BA/FM)
OC (%) = 0.48 + 0.21 *(R)* (R^2 = 0.816) (BA/PM)
Village 8: OC (%) = 0.98 + 0.22 (R) (R^2 = 0.895) (BA/FM)
OC (%) = 0.97 + 0.23 *(R)* (R^2 = 0.971) (BA/PM)
Nile valley: OC (%) = 1.59 + 0.25 (R) (R^2 = 0.943) (BA/FM)
OC (%) = 1.54 + 0.27 *(R)* (R^2 = 0.954) (BA/PM)

In other words, at the end of the experiment, the residual organic carbon content of these soils varied between 80 and 98% depending on the addition rates used.

Statistical analyses of the addition rate effects on residual organic carbon content of the three soils are shown in Table 6. This reveals highly significant differences among soils and addition rates. This significant interaction indicates that the magnitude of increase in organic carbon was related with the main physical, chemical and pedagogically features (Gale et al., 2000 and Six et al., 2000; Khadem et al., 2021). However, there was insignificant differences between BA/FM and BA/PM mixtures.

Table 6. Residual organic carbon (OC%) in three soils amended with BA/FM and BA/PM mixtures.

Soil	**Addition rate (%)**	**Organic Carbon (OC %) BA/FM**	**Organic Carbon (OC %) BA/PM**
Village 7 sandy soil	0	0.13	0.13
	2	0.33	0.41
	4	0.43	0.50
	6	0.47	0.57
	10	0.53	0.65
Means		0.378	0.452
Village 8 sandy soil	0	0.25	0.25
	2	0.51	0.55
	4	0.59	0.66
	6	0.61	0.73
	10	0.67	0.78
Means		0.526	0.594
Nile valley clay soil	0	1.51	1.51
	2	1.63	1.71
	4	1.71	1.81
	6	1.81	1.96
	10	1.93	2.21
Means		1.718	1.84
LSD ($P <0.050$)	Soils	0.08	0.09
	Rates	0.03	0.05
	Mixtures	1.06	

Additionally, the regression equations (given in Table 7) reveal connections between the amount of remaining organic carbon and both the capacity for holding water and the stability of aggregates.

Table 7. Regressions between residual organic carbon % (X), the aggregate stability (AS) and the available water capacity (AWC).

Solis	**Dépendent variable (*Y*)**	**Régression équation**	**R^2**
Village 7	AS (%)	$Y = 5.62 + 1.55 X$	0.956
	AWC (%)	$Y = 17.96 + 1.11 X$	0.778
Village 8	AS (%)	$Y = 12.11 + 1.97 X$	0.907
	AWC (%)	$Y = 21.65 + 1.51 X$	0.855
Nile Valley	AS (%)	$Y = 35.15 - 0.96 X$	0.588
	AWC (%)	$Y = 25.96 + 1.27 X$	0.637

With larger rates of mixture addition, residual organic matter increased, which had a direct impact on the stability of aggregates and the increase in available water capacity for all three soils (Haddad et al., 2022). For the sandy soil (village 7), variations in residual organic carbon were responsible for 95 and 77% of the variance in aggregate stability to water and available water capacity, respectively. For the sandy calcareous soil (Village 8), the corresponding values were 89 and 83%, and for the alluvial clay soil, they were 59 and 63%.

The negative slope of the linear regression equation for the aggregate stability-organic carbon relationship for the clay soil confirms the disaggregating effect of high addition rates of FA/FM and FA/PM mixtures. These results are in agreement with several previous studies (Lee *et al*., 2006 and Tiwari *et al*., 2007; Abd El-Azeim et al., 2021).

Landscape quality and grass covering area.

The use of grass in agricultural projects has increased in recent years to reduce erosion, to improve soil structure and nutrient cycling, to contribute N to the main crop and to uptake N that exceed crop requirements, and finally, to be used for landscape and grazing. These results revealed that incorporation of such mixtures into sandy or clay soils have established sufficient plant growth and grass covering area to fully protect the soil against erosion. The grass sown in the treated sandy or clay soils pots appeared and grew regularly with no sign of nutritional deficiencies or water stress and the covering area was nearly 100% in all incorporating pots.

