Asian Journal of Soil Science and Plant Nutrition

Volume 9, Issue 3, Page 60-88, 2023; Article no.AJSSPN.101374
ISSN: 2456-9682

Effect of Soil Amendments and Spraying with Antioxidants on Some Clay Soil Properties and Wheat Production under Climate Change Conditions

Rasha A. El-Awady [a*], Kholoud A. El-Naqma [b], and Saffaa S. M. Abd El-Al [c]

[a] Soil Physics and Chemistry Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center (ARC), Giza, Egypt.
[b] Soil Fertility and Plant Nutrition Department, Soils, Water and Environment Research Institute, Agricultural Research Center (ARC), Giza, Egypt.
[c] Environment Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center (ARC), Giza, Egypt.

Authors' contributions

"This work was carried out in collaboration between all authors. Author RAEA designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors KAEN and SSMAEA performed the statistical analysis, managed the analyses of the study, managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJSSPN/2023/v9i3186

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101374

Original Research Article

Received: 25/04/2023
Accepted: 19/06/2023
Published: 06/07/2023

ABSTRACT

Climate change is anticipated to a vigorous impact on soils and ecosystems due to elevated temperature and changes in precipitation lead to reduce in wheat yield. Thus, afield experiment was performed throughout two seasons 2021 and 2022 at Agricultural Research Station farm,

**Corresponding author: Email: alawadydrrasha@gmail.com;*

Sakha, Kafr El-Sheikh Governorate, Egypt (30^o 56 N latitude and 31^o 05 E longitude) to investigate the effect of compost and biochar in the main plots in addition, applied of salicylic acid, potassium silicate and seaweed extract as plant spraying in the subplots on improving some physio-chemical properties of the clay soil, some biochemical constituents and productivity of wheat plants under climate change. The experiment was arranged in a split-plot design with three replicates. Data indicated that applying compost treatment appears to be more successful in reducing pH and bulk density of soil than biochar. Application of biochar treatment reduced electrical conductivity meanwhile, compost increased it. Hydraulic conductivity, total porosity, organic matter content, moisture constants of soil, cation exchange capacity were increased by applying all tested soil amendments in two seasons. All Soil amendments caused a marked improve in soil available nitrogen, phosphorus and potassium content. Meanwhile, compost treatment was the best one in increasing available nitrogen and potassium content. Compost application with all foliar spray had given a first order while foliar application under biochar addition had the second one. Data investigated that potassium silicate treatment increased grain & straw yield, harvest index, yield efficiency, 1000 grain weight, carbohydrates and protein. It is clearly observed that compost with potassium silicate treatment was superior to biochar with all foliar treatments of increasing nitrogen, phosphorus, and potassium concentration of grain and straw yields and its uptakes.

Keywords: Climate change; compost; biochar; antioxidants; wheat.

1. INTRODUCTION

Climate change is global phenomena and occurring continuously since the earth came into existence and has become a major scientific issue during the last decade [1]. Egypt is distinguished by high temperatures, high evapotranspiration and low rainfall. Climate change is projected to have significant impacts on agriculture through indirect and direct effects on soils and crops. Factors that contribute to climate change, like moisture and temperature are anticipated to have a range of effects on several soil processes that are useful for production and soil fertility [2]. Comprehensive strategies are needed to reuse plant residues in agriculture that minimize the adverse effects of climate change. Compost, the biodegradation of organic waste product, increases soil moisture and affects organic matter dissolution and nutrient availability [3] and is considered one of the best move for reuse of waste. Organic soil amendments are commonly added to soil for improving its physio-chemical properties which promote plant growth [4]. Organic fertilizer use has gained a great attention as a means to enhance soil fertility and crop nutrients. Organic fertilizers have a main function in improving the organic matter in the root zone [5].

Biochar (BC) is a new multifunctional carbon material that is widely used as an amendment for improving soil quality and increase plant productivity [6]. It is output by the pyrolysis process in absence of oxygen from different straw materials such as rice straw, cotton stalks, peanut hulls, grass and animal wastes, as found in [7]. It is a stable carbon material that can remain in soil for a long time [8]. Moreover, Hussain et al. [9] suggested that increase rate of biochar application under alkali soil conditions, reduced wheat yields because of immobilization of N and micronutrients, its suitability to plants declined. Additionally, it has residence long times [10], due to its resistance to microbial decay. Therefore, the using biochar could be useful to soil fertility restores.

Wheat is acclimated to a cool growth environment and 18–22 °C is the proper temperature for grain-filling [11]. When temperature rises and high humidity weather frequently occurs in the late stage of wheat growth. Days with a daily average temperature higher than the optimal grain-filling temperature of wheat account for 1/3 of the period from heading to maturity. Especially in the mid and late stages of grain filling, the temperature rises sharply. When the constant high temperatures cause plants to mature more quickly, which causes early withering of the leaves, a shorter grain-filling period, and decreased grain weight [12]. Since the expected increase in world temperature (NOAA, 2020; IPCC, 2022), and change in the precipitation of dry land agriculture [13], day and night light ratio 5–25 _C [14]. The data of these stresses would disrupt biochemical, morphological, and physiological processes more than any other environmental stresses [15]. Antioxidants have established extreme tolerance against oxidative stress deterioration to cells [16].

Potassium silicate (K-silicate) is a source of highly soluble potassium and silicon. It is mostly employed in agricultural production systems as a silica amendment and modest amounts of K are supplied to the plants. K, present in plants as the cation K^+ is crucial for controlling how plant cells' osmotic potential is regulated [17]. It also activates many enzymes interested in respiration and photosynthesis. Recent studies suggest that silicon is useful in protecting the plants from all stresses through stimulating the expression of natural defense reaction and the creation of antioxidant-acting phenolic compounds [18]. Foliar spray with potassium silicate showed an increment in chlorophyll content and plant growth [19] and ameliorates abiotic stresses (i.e., high temperature) [20].

Salicylic acid (SA) can increase stress tolerance, decrease ethylene synthesis, and inhibit the actions of associated enzymes to prevent the programmed cell death that endogenous ethylene can start during stressful conditions [21]. Also, improved photosynthetic rate and a decreased level of membrane damage and membrane lipid peroxidation caused by high temperature stress which was mainly due to its ability to initiate the overall antioxidant defense system [22].

Seaweed extracts are a kind of bio stimulant extracted from seaweed (i.e., brown algae) that may improve crop growth, promote crop quality, and enhanced resistance of plant to abiotic stress [23], increased yield [24] and increased the absorption of soil nutrients by plants (N, P, and K) under stress [25]. Seaweed mainly contains natural hormones, such as auxin, cytokinin, gibberellin, abscisic acid, vitamins, antioxidants and other effective substances such as seaweed polysaccharide, sugar alcohol, betaine, and phenolic compounds [26].

In this regard, the current study aims to investigate the effects of two soil amendments (compost and biochar) in addition, applied of foliar treatments i.e., (salicylic acid, potassium silicate and seaweed extract) on improving some clay soil properties, some biochemical constituents and productivity of wheat plants under climate change.

2. MATERIALS AND METHODS

2.1 Experimental Sites and Soil

A field experiment was occurred at Agriculture Research Station, Kafr El-Sheikh Governorate, Egypt (30^o 56 N latitude and 31^o 05 E longitude) during two winter growing seasons 2020/2021 and 2021/2022 to investigate the effect of two soil amendments (compost and biochar) in addition salicylic acid, potassium silicate and extract from seaweed as plant spraying on improving some physio-chemical properties of the clay soil, yield &its components and some biochemical constituents of wheat (*Triticum asetivum* L.) variety Shandwell 1 under climate changes conditions. Some physical and chemical properties of the tested soil before cultivation are shown in Table 1.

2.2 Climatic Conditions

Egypt's climate is hot, dry and dominated by desert which has a moderate winter season with rain falling along coastal areas and dry and a hot summer season from May to September. The average data recorded of the past winter months (from 2020/2021 to 2021/2022) including maximum and minimum temperatures air, relative humidity, wind speed, rainfall. The prevailing climate of the area is semi-arid. The monthly average data of previous parameters from November until May (wheat growing season) are shown in Table 2.

2.3 The Experimental Design

The experiment was laid out in a split plot design with three replicates. The layout was made distributing two soil amendments (compost and biochar) to the main plots:

1- Control (ck) without added.
2- Compost treatment (C) (7 t fed^{-1})
3- Biochar treatment (BC) (4.2 t fed^{-1})

The sup plots as follows foliar spraying with:

1- Control (T) (spray with fresh water).
2- Salicylic acid (SA) (0.2 g/l)
3- Potassium silicate (Ksi) (0.6 g/l)
4- Seaweed extract (SW) (5 cm^3/l)

The used biochar in the experiment was manufactured by a local biochar company. It was produced from the pyrolysis of citrus trees wood. Biochar was uniformly spread on the surface of the wheat planting soil. Some chemical analyses of both compost and biochar are shown in Tables (3, 4), respectively.

Table 1. Mean values of some physical and chemical characteristics of the studied soil before cultivation in the two growing seasons

Characteristic	Soil depths (cm)		
	0-20	20- 40	40- 60
Particle size distribution (%)			
Coarse Sand	6.4	4.5	4.0
Fine sand	14.1	15.4	16.3
Silt	35.2	34.6	36.0
Clay	44.3	45.5	43.7
Texture class	Clayey		
Bulk density (g/cm^3)	1.22	1.27	1.22
Hydraulic conductivity (cm/h)	0.45	0.40	0.35
Soil moisture constants			
Field capacity (%)	38.4	39.1	40.1
Wilting point (%)	21.1	21.5	21.79
Available water (%)	17.3	17.6	18.31
Chemical analysis			
pH (1:2.5 soil: water suspension)	7.89	7.95	7.78
OM (%)	1.34	1.22	1.08
EC (dS/m) soil paste extracted	3.2	3.42	4.1
Soluble cations (meq/l)			
Ca^{++}	8.1	8.0	8.4
Mg^{++}	4.4	5.5	6.2
Na^{+}	18.3	19.2	25.8
K^{+}	1.2	1.5	0.6
Soluble anions (meq/l)			
CO_3^{--}	--	--	--
HCO_3^{-}	0.3	0.4	0.5
Cl^{-}	24.2	25.5	35.0
SO_4^{--}	7.5	8.3	5.5
CEC (Cmolekg-1)	40.12	39.01	35.8
Available macro nutrients (mg/kg)			
Available N	21	18.4	16.3
Available P	4.6	5.2	3.1
Available K	119.4	155.6	111.3

EC: electrical conductivity (salinity); OM: organic matter of soil and CEC: cation exchange capacity

Table 2. Mean Monthly agro-meteorological data of (2020/2021 to 2021/2022) from November until May (Wheat growing season)

