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Composting Animal and Plant Residues for Improving the Characteristics of a Clayey Soil and Enhancing the Productivity of Wheat Plant GrownThereon

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Abstract

Wheat is a strategic crop in Egypt. Its local consumption is increasing continuously accordingly; Egypt has become the largest wheat importer worldwide. The sustainable approach for increasing wheat productivity is probably through organic additives. For this reason, animal, chicken and plant residues were collected from an experimental farm for preparation of (1**)** **plant residue compost (PRC)** via composting a mixture of air-dried and chopped rice and soybean straw at a rate of 1:1 and (2) **animal residue compost (ARC)** via composting a mixture of chicken and cattle manure at a rate of 1:1. The main aim of this study is to compare between the implications of amending a clayey soil with animal versus plant residues for improving soil physical and chemical characteristics. Also, this study considers the changes in soil fertility owing to these additives, hence their outcomes on wheat growth and productivity. To achieve this goal, a field investigation was conducted following a split-split design in which the two types of composts were plotted in main plots while the rates of compost application (15 and 25 Mg per hectare) were plotted in subplots. Non-amended control plots were also included for data comparison. All plots were cultivated with wheat seeds in winter 2018 and received the recommended doses of NPK fertilizers to compare between the two types of composts as conditioners not as fertilizers. The experiment lasted for 160 days until maturity. All composts improved considerably soil physical (soil bulk density, total porosity, saturated hydraulic conductivity and penetration resistance) and chemical (soil organic matter and CEC) characterises, especially with increasing their rate of application. In this concern, the results of the two types of composts were comparable. Also, these additives boosted grain and straw yields, yield components (spike length, spike weight, number of spikelets/ spike, 100-grain weight). Moreover, theyenriched soils with N, P, K, Fe, Mn, Zn and Cu in available forms; hence raised their contents within wheat shoots and grains, with superiority for ARC versus PRC. There were significant positive correlations between shoot and grain yields in relation to the nutritional status of these plant parts. Accordingly, organic additives, especially animal residues, should be included in the coming sustainable approaches for increasing wheat production.

Keywords: Wheat; Plant residue compost; Animal residue compost; Physical propertues; Chemical properties; Soil fertility

1. Introduction

Wheat is an important strategic crop in Egypt (Elmetwalli et al., 2022). Its annual consumption is increasing continuously due to the concurrent increases in population (Ouda and Zohry, 2017). To lessen the gap between production and consumption, Egypt has become the largest wheat importer worldwide (Abdelmageed et al., 2019). In parallel, the Egyptian government espoused wheat intensification strategies e.g. increase wheat productivity per unit area as well as expanding the cultivated areas (Ouda and Zohry, 2017; Mosa et al., 2020; Elzemrany and Faiyad, 2021). Because of such intensification plans, the use of chemicals was exaggerated and soil degradation turns out to be a global problem (Babla et al., 2022). Probably recycling organic residues may lessen soil degradation (Bationo et al., 2007; El-Ramady et al., 2022) via substituting (partially or totally) chemical fertilizers (Wang et al., 2018; Sarhan and Bashandy, 2021) and, at the same time, increasing the organic

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carbon and nitrogen contents in soils (Maris et al., 2021).

Different forms of organic amendments can be used to attain this aim after being processed via composting (Barthod et al., 2018; Farid et al., 2021c; Awwad et al., 2022) or pyrolysis forming a product called biochar (Abdelhafez et al., 2014; Mohamed et al., 2018; Bassouny and Abbas, 2019; Abdelhafez et al., 2021; Lalarukh et al., 2022). In a study made by Simiele et al. (2022), compost seemed to have a superior effect on plant growth than biochar. Accordingly, the use of compost as a soil conditioner would be a matter of concern in the current study.

Composting is the conversation of farm wastes into valuable products (Barthod et al., 2018) with the aid of microorganisms (Ayilara et al., 2020) to improve the agro-ecosystem health (El-Akhdar et al., 2018). Compost has a sustainable value (Dahlin et al., 2019) as an efficient low cost additive (Song and Lee, 2010) that is used to restore fertility (Sanasam and Talukdar, 2017;Acharya et al., 2019) and enhance plant growth (Babla et al., 2022). Probably, the effect of compost on increasing the productivity of crop yields is equivalent to or superior to the effect of chemical fertilizers (Morra et al., 2021).

Compost is produced from plant (Farid et al., 2018) or animal resides (Ravindran et al., 2019). The lignin content of plant residues is high enough, especially in the fresh remains (Almagro et al., 2021) to lessen considerably its degradation rate in soil (Kamimura et al., 2019); hence, guarantee long-term sustainment and improvements for soil physical characteristics. On the other hand, animal residues are easily biodegradable (Muchanga et al., 2019) and could enrich soils with nutrients (Brust, 2019). It is thought that plant growth is a resultant component of improvements in soil physical and chemical characteristics.

