Annals of Agricultural Science (2016) 61(2), 257–265

HOSTED BY

ELSEVIER

Faculty of Agriculture, Ain Shams University

Annals of Agricultural Science

www.elsevier.com/locate/aoas

Influence of biochar and seaweed extract applications on growth, yield and mineral composition of wheat (*Triticum aestivum* L.) under sandy soil conditions

Bahaa Badry Mosa Salim

Agricultural Botany Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt

Received 4 June 2016; revised 13 June 2016; accepted 15 June 2016
Available online 1 September 2016

KEYWORDS

Wheat;
Triticum aestivum L.;
Biochar;
Seaweed extract;
Mineral composition;
Growth;
Yield

Abstract Two pot experiments were conducted during 2013/2014 and 2014/2015 winter seasons to study the effect of biochar (BC) as soil amendments at two rates 2% and 5%, seaweed extract (SWE) as foliar applications at 1 and 2 g/l and the combination between BC 2% and SWE treatments on growth, yield attributes and some macro- and micronutrients concentration in roots, leaves and grains of wheat (*Triticum aestivum* L.) cultivar Sakha 93. Two samples were taken at 105 and 150 days after sowing. At the first sample date, plant height, leaves number per main tiller, number of tillers/plant, shoot fresh weight, root length, root fresh weight, chlorophyll reading, spikes number per plant, main spike length and N, P, K, Mg, Ca, Fe, Mn, Zn and Cu concentrations in roots and leaves were determined. At the second sample date (harvesting time), spike weight, number of grains per spike, weight of grains/spike and weight of 100 grains were recorded and nutrients concentrations in grains were determined. Obtained results revealed that, adding biochar, sprayed seaweed extract treatments individually or in combination have stimulating effect on the most of morphological characters and yield components as compared with control plants in both seasons. Generally, using the low level of BC at 2% individually or in combination with SWE treatments has more promotion effect on the most of growth parameters and yield components and achieved the highest concentrations on the most of macro- and micronutrients in roots, leaves and grains as compared with the control in both seasons.

© 2016 Production and hosting by Elsevier B.V. on behalf of Faculty of Agriculture, Ain Shams University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Wheat (*Triticum aestivum* L.) is the principal winter crop and the most important grains crop in the world and in Egypt over half of the country's needs are important (Abo Soliman et al.,

E-mail address: dr.bahaa_badry@yahoo.com

Peer review under responsibility of Faculty of Agriculture, Ain-Shams University.

http://dx.doi.org/10.1016/j.aoas.2016.06.001
0570-1783 © 2016 Production and hosting by Elsevier B.V. on behalf of Faculty of Agriculture, Ain Shams University.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

2008). Also, it is considered as the major cereal crop in the world in respect of the cultivated area and total production. It provides an almost 20% of food energy for people in the world as well as in Egypt. Increasing wheat production is the ultimate goal to reduce the wide gap between productivity and consumption (Flowers et al., 1997; El-Maghraby et al., 2005; Sajid et al., 2008).

Biochar (BC) is an activated carbon soil conditioner as well as organic fertilizer using as soil amendment. It is a black carbon organic nature compound that is manufactured by the process of pyrolysis of residues under anaerobic conditions and high temperature in pyrolyzer (thermo conversion in the absence of oxygen) may offer an alternative to produce energy as well as return carbon and nutrients and among the potential benefits of BC for soil the slow release of plant macronutrients contained in the BC is considered as possibility to reduce the need for adding the different chemical fertilizers in agriculture (Lehmann, 2007; Laird, 2010; Zhang et al., 2012). Further, BC can also lead to increase water and nutrients holding capacity (Gaskin et al., 2008; Uzoma et al., 2011; Kloss et al., 2012).

Favorable changes under biochar amendments like decreased soil compaction, increased the soil water-retention capacity and some nutrients content (total N and the available contents of P, K, Mg, Cu and Zn) led to an increase in fine root proliferation (increasing specific root length and reducing root tissue density), promoted crop development, higher relative growth and net assimilation rates, aboveground biomass and yield by improving the physical and biochemical properties of cultivated soils (Asai et al., 2009; Major et al., 2010; Alburquerque et al., 2013; Olmo et al., 2014).

Seaweed extract (SWE) concentrates are known to cause many beneficial effects on plants and it contains growth promoting hormones such as indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and Cytokinins, trace elements (Fe, Cu, Zn, Co, Mo, Mn and Ni), vitamins and amino acids (Bhaskar and Miyashita, 2005; Khan et al., 2009). Seaweed extracts have been reported to stimulate the growth and yield of plants, enhance tolerance to environment stress, and improve nutrients availability and nutrients uptake from the soil (Rathore, 2009; Aziz et al., 2011). So, the objectives of the present study were to investigate the following:

- Increasing cultivation use efficiency of sandy soil.
- The influence of adding of biochar, seaweed extract and their combinations on growth and yield of wheat.
- Assessment of the minerals status and nutrients distribution in different tissues of wheat plants.

Material and methods

Two pot experiments were conducted during the two successive winter seasons of 2013/2014 and 2014/2015 at The Experimental Farm, Faculty of Agriculture, Ain Shams University, Cairo, Egypt. The experiments were performed in sandy soil to study the effect of using biochar (BC) as soil application with two rates (2% & 5%) before cultivation, and seaweed extract (SWE) was applied three times of foliar application (30, 60 and 90 days from sowing date) and the combination between BC 2% and SWE treatments on growth, yield parameters and mineral composition of wheat (*T. aestivum* L.). Wheat cultivar Sakha 93 was kindly obtained from Agricultural Research Center, Ministry of Agric., Dokki, Giza, Egypt. The experiment was arranged in complete randomized block design with three replicates. In both seasons, grains of wheat cultivar *cv.* Sakha 93 were sown at 15th November in plastic pots internal dimensions of 25 × 20 cm. Each pot was filled with 14 kg acid washed sandy soil. Plants were thinned after 3 weeks. All pots were irrigated and fertilized with Hoagland solution (Hoagland and Arnon, 1950)

Nutrient solution is prepared for each salt, and the amounts used are 1 cm^3 potassium phosphate KH_2PO_4, 5 cm^3 potassium nitrate KNO_3, 5 cm^3 calcium nitrate $Ca(NO_3)_2$ and 2 cm^3 magnesium sulfate $MgSO_4$ in a liter of nutrient solution and prepare a supplementary solution which will supply boron, manganese, zinc, copper, and molybdenum by grams dissolved in 1 l of H_2O at concentrations 2.86 g boric acid H_3BO_3, 1.81 g manganese chloride $MnCl_2{\cdot}4H_2O$, 0.22 g zinc sulfate $ZnSO_4{\cdot}7H_2O$, 0.08 g copper sulfate $CuSO_4{\cdot}5H_2O$ and 0.02 g molybdic acid $H_2MoO_4{\cdot}H_2O$.