Month	Temperature (°C)				Wind Speed ($km\ day^{-1}$)		RH (%)		Rainfall ($mm\ month^{-1}$)	
	Max	Min	Max	Min						
		2020		2021	2020	2021	2020	2021	2020	2021
November	24.88	15.36	28.06	16.58	1.21	2.22	66.41	66.51	1.40	3.95
December	22.82	11.98	19.86	10.58	2.24	2.79	67.66	72.91	0.07	1.52
January	21.62	10.32	16.20	7.20	2.76	2.75	68.14	72.72	0.46	2.18
February	21.74	10.01	18.26	8.12	2.72	2.58	68.36	72.30	1.62	0.48
March	22.30	10.65	20.24	8.45	2.85	3.01	67.11	63.54	5.56	2.00
April	27.29	11.58	29.01	13.61	2.45	3.32	60.32	52.32	0.05	0.02
May	35.78	17.90	31.81	17.05	2.97	3.46	49.54	52.46	0.0	0.17

Source: Meteorological station at Sakha Agricultural Research Station.
Min Temp is (minimum air temperature °C), Max Temp is (maximum air temperature °C) and RH is relative humidity

Table 3. Some chemical analyses of compost (C) used in the experiment

Analysis		EC (1:10 extract) dS/m	pH (1:10 extract)	N %	C:N	P %	K %	OM %	OC %
Compost	2020	3.5	7.9	1.39	16.55	0.39	2.22	41.73	23
	2021	3.2	7.8	1.35	15.56	0.37	1.95	38.0	21

Table 4. Some chemical analyses of biochar (BC) used in the experiment

Analysis		EC (1:10 extract) dS/m	pH (1:10 extract)	OC %	N %	C:N	P %	K %
Biochar	2020	0.53	8.10	47.0	1.26	37.30	0.95	1.42
	2021	0.52	8.09	45.5	1.20	37.92	0.93	1.39

The soil used treatments (compost and biochar) was added at the rate 7 t fed^{-1} and 4.2 t fed^{-1}, respectively and thoroughly incorporated into the top soil (0-20 cm depth), before cultivation except control. Foliar spraying with salicylic acid, potassium silicate and sea weed extract was two times after 30 and 45 days from planting at the rate 200 ppm (0.2 g salicylic acid/l) , 200 ppm (0.6 g potassium silicate /l) and 5 cm^3/l, respectively.

2.4 Culture Practices

In the two growth seasons, wheat grains (*Triticum asetivum* L.) variety Shandwell 1 was used as a tested plant in different climate conditions. The Department of Cereal Research, Agricultural Research Station, Sakha, Kafr El-Sheikh developed the seeds. Date of planting was on 15th November in 2020, 2021 by using 142.8 kg ha^{-1} (60 kg fed^{-1}) grain rate. NPK was applied to the soil in the following amounts: phosphorus was applied during soil preparation as calcium superphosphate (15.5% P_2O_5) 15 kg P_2O_5 fed^{-1}. Potassium was applied as potassium sulphate (48% K_2O) 24 kg K_2O fed^{-1}, Nitrogen fertilizer was applied as urea (46.5% N) 75 Kg fed^{-1}, in equal two doses, the first dose was at Mohayah irrigation (30 days after sowing); while the second addition was at the second irrigation after Mohayah irrigation directly (30 days after the first addition). Through the two growing seasons, wheat plants' agricultural practices were added in the amounts advised by the Egyptian Ministry of Agriculture.

2.5 Initial Soil Sampling

Soil samples were taken at three depths (0-20, 20-40 and 40-60 cm) before sowing of wheat, air-dried, ground, sieved through a 2 mm sieve for initial analyses of soil properties.

2.6 Soil Measurements

At harvest, soil samples were collected from each plot at the 1st and 2nd seasons, of two consecutive depths (0-20, 20- 40 cm). The soil samples were air-dried and analyzed for some the chemical characteristics, i.e., Soil pH according to [27]. The total soluble salts (EC) were determined using electrical conductivity meter at 25°C in soil paste extract as dS/m [28]. Cation exchange capacity (CEC) expressed in (C moles kg^{-1}) was determined by sodium acetate (NaOAC) method [29]. Organic matter content was determined according to Bhattacharyya et al. [30]. Soil available N was determined according to Matsumoto et al., [31], available P and K were determined according to Tian et al., [32]. The undisturbed soil samples were used to evaluate some the physical properties, i.e., Soil bulk density (gcm^{-3}) and Total porosity (%) was determined according to Campbell [33]. Saturated hydraulic conductivity (HC) (cm/h) was determined using undisturbed core samples according to Klute and Dirkoson, [34]. Field capacity (FC) and permanent wilting point (PWP) were obtained by the pressure plate method, using pressure of 0.033 and 1.5 MPa, respectively according to Klute and Dirkoson, [34]. The water percentage at each pressure level was calculated. Plant available water content (PAW) was calculated from the difference between the moisture content of field capacity and wilting point. All measurements were made in triplicate.

2.7 Crop Growth and Yield Measurements

Five wheat plants were chosen at random from each plot to measure the biological yield Mg/ha, grain and straw yield Mg/ha, harvest index (%), yield efficiency (%), 1000 grain weight (g), carbohydrate (%), protein in grain (%), Nitrogen, phosphorus, and potassium in (grains and straw) were determined using Kjeldahl method, spectrophotometrically and flam photometer, respectively according to Walinga et al., [35], where samples were digested by a mixture of sulfuric and perchloric acids at a ratio of 1:1 then total N, P and K% were determined. Protein content was calculated by using the following formula: Protein % = (N%) × 5.75 depending on Anonymous[36]. Total carbohydrates in grains were estimated according to Cipollini et al., [37]. Nutrient uptake (kg ha^{-1}) was determined according to the following formula; nutrient concentration x dry weight (g $plant^{-1}$).

2.8 Statistical Analysis

Data obtained from the two seasons were statistically analyzed by the following analysis of variance (IRRISTAT) described by Gomez and Gomez, [38]. Differences among treatment means were compared by least significant difference at P≤0.05.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Characteristics

3.1.1 Soil bulk density, total porosity and hydraulic conductivity

Data in Table 5 showed that, soil bulk density was increased with increasing soil depths. This increment may be resulted from increasing soil compaction. Bulk density, which is intimately related to soil textural characteristics and organic matter content, is also climate dependent [39]. Increasing temperature could expedite the decomposition of organic matter or soil erosion may increase bulk density, leading to soil compaction [40] with all its consequences, climate change may affect root development and microbial activity by altering soil water and temperature regimes and its hydro-physical characteristics, such as alterations in bulk density [41]. Application of soil amendments (compost and biochar) reduced significantly bulk density of soil, especially (0- 20 cm depth) at wheat harvesting. Bulk density of soil in control treatment varied from 1.22 to $1.27 gcm^{-3}$.

Data demonstrated that compost treatment was more effective than biochar one in decreasing bulk density of soil at both seasons. This might be due to apply of organic matter, which improvement of soil aeration and porosity [42]. The portion of macro-pores is increased by compost because of a promoted soil aggregation and stabilization significantly started by different soil organisms [43]. Additionally, the organic portion of soil is much lighter in weight than the mineral fraction. As the result, increases in the organic fraction reduce the total weight and bulk density of soil [44]. For instance, the bulk density values in the 0-20 cm soil depth were 1.16 and 1.18 g/cm^3 for C and BC treatments at the 1st season, respectively and were 1.23 and 1.26 g/cm^3 for C and BC treatments at the same season in 20- 40 cm depth, respectively compared to untreated plots.

Values of total porosity take almost the opposite trend to that encountered with bulk density. Data in Table 5 revealed that the overall total porosity values were increased significantly and this increment were more pronounced in the top soil (0- 20 cm) than the subsurface soil depth (20- 40 cm) for all treatments. Compost aids to improve porosity of the clay soil, making it drain easier so that it does not stay water logged and does not dry out into a bricklike substance. These results agreed with Ondrasek and Rengel [45] who said that the porosity and hydraulic conductivity were improved by adding organic amendments in saline soil.

Table 5. Effect of compost and biochar on bulk density (BD), total porosity (TP) and hydraulic conductivity (HC) in soil during the two growing seasons after wheat harvest

1st season						
Treatments	**BD (gcm^{-3})**		**TP (%)**		**HC (cm/h)**	
	0-20cm	**20-40cm**	**0-20**	**20-40**	**0-20**	**20-40**
Control	1.223a	1.27a	53.83c	52.2c	0.456c	0.396c
Compost	1.164c	1.23c	56.103a	53.58a	0.733a	0.666a
Biochar	1.18b	1.26b	55.47b	52.5b	0.613b	0.593b
LSD at 0.05	0.010	0.010	0.110	0.109	0.017	0.019
F. test	**	**	**	**	**	**
2nd season						
Control	1.213a	1.266a	54.22c	52.2c	0.433c	0.396c
Compost	1.14c	1.21c	56.98a	54.34a	0.83a	0.766a
Biochar	1.16b	1.246b	56.22b	52.9b	0.663b	0.593b
LSD at 0.05	0.019	0.009	0.143	0.111	0.027	0.026
F. test	**	**	**	**	**	**

Regarding to the soil hydraulic conductivity, results in Table 5 indicated that compost and biochar treatments increased significantly HC in soil layers after both growing seasons compared to ck. The results showed that, compost treatment is superior to biochar one in promoting soil hydraulic conductivity, especially at the 2nd season. Also, the HC values were higher in the surface soil layer than the subsurface one of both seasons. Meanwhile, no obvious different between HC values in 20- 40 cm soil depth at BC treatment of both seasons. Hydraulic conductivity before treatments application was 0.45 cm/h meanwhile, after applied of compost and biochar treatments in 0-20 cm soil depth were 0.73 and 0.61 cm/h at the 1st season, respectively over to ck. The improvement of hydraulic conductivity after applied of biochar can be explained to the rise in soil aggregate stability, which directly assisted in increasing the soil porosity thereby enhancing soil HC. Similar results were obtained by Baghbani-Arani et al. [46]. It could be observed from above results the compost treatment in 0-20 cm depth especially at 2nd season seemed to be the most effective treatment in improving the soil physical characteristics compared to other ones.

3.1.2 Soil moisture content

Soil hydrophysical characteristics can be significantly impacted by climatic changes like precipitation intensities or seasonal temperatures. These changes impact on the soil water regime, which may lately affect the economic and environmental development of a given area. Precipitation and solar radiation are the base sources of moisture and energy, respectively for both biological and soil operation [47].