Thus, the current study aimed at comparing the effects of composts prepared from animal (more easily decomposable product) versus plant (less degradable one) residues to restore soil fertility and enhance the growth and productivity of wheat plants. Rice straw was selected for preparation of plant residues compost (PRC) because of its high content of lignin (Vu et al., 2017) and cellulose substances (Abaide et al., 2019; Freitas et al., 2022). To increase its content of N, soy bean residues is guaranteed (Sun et al., 2021) to be mixed with the rice straw residues.

In the current study, two rates of compost (prepared from either plant or animal residues) i.e.15 and 25 Mg / ha were applied to a clayey soil which was planted with wheat under field conditions and this investigation lasted until wheat harvest stage. This soil received the recommended doses of NPK fertilizers in order to compare between the two types of composts (plant-based versus animal-based residues) as conditioners not as fertilizers.

Specifically, we anticipate that application of composts upgrades soil physical characteristics (hypothesis 1), especially the one prepared from mixing plant residues (hypothesis 2). They also improve soil chemical characteristics (hypothesis 3) and enhance plant growth (hypothesis 4); however, the effect of compost prepared from animal residues outstands that prepared from plant resides in this context because it is more easily biodegradable (hypothesis 5). Accordingly, we believe that the results of this study will be helpful inimproving our knowledge about the sustainable production of wheat in Egypt

2. Materials and Methods

Materials of study

A wheat cultivar (Gimeza 11) was obtained from Agriculture Research Center (ARC), Ministry of Agriculture (Egypt). A surface soil sample (0-30 cm) was collected from the experimental farm of the Faculty of Agriculture at Moshtohor, Benha University (31° 22' 26" E and 30° 36' 02" N) prior to wheat cultivation. This sample was air dried, crushed and sieved via a 2 mm sieve then analyzed for its chemical characteristics as outlined by Sparks *et al.* (1996). Undisturbed dried soil sample was used for determining the physical properties as outlined by Klute (1986) and the obtained results are presented in Table 1.

TABLE 1. Physical and chemical characteristics of the investigated soil

Character	value	Character	Value
Sand (%)	24.97	Bulk density (Mg m^{-3})	1.31
Silt (%)	18.95	Hydraulic conductivity (cm h^{-1})	1.95
Clay (%)	56.08	Available nutrients (mg kg^{-1})	
Textural class	Clay	N	19.54
pH*	7.71	P	7.59
EC** (dS m^{-1})	1.27	K	112.89
SOC (g kg^{-1})	13.3	Fe	24.29
$CaCO_3$ (g kg^{-1})	14.2	Mn	9.36
Cation exchange capacity (CEC) ($cmol_c$ kg^{-1})	30.78	Zn	7.55
Exchangeable sodium percentage (ESP)	10.35	Cu	3.58

*pH was determined in a soil:water suspension prepared at a ratio of 1:2.5

**EC was determined in a soil paste extract

Composting animal and plant residues

Two types of composts were used in this investigation i.e. (1) plant residue compost (PRC) prepared via composting a mixture of air-dried and chopped rice and soybean straws at a ratio of 1:1 and (2) animal residue compost (ARC) prepared from chicken and cattle manure mixed at a ratio of 1:1. These residues were collected from the farm of the Faculty of Agriculture at Moshtohor and organized in piles as outlined by Farid et al. (2022**)** forming cone shapes of approximately 1m height and then piles were dampened with tap water to bring their moisture content up to approximately 50% of its weight. Piles were then turned upside down from-time-to-time to improve the aeration conditions while being composted until maturity. The characteristics of the prepared composts are presented in Table 2.

TABLE 2. Characteristics of the prepared composts

	pH	EC (dS m^{-1})	Bulk density (Mg m^{-3})	Organic Carbon (%)	Macro-nutrients (%)			C:N ratio	Micro-nutrient content (mg kg^{-1})			
					N	P	K		Fe	Mn	Zn	Cu
ARC	6.99	2.45	0.540	37.23	1.15	0.65	0.77	32.9	265	23	16	14
PRC	7.31	2.62	0.380	34.12	1.03	0.52	0.47	30.1	218	19	13	11

PRC: plant residue compost; ARC: animal residue compost, the pH and EC were determined in a compost: water extract prepared at a raio of 1:10

The field investigation

A split-plot design was used to attain the aim of the current study in which the different organic sources were added in main plots while the two rates of application i.e.,15 and 25 Mg ha^{-1}were plotted in subplots. Non-amended control plots were also included for data comparison (see the experimental design scheme in Fig 1).