The results of the grass covering areas revealed that all the treated pots resulted in a significantly greater percentage of grass covering than the control. Also, the results show that application of both BA/FM and BA/PM amendment at all application rates caused slight insignificant differences in promoting the increase of grass covering. There were no significant differences ($P \leq 0.05$) between different application rates and mixtures type. In the case of the clay soil (Nile valley), the range in grass covering area was from a low of 64.3% for the control to nearly 100% for all treated pots at all application rates. In the case of the sandy soils (Village 7 and village 8), the range in grass covering was from a low of 15.9% for the control to nearly 100% for all treated pots at all application rates. Finally, several drawbacks to the use of BA as a soil amendment are cited in the literature. The most cited detrimental effects are salt toxicity and high availability of trace elements in BA-amended soil (Tolle et al., 1983; Carlson and Adriano, 1993 and Keefer, 1995; Abbas *et al*., 2022). Therefore, an increase in research effort is needed to address these detrimental effects under arid conditions prior to initiation of biochar ash addition to sandy soil reclamation projects or clay soil in the Nile Valley.

CONCLUSIONS

Results of this study revealed that there are several physical potential benefits of applying biochar ash mixed with organic manures into the investigated soils. Physical benefits may be indicated from the addition of organic matter, which contributes to the aggregate stability, soil structure, water retention, cation exchange capacity, improves the biological diversity, increases the availability of macro and micro-plant nutrients, and overall modifies the soil to provide more conducive matrices for plant growth. Effects of BA/FM and BA/PM additions on soil physical properties largely depend on the method of application, the rate of amendment and their contribution to soil residual organic carbon. The observed improvements in soil physical properties were due to effects of added organic materials and only sustained by repeated application. So that organic materials level and decomposition rate under arid conditions needs to be assessed prior to termination of amendment addition to soils especially newly reclaimed sandy soils.

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تأثير رماد الفحم الحيوي والمخلفات العضوية على بعض الصفات الطبيعية للأراضي وجودة المسطح الأخضر

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الملخص

رماد الفحم الحيوي هو منتج نفايات لعملية إنتاج الفحم التقليدية في غياب الأكسجين ويتكون من تراب عضوي شبيه بالأسمنت يتم جمعه من أرضية المكامر التقليدية. استعمال رماد الفحم وحدة كمحسن للتربة يكون مصدراً ضعيفاً للمغذيات الكبرى مثل النتروجين والفوسفور. بخلط الرماد مع المخلفات العضوية يمكن بذلك أن تزيد هذه المغذيات الكبرى بينما يقل انبعاث الروائح الكريهة ويسهل التعامل مع المخلفات العضوية. هذه الدراسة اختبرت التغيرات في بعض الصفات الطبيعية للأرض وإنتاج مسطح أخضر جيد ينتج عن استعمال مثل هذا المخلوط في الأراضي تحت الاختبار. رماد الفحم الحيوي جُمع من مخلفات المكامر التقليدية لإنتاج الفحم واستعمل كمخلوط مع كلاً من سماد المزرعة وزرق الدواجن بنسبة 1:1 على أساس المادة الجافة وأضيف هذا المخلوط بنسب صفر، 2، 4، 6 و10% إلى الأصص التي يحتوي كلاً منها على 10 كجم من هذه الأرض الرملية. إضافة المخلوط أدى إلى زيادة قوة حفظ الأرض للماء وكذلك زيادة الماء الميسر عند كل التركيزات بالمقارنة بالكنترول. ثبات التجمعات الأرضية عند تعرضها للمياه زاد بزيادة إضافة المخلوط بالمقارنة بالكنترول. رماد الفحم كمحسن أدى إلى تناقص نسبة التفرقة في التجمعات الأرضية وكان له تأثيرات معنوية على ثبات التجمعات الأرضية. كل هذه التحسينات في الصفات الطبيعية للأراضي كانت غير مختلفة معنوياً عند معاملة التربة برماد الفحم مخلوطاً مع كل من سماد المزرعة وزرق الدواجن. خلط رماد الفحم مع الأرض الرملية كون غطاء عشبي كافي من ناحية جودة المسطح الأخضر بالمقارنة بالكنترول. أفضلية الأراضي المعاملة بالنسبة للكنترول فيما يخص الصفات الطبيعية المختبرة كانت بسبب التأثيرات المثبتة لرماد الفحم وكذلك الزيادات في محتوى الكربون العضوي المتبقي في الأرض المعاملة بالمخلوط. بعد التعرف على الفوائد المحصولية والتأثيرات البيئية لاستعمال رماد الفحم كمحسن للتربة يجب إجراء دراسة جدوى اقتصادية لتحديد ما إذا كان يجب أن تدفن مخلفات انتاج الفحم ومنتجاته الثانوية ام يفضل استخدامه في مشاريع استصلاح الأراضي.

الكلمات المفتاحية: رماد الفحم، ثبات التجمعات الأرضية، تفرقة التربة.