The values of soil wilting point (WP), field capacity (FC) and the calculated available water (AW) which is considered to be the three main constant of soil moisture were responded to applied treatments Table 6. Application of soil amendments (compost and biochar) increased significantly FC after both growing seasons relative to ck. Meanwhile, these amended have insignificant effect on WP and AW contents. It was observed that the lowest values of soil moisture constants (FC, WP and AW %) was found with ck treatment. The water content in the soil depths before irrigation follows the rule of a gradual increase from top to bottom due to the water evaporation from the topsoil as a result from subjecting to high temperature. Compost treatment is superior to biochar one in promoting soil moisture constants especially at the 2nd season. For instance, in 0- 20 cm layer of soil, the increment percentage of (FC, WP and AW %) being 9.03, 9.97 and 7.90 % and being 3.38, 3.11 and 3.69 % in 20-40 cm layer of soil at the 2nd season, respectively due to application of C treatment after harvesting wheat plots relative to untreated plots. However, the soil moisture constants under C treatment in the 2nd season were obviously greater than that in 1st season. This mean that increased capacity for water retention as a result of used organic matter is a clear indication of its positive effect on modifying porosity and physical conditions of soil. Similar results were obtained by Li et al. [3]. The possible explanation of improved water retention in the biochar treated soil involves water that is held in the biochar pores and between its particles because of capillary forces and/or water attraction of the exterior surface of biochar. These results are in consistent with Sun and Lu [48] who showed that biochar improved water retention and pore space characteristics of clayey soil and that biochar may be considered as a soil amendment to improve poor physical characteristic of clayey soil. Biochar can be applied to ameliorate climate change by gathering carbon for atmosphere, or to enhance soil fertility by improving nutrient retention and moisture holding capacity [49].

3.2 Soil Chemical Properties

3.2.1 Soil pH

Data in Fig. 1 revealed that values of soil pH in both soil depths (0-20 and 20-40 cm) were significantly decreased; because of the good effectiveness of compost and biochar application. This reduction was more obvious at compost treatment than biochar one after two seasons compared to ck. The slight decrease of values of soil pH may reflect the activity of microorganisms in decomposing OM and releasing organic acids. Values of soil pH were not affected with SA, Ksi and SW extract during two seasons as compared to control. Additionally, data in Fig. 1 showed that no obvious different between values of soil pH in both depths because of the interaction between soil amendments and foliar application. These results agreed with Cheng et al. [50], who found that pH decreased with biochar application in alkaline soils. The reduction in soil pH might be due to release the protons (H^+) from the exchange sites of biochar, and due to the proliferation of acid producing soil microorganisms. It is also likely that the production of organic acids during the decomposition of OM present in soil and biochar might have also contributed for the reduction in soil pH.

Table 6. Effect of compost and biochar on soil moisture constants during the two seasons after wheat harvest

Treatments	FC%		WP %		AW %	
	0-20cm	**20-40cm**	**0-20**	**20-40**	**0-20**	**20-40**
1st season						
Control	38.47b	39.17b	21.15b	21.50a	17.32a	17.67a
Compost	42.56a	41.46a	23.39a	22.38a	19.16a	19.08a
Biochar	41.40a	40.46a	22.28ab	21.83a	19.11a	18.63a
LSD at 0.05	1.32	1.24	1.19	-	-	-
F. test	**	**	**	Ns	Ns	Ns
2nd season						
Control	40.76b	41.43a	22.16b	22.49a	18.60a	18.94a
Compost	44.44a	42.83a	24.37a	23.19a	20.07a	19.64a
Biochar	43.26a	42.15a	23.51ab	22.91a	19.75a	19.24a
LSD at 0.05	1.77	-	-	-	-	-
F. test	**	Ns	Ns	Ns	Ns	Ns

FC= field capacity, WP= wilting point and AW= available water

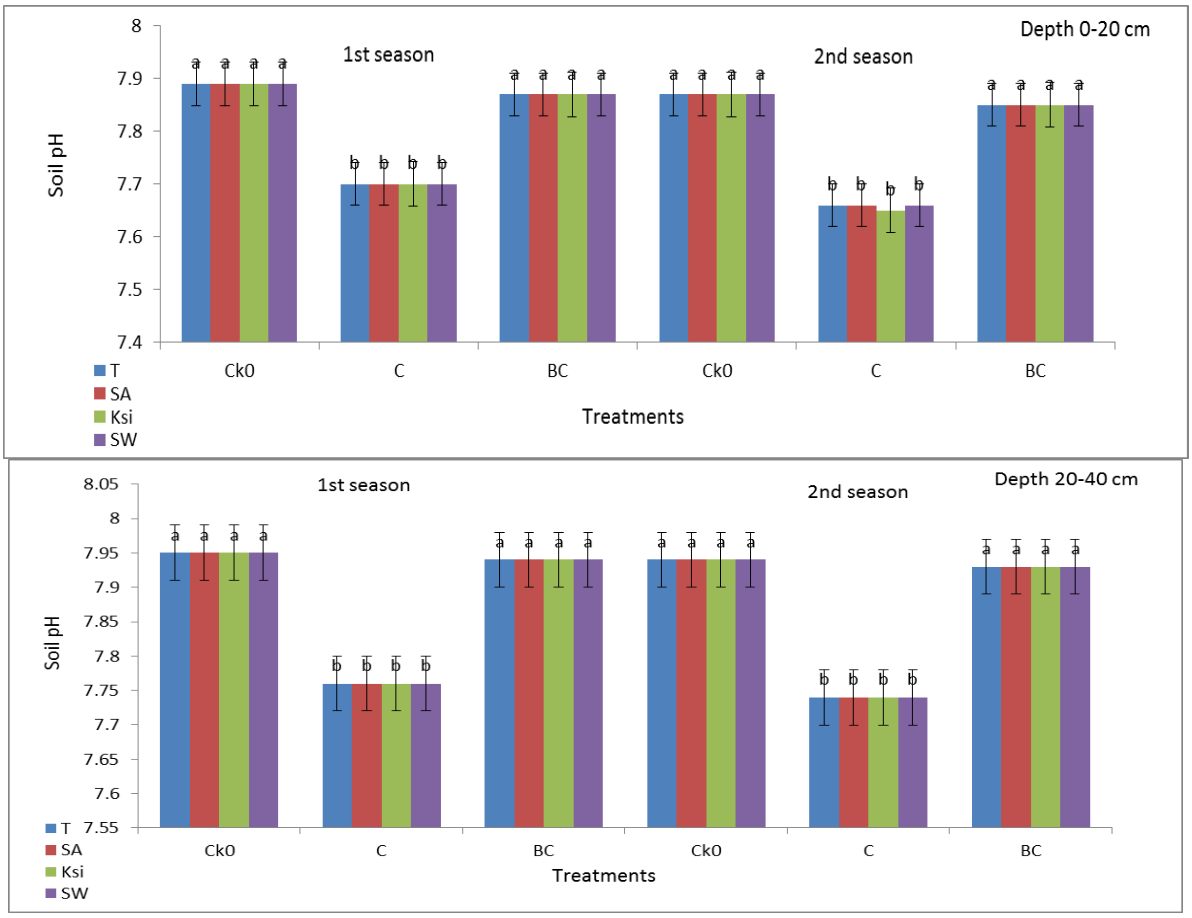

Fig. 1. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil pH compared to control during the two growing seasons after wheat harvest

3.2.2 Soil Electrical Conductivity (EC)

Electrical conductivity of two studied soil layers (0- 20 and 20- 40 cm) as affected by different treatments was presented in Fig.2. Applied of biochar alone or as duality treatment with plant spraying decreased significantly EC of soil due to biochar while, applied of compost one increased significantly the same character from two seasons as compared to control. It can be noticed that, soil EC values can be arranged according to soil depths as the following order: the top soil (0- 20 cm) < subsurface soil depth (20- 40 cm). This means that integration of composts into soil raise the salt content as well as soil electrical conductivity, because of the high salinity of composts [51]. The incorporation of compost to the soil led to slightly increase in EC values compared with control. Although compost treatment rose the EC of soil but the actual values did not cross the critical limit of 4.0 dSm^{-1}. Similar results were in agreement with those obtained by Mahmoud et al. [52]. On contrast, Yao et al. [53] demonstrated that the salinity amelioration is due to the rise water diffusion rate caused by the biochar addition. Sun et al. [54], investigated that the applied of biochar decreased soil salinity by Na^+ removal with leaching or adsorption, which might be the reason for the raise in soil depths of EC. Also, the data revealed that SA, Ksi and SW extract treatments singly had no effect on the soil EC (Fig.2). For instance, in 0- 20 cm soil depth, the increment percentage of soil EC being 16% a result of application of C treatment meanwhile, the decrement percentage of the same character being 12 % of BC treatment at 2nd season compared to ck.