The experimental plot area was 8 m^2 and each treatment was replicated three times. Organic amendments were mixed with the surface soil layer, a week before wheat cultivation. On the 25th of October 2018, all plots were planted with wheat seeds at a rate of 145 kg ha^{-1}. All plots received the recommended NPK doses according to the recommendations of the Egyptian Ministry of Agriculture *i.e.*, 180 kg N ha^{-1} as urea (46 % N), 75 kg P ha^{-1} as mono calcium phosphate (6.6% P) and 120 kg K ha^{-1} as potassium sulfate (40% K). After 160 days of planting, wheat plants reached the maturity stage. Plants were harvested and their straw, gain and biological (grain yield + straw) yields were determined. Plant growth parameters were also estimated by selecting 10 plants randomly from the inner square meter of each plot to assess the following: (1) plant height: measured from the soil surface up to the spike top (excluding the awans), (2) number of tillers/m^2, (3) spike length, (4) number of spikelets/spike, (5) weight of spike (g) and (6) 1000-grain weight (g).

Plant residue compost			**Animal residue compost**		
PRC 0	PRC 0	PRC 0	ARC 0	ARC 0	ARC 0
PRC 15	PRC 15	PRC 15	ARC 15	ARC 15	ARC 15
PRC 25	PRC 25	PRC 25	ARC 25	ARC 25	ARC 25

Fig 1. A schematic diagram of the experiment. PRC 0: no added plant residue compost (control); PRC 15: plant manure compost applied at a rate of 15 Mg ha^{-1}, PRC 25: plant manure compost applied at a rate of 25 Mg ha^{-1}; ARC0: a no applied animal manure compost (compost); ARC 15: animal manure compost applied at a rate of 15 Mg ha^{-1}, ARC 25: animal manure compost applied at a rate of 25 Mg ha^{-1}.

Soil and plant analyses

Plant samples were collected from each plot, oven dried at 70° C for 48 hr, then portions of the dried-plant materials were wet digested via a mixture of sulfuric (H_2SO_4) and perchloric ($HClO_4$) acids, at a rate of 4:1, according to Gotteni et al. (1982) to determine their contents of macro- and micro-nutrients. Nitrogen (N) was determined in the plant digest by the micro-kjeldahl method. Potassium (K) was determined in these digests by flame photometer (model FP910-4) and phosphorus (P) was determined by Spectrophotometer (UH4150ADUV-Vis- NIR) following the molybdenum blue-ascorbic acid methods.

Soil physical properties

Undisturbed soil samples were also collected from the rhizosphere of each plot to assess the following measures as outlined by Klute (1986): soil bulk density (BD) using a steel cylinder of 100 cm^3, saturation hydraulic conductivity in the laboratory using the constant-head method and soil penetration rate by penetrometer, then converted into MPa (100 kg/cm2 = 9.80 MPa). Total soil porosity (TP) was calculated from bulk density and average particle size density (2.65 Mg m^{-3})

Chemical characteristics

All chemicals of study were of analytical grade reagent. Soil organic matter was quantified in the collected soil samples by the Walkley and Black method (Sparks et al., 1995), and the pH (in soil:water suspension prepared at a rate of 1:2.5), EC (in soil paste extract) and CEC were also determined in these samples. Available NPK were extracted from the soil samples as outlined by Page *et al.*(1982) as follows: (1) available N was extracted by K_2SO_4 (1%), then determined using micro Kjeldahel apparatus in the presence of Devarda alloy and (2) available P was extracted by $NaHCO_3$ (0.5*N*, pH 8.5) then determined colormetrically (3) available K was extracted by ammonium acetate method according to Hesse (1971) then measured by the flame photometer. Available concentrations of Fe, Mn, Zn and Cu were extracted by AB-DTPA as outlined by Soltanpour (1985). Total contents of micro-nutrients in plant digests and the AB-DTPA extractable contents were determined by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) Model PERKIN ELMER Optima 3000

Statistical analysis

All data were statistically analyzed via one-way anova by means of PASW 18 statistical software. Graphs were plotted using Sigma Plot 10.