Treatments were as follows:

1. Biochar (BC) 2%
2. Biochar 5%
3. Seaweed extract (SWE)1 g/l
4. Seaweed extract 2 g/l
5. Biochar 2% plus seaweed extract 1 g/l
6. Biochar 2% plus seaweed extract 2 g/l
7. Control

Biochar (BC) perpetrated from the homemade products of different plant material wastes of experimental farm at faculty of Agriculture by the process of slow pyrolysis of these selected young branches which fractionated and were burned incompletely in cylindrical metal oven using an oxygen-limited conditions and high temperature. The air-dried biochar with fine particle size material was spread manually on the sandy soil surface before cultivation. The biochemical analysis of seaweed extract was presented in Table 1 according to UAD company, Egypt.

Growth parameters and yield components

Plant samples were taken after 105 days from sowing. The growth parameters of wheat include, plant height, number of

Table 1 Biochemical analysis of seaweed extract, according to UAD® Company.

Organic component	Macro elements
Carbohydrates 35.02%	N 2.83%
Total amino acid 6.11%	P 2.60%
Alginic acid 8.50%	K 4.47%
Mannitol 4.23%	Mg 0.65%
Betaines 0.037%	S 3.00%
–	Ca 0.28%
Growth regulators	**Micro elements**
IAA 0.024%	Fe 0.0162%
Cytokinins 0.018%	Mn 0.0012%
–	Zn 0.0057%
–	B 0.0046%

tillers per plant, leaves number per main tiller, shoot fresh weight, root length, root fresh weight, spikes number per plant, main spike length and also spike weight, number of grains per spike, weight of grains/spike and weight of 100 grains at 150 days from sowing in both seasons.

Total chlorophyll reading

SPAD value of the flag leaf was determined using chlorophyll meter (SPAD-502) according to Soil Plant Analysis Department Section, Minolta Camera Co., Osaka, Japan, as reported by Minolta (1989).

Estimation of macro- and micronutrients

Leaf samples were taken for nutritional studies; 0.1 g dry sample of ground plant materials was wet digested using (H_2SO_4/H_2O_2) mixture as described by Cottenie (1980). Total nitrogen concentration (N) was determined in the dried leaves using micro-Kjeldahl method as described by A.O.A.C. (1975). Total phosphorus (P) in plant was determined calorimetrically using ascorbic acid method described by Watanabe and Olsen (1965). The concentration of potassium (K) was determined in the digested material using flame photometer as described by Eppendrof and Hing (1970). The concentrations of calcium, magnesium, iron, manganese, zinc and copper were determined by inductively coupled plasma atomic emission spectroscopy (Stefansson et al., 2007). All nutrients were determined in the Central Soil and Plant Analysis Laboratory, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Statistical analysis

Experiments were complete randomized block design with three replicates. The statistical analysis of data was done by SAS (2006). For separation between means, Tukey's test was used.

Results

Morphological characters and yield

Data presented in Tables 2–4 show the effect of application with biochar (BC at 2% & 5%), seaweed extract (SWE at 1 & 2 g/l) and the combinations between BC at the rate 2% and SWE treatments on the growth and yield components. These data included plant height, tillers number per plant, leaves number/main tiller, shoot fresh weight per plant, roots length, root fresh weight, chlorophyll reading, number of spikes per plant, main spike length, grains number per main spike, grains weight/spike and the weight of 100 grains of wheat plants.

Data revealed that plant height, roots length and chlorophyll reading were significantly increased by all treatments as compared with the control at 105 days after sowing in both seasons. Also, all studied treatments (Tables 2–4) gave significant increments in shoot fresh weight, root fresh weight, main spike length and the weight of 100 grains when compared with control plants in the first season but all treatments achieved significant increase in grains number per main spike in the second season.

In general, adding biochar, sprayed seaweed extract treatments individually or in combination enhanced all morphological characteristics of wheat growth and yield components when compared with control plants in both seasons. Moreover, the addition of biochar treatments at 2% and 5% has stimulated effect upon most studied growth parameters and yield attributes of wheat plants as compared to control in both seasons especially BC at 2% led to significant increase in plant height, tillers number per plant, chlorophyll reading, shoot fresh weight, root length, main spike length and number of spikes per plant as compared to control plants in both seasons. The same treatment achieved significant increments in leaf area and grains number per spike as compared with control plants in the both seasons.

On the other hand, the highest values of plant height, number of tillers per plant, shoot fresh weight, root fresh weight, chlorophyll reading, spike number per plant, grains weight per spike and the weight of 100 grains were observed with the combination treatment between biochar at 2% and seaweed extract at 1 g/l as compared to the control in both seasons while treated plants with the combination treatment between biochar at 2% and seaweed extract at 2 g/l produced the highest values of leaves number per main tiller, roots length, main spike length, grains number per spike and spike weight when compared to control plants in both seasons. In addition, application of seaweed extract (SWE at 2 g/l) treatment recorded the highest significant values of leaf area as compared to the control in both seasons.

Mineral composition

Tables 5 and 6 show the effect of biochar application (BC at 2% & 5%), seaweed extract (SWE at 1 & 2 g/l) and their combinations between BC 2% and SWE treatments on the concentrations of macro- and micronutrients in wheat tissues (roots, leaf and grains). The studied macronutrients were nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) as well as some micronutrients like, iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) in roots, leaves and grains of wheat plants in both seasons 2013/2014 and 2014/2015.