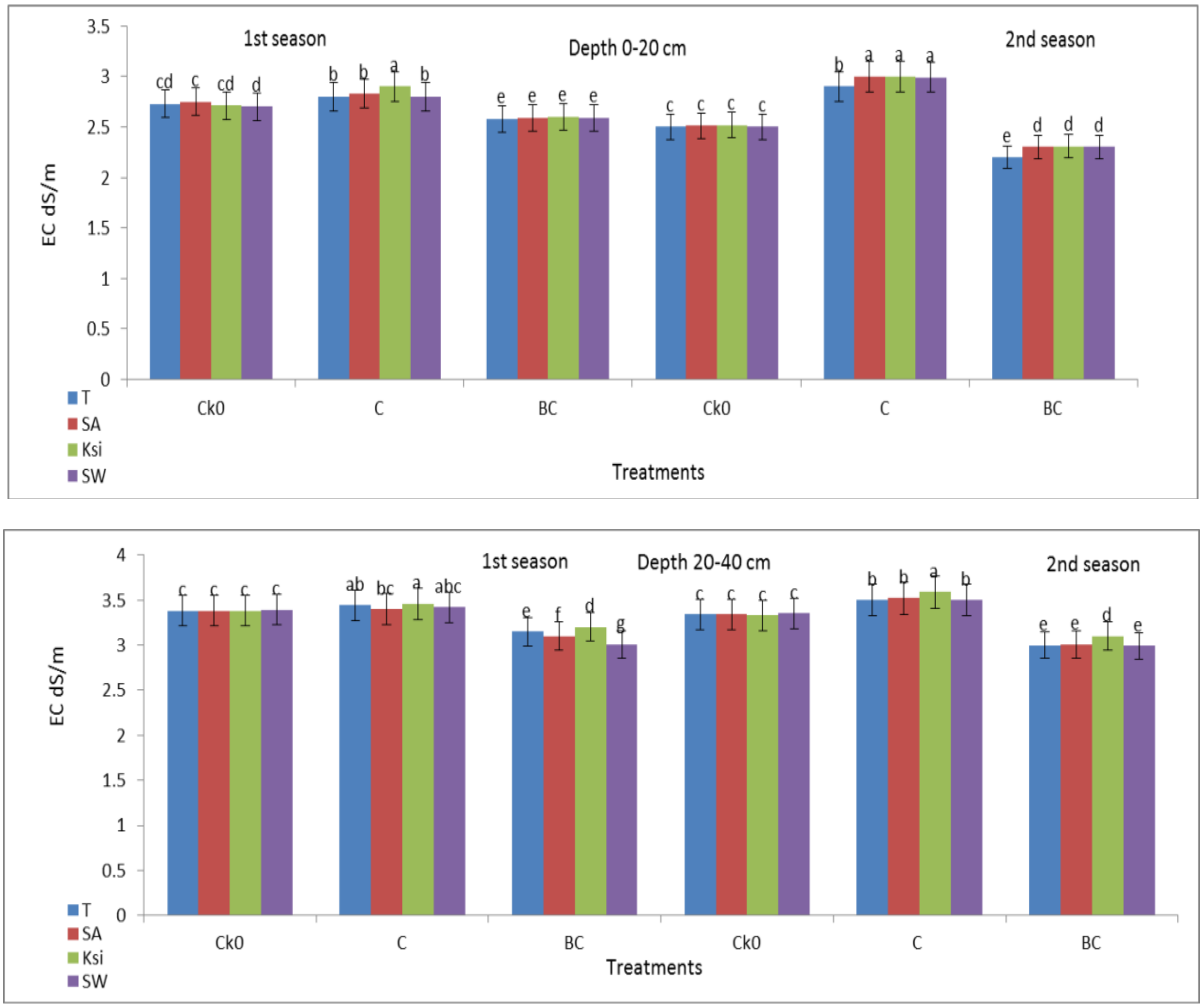

Fig. 2. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil electrical conductivity (EC dS/m) compared to control during the two growing seasons after wheat harvest

3.2.3 Soil organic matter

Organic matter plays a significant function in soil, because of its higher CEC and water holding capacity as well as its chelation ability and influence on soil stability. It is considered as a good resource of available nutrients. It promotes soil structure, aeration and aggregation [55]. Data in Fig. 3 showed a remarkable increase in the OM (0-20 and 20-40 cm soil depths) by applying soil amendments of two seasons compared to ck. But, compost was more effective in enhancing soil OM than biochar. Also, it was more pronounced in the top soil (0- 20 cm) than the subsurface one (20- 40 cm). These results are in consistent with those obtained by Li et al. [3]. Lützow et al. [56] indicated that the environmental conditions in the subsurface soil are different from those in the topsoil. For instance, in the subsoil, the temperature change is little and the nutrient availability is low, which might led to reduce in OM mineralization associated with a potential increase in OM accumulation in the subsoil. Organic fertilizer use has gained a great attention as a means to improve crop nutrients and fertility of soil. Organic fertilizers have a main function in improving the quantity of OM in the root zone [5]. Meanwhile, the data investigated that SA, Ksi and SW extract as a plant spraying alone had no obvious impact on the values of soil OM in both layers compared to control (Fig.3). Significant increments in the organic matter by applying all treatments (soil amendments + foliar application). For instance, in 0- 20 cm depth, the increments of soil OM were 26.12, 25.37 and 26.87 % for the C + SA, C + Ksi and C + SW treatments at 1st season, respectively and 11.94 % for the BC + SA treatment at the same layer. Moradi et al. [57] condensed the boosting of SOC by biochar application because of the reality that biochar is carbon-rich organic matter. Jiang et al. [58] observed that there are two forms of C in biochar, the labile form which is very degradable and release CO_2, and condensed C which is resistant to degradation, and Lu et al. [59] announced that around 70% of labile C contributed to CO_2 emissions from biochar.

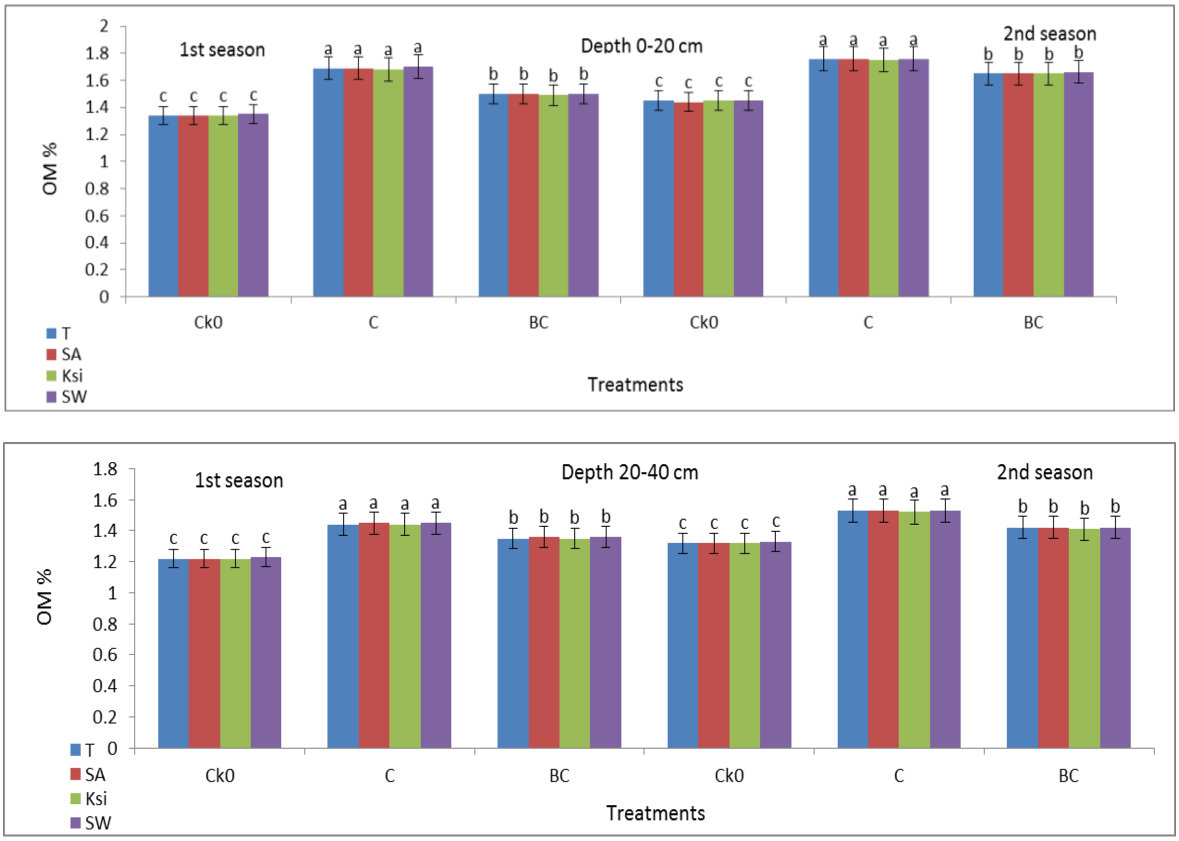

Fig. 3. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil organic matter (OM%) compared to control during the two growing seasons after wheat harvest

3.2.4 Soil cation exchange capacity (CEC)

The cation exchange capacity is a very important soil property which determines nutrients adsorption/desorption and thus their availability in soil [60]. The applied of C and BC singly or alternative treatments with plant spraying increased significantly CEC in 0-20 cm depth of both seasons due to soil amendments Fig. 4. Meanwhile, the results investigated that SA, Ksi and SW extract as a plant spraying alone had no effect on the CEC values at the same soil depth compared to control. Cation exchange capacity was increased with applied of C and BC treatments by 21.78 and 18.62 % in 0 - 20 cm soil depth at 1st season, respectively compared to ck. Biochar is a substance rich in carbon, has large specific surface area, rich functional groups and a porous porosity [61], thus increases soil cation exchange capacity. This result agreed with Ali [62] who observed that CEC of soil was increased with biochar addition. A shift to humid climate conditions may drastically convert the surface chemical characteristics existing in drier soils, as weathering exhausts primary minerals, which could be further lost due to leaching, and causing a substantial alternation in surface chemistry. Lavee et al. [63] demonstrated that relatively small variation in climate may push many Mediterranean areas into a lot of arid, featuring a higher in SAR and a lower in OM content, stability and aggregate size. A lower content of OM in the soil means smaller available surfaces for adsorption and leads to reduce in CEC.

3.3 Soil Available Nutrients Content

Data investigated that soil amendments increased significantly soil available N content after two seasons compared to untreated plots (Fig. 5). The compost treatment was more efficient in enhancing soil available N content than biochar one. These increments were more pronounced in the top soil than the subsurface one; because of the compost might have produced more residual nitrogen in soil during mineralization process than those in biochar treatment. Remarkable amount of nitrogen is available for plant because of OM and proper moisture in soil [64]. When CO_2 enrichment increases the soil C:N ratio, decomposing organisms need more N, which can reduce N mineralization in soil [65]. Mineralization is a base step in supplying N to plants [66]. Therefore, if N mineralization is reduced, it would be expected that plant-available N levels in the soil would also be reduced and productivity of plant would be negatively affected, but that increased temperatures stimulate N availability in the soil leading to more terrestrial C uptake than would be expected [67]. The data observed that SA, Ksi and SW extract as plant spraying alone had no effect on available N content in the two soil depths during two seasons compared to control. Remarkable increment in content of available N in soil was observed with application of all the tested materials. For instance, in 0- 20 cm layers soil, the increment percentage of available N content and pretreated with C + SA and C + SW treatments were 68.07 and 68.35%,