3. Results and Discussion

Effects of animal and plant residues composts on soil physical characteristics

Application of composts prepared from either plant or animal residues lessened slightly both the bulk density of the clayey soil and plant penetration resistance; however, such reductions became significant only with the application of the higher doses of these conditioners i.e.25 $Mgha^{-1}$ (Fig. 2). This is because these conditioners contained high contents of organic carbon (see Table 2) besides being characterized by their high surface area, which enhanced formation of soil inter- and intra-particles (Haque et al., 2021; Navarro-Pedreño et al., 2021) Moreover, organic amendments are of low density versus the mineral components of the soil (Hammad *et al*., 2020).On the other hand, application of each of plant and animal residue composts significantly raised up soil total porosity and the saturated hydraulic conductivity, especially with increasing the dose ofcompost application. In particular, animal residues were more effective in increasing the saturated hydraulic conductivity than the plant residues, probably because it had a narrow C/N ratio which made this amendment more easily degradable in soil

Similar results indicate that compost application enhanced root growth to penetrate the surface soil layer (Shahzad et al., 2018) and in general improved soil physical characteristics (Tejada et al., 2009;

Elshony et al., 2018; Jiang et al., 2018; Farid et al., 2022). Because of the positive consequences of compost applications on soil physical characteristics, the first assumption becomes valid. Nevertheless, the impacts of both ARC and PRC on the studied physical characteristics were comparable, except for the saturated hydraulic conductivity; thus we cannot accept the second hypothesis.

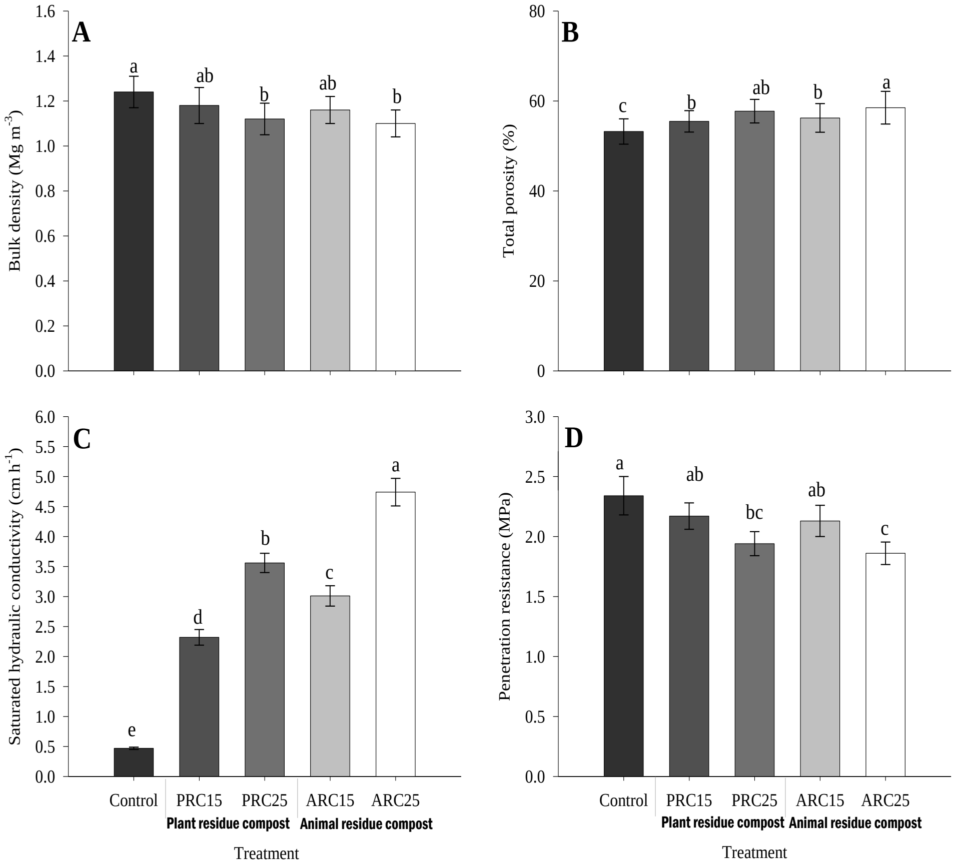

Fig. 2. Physical properties (Bulk density,penetration resistance,saturated hydraulic conductivity,and Total porosity) of the clayey soil (means± standard deviations) as affected by ARC and PRC applications See footnote of Fig 1. Similar letters indicate no significant variations among treatments

Effect of animal and plant residue composts on soil chemical characteristics

Application of the investigated composts raised significantly soil EC while recorded no significant impacts on soil pH (Fig 3 A and B). Such increases were noticeable with increasing the dose of application. This is probably because these conditioners underwent degradation in soil (Leifeld et al., 2002); as a result soluble ions were set free (Gondek et al., 2020) to increase soil EC (Filcheva and Tsadilas, 2002). Ammonification of the organic nitrogen might also raise soil pH (Huang and Chen, 2009); however, in this study, the increases seemed to be insignificant. Generally, the increases in soil EC were higher in the soil amended with animal residue compost (ARC) than the one amended with plant residue compost (PRC) because ARC exhibited narrower C/N ration versus PRC; hence being more easily degradable to set more ions free in the soil solution. Moreover, the latter amendment contained higher contents of lignin cellulose, and hemicellulose which are difficult to biotransform (Greff et al., 2022).