Macronutrients

Data in Table 5 reveal that, biochar as individual applications at 2% caused a significant increase in K concentration in roots as compared to control plants while the biochar 5% showed insignificant increase in both seasons. Also, biochar treatments gave insignificant increase in N, P, Mg and Ca concentrations in wheat roots when compared with control plants in both seasons.

Seaweed extract (SWE) treatments led to insignificant decrease in all estimated macronutrients in roots of wheat plants as compared with control plants in both seasons. The combination treatment between BC 2% and seaweed extract at 1 g/l improved N, P and K concentrations in roots as compared to control plants in both seasons. The same treatment caused a significant reduction in Mg concentration and insignificant reduction in Ca concentration in roots of wheat plants as compared with control plants in both seasons. In this concern, the highest concentrations of N, P, K, Mg and Ca in

Table 2 Effect of biochar, seaweed extract and their combination treatments on growth characters of wheat plants in both seasons (2013/2014 and 2014/2015).

Treatments	Plant height (cm)		Tillers number/plant		Leaves number/main tiller		Leaf area (cm^2)		Shoot fresh weight/plant (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	66.33^{d}	64.00^{c}	2.66^{c}	3.33^{c}	5.33^{c}	5.00	26.57^{c}	36.00^{c}	8.67^{e}	9.03^{c}
Biochar 2%	82.33^{ab}	85.67^{ab}	7.33^{a}	8.66^{a}	6.33^{ab}	5.66	31.78^{bc}	47.00^{ab}	41.55^{b}	40.10^{b}
Biochar 5%	78.00^{bc}	77.67^{b}	5.00^{b}	5.66^{b}	5.66^{bc}	5.33	30.71^{c}	44.97^{a-c}	32.92^{c}	35.77^{b}
Seaweed extract 1 g/l	76.00^{bc}	88.33^{a}	4.66^{b}	4.33^{bc}	6.33^{ab}	5.33	29.95^{c}	46.25^{ab}	23.00^{d}	24.20^{bc}
Seaweed extract 2 g/l	81.67^{a-c}	85.33^{ab}	4.70^{b}	5.66^{b}	7.00^{a}	5.66	44.87^{a}	49.55^{a}	30.33^{c}	31.94^{bc}
BC 2% plus SWE 1 g/l	88.33^{a}	93.33^{a}	7.66^{a}	9.66^{a}	6.66^{ab}	6.33	34.20^{a-c}	37.92^{bc}	59.20^{a}	70.25^{a}
BC 2% plus SWE 2 g/l	74.67^{c}	85.67^{ab}	4.33^{bc}	4.66^{bc}	7.00^{a}	6.66	43.58^{ab}	43.77^{a-c}	31.20^{c}	33.25^{b}
MSD at 5%	7.5744	9.4252	1.8252	2.1936	1.2168	NS	12.351	10.075	6.4614	23.356

NS = Non Significant.
Means followed by different letters are significantly different at $P \leqslant 0.05$ level.

Table 3 Effect of biochar, seaweed extract and their combination treatments on root length, root fresh weight, chlorophyll reading, spikes number per plant and main spike length of wheat plants in both seasons (2013/2014 and 2014/2015).

Treatments	Root length (cm)		Root fresh weight (g)		Chlorophyll reading (SPAD)		Spikes number/plant		Main spike length (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	11.33^{d}	12.00^{d}	2.10^{d}	2.40^{d}	44.33^{c}	43.67^{b}	2.66^{c}	3.00^{c}	9.33^{c}	9.50^{c}
Biochar 2%	20.00^{b}	22.00^{ab}	10.50^{c}	10.58^{c}	55.33^{ab}	54.33^{a}	6.66^{a}	7.66^{ab}	13.00^{a}	12.50^{a}
Biochar 5%	16.00^{c}	17.00^{c}	7.83^{c}	8.30^{cd}	52.00^{ab}	52.33^{a}	4.66^{b}	5.33^{bc}	11.50^{b}	10.50^{bc}
Seaweed extract 1 g/l	17.33^{bc}	18.00^{bc}	8.89^{c}	9.03^{cd}	50.00^{b}	50.67^{a}	4.00^{bc}	4.00^{c}	12.33^{ab}	10.33^{bc}
Seaweed extract 2 g/l	18.33^{bc}	20.00^{bc}	9.73^{c}	10.20^{c}	51.33^{ab}	51.33^{a}	4.33^{bc}	5.00^{bc}	13.20^{a}	11.33^{ab}
BC 2% plus SWE 1 g/l	19.00^{b}	20.00^{bc}	26.03^{a}	28.59^{a}	56.33^{a}	54.00^{a}	7.00^{a}	9.00^{a}	12.33^{ab}	12.33^{a}
BC 2% plus SWE 2 g/l	23.66^{a}	25.00^{a}	18.00^{b}	20.33^{b}	52.33^{ab}	51.67^{a}	4.33^{bc}	4.66^{c}	13.66^{a}	11.20^{ab}
MSD at 5%	2.8536	4.2151	5.3251	7.005	5.4075	4.82895	1.7208	2.788	1.3604	1.4268

Means followed by different letters are significantly different at $P \leqslant 0.05$ level.

Table 4 Effect of biochar, seaweed extract and their combination treatments on yield attributes of wheat plants in both seasons (2013/2014 and 2014/2015).

Treatments	Spike weight (g)		Grains number per spike		Grains weight per spike (g)		Weight of 100 grains (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	3.00^{c}	3.12^{d}	21.00^{d}	23.67^{c}	1.72^{c}	1.47^{d}	5.30^{c}	5.35^{c}
Biochar 2%	4.05^{bc}	4.25^{b-d}	42.00^{ab}	47.00^{a}	3.01^{ab}	3.09^{a-c}	6.72^{ab}	6.76^{ab}
Biochar 5%	3.70^{c}	3.87^{cd}	41.00^{ab}	40.33^{ab}	2.31^{a-c}	2.45^{b-d}	6.53^{ab}	6.60^{a-c}
Seaweed extract 1 g/l	3.62^{c}	3.77^{cd}	32.67^{bc}	35.00^{b}	2.06^{bc}	2.10^{cd}	6.33^{b}	6.38^{bc}
Seaweed extract 2 g/l	5.20^{a}	5.33^{ab}	30.33^{cd}	33.67^{b}	2.33^{a-c}	2.38^{b-d}	6.40^{b}	6.40^{bc}
BC 2% plus SWE 1 g/l	5.00^{ab}	4.95^{a-c}	39.33^{a-c}	43.00^{ab}	3.46^{a}	3.58^{a}	7.23^{a}	7.82^{a}
BC 2% plus SWE 2 g/l	5.83^{a}	5.50^{a}	44.00^{a}	45.00^{a}	3.06^{ab}	3.25^{ab}	6.73^{ab}	6.83^{ab}
MSD at 5%	1.101	1.2309	10.107	9.8852	1.1679	1.0821	0.8027	1.2616

Means followed by different letters are significantly different at $P \leqslant 0.05$ level.

roots of wheat plants resulted in plants treated with biochar 2% in both seasons.