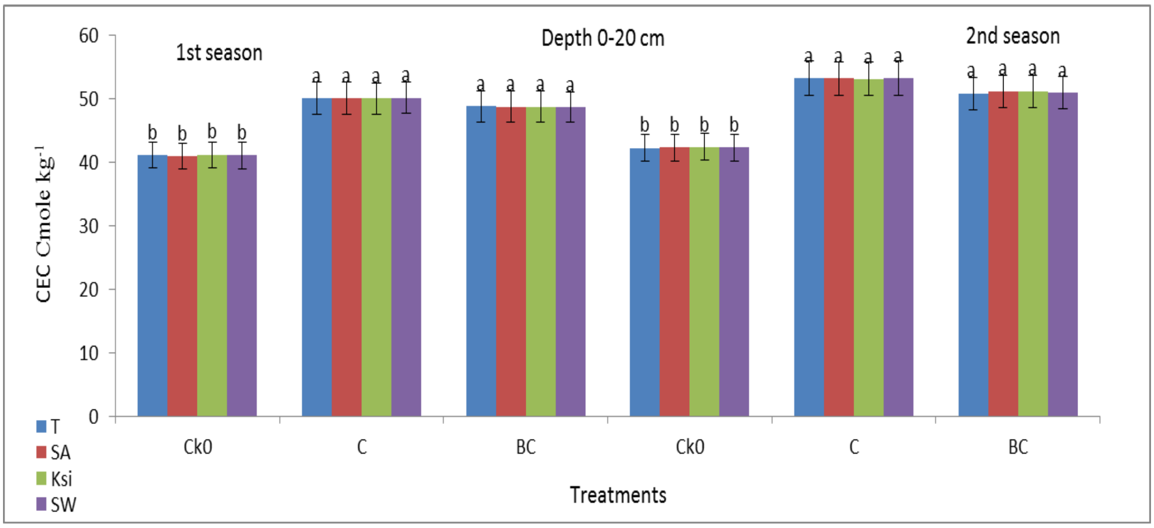

Fig. 4. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on cation exchange capacity (CEC Cmole kg^{-1}) compared to control during the two growing seasons after wheat harvest

respectively at the 2nd season. Available nitrogen content rose with BC application at 0- 20 cm depth by 29.19% in 1st season. As well N content rose with BC by 25.36% in 20- 40 cm depth at the same season over to ck. These results are agreed with Barnes et al. [68] who found that applying of biochar significantly increased nitrogen concentration. This increment is due to biochar capability to adsorb ammonia and nitrate [69] and reducing nitrate leaching and improve nitrogen fertilizer use efficiency [70]. Nigussie et al. [71] also found that nitrogen significantly increase by applying biochar at different rate of 5 and 10 t ha^{-1}.

Concerning the soil available phosphorus content, the impact of soil amendments applied either separately or as duality treatment with plant spraying on P content in soil depths were recorded in Fig. 6. A remarkable increment was detected in phosphorus content of two soil depths due to application of compost and biochar treatments of both seasons compared to ck. But the biochar treatment was more effective than compost one in promoting soil available phosphorus content. Yuan et al. [72] reported that biochar might be carried a large amounts of negative charges on its surfaces, whereas for phosphorus concentration, Zhang et al. [73] confirmed that biochar contains considerable levels of phosphorus, which increases the total and available phosphorus in the soil. Also, Liu et al. [74] showed that biochar could promote the amount and division of solubilizing bacteria in soil, resulting in the liberation of abundant N, P and K levels. It was noticed that the lowest value of soil phosphorus content was obtained by control treatment. Also, no obvious different between soil available phosphorus values in application of the foliar treatments alone compared to T Fig. 6. These results are in the same line as these reported by Mahmoud et al. [52]. For instance, in 0- 20 cm layers of soil, the increment percentage of available P content was 35.25 and 34.53% as a result of applied of BC + Ksi treatment at the 1st and 2nd seasons, respectively compared to control.

It is clearly observed from Fig. 7 that the soil available potassium content in two depths was increased significantly by applying soil amendments either alone or alternative treatments with plant spraying of both seasons compared to control. This increment was because of C and BC, which have high K content. Data illustrated that compost treatment was better than biochar one in increasing soil K content after two seasons. This increment was more obvious in the top soil (0- 20 cm) than in the subsurface one (20- 40 cm). It might be observed that application of foliar treatments separately had no effect on available K content. The applied of OM to the soil led to increase of the bioavailability of elements [75]. The organically rich substances which breakdown during passage through the gun, biological grinding, together with enzymatic influence on finer soil particles, were likely responsible for enhancing the different forms of potassium [76]. The increase of soil OM resulted in decrease potassium fixation and subsequent increase potassium availability [77]. Verma et al. [78] reported that prolonged use of mineral fertilizers, manure, compost and other ameliorants increases the potassium content in the soil. Because of high amount of potassium in organic amendments that increases CEC, the potassium amount rises in soil. Additionally, Silber et al. [79] observed that the fast degradation of biochar and the phenomenon of proton consumption may be implicated in mineral nutrients being liberation from the organic amendment.

3.4 Yield and its Components

Heat stress has a negative effect on the plants yield, because of the adverse impact of high temperature on wheat Biological yield development as translocation of assimilate; duration and the grain filling rates. It hastens the crop development thus resulting in smaller and shrinkage and light weight kernels and adversely affects the yield [80]. It led to decline in photosynthesis rate, and in return cause decreased grain yield per plant and reduce thousand kernel weight [81].

Table 7 show the impact amendments of soil (compost, biochar), foliar applications treatments, and their interactions on Biological, grain and straw yields, Mg ha^{-1}) in both two successful winter seasons (2020 and 2021) respectively.

Regarding the impact of soil amendments as (compost) treatment was the superior treatment compared to others then the biochar treatment and lately controls treatment (without any organic material addition). Both seasons showed this trend. Treatment of compost had given the best values from biological, grain and straw yields Mg ha^{-1} (15.35, 6.04 and 9.28) and (13.68, 5.82 and 7.84) in 1st and 2nd seasons, respectively compared to control.

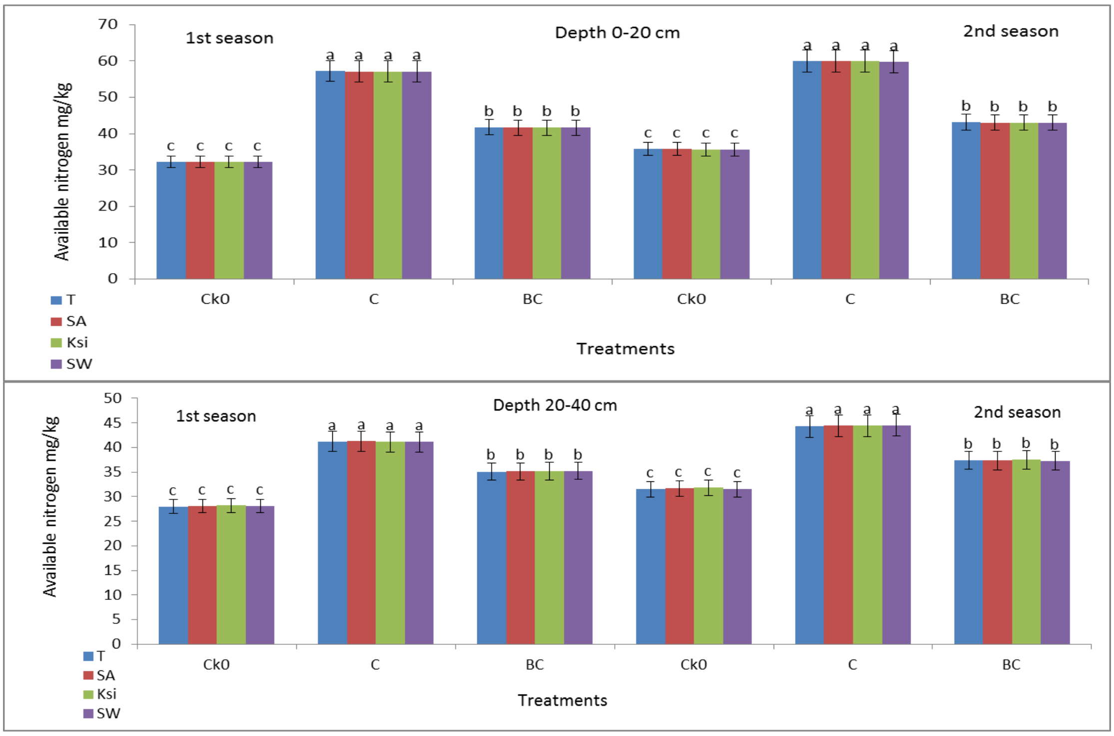

Fig. 5. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil available nitrogen content (mg/kg) compared to control during the two growing seasons after wheat harvest

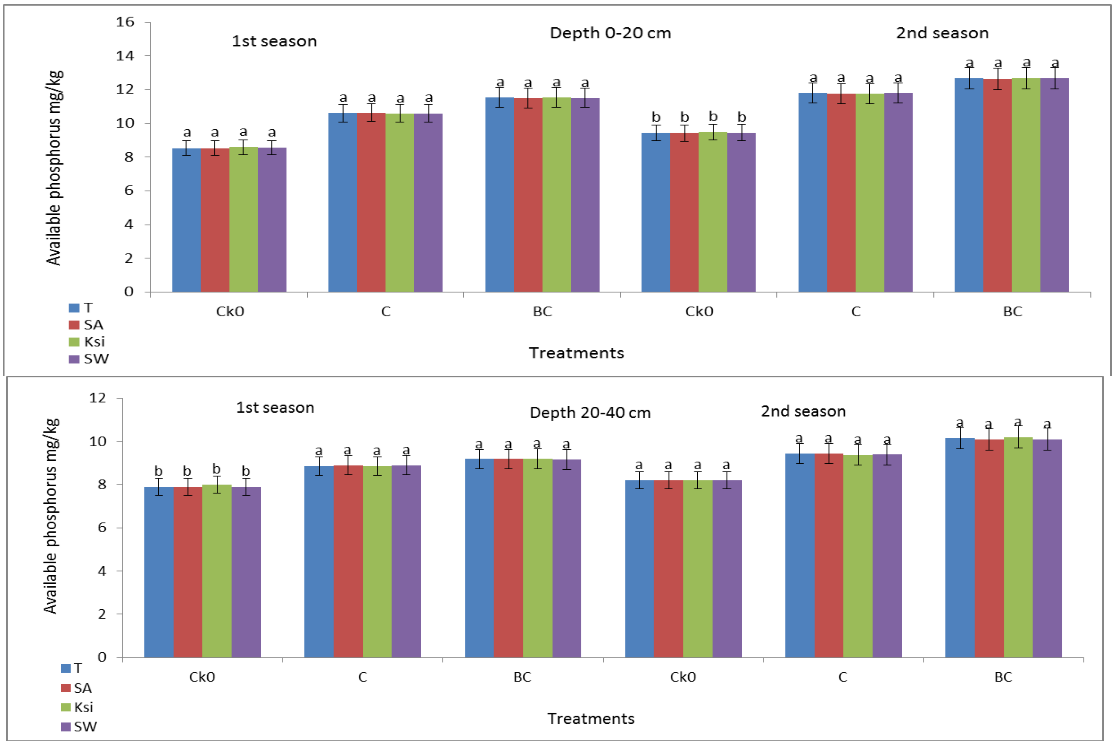

Fig. 6. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil available phosphorus content (mg/kg) compared to control during the two growing seasons after wheat harvest