Organic matter content and soil CEC increased significantly owing to application of these additives i.e. PRC and ARC (Fig. 3C and D). Such increases were substantial in the soil amended with ARC versus the one that received PRC, specifically with increasing the rate of application i.e.25 Mg versus15 Mgha^{-1}. This result is stunning because the C/N ratio is narrower in ARC than in PRC and it is well known that residues of narrower C/N ratio undergo rapid degradation versus those that exhibited a wider C/N ratio (Calisti et al., 2020). Probably, the biproducts of soil biota were higher in the case of the easily biodegradable compost (Farid et al., 2021b); and these products are responsible of the build-up of more microbial resistance organic carbon than the original compost (Abdelhafez et al., 2018) which is trapped among soil aggregates (Elcossy et al., 2020; Zhou et al., 2020; Mohamed et al., 2021). The aboveresults authorize the third hypothesis.

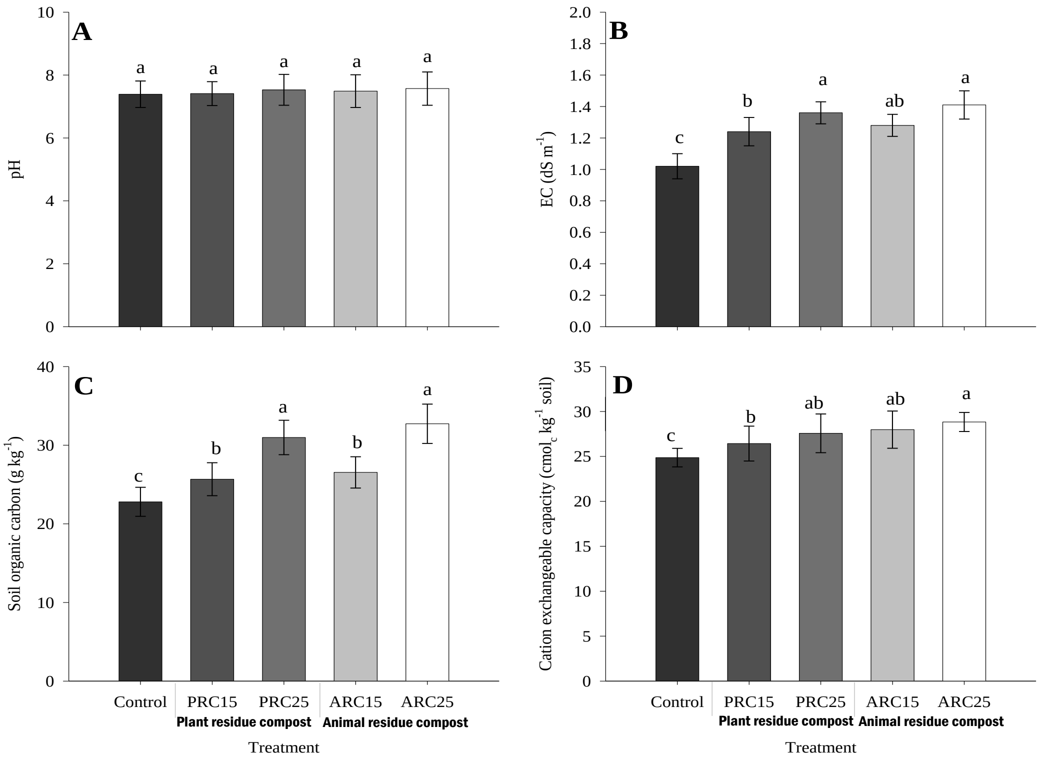

Fig. 3. Chemical properties (means± standard deviations) of the investigated clayey soil after 160 days of compost applications

See footnote Fig 1. Similar letters indicate no significant variations among treatments

Effect of animal and plant residue composts on plant growth parameters and yield attributes

Grain, straw and the biological yields of wheat increased significantly owing to application of either of PRC and ARC (Table 3). Such increases were more detectable with increasing the rate of applied composts from 15 Mg to25 Mg ha^{-1}. Similar results indicate the significant effect of compost on wheat (Elshony et al., 2019), maize (Pandit et al., 2020), zucchini (Tolba et al., 2021), faba bean (Farid et al., 2018 and 2021 a and b). Maybe these amendments enriched the soil with macro and micro-nutrients (Elshony et al., 2018); hence increased the chlorophyll fluorescence, chlorophyll content and membrane stability (El-Mageed et al., 2019). The uptake of macro- and micro nutrients by the grown plants would be discussed latter.