Moreover, all treatments enhance the concentrations of N, P and K in leaves of wheat plants as compared with control plants in both seasons. In this respect, the highest values of N concentration were found in wheat plants treated with seaweed extract at 2 g/l in both seasons. The addition of BC 5% caused a significant increase in phosphorus concentration as

Table 5 Effect of biochar, seaweed extract and their combination treatments on macronutrient concentration (%) in roots, leaves and grains of wheat plants in both seasons (2013/2014 and 2014/2015.

Treatments		N		P		K		Mg		Ca	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	**Root**	0.110^{ab}	0.112^{ab}	0.0427	0.0425	0.029^{b}	0.028^{b}	0.144^{ab}	0.143^{ab}	0.050^{ab}	0.051^{ab}
Biochar 2%		0.161^{a}	0.162^{a}	0.0505	0.0509	0.104^{a}	0.103^{a}	0.194^{ab}	0.198^{a}	0.068^{a}	0.069^{a}
Biochar 5%		0.160^{a}	0.161^{a}	0.0447	0.0450	0.086^{ab}	0.087^{ab}	0.160^{ab}	0.165^{ab}	0.065^{a}	0.066^{a}
Seaweed extract 1 g/l		0.087^{b}	0.088^{b}	0.0403	0.0405	0.063^{ab}	0.046^{ab}	0.109^{bc}	0.110^{bc}	0.043^{ab}	0.042^{ab}
Seaweed ex'ract 2 g/l		0.092^{b}	0.095^{b}	0.0423	0.0425	0.054^{ab}	0.063^{ab}	0.094^{bc}	0.095^{bc}	0.036^{ab}	0.035^{ab}
BC 2% plus SWE 1 g/l		0.133^{ab}	0.134^{ab}	0.0433	0.0441	0.083^{ab}	0.084^{ab}	0.055^{c}	0.054^{c}	0.024^{ab}	0.023^{b}
BC 2% plus SWE 2 g/l		0.097^{b}	0.098^{b}	0.0463	0.0470	0.046^{ab}	0.054^{ab}	0.044^{c}	0.043^{c}	0.019^{b}	0.018^{b}
MSD at 5%		0.0583	0.0581	NS	NS	0.0722	0.0724	0.081	0.0809	0.0337	0.0341
Control	Leaf	0.267	0.274^{b}	0.0342^{b}	0.0365^{c}	0.282^{b}	0.285^{b}	0.287	0.289	0.056	0.055
Biochar 2%		0.499	0.492^{ab}	0.0534^{a}	0.0540^{ab}	0.375^{ab}	0.376^{ab}	0.131	0.133	0.044	0.045
Biochar 5%		0.418	0.421^{ab}	0.0598^{a}	0.0605^{a}	0.446^{ab}	0.446^{ab}	0.219	0.221	0.046	0.047
Seaweed extract 1 g/l		0.399	0.416^{ab}	0.0548^{a}	0.0558^{ab}	0.340^{ab}	0.338^{ab}	0.288	0.296	0.062	0.063
Seaweed extract 2 g/l		0.570	0.573^{a}	0.0456^{ab}	0.0458^{bc}	0.371^{ab}	0.376^{ab}	0.287	0.155	0.040	0.042
BC 2% plus SWE 1 g/l		0.423	0.423^{ab}	0.0450^{ab}	0.0464^{a-c}	0.530^{a}	0.540^{a}	0.208	0.209	0.062	0.064
BC 2% plus SWE 2 g/l		0.477	0.477^{ab}	0.0545^{a}	0.0547^{ab}	0.473^{ab}	0.477^{ab}	0.295	0.290	0.078	0.080
MSD at 5%		NS	0.2919	0.0151	0.0144	0.2055	0.1987	NS	NS	NS	NS
Control	Grain	0.34	0.35	0.0480	0.0482	0.070	0.072	0.229	0.231	0.047	0.046
Biochar 2%		0.41	0.40	0.0500	0.0484	0.100	0.098	0.144	0.145	0.0198	0.020
Biochar 5%		0.46	0.47	0.0460	0.0464	0.090	0.092	0.157	0.157	0.021	0.021
Seaweed extract 1 g/l		0.49	0.50	0.0480	0.0490	0.077	0.078	0.162	0.160	0.025	0.024
Seaweed extract 2 g/l		0.43	0.42	0.0510	0.0502	0.090	0.092	0.152	0153	0.024	0.023
BC 2% plus SWE 1 g/l		0.47	0.48	0.0460	0.0453	0.096	0.095	0.146	0.145	0.025	0.024
BC 2% plus SWE 2 g/l		0.45	0.45	0.0510	0.0503	0.087	0.086	0.145	0.143	0.023	0.024
MSD at 5%		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non Significant Means followed by different letters are significantly different at $P \leqslant 0.05$ level.

compared with control plants and it gave the highest values of P concentration in both seasons. Application of biochar 2% plus seaweed extract 1 g/l led to a significant increase in potassium concentration as compared with control plants and it gave the highest values of K concentration in both seasons.

Biochar treatments at 2% and 5% gave insignificant reduction of the concentration of Mg and Ca in leaves of wheat plants as compared to control plants in both seasons. In this concern, the highest values of Mg and Ca in wheat plants were achieved by the combination treatment between biochar 2% and seaweed extract at 2 g/l in both seasons.