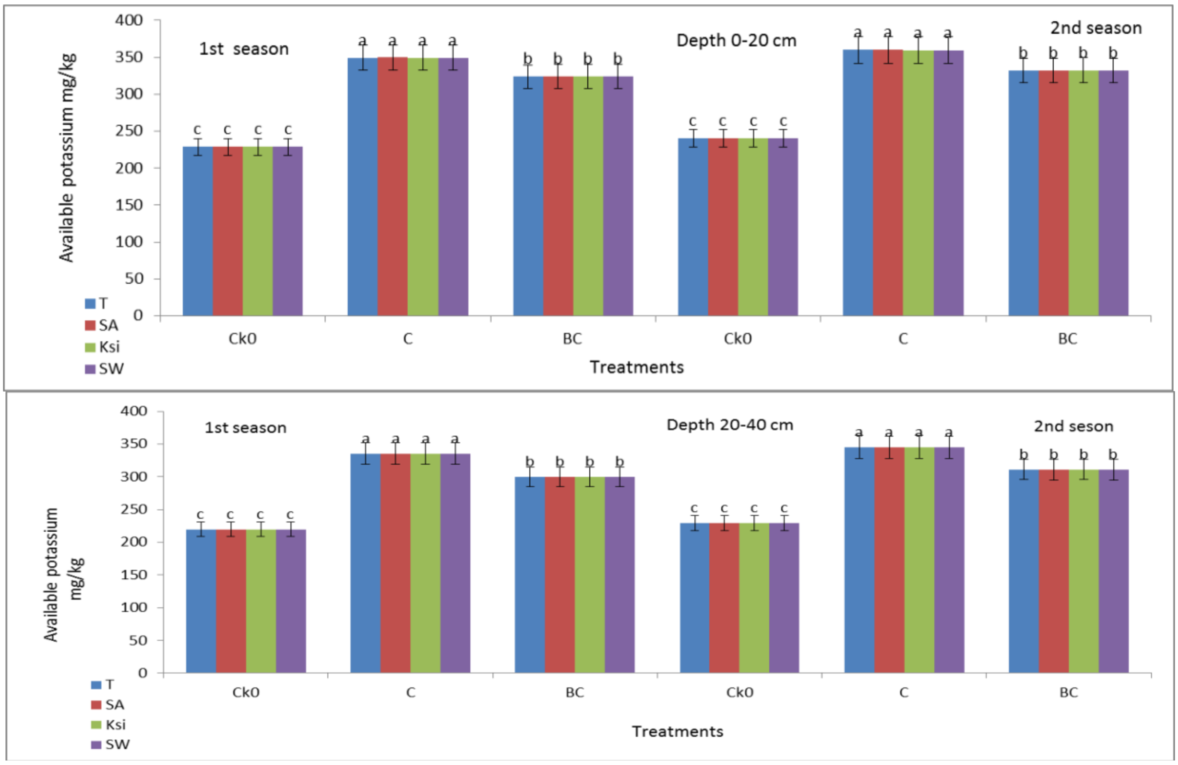

Fig. 7. Effect of compost (C), biochar (BC), salicylic acid (SA), potassium silicate (Ksi), seaweed extract (SW) and their interaction on soil available potassium content (mg/kg) compared to control during the two growing seasons after wheat harvest

The superiority of the compost treatment under two growing seasons may be explained to it being a high action exchangeable capacity, a rich source of nutrient elements in addition, its ability in promoting soil chemical, and biological characteristics and providing the energy of micro flora and supply nutrients compared to a biochar that has a CEC lower than compost and compared with soil treatment which without organic material addition.

All foliar treatments resisted a change heat and increased wheat yield compared to control treatments (water spray). Treatment of potassium silicate was superior rather than other material such as Salicylic acids and seaweeds as antioxidant treatments. Also, these results were found in both seasons. Potassium silicate's superiority compared to other studied foliar under both seasons is attributed to the role of Salicylic acid (SA), Potassium silicate K_2SiO_3 and seaweed (SW).

Generally, the interaction among the studied treatments was significant under both studied seasons, but the aforementioned values traits under addition compost with foliar all antioxidant materials especially, potassium silicate were greater than that under another treatment (16.89 & 14.52) from biological yield Mg ha^{1} , with parallel increment (34.26 and 19.40%), (6.55 & 6.24) from grain yield Mg ha^{-1} with parallel increment (27.18 and 23.56%) and (10.34 &8.27) from straw yield Mg ha^{-1} with parallel increment (39.16 and 16.31%) comparison to control in two seasons respectively. Also, in a similar table the treatment of (compost + seaweed) had given a second better result in contrast, biochar addition to soil with foliar treatment had given also a good results especially (BC + Ksi) treatment with percentage (14.84 and 7.73%), (14.77 and 8.91%) and (17.09 and 6.89%) from biological, grain and straw yield in two seasons, respectively compared to control.

Data from Table 8 indicated that all the tested treatments significantly affected agronomic traits of harvest index%, yield efficiency% and 1000 grain weight (g) in a similar table data demonstrated that compost treatment possessed the highest values of the aforementioned characteristics under both studied (41.45 and 42.54), (69.49 and 74.21) and (51.40 and 51.03),

Table 7. Effect of some soil amendments, antioxidant foliar applications, and their interactions on biological, grain and straw yield Mg.h^{-1} during the winter seasons of 2020/2021

Treatments		Biological yield, Mg.h^{-1}		Grain yield, Mg.h^{-1}		Straw yield, Mg.h^{-1}	
		1st	2nd	1st	2nd	1st	2nd
		A- Soil amendments :					
Ck		11.82 c	11.31c	4.84 c	4.64c	6.97 c	6.67c
C		15.35 a	13.68a	6.04 a	5.82a	9.28 a	7.84a
BC		13.41 b	12.51b	5.39 b	5.22b	8.02 b	7.29b
L.S.D 0.05		**0.1270**	**0.1353**	**0.0646**	**0.06281**	**0.0765**	**0.0540**
F. test		**	**	**	**	**	**
		B- Antioxidant foliar applications:					
T		12.21 d	11.58d	4.09 d	4.77d	7.23 d	6.81d
SA		13.38 c	12.28c	5.36 c	5.12c	8.01 c	7.14c
Ksi		14.64 b	13.26a	5.81 a	5.59a	8.82 a	7.66a
SW		13.88 a	12.88b	5.58 b	5.42b	8.29 b	7.45b
L.S.D 0.05		**0.0978**	**0.1484**	**0.0446**	**0.06696**	**0.0638**	**0.0986**
F. test		**	**	**	**	**	**
		C- Interactions between soil amendments and antioxidants :					
Ck	**Ck**	10.60 j	10.23i	4.30 i	4.10i	6.29 k	6.12h
	SA	11.87 i	11.23h	4.92 h	4.61h	6.95 i	6.62g
	Ksi	12.58 g	12.16e	5.15 f	5.05e	7.43 g	7.11e
	SW	12.22 h	11.62g	5.01 g	4.80g	7.21 h	6.82f
C	**T**	14.32d	12.80d	5.61 e	5.37d	8.63 d	7.42d
	SA	14.87 c	13.67b	5.96 c	5.80b	8.88 c	7.81b
	Ksi	16.89 a	14.52a	6.55 a	6.24a	10.34 a	8.27a
	SW	15.34 b	13.73b	6.07 b	5.88b	9.27 b	7.85b
BC	**T**	11.72 i	11.72fg	4.94gh	4.84fg	6.78 j	6.88f
	SA	13.41 f	11.94ef	5.20 f	4.95ef	8.21 f	6.98ef
	Ksi	14.45 d	13.10c	5.75 d	5.50c	8.70 d	7.60c
	SW	14.08e	13.28c	5.67 e	5.58c	8.41 e	7.70bc
L.S.D 0.05		**0.1694**	**0.2571**	**0.0773**	**0.1256**	**0.1105**	**0.1709**
F. test		**	**	**	**	**	**

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds

while all parameters without any organic addition to soil (control treatment) obtained the lowest values of all aforementioned characteristics (40.62 and 41.01), (65.21 and 69.54) and (43.16 and 42.53) for harvest index%, yield efficiency% and 1000 grain weight (g) compared to control.

Regarding foliar applications, Ksi had the first order and SW put in the second order, but SA put in the third order while the control treatment (spray with water) let in the last order. This trend was observed in both seasons.

Generally, the interaction among the studied treatments was significant under both studied seasons, but the aforementioned traits values under addition compost with foliar all antioxidant materials especially, potassium silicate were higher than another treatment for harvest index%, yield efficiency% and 1000 grain weight over the control treatment in both seasons respectively. Also, in the same Table the treatment of (C + SW) had given a second better result. Furthermore, biochar supplement to soil with plant spraying treatments have given also a good results especially (BC +Ksi) treatment which the second order had given with (BC +SW) in both seasons, respectively compared to control.

As mentioned above the vital role of plant spraying (SA, Ksi and SW) on wheat yield. The obtained findings are in harmony with the results of Kizilgeci et al. [82] and Maghsoudi et al. [83] who demonstrated that wheat takes a vital status between cereals around the world and shares a significant part of biological yield. Silicon also can enhance the anti–oxidative defense mechanisms thus; evade deterioration from produced of ROS by diverse abiotic stresses.

Data investigated that result in the 2nd season superior than first seasons. This may be due to change in temperature and rainfall rate between the two seasons which decrease water absorption and photosynthesis activity. These results agree with Sharma et al. [84], Sattar et al. [85] who demonstrated that photosynthesis activity is reduced firstly by closing of stomata, membrane damage and altered functioning of various enzymes, particularly those which are accomplice with ATP synthesis. Silicon can promote anti-oxidative in both enzymatic and non-enzymatic defense mechanisms thus, evade deterioration from ROS produced by diverse abiotic stresses. Furthermore, Ksi are considered as a protecting to production especially under difficult conditions [86]. Wheat plants providing with potassium silicate is considered as an essential action, especially under severe water deficiency, to increase the resistance of plants with lowering production losses [87].

Previous studies on potassium silicate in agriculture have mostly been in terms of salt and alkali resistance and plant spraying [88]. When the silicon concentration in tissues of plant is increased, plants resistance to a range of biological and stresses can be improved. When sprayed with potassium silicate, the leaves could not be utilized and absorbed by plant tissues as effectively [89]. The growth and yield of wheat, maize and rice could be improved by spraying Si on the leaves [90]. Previous studies have investigated that Si application can reduce heat, drought damage to crops and increase yields [91].

Also, seaweed could be employed as bio-fertilizers supporting wheat growth. Seed priming allows seeds to function better in both stressful and normal situations. Seed priming boosts pre-germination metabolic activities, boosts antioxidant system activity, and speeds up membrane mending except for 20 and 30% *C. officinalis*, seaweed extracts reduced alkaloid accumulation in wheat seedlings. To be facing the environmental stress, plants have incubated metabolic modification. In addition to their protective activities versus biotic and abiotic stress, alkaloids serve as nitrogen reservoirs [92].