The investigated amendments also raised the harvest index of wheat, especially ARC versus PRC. Increasing the rate of application recorded no further increases in this index which is a proportion between harvested grain yield and the total dry matteryield according to Duan et al. (2018) and Dianatmanesh et al. (2022). A high harvest indexindicates better grain yield productivity

Plant height and the yield attributes of wheat (spike length and weight, number of spikelets/spike, number of tillers in each square meter and the 1000 grain weight) also increased significantly owing to the application of compost prepared from either animal or plant residues. In this regard, the increases recorded for ARC application were higher than the corresponding ones attained for PRC addition. Probably, the rice straw which is mainly used for PRC is of relatively low degradation (Wu et al., 2019) because it is rich in lignocellulose (El-Akhdar et al., 2018) which is a complicated substrate for enzymes (Andlar et al., 2018; Wilhelm et al., 2019).

Higher doses of compost applications resulted in further significant improvements in the abovementioned plant growth parameters and yield components. These results agree with those of Mohamed et al. (2019) and (2020) who found that compost applications increased noticeably nutrient availability in soil;hence,improved the nutritional status in plants. This finding stands in well agreement with those of many researchers (Erdal and Ekinci, 2020; Boutasknit et al., 2021).

TABLE 3. Plant growth parameters, crop yield and yield components

Characteristic	Control	Plant residue compost		Animal residue compost	
		PRC 15	PRC 25	ARC 15	ARC 25
Biological yield (Mg ha^{-1})	14.57±0.91^{d}	16.58±0.86^{cd}	19.32±1.30^{ab}	17.89±1.05^{bc}	21.46±1.83^{a}
Grain yield (Mg ha^{-1})	5.93±0.32^{d}	7.87±0.49^{c}	9.38±0.66^{b}	8.95±0.53^{bc}	10.84±0.77^{a}
Straw yield (Mg ha^{-1})	8.64±0.53^{b}	8.71±0.64^{b}	9.94±0.52^{ab}	8.94±0.62^{b}	10.62±0.72^{a}
Harvest index (%)	40.70±0.21^{b}	47.46±0.27^{a}	48.55±2.84^{a}	50.02±0.31^{a}	50.51±3.78^{a}
Plant height (cm)	85.87±0.53^{b}	91.62±0.63^{ab}	99.84±6.75^{a}	96.23±0.59^{ab}	102.65±6.53^{a}
Spike length (cm)	11.31±0.74^{d}	12.57±0.72^{cd}	14.11±1.08^{ab}	13.34±0.93^{b}	15.83±0.96^{a}
Spike weight (g)	7.62±0.49^{d}	8.43±0.61^{cd}	10.99±0.68^{ab}	9.65±0.65^{bc}	12.12±0.97^{a}
No.of spikelets/spike	13.23±0.99^{c}	14.27±1.06^{c}	16.62±1.18^{b}	15.38±1.09^{c}	17.69±1.13^{a}
No of tillers/m^{2}	332.52±21.51^{c}	375.12±18.77^{bc}	411.75±28.61^{ab}	398.93±29.43^{b}	457.89±28.62^{a}
1000 grain weight (g)	40.67±2.83^{b}	45.91±2.64^{ab}	49.84±2.19^{a}	46.82±2.53^{ab}	52.18±3.79^{a}

* See footnote of Fig 1. Similar letters within each raw indicates no significant variations among treatments

Effect of ARC and PRCcomposts on the available contents of macro- and micro-nutrients in soil and their contents in wheat shoots and grains

Available contents of soil macro-and micro-nutrients (Fig. 4) as well as the nutritional status of wheat plants (roots and shoots) increased significantly owing to the application of either ARC or PRC composts, particularly with increasing the rate of application (Table 5).