Concerning, the concentration of macronutrients in grains of wheat plants which are presented in Table 5, data showed that, no significant differences were noticed in all estimated macronutrients in grains of wheat plants in both seasons. All treatments caused insignificant increase in the concentration of N and K elements and decreased in Mg and Ca concentrations in wheat grains as compared with control plant.

In this respect, adding biochar at 2% alone or plus seaweed extract at 2 g/l treatment gave an increase in P concentration in grains as compared to control plants in both seasons.

Micronutrients

Data presented in Table 6 reveal that, adding biochar at 2% and 5%, seaweed extract at 1 and 2 g/l and their combination between BC 2% plus SWE 1 g/l were insignificantly reduced iron concentration in roots tissue in both seasons while the application of the combination between BC 2% plus SWE at rate 2 g/l treatment led to a significant decrease in this concern.

Application of biochar at 2% gave an insignificant increase in Mn concentration in roots of wheat when compared with control. The lowest values of Mn resulted in roots of wheat plants treated with the combination between BC 2% plus SWE at rate 2 g/l treatment in the both seasons.

All treatments led to an increase in zinc and copper concentrations as compared to control plants in the both seasons. The highest concentration of Zn in roots tissue produced in wheat plants achieved by the combination treatment between biochar 2% and seaweed extract at 1 g/l in both seasons. The individual application of biochar at 2% and seaweed extract at 1 g/l caused a significant increase in Cu concentration in roots when compared with control.

As for the effect of biochar at 2% and 5%, seaweed extract at 1 g/l and 2 g/l as well as the combination between BC 2% plus SWE 1 g/l treatments on Fe, Mn, Zn and Cu concentration in (Table 6), data reveal that all treatments increased Fe concentration in leaves of wheat as compared with control in both seasons. Biochar 2% plus seaweed extract by rate 2 g/l gave a significant increase in iron concentration in wheat leaves as compared with control in both seasons.

Table 6 Effect of biochar, seaweed extract and their combination treatments on micronutrients concentration (mg/kg d. wt.) in roots, leaves and grains of wheat plants in both seasons (2013/2014 and 2014/2015).

Treatments		Fe		Mn		Zn		Cu	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	Root	63.66^{a}	64.33^{a}	47.66^{a}	48.70^{ab}	29.00	28.66^{b}	3.33^{c}	4.33^{b}
Biochar 2%		40.00^{ab}	41.70^{ab}	50.33^{a}	52.00^{a}	32.70	34.00^{ab}	9.00^{ab}	10.00^{a}
Biochar 5%		49.66^{ab}	50.00^{ab}	28.00^{bc}	29.00^{cd}	29.33	31.00^{ab}	6.33^{a-c}	7.33^{ab}
Seaweed extract 1 g/l		37.33^{ab}	35.00^{ab}	23.00^{bc}	24.33^{cd}	31.00	30.70^{ab}	9.33^{a}	10.00^{a}
Seaweed extract 2 g/l		45.00^{ab}	43.67^{ab}	30.70^{b}	31.67^{bc}	33.67	34.66^{ab}	7.00^{a-c}	6.66^{ab}
BC 2% plus SWE 1 g/l		47.67^{ab}	46.00^{ab}	22.33^{bc}	23.00^{cd}	35.70	37.00^{a}	7.70^{a-c}	8.00^{ab}
BC 2% plus SWE 2 g/l		27.33^{b}	29.00^{b}	13.00^{c}	14.00^{d}	34.66	35.70^{ab}	4.00^{bc}	4.66^{b}
MSD at 5%		32.405	31.088	16.404	17.304	NS	7.4014	5.3038	4.7517
Control	Leaf	406.00^{b}	404.33^{b}	33.33^{b}	30.00^{b}	66.00^{ab}	67.33^{ab}	13.67^{bc}	12.66^{bc}
Biochar 2%		447.00^{ab}	448.00^{ab}	41.33^{ab}	42.70^{ab}	107.00^{a}	108.33^{a}	71.70^{a}	73.67^{a}
Biochar 5%		466.70^{ab}	469.33^{ab}	37.70^{b}	39.33^{b}	79.00^{ab}	77.70^{ab}	19.00^{b}	20.33^{b}
Seaweed extract 1 g/l		491.33^{ab}	493.33^{ab}	56.70^{a}	56.66^{a}	25.67^{b}	24.67^{b}	6.67^{bc}	7.33^{c}
Seaweed extract 2 g/l		445.33^{ab}	447.00^{ab}	36.70^{b}	34.70^{b}	33.00^{b}	31.33^{b}	4.67^{c}	5.33^{c}
BC 2% plus SWE 1 g/l		516.33^{ab}	518.33^{ab}	13.00^{c}	14.33^{c}	35.67^{b}	37.67^{b}	9.00^{bc}	10.00^{bc}
BC 2% plus SWE 2 g/l		564.33^{a}	566.33^{a}	8.70^{c}	7.00^{c}	28.33^{b}	31.00^{b}	16.00^{bc}	16.70^{bc}
MSD at 5%		123.9	125.59	16.188	14.627	58.973	57.408	13.091	12.289
Control	Grain	293.67	320.00	9.70^{b}	11.33^{c}	29.33	28.33^{b}	16.70	16.60
Biochar 2%		309.00	311.70	10.33^{b}	14.00^{bc}	30.70	31.33^{ab}	10.00	9.00
Biochar 5%		306.67	308.67	11.66^{b}	13.33^{bc}	32.00	31.00^{ab}	6.70	5.66
Seaweed extract 1 g/l		323.67	293.00	11.70^{b}	9.67^{c}	35.33	33.00^{ab}	6.33	6.00
Seaweed extract 2 g/l		301.33	300.00	20.00^{ab}	19.00^{a-c}	34.70	34.66^{ab}	14.00	14.67
BC 2% plus SWE 1 g/l		318.67	323.00	33.00^{a}	30.70^{ab}	36.33	37.33^{ab}	16.66	15.00
BC 2% plus SWE 2 g/l		352.33	354.33	32.00^{a}	36.00^{a}	36.00	37.70^{a}	4.67	5.00
MSD at 5%		NS	NS	19.92	18.593	NS	9.2467	NS	NS

NS = Non Significant Means followed by different letters are significantly different at $P \leqslant 0.05$ level.