Through morphological, physiological, and other mechanisms, SA considered as plant hormone plays a significant part in the induction of a plant's defense versus a diverse of abiotic and biotic stress [93].

3.5 Protein and Carbohydrate

Generally, data in Table 9 show the values of wheat grain quality (carbohydrates % and protein %) in both seasons as affected by compost treatment. The data observed that treatment of compost have a significant impact on protein% and carbohydrates % of wheat grain.

The same Table's data shows that wheat grain quality (carbohydrate and protein content) had the highest values when potassium silicate was sprayed under both seasons followed by that grown with (salicylic acid and seaweed) treatments, compared with control treatment. Treatment of Ksi had given the best values (68.99 and 67.31%) for carbohydrates and (12.82% and 12.36%) for protein% in both seasons respectively.

Table 8. Effect of some soil amendments, antioxidant foliar applications, and their interactions on harvest index %, yield efficiency% and 1000 grain weight (g) during the winter seasons of 2020/2021

Treatments		Harvest index (%)		Yield efficiency (%)		1000 Grain weight (g)	
		1st	2nd	1st	2nd	1st	2nd
A. Soil amendments:							
Ck		39.39c	41.01c	65.21 c	69.54c	43.16c	42.53c
C		40.99a	42.54a	69.49a	74.21a	51.40a	51.03a
BC		40.24b	41.7b	67.41 b	71.54b	46.59b	46.20b
L.S.D 0.05		**0.3902**	**0.2610**	**0.8185**	**0.7421**	**0.0989**	**0.0830**
F. test		**	**	**	**	**	**
B. Foliar Antioxidants Treatments:							
T		39.82c	41.14c	66.21c	69.94c	43.78d	43.33d
SA		40.10b	41.65b	67.06 b	71.59b	46.65c	46.08c
Ksi		40.65a	42.16a	68.78 a	72.91a	49.65a	49.24a
SW		40.27b	42.05a	67.44 b	72.62a	48.13b	47.70b
L.S.D 0.05		**0.2516**	**0.3339**	**0.6417**	**0.8841**	**0.0709**	**0.0511**
F. test		**	**	**	**	**	**
C- Interactions between Soil amendments and antioxidants:							
ck	**T**	38.76k	40.14e	63.30l	67.08l	40.29k	39.80l
	SA	38.77j	41.06d	63.32k	69.68k	43.52j	42.28k
	Ksi	39.77g	41.50cd	67.06g	70.95g	44.62h	44.20h
	SW	39.55h	41.33d	65.45i	70.47i	44.20i	43.84i
C	**T**	40.26e	41.99bc	68.43e	72.40e	47.02f	46.46f
	SA	40.62d	42.41ab	69.45c	74.19c	51.28c	51.1c
	Ksi	42.16a	42.99a	72.90a	75.42a	54.92a	54.50a
	SW	41.45b	42.79a	70.81b	74.83b	52.39b	52.06b
BC	**T**	39.16i	41.29d	65.00j	70.34j	44.03i	43.73j
	SA	40.08f	41.48cd	66.03h	70.90h	45.15g	44.85g
	Ksi	40.98c	41.98bc	69.276	72.55d	49.41d	49.02d
	SW	40.92c	42.04bc	67.41f	72.37f	47.79e	47.22e
L.S.D 0.05		**0.5601**	0.**5784**	**1.1114**	**1.5313**	**0.1979**	**0.0885**
F. test		**	**	**	**	**	**

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds.

Table 9. Effect of soil amendments, antioxidant foliar applications and their interactions on grain wheat quality (Carbohydrates, % and Protein, %) during the winter seasons of 2020/2021

Treatments		Carbohydrates, %		Protein, %	
		1st	2nd	1st	2nd
A. Soil amendments					
ck		51.24c	49.32c	8.70 c	8..07a
C		68.99a	67.31a	12.82 a	12.36c
BC		65.36b	63.45b	11.62 b	11.10b
L.S.D 0.05		**1.1651**	**0.4235**	**0.2065**	**0.3409**
F. test		**	**	**	**
B. Foliar Antioxidants Treatments					
T		56.32d	54.01d	10.04 d	9.53d
SA		61.74c	59.48c	12.12 c	11.06c
Ksi		65.33a	63.94a	13.61 a	12.72a
SW		64.06b	62.67b	13.01 b	12.44b
L.S.D 0.05		**0.92011**	**0.62170**	**0.1607**	**0.1718**
F. test		**	**	**	**
C. Interactions between soil amendments and antioxidants.					
ck	**T**	44.72i	43.26i	6.51 j	5.96k
	SA	50.31h	48.45h	8.66 i	8.07j
	Ksi	56.23f	54.69f	10.15 g	9.36h
	SW	53.72g	50.87g	9.50 h	8.89i
C	**T**	62.77d	60.65d	11.61 e	11.09f
	SA	69.51b	66.81b	12.13 d	11.67e
	Ksi	71.93a	70.45a	12.99 a	12.65a
	SW	71.77a	71.32a	12.53 b	12.36b
BC	**T**	61.48e	58.11e	10.23 g	9.90g
	SA	65.42c	63.18c	10.98 f	10.43f
	Ksi	67.82b	66.69b	13.06 d	12.25d
	SW	66.71b	65.81b	12.20 e	11.82e
L.S.D 0.05		**1.5936**	**1.0768**	**0.2784**	**0.2975**
F. test		**	**	**	**

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds.

Similar Table, concerning the interaction effect, the highest values of the aforementioned traits under both seasons were realized with treatments of (C + Ksi) and (C + SW) (71.93% and 70.45%) and (71.77% and 71.32%) for carbohydrate in 1st and 2nd seasons and (12.99 and 12.65%) and (12.53% and 12.36%) for protein% in 1st and 2nd seasons, respectively.

These results may be due to the effect of potassium silicate on stressed wheat. Therefore, spraying potassium silicate on wheat plants is recognized as a key step for keeping the production, especially in challenging environmental conditions. Potassium may help in maintaining a normal balance between carbohydrates and proteins. It is a major nutrient for photosynthesis and the transport of assimilates [86].

Also, Seaweed plays a great role in tolerance stress such as heat. Amino acids, phytohormones, alginates, carbohydrates, essential macro- and micronutrients, betaines and vitamins are among the physiologically active compounds present in seaweed extracts that promote plant growth of wheat and its development which protects the plant from the detrimental effects of ROS generated during cellular metabolism. Also, as a nitrogen reserve, alkaloids may be diverted into other metabolic pathways to create structural nitrogenous molecules, such proteins, and amino acids, because plants can dispense the protective role of alkaloids in this situation. The capacity and efficiency of the photosynthetic process, in addition nutrient availability and absorption, have improved, resulting in enhanced carbohydrate production [94].

Also, these results agree with Kousar et al. [93] who observed that SA improved the physiological characteristics and wheat yield through conferring tolerance against temperature stress. The high protein content could be explained to the synthesis of defensive enzymes and other protein established compounds by plants after treatment with SA to raise plants in restraint to diverse stresses. Least protein content was observed in control treatment.

3.6 Nutritional Wheat Grain Composition (%)

It is clear that chemical constituent (nitrogen, phosphorus and potassium %) in grain (Table 10) were affected significantly by the studied treatments. The highest values were obtained with compost (2.23, 0.367 and 3.055) in first season (2.15, 0.364 and 2.993) in 2nd season over to biochar and control treatments.

Also, the same parameters, the grain concentration of nitrogen, phosphorus and potassium enhanced with Ksi in both seasons, while the third treatment (SW) had given the second superiority compared with Ksi and control (water) treatments. The relative increased were (35.63 %, 19.77% and 21.71%) for nitrogen, phosphorus and potassium concentration in first seasons over control treatment and so on, in 2nd season the relative increase were (33.53%, 18.70% and 21.28%) in nitrogen, phosphorus and potassium concentration compared with all treatments.

Data presented in the same Table reveal that compost treatment with Ksi produced the highest percentages of N% in wheat grain (2.15, 2.04), P% (0.296, 0.279), K% (2.61, 2.44), Carbohydrates %(68.21, 64.17) and protein%(12.34, 11.71) in 1st and 2nd soil respectively compared with control treatment.

All treatments from soil amendments (compost and biochar) with foliar applications have the highest values of N, P and K concentration in wheat grain compared with the control treatments (without soil amendments with foliar applications), but data observed that, treatments of (compost+ all foliar applications) outweighed biochar amendments with the same antioxidant foliar applications. More precisely, compost with potassium silicate and seaweed has highest values compared with salicylic acid and control treatments.

Generally, data showed that, there is no obvious significant effect between (C + Ksi) and (C+ SW) in nitrogen wheat grain concentration (2.26a and 2.20a) in first season and (2.18a and 2.15a) in second season, respectively compared with the control treatments. Furthermore, there is a high significant impact of P and K concentration in all treatments under compost amendments compared with control treatment. The highest vales of grain phosphorus and potassium % with (C + Ksi) (3.92 and 3.88%) for P% in 1st and 2nd seasons respectively and (3.226 and 3.133%) for K% in 1st and 2nd seasons respectively over the control treatments.

Table 10. Effect of soil amendments, antioxidant foliar applications and their interactions on nutrient status and qualitative traits of grains during the winter seasons of 2020/2021

Treatments		N%-grain		P%-grain		K%-grain	
		1st	2nd	1st	2nd	1st	2nd
A. Soil amendments							
Ck		1.51 c	1.41c	0.213 c	0.210c	1.652 c	1.595c
C		2.23 a	2.15a	0.367 a	0.364a	3.055 a	2.993a
BC		2.02 b	1.94b	0.299 b	0.297b	2.726 b	2.668b
L.S.D 0.05		**0.0356**	**0.5991**	**0.00242**	**0.00194**	**0.0335**	**0.0214**
F. test		**	**	**	**	**	**
B. Foliar Antioxidants Treatments							
T		1.74 d	1.67d	0.263 d	0.262d	2.224 d	2.175d
SA		2.11 c	1.94c	0.288 c	0.285c	2.395 c	2.323c
Ksi		2.36 a	2.23a	0.315 a	0.311a	2.707 a	2.638a
SW		2.26 b	2.18b	0.307 b	0.304b	2.584 b	2.0038b
L.S.D 0.05		**0.0280**	**0.0301**	**0.00245**	**0.00158**	**0.0199**	**0.0288**
F. test		**	**	**	**	**	**
C. Interactions between soil amendments and antioxidants.							
Ck	**T**	1.13 j	1.04k	0.189 l	0.186l	1.346 j	1.283j
	SA	1.50 i	1.41j	0.210 k	0.207k	1.536 i	1.476i
	Ksi	1.30 g	1.64h	0.231 i	0.228i	1.930 g	1.883g
	SW	1.65 h	1.56i	0.222 j	0.221j	1.796 h	1.740h
C	**T**	2.02 c	1.93c	0.333 d	0.331d	2.930 d	2.876d
	SA	2.11 b	2.03b	0.362 c	0.359c	3.026 b	2.943c
	Ksi	2.26 a	2.20a	0.392 a	0.388a	3.226 a	3.133a
	SW	2.18 a	2.15a	0.383 b	0.379b	3.036 b	3.020b
BC	**T**	1.78 g	1.73g	0.269 h	0.270h	2.396 f	2.366f
	SA	1.91 f	1.83f	0.291 g	0.289g	2.623 e	2.550e
	Ksi	2.19 d	2.10d	0.321 e	0.317e	2.966 c	2.900cd
	SW	2.12 e	2.07e	0.316 f	0.312f	2.920 d	2.850d
L.S.D 0.05		**0.0485**	**0.0521**	**0.00425**	**0.0029**	**0.0346**	**0.0499**
F. test		**	**	**	**	**	

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds

The superiority impact of compost treatment may be due to that it helped wheat plants easily absorb nutrients from the soil which mixed with compost (a high CEC), may be due to the products of the decay of organic matter which increased the solubility of phosphorous.