Table 4. Macro- and micro-nutrients within wheat plants

Nutrient	Control	Shoots				Control	Grains			
		PRC		ARC			PRC		ARC	
		PRC 15	PRC 25	ARC 15	ARC 25		PRC 15	PRC 25	ARC 15	ARC 25
					Macro-nutrient (g kg^{-1})					
N	12.40±0.90^{d}	37.46±2.72^{c}	46.12±3.76^{a}	41.69±3.39^{b}	48.88±4.21^{a}	16.03±0.93^{a}	17.28±0.10^{a}	17.80±1.23^{a}	17.48±1.20^{a}	17.96±1.03^{a}
P	1.21±0.06^{e}	2.23±0.18^{d}	3.44±0.12^{b}	2.71±0.18^{c}	3.73±0.27^{a}	1.75±0.14^{d}	2.23±0.17^{c}	3.25±0. 25^{a}	2.62±0.12^{b}	3.29±0.22^{a}
K	19.55±1.11^{c}	61.83±3.06^{b}	73.61±4.11^{a}	65.79±3.91^{b}	76.42±4.31^{a}	16.50±1.10^{c}	17.60±1.09^{bc}	25.6±1.17^{a}	19.2±1.23^{b}	27.5±1.92^{a}
					Micro-nutrient (mg kg^{-1})					
Fe	35.60±1.90^{d}	41.20±2.00^{d}	74.80±4.03^{b}	58.40±3.15^{c}	83.90±5.32^{a}	60.8±4.43^{e}	81.6±5.32^{d}	133.8±8.08^{b}	96.7±6.12^{c}	153.9±9.80^{a}
Mn	5.64±0.34^{d}	7.57±0.53^{c}	11.42±0.76^{b}	8.34±0.57^{c}	12.63±0.83^{a}	10.32±0.61^{d}	14.56±0.94^{c}	21.51±1.64^{b}	16.13±1.00^{c}	23.92±1.83^{a}
Zn	12.54±0.79^{d}	15.83±0.74^{c}	21.43±1.14^{b}	16.92±0.94^{c}	23.76±1.19^{a}	23.12±1.80^{e}	34.79±1.70^{d}	52.75±3.82^{b}	42.98±2.80^{c}	76.32±0.59^{a}
Cu	3.13±0.22a	3.12±0.18^{a}	3.07±0.18^{a}	3.11±0.22^{a}	3.05±0.28^{a}	7.65±0.44^{d}	8.96±0.59^{c}	12.47±0.77^{b}	9.68±0.51^{c}	14.13±0.82^{a}

PRC: Plant residue compost, ARC: animal residue compost. Similar results indicate no significant variations among treatments

These conditioners are rich in nutrients (Table 2) that released in available forms upon organic matter degradation (Mahmoud et al., 2015; Oldfield et al., 2018; Manirakiza and Şeker, 2020) to be taken up by plants; hence, improve the nutritional status of the grown plants (Pandit et al., 2020; Farid et al., 2021 a and b). In this regard, NPK available contents were almost doubled due to the application of either PRC or ARC while their contents within plants increased by 3 folds or higher, with superiority for ARC compost. A point to note is that the yields of each of wheat straw and grains were correlated significantly and positively with the concentrations of macro- (NPK) and micro-nutrients (Fe, Mn, Zn and Cu) in these plant parts and this result supports the fourth hypothesis. Because ARC enrich soils with macro- and micro-nutrients at concentrations exceeding those attained for PRC; thus, the effect of compost prepared from animal residues on wheat nutritional status and hence wheat growth and productivity outstands the effect of plant and this result justifies the fifth hypothesis.