Treated wheat plants with seaweed extract at 1 g/l produced a significant increase in Mn concentration in wheat leaves as compared with control. The treatments of biochar (2% & 5%) and SWE at 2 g/l in both seasons led to insignificant increase on Mn concentration in leaves of wheat plants when compared with control in both seasons. Moreover, adding biochar 2% produced an increase on Zn and Cu concentrations in leaves of wheat plants as compared with control in both seasons. The concentration of Zn in wheat leaves resulted from the application of biochar at 2% was insignificantly increased when compared with control in both seasons.

On the other hand, no significant differences were noticed in Fe and Cu concentrations in grains of wheat by all treatments. In this concern, the highest concentration of Fe, Mn, Zn and the lowest concentration of Cu in grains was achieved in wheat plants treated with the combination treatment between biochar at 2% plus seaweed extract at 2 g/l in both seasons. In this respect, all treatments reduce copper concentration in grains of wheat plants as compared with control plants in both seasons.

Discussion

Data presented in Tables 2–4 reveal the synergistic effect of biochar (BC) addition especially by rate 2% and its combinations with seaweed extract (SWE) treatments on most morphological characters and yield attributes of wheat plants, which attributed to the promotion effect of biochar on macro- and micronutrients concentration presented in Tables 5 and 6. Also, that may be due to the changes in soil characteristics and/or the availability of nutrients (Chan et al., 2007; Sohi et al., 2010). However, the improvement of soil water-holding capacity by biochar addition could maintain a better moisture level between irrigation periods, being considered a key factor to obtain good grains yield in wheat (Gooding and Davies, 1997). Also, Liang et al. (2006) suggested that, biochar ability to retain the cations in soil is far greater than the organic matter. This property of biochar is achieved due to its high surface area. Moreover, the biochar application in the soil and its surface oxidation by biotic and abiotic agents result in the development of negative charges that give ability to biochar to sorb more cation nutrients (Cheng et al., 2006, 2008).

Like that, those authors Asai et al. (2009), Major et al. (2010), Alburquerque et al. (2013) and Olmo et al. (2014) demonstrated some benefits through the application of biochar as for as increasing the soil water-retention capacity, total N and the available contents of P, K, Mg, Cu and Zn led to an increase in fine root proliferation (increasing specific root length and reducing root tissue density), promoted crop development, higher relative growth and net assimilation rates, aboveground biomass and yield by improving the physical and biochemical properties of cultivated soils.

The addition of biochar to soil increases the immobilization of nutrients through adsorption reactions (Beesley et al., 2011). Moreover, Atkinson et al. (2010) reviewed several mechanisms which can enhance P availability and P uptake by plant after biochar addition to soil which acts as source of soluble P salts and exchangeable P forms, and avoids P precipitation by modifying soil pH or enhancing microbial activity leading to changes in P availability.

Lehmann et al. (2006) and Danish et al. (2014) suggested that this increase in almost all the attributes of wheat yield was due to biochar application that not only improves the availability of nutrients but also promotes vegetative growth by improving the photosynthetic pigments productions in *T. aestivum* L. which was observed by biochar addition at rates 1% and 2%.

Alburquerque et al. (2013) indicated that, adding biochar led to enhance wheat yield and led to about 20–30% increase in grains yield compared with the use of the mineral fertilizer alone, both biochars acted as a source of available P, which led to beneficial effects on crop production and affected on plant nutrients uptake by increasing P and Mg (olive tree pruning biochar) or Zn and Cu (wheat straw biochar) and decreasing Cu (olive tree pruning biochar) or K, Ca, and Mg (wheat straw biochar) both biochars decreased plant uptake of N, Na, Fe, and Mn. However, under field conditions, the fact that biochar addition can avoid nutrient losses by leaching may favor an increase in the availability of nutrients in soil in the long term.

On the other hand, the stimulation effect for spraying with seaweed extract (SWE) treatments on growth characteristics and yield components of wheat plants presented in Tables 2–4, was supported by Salim and Abdel-Rassoul, 2016. They mentioned that spraying wheat plants with SWE at rate 2000 ppm led to a significant increase in the weight of 100 grains and gave the highest significant values of grains yield/-plant under salt stress conditions. The superiority was due to the benefits of seaweed components providing an excellent source of bioactive compounds such as macro- and micronutrients, essential fatty acids, amino acids, vitamins, cytokinins, auxins like growth promoting substances affecting cellular metabolism in treated plants leading to enhance growth and productivity (Sharma and Hall, 1992; Stirk et al., 2003; Ördög et al., 2004; Khan et al., 2009).

As for as, stimulating growth, yield characteristics, root growth, minerals uptake (macro- and micronutrients), photosynthetic capacity, and stress tolerance in different plants treated with seaweed extracts have been attributed to plant growth regulators, and possibly micronutrients (Sharma and Hall, 1992; Bhaskar and Miyashita, 2005; Khan et al., 2009; Chernane et al., 2015; Salim and Abdel-Rassoul, 2016). Moreover, the adding of seaweed extract treatments which is a bio stimulant that has been used as soil conditioner or foliar application for improving plant growth, yield, quality and activated antioxidant system (Cardozo et al., 2007; Chernane et al., 2015).

Also, Kasim et al. (2015) mentioned that using seaweed extract of *Sargassum* or *Ulva* antagonizes the oxidative damaging effects of drought not only directly through activating the antioxidative system, such as catalase, peroxidase and ascorbate, but also through providing hormones and micro nutrients essential for wheat growth especially, the root depth, shoot height and leaf area were increased compared with the single treatment of drought stress.

On the other hand, Tables 5 and 6 shows the benefits of effect of using SWE treatments and their combination with biochar at 2% to increase the concentration of most macro- and micronutrients in wheat tissue, and the hormonal content of seaweed extract presented in Table 1, mainly cytokinins, indole-3-acetic acid (IAA) and some organic compounds especially betaines which were sufficient to produce biological changes in wheat plants. In addition, seaweed extracts (SWE) improve the absorption of nutrients through the roots causing additional strong overall growth of the plant (Crouch et al., 1990; Stirk and Van Staden, 2006). Also, Khan et al. (2009) demonstrated the positive effects of seaweed extracts applications on plant growth have been attributed to plant growth regulators, that stimulate root growth, minerals uptake and photosynthetic capacity.