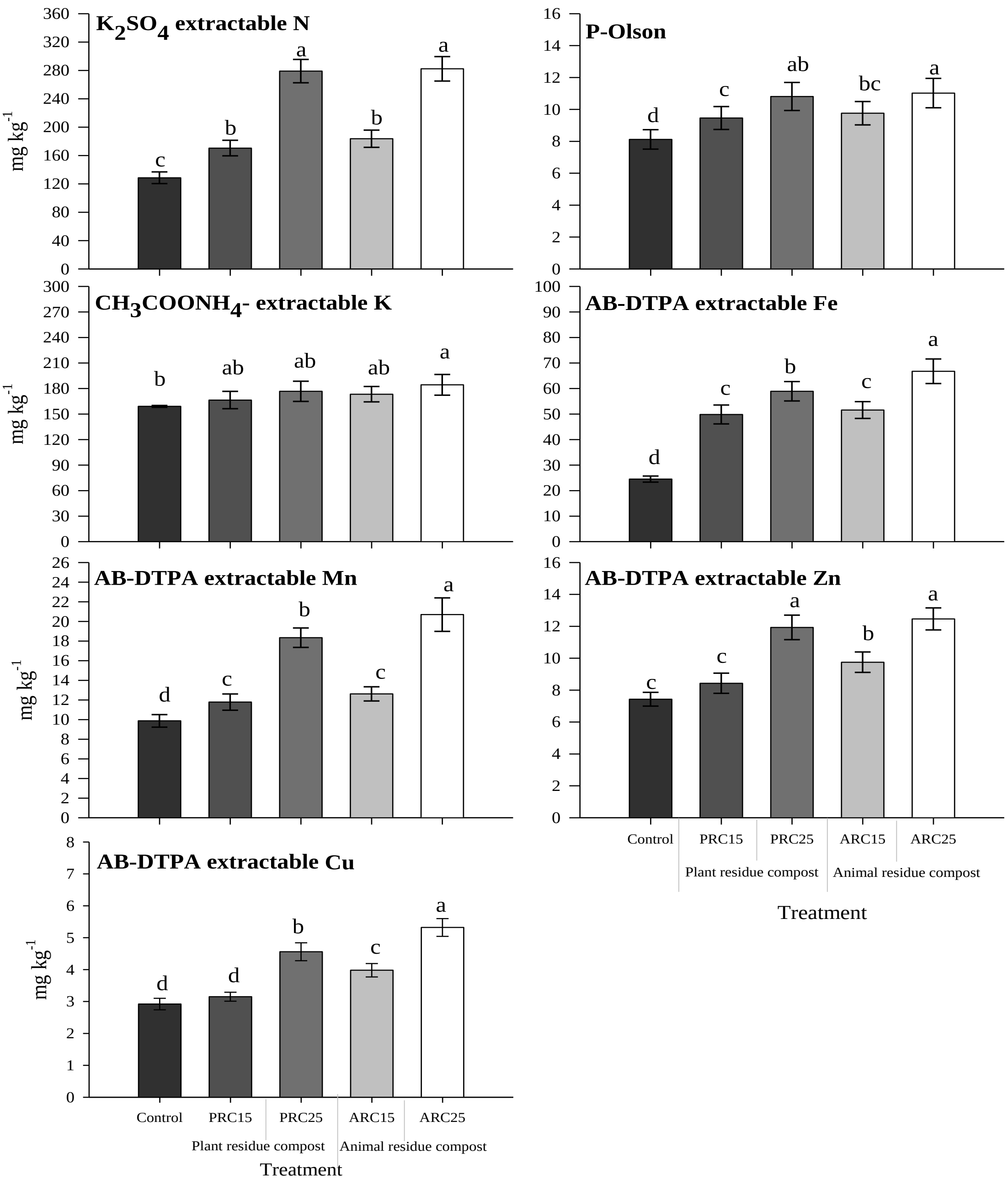

Fig. 4. Soil available macro- and micro-nutrients after wheat plants (means± standard deviations).
See footnote of Fig 1. Similar results indicate no significant variations among treatments

TABLE 5. Coefficients of determination (r^2) between wheat straw and grain yields in relation to their nutritional status

	Grain yield	Straw yield	N-shoot	P-shoot	K-shoot	N-grain	P-grain	K-grain	Fe-shoot	Mn-shoot	Zn-shoot	Cu-shoot	Fe-grain	Mn-grain	Zn-grain
Straw yield	0.843**														
N-shoot	0.928**	0.634*													
P-shoot	0.965**	0.785**	0.948**												
K-shoot	0.911**	0.612*	0.998**	0.933**											
N-grain	0.777**	0.808**	0.707**	0.689**	0.706**										
P-grain	0.891**	0.616*	0.833**	0.821**	0.807**	0.658**									
K-grain	0.886**	0.907**	0.763**	0.923**	0.739**	0.653**	0.661**								
Fe-shoot	0.930**	0.846**	0.830**	0.962**	0.802**	0.631*	0.795**	0.972**							
Mn-shoot	0.938**	0.861**	0.864**	0.975**	0.846**	0.667**	0.733**	0.982**	0.979**						
Zn-shoot	0.951**	0.879**	0.870**	0.974**	0.852**	0.703**	0.749**	0.979**	0.974**	0.998**					
Cu-shoot	0.109	0.394	-0.019	-0.044	-0.012	0.684**	0.08	0.037	-0.042	-0.024	0.023				
Fe-grain	0.937**	0.859**	0.850**	0.971**	0.828**	0.642**	0.751**	0.983**	0.988**	0.998**	0.995**	-0.048			
Mn-grain	0.950**	0.851**	0.887**	0.984**	0.870**	0.678**	0.757**	0.973**	0.977**	0.999**	0.998**	-0.024	0.996**		
Zn-grain	0.943**	0.835**	0.824**	0.934**	0.798**	0.605*	0.801**	0.935**	0.953**	0.960**	0.965**	-0.069	0.971**	0.962**	
Cu-grain	0.930**	0.897**	0.819**	0.951**	.797**	0.672**	0.722**	0.991**	0.976**	0.994**	0.995**	0.019	0.995**	0.990**	0.970**

* Significant at $P<0.05$ ** Significant at $P< 0.01$

Conclusions

Amending the clayey soil with animal or plant residue composts improved considerably soil physical and chemical characteristics. Moreover, these conditioners enriched the soil with macro- and micro- nutrients which in turn improved the nutritional status of the grown plants. A point to note is that the increases that occurred in wheat growth and productivity were correlated positively and significantly with the nutritional status of wheat plants. In this concern, the animal residue compost was superior to the plant residue one in improving the nutritional status of the grown plants hence recorded higher increases in wheat growth and productivity.

Although, wheat plants received the recommended doses of NPK; yet the nutritional value of the amended organic conditioners determine substantially wheat growth and productivity. Accordingly, the organic applications are guaranteed to boost wheat productivity.

3. Conflicts of interest

There are no conflicts to declare.

4. Author Contributions

All authors contributed equally.

5. Formatting of funding sources

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