Stamatiadis et al. (2014) indicated that, foliar applications of an *Ascophyllum nodosum* seaweed extract stimulated the plants to utilize with soil mineral N, possibly other available nutrients more efficiently, caused increased grain K uptake and gave a 25% increase in yield of wheat plants. In this respect, Crouch et al. (1990) indicated that using seaweed concentrate led to significantly increased K, Mg and Ca concentrations in the leaves of lettuce plants which are receiving an adequate supply of nutrients but had little effect on nutrients stressed plants. In addition, nitrogen, phosphorus and magnesium were significantly increased, while calcium was decreased by the algae extraction (0.1%) compared with untreated and treated plants. Abbas (2013) concluded that, the application of the bio-stimulants in small quantities has the effect on several metabolic processes and enhances plant growth and development *via* the increase of photosynthesis, endogenous hormones, nutrients uptake, and protein synthesis as well as with relatively higher ability for increasing available micronutrients in the soil.

Conclusion

- From the abovementioned results it can be concluded that, the application of some bio stimulants as biochar (BC), seaweed extract (SWE) and their combinations positively enhanced plant growth, development, yield and the mineral composition of wheat plants *cv.* Sakha 93 cultivated in sandy soil.
- The promotion effect of such treatments (BC, SWE and their combinations) on enhancing the growth, development and yield of wheat plants is due to enhancing cultivation use efficiency of sandy soil by increasing water holding capacity, ion exchange and nutrients availability and can reduce the application of the chemical fertilizers.

References

A.O.A.C., 1975. Official Methods of Analysis. 12th Association Official Analytical Chemists. Washington, D.C. (U.S.A.).

Abbas, S.M., 2013. The influence of biostimulants on the growth and on the biochemical composition of *Vicia faba cv.* Giza 3 beans. Romanian. Biotechnol. Lett. 18 (2), 8061–8068.

Abo Soliman, M.S.M., Shams El-Din, H.A., Saied, M.M., El-Barbary, S.M., Ghazy, M.A., El-Shahawy, M.I., 2008. Impact of field irrigation management on some irrigation efficiencies and production of wheat and soybean crops. Zagazig J. Agric. Res. 35 (2), 363–381.

Alburquerque, J.A., Salazar, P., Barrón, V., Torrent, J., del Campillo, M.C., Gallardo, A., Villar, R., 2013. Enhanced wheat yield by biochar addition under different mineral fertilization levels. Agron. Sustain. Dev. http://dx.doi.org/10.1007/s13593-012-0128-3.

Asai, H., Samson, K.B., Stephan, M.H., Songyikhangsuthor, K., Homma, K., Kiyono, Y., 2009. Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. Field Crops Res. 111, 81–84.

Atkinson, C.J., Fitzgerald, J.D., Hipps, N.A., 2010. Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant Soil 33, 1–18. http://dx.doi.org/10.1007/s11104-010-0464-5.

Aziz, N., Mahgoub, M., Siam, Z., 2011. Growth, flowering and chemical constituents performance of amaranthus tricolor plants as influenced by seaweed (*Ascophyllum nodosum*) extract application under salt stress conditions. J. Appl. Sci. Res. 7, 1472–1484.

Beesley, L., Moreno-Jiménez, E., Gomez-Eyles, J.L., Harris, E., Robinson, B., Sizmur, T., 2011. A review of biochars' potential role in the remediation, revegetation and restoration of contaminated soils. Environ. Pollut. 159, 3269–3282. http://dx.doi.org/10.1016/j.envpol.2011.07.023.

Bhaskar, N., Miyashita, K., 2005. Lipid composition of *Padina tetratomatica* (*Dictyotales, Phaeophyta*), a brown seaweed of the west coast of India. Indian J. Fish. 52, 263–268.

Cardozo, K.H.M., Guaratini, T., Barros, M.P., Falcao, V.R., Tonon, A.P., Lopes, N.P., Campos, S., Torres, M.A., Souza, A.O., Colepicolo, P., Pinto, E., 2007. Metabolites from algae with economic impact. Com. Biochem. Physiol. 146, 60–78.

Chan, K.Y., Van Zwieten, L., Meszaros, I., Downie, A., Joseph, S., 2007. Agronomic values of green waste biochar as a soil amendment. Aust. J. Soil Res. 45, 629–634. http://dx.doi.org/10.1071/SR07109.

Cheng, C., Lehmann, J., Engelhard, M.H., 2008. Natural oxidation of black carbon in soils: changes in molecular form and surface charge along a climosequence. J. Geochim. Cosmochim. Acta 72 (6), 1598–1610.

Cheng, C.H., Lehmann, J., Thies, J.E., Burton, S.D., Engelhard, M. H., 2006. Oxidation of black carbon by biotic and abiotic processes. J. Org. Geochem. 37 (11), 1477–1488.

Chernane, H., Latique, S., Mansori, M., El Kaouam, M., 2015. Salt stress tolerance and antioxidative mechanisms in wheat plants (*Triticum durum* L.) by seaweed extracts application. J. Agric. Vet. Sci. 8 (3), 36–44.

Cottenie, A., 1980. Soils and plant testing as a basis of fertilizer recommendation. FAO Soil Bull., 3812

Crouch, I.J., Beckett, R., Van Staden, J., 1990. Effect of seaweed concentrate on the growth and mineral nutrition of nutrient stressed lettuce. J. Appl. Phycol. 2, 269–272.

Danish, S., Ameer, A., Qureshi, T.I., Younis, U., Manzoor, H., Shakeel, A., Ehsanullah, M., 2014. Influence of biochar on growth and photosynthetic attributes of *Triticum aestivum* L. under half and full irrigation. Int. J. Biosci. 5 (7), 101–108.

El-Maghraby, M.A., Moussa, M.E., Hana, N.S., Agrama, H., 2005. Combining ability under drought stress relative to SSR diversity in common wheat. Euphytica 141, 301–308.

Eppendrof, N., Hing, G., 1970. Interaction manual of flame photometer B 700-E. Measuring method, Description of the apparatus and Instructions for use.

Flowers, T.J., Garcia, A., Koyama, M., Garcia, J.A., Koyama, M., Yeo, A.R., 1997. Breeding for salt tolerance in crop plants: the role of molecular biology. Acta Physiol. Plant. 19, 427–433.

Gaskin, J.W., Steiner, C., Harris, K., Das, K.C., Bibens, B., 2008. Effect of low-temperature pyrolysis conditions on biochar for agricultural use. Trans. ASABE 51, 2061–2069.

Gooding, M.J., Davies, W.P., 1997. Wheat Production and Utilization: Systems, Quality and the Environment. CAB International, Wallingford, UK.

Hoagland, D.R., Arnon, D.I., 1950. The water-culture for growing plants without soil. Calif. Agric. Exp. Stn. Circ. 347 (Rev.).

Kasim, W.A., Elsayed, A.M.H., Shams El-Din, N.G., Eskander, S.K., 2015. Influence of seaweed extracts on the growth, some metabolic activities and yield of wheat grown under drought stress. Int. J. Agron. Agric. Res. 7 (2), 173–189.

Khan, W., Rayirath, U., Subramanian, S., Jithesh, M., Rayorath, P. D., Hodges, M., Critchley, A., Craigie, J., Norrie, J., Prithiviraj, B., 2009. Seaweed extracts as biostimulants of plant growth and development. J. Plant Growth Regul. 28 (4), 386–399.

Kloss, S., Zehetner, F., Dellantonio, A., Hamid, R., Ottner, F., Liedtke, V., Schwanninger, M., Gerzabek, M.H., Soja, G., 2012. Characterization of slow pyrolysis biochars: effects of feed stocks and pyrolysis temperature on biochar properties. J. Environ. Qual. 41 (4), 990–1000.

Laird, D.A., 2010. The charcoal vision: a win-win-win scenario for simultaneously producing bioenergy, permanently sequestering carbon, while improving soil and water quality. Agron. J. 100, 178–181.

Lehmann, J., Gaunt, J., Rondon, M., 2006. Biochar sequestration in terrestrial ecosystems – a review. Mitig. Adapt. Strat. Glob. Change 11 (2), 403–427.

Lehmann, J., 2007. Carbon sequestration in dryland ecosystems. J. Environ. Manage. 33, 528–544.

Liang, B., Lehmann, J., Solomon, D., 2006. Black carbon increases cation exchange capacity in soils. J. Soil Sci. Soc. Am. 70 (5), 1719–1730.

Major, J., Rondon, M., Molina, D., Riha, S.J., Lehmann, J., 2010. Maize yield and nutrition after 4 years of doing biochar application to a Colombian savanna oxisol. Plant Soil 333, 117–128.

Minolta, 1989. Chlorophyll meter SPAD-502. Instruction Manual. Minolta Co., Ltd., Radiometric Instruments Operations, Osaka, Japan.

Olmo, M., Alburquerque, J.A., Barrón, V., del Campillo, M.C., Gallardo, A., Fuentes, M., 2014. Wheat growth and yield responses to biochar addition under mediterranean climate conditions. SPECIAL ISSUE, Biol. Fertil. Soils, Springer-Verlag Berlin Heidelberg, doi:http://dx.doi.org/10.1007/s00374-014-0959-y.

Ördög, V., Stirk, W.A., van Staden, J., Novak, O., Strnad, M., 2004. Endogenous cytokinins in the three genera of microalgae from the chlorophyta. J. Phycol. 40, 88–95.

Rathore, S., 2009. Effect of seaweed extract on the growth, yield and nutrient uptake of soybean (*Glycine max*) under rainfed conditions. South African J. Botany 75, 351–355.

Sajid, A., Khan, A.R., Mairaj, G., Fida, M., Bibi, S., 2008. Assessment of different crop nutrient management practices for yield improvement. Austral. J. Crop Sci. 2 (3), 150–157.

Salim, B.B.M., Abdel-Rassoul, M., 2016. Effect of foliar applications of seaweed extract, potassium nitrate and potassium silicate on growth, yield and some biochemical constituents of wheat plants under salt stress. J. Biol. Chem. Environ. Sci. 11 (2), 371–391.

SAS, 2006. Statistical Analysis System. SAS User's Guide: Statistics. SAS Institute Inc., Cary, N.C.

Sharma, P.K., Hall, D.O., 1992. Changes in carotenoid composition and photosynthesis in Sorghum under high light and salt stress. J. Plant. Physiol. 140, 661–666.

Sohi, S.P., Krull, E., López-Capel, E., Bol, R., 2010. A review of biochar and its use and function in soil. Adv. Agron. 105, 47–82. http://dx.doi.org/10.1016/S0065-2113(10)05002-9.

Stamatiadis, S., Evangelou, L., Tsadilas, C., Yvin, J.C., Cruz, F., Mina, J.M.G., 2014. Responses of winter wheat to *Ascophyllum nodosum* (L.) Le Jol. extract application under the effect of N fertilization and water supply. J. Appl. Phycol. 26 (3). http://dx.doi.org/10.1007/s10811-014-0344-0.

Stefansson, A., Gunnarsson, I., Giroud, N., 2007. New methods for the direct determination of dissolved inorganic, organic and total carbon in natural waters by reagent- free ion chromatography and inductively coupled plasma atomic emission spectrometry. Anal. Chim. Acta 582 (1), 69–74.

Stirk, W.A., Van Staden, J., 2006. Seaweed products as biostimulants in agriculture. World Seaweed Resources: An Authoritative Reference System (pp. A multimedia, Interactive DVD ROM). ETI Bioinformatics, Amsterdam.

Stirk, W.A., Novak, M.S., Van Staden, J., 2003. Cytokinins in macroalgae. Plant Growth Regul. 41, 13–24.

Uzoma, K.C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, Z., Nishihara, E., 2011. Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use Manage. 27, 205–212.

Watanabe, F.C., Olsen, S.R., 1965. Test of ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soils. Soil Sci. Soc. Am. Proc. 29, 677–678.

Zhang, A., Liu, Y., Pan, G., Hussain, Q., Li, L., Zheng, J., Zhang, X., 2012. Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. Plant Soil 351, 263–275.