Organic matter after its decomposing gives different organic acids, which form complex substances with calcium, and this led to the liberation of significant amounts of phosphorous. Furthermore, the decay of organic matter led to the formation of carbon dioxide, which dissolved in water forming carbonic acid to dissolve the tri calcium phosphate and turn into di calcium (HPO_4^{-2}) or high soluble form ($H_2PO_4^-$), which is the most convenient form of the plant. Generally, the presence of microbial media of bio-fertilizer and compost led to produces active inorganic and organic acids, which led to a reduce values of soils pH, thus increases in P availability occurred.

Also, Salem et al. [86] found that, Si promotes the plant growth by modulating the uptake and phytohormone levels and alleviating plant stress levels. Furthermore, potassium is an essential nutrient for growth with protecting cell turgor and regulating the water content to plant cells. Moreover, potassium supply is crucial for controlling osmotic potential, enhancing water absorption, and preventing K^+ depletion. Potassium silicate fertilization is therefore considered as a key step in maintaining productivity, especially under difficult conditions.

Also, Gupta et al. [95] who indicated that foliar spray with seaweed extracts is thought to be capable of enhancing nutrient concentrations in the leaves by integrating growth hormones in the movement and absorption of these nutrients in the plant, in addition increasing the level of other growth activating compounds, resulting in an enhance in plant biomass.

3.7 Nutritional Composition of Wheat Straw

It is clear that chemical composition of wheat straw with compost treatment had performance better than biochar. Compost increases N%, P%, K% and protein% in 1st and 2nd season.

The same Table indicated that wheat straw performance expressed in chemical composition (nitrogen, phosphorus and potassium %) at harvest stage (Table 11) were significantly affected by the studied treatments, where N, P and K concentration had the highest values with Ksi treatments compared with other treatments. The seaweed treatment put in the second-order and salicylic treatment put in the third order, while the control one put in the last order.

Data of Table (11) illustrate the interaction effect among the studied treatments on chemical composition of the wheat straw at harvest stage. The superior combined treatment was with compost as soil addition and foliar spraying by potassium silicate. The lowest values of whole abovementioned characteristics were realized when wheat plants were grown on soil without any amendments and without any foliar treatments (control). These results might be attributed to compost addition improves most soil characteristics and increase its fertility, which affect positively on productivity of wheat plants. These results agree with Salem et al. [86] who found that, Si and K promote the plant growth by modulating the uptake and phytohormone levels and alleviating plant stress levels.

Moreover, potassium supply plays an essential role in enhancing water uptake ability, organizing osmotic potential, and avoiding K^+ depletion. Therefore, providing wheat plants with potassium silicate are considered as an important action for maintain of production especially under hard status.

3.8 N, P and K Uptake of Wheat Grains (kg ha^{-1})

Owing to Higher heat, caused reduction in leaf pigments and soluble sugars, hence dry matter accumulation and nutrient uptake decreased [96].

Table 12 showed that, the difference between compost and biochare additions to soil before sowing on (Nitrogen, phosphorus and potassium uptake) were significant. The control treatment have been the lowest mean of nitrogen uptake while, compost addition gave the highest average of this parameters. Also, recommended dose from mineral nitrogen was gave the highest values of both seasons.

Furthermore, data in Table 12 demonstrated that, N, P, K uptake raised with treatment of potassium silicate in both seasons. Seaweed had given the second superiority compared with salicylic acid and control treatments for nitrogen, phosphorus and potassium uptake in 1st and 2nd seasons, respectively compared to control.

Data in Table 12 present the interaction effects between soil amendments and foliar spray applications on nitrogen, phosphorus and potassium uptake kg ha^{-1}. Data show that a marked effect was detected, where the control treatment had the lowest values, while compost with potassium silicate gave the highest values of nitrogen, phosphorus and potassium uptake (190.66 and 183.59), (35.80 and 32.14) and (379.84 and 332.77) of N, P and K-uptake in 1st and 2nd seasons respectively compared the control treatment.

These findings may be attributed to the presence of growth-promoting materials such as indole-3-acetic acid, indole butyric acid, gibberellins, cytokines, micronutrients (Fe, Cu, Co, Zn, Mn, Mo, and Ni), vitamins, and amino acids in sea weeds. It might be owing to high levels of minerals like Fe, Zn, Cd, Cu, and Mn. These minerals have an effect on specific enzymatic processes and immediately depolarize the root cell membrane, increasing membrane permeability and impeding plant uptake of nutrients. As a result, cell division is reduced and it is unable to provide among of the nutrients a plant needs in sufficient concentrations [97]. Also, these results might be attributed to, Potassium which is essential in nearly all processes needed to sustain plant growth and reproduction. Plants deficient in potassium are less resistant to stresses as high and low temperatures [98].This due to that potassium enhances the overall health of plants growth and assists them fight against disease, it is known as the "quality" nutrient. Potassium affects quality factors such as shape, size, vigor and color of the seed or grain. Potassium plays an essential role of carbohydrates in the tissue of plant. It's shared with activation of enzyme [99] within the plant, which affects protein, starch and adenosine triphosphate (ATP) production [100].The production of ATP can organize the

Table 11. Effect of soil amendments, antioxidant foliar applications and their interactions on nutrient status and qualitative traits of wheat straw and its quality during the winter seasons of 2020/2021

Treatments		N%-Straw		P%- Straw		K%- Straw		Quality Protein%	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
A. Soil amendments									
ck		0.34c	0.29c	0.071c	0.0625c	1.290c	1.302c	1.95c	1.65c
C		0.54a	0.50a	0.092a	0.0907a	1.530 a	1.550a	3.09a	2.87a
BC		0.45b	0.41b	0.082b	0.080b	1.426 b	1.450b	2.52b	2.31b
L.S.D 0.05		**0.00925**	**1.3168**	**2.2614**	**1.1754**	**0.01034**	**7.7146**	**0.00388**	**0.00597**
F. test		**	**	**	**	**	**	**	**
B. Foliar Antioxidants Treatments									
T		0.39d	0.34d	0.075d	0,071d	1.337d	1.366d	2.22d	1.96d
SA		0.43c	0.39c	0.081c	0.075c	1.392 c	1.413c	2.43c	2.22c
Ksi		0.49a	0.44a	0.087a	0.084a	1.490a	1.510a	2.81a	2.55a
SW		0.46b	0.41b	0.084b	0.080b	1.443b	1.453b	2.62b	2.38b
L.S.D 0.05		**0.00330**	**8.2784**	**1.7917**	**1.3956**	**0.01039**	**2.0336**	**0.00320**	**0.00285**
F. test		**	**	**	**	**	**	**	**
C. Interactions between soil amendments and antioxidants									
ck	**T**	0.28k	0.23k	0.061l	0.053l	1.233j	1.25j	1.65k	1.31k
	SA	0.32j	0.28j	0.070k	0.058k	1.256i	1.27i	1.82j	1.60j
	Ksi	0.40h	0.34h	0.079i	0.071i	1.356g	1.36g	2.28g	1.94h
	SW	0.36i	0.31i	0.075j	0.068j	1.313h	1.33h	2.05i	1.77i
C	**T**	0.49d	0.44d	0.086d	0.086d	1.416f	1.44e	2.80d	2.51d
	SA	0.53c	0.49c	0.091c	0.089c	1.506c	1.51c	3.02c	2.79c
	Ksi	0.59a	0.56a	0.098a	0.096a	1.630a	1.66a	3.36a	3.19a
	SW	0.56b	0.52b	0.094b	0.092b	1.570b	1.59b	3.19b	2.96b
BC	**T**	0.40g	0.36g	0.077h	0.075h	1.363g	1.41f	2.22h	2.05g
	SA	0.43f	0.40f	0.081g	0.079g	1.413f	1.46d	2.45f	2.28f
	Ksi	0.49d	0.44d	0.086e	0.085e	1.483d	1.51c	2.79d	2.51d
	SW	0.46e	0.42e	0.083f	0.081f	1.446e	1.44e	2.62e	2.40e
L.S.D 0.05		**0.00571**	**2.6337**	**3.1033**	**2.4173**	**0.02069**	**2.4173**	**0.00555**	**0.00495**
F. test		**	**	**	**	**	**	**	**

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds.

Table 12. Effect of soil amendments, antioxidant foliar applications and their interactions on nutrient uptakes of wheat plants (grains+ straw) kg/ha during the winter seasons of 2020/2021

Treatments		N-uptake(kgha^{-1})		P-uptake(kgha^{-1})		K-uptake(kgha^{-1})	
		1st	2nd	1st	2nd	1st	2nd
A. Soil amendments							
Ck		96.77c	84.76c	15.42c	13.90c	169.86c	160.84c
C		184.80a	164.33a	30.69a	28.29a	326.50a	295.71a
BC		144.96b	131.14b	22.68b	21.33b	261.29b	244.96b
L.S.D 0.05		**2.6170**	**4.0780**	**0.3684**	**0.2429**	**1.7818**	**1.0563**
F. test		**	**	**	**	**	**
B. Antioxidant foliar treatments							
T		99.35d	102.80d	16.17d	17.32d	187.762d	196.76d
SA		140.32c	127.16c	20.85c	19.94c	239.86c	216.81c
Ksi		180.32a	158.35a	25.97a	23.81a	288.685a	263.127a
SW		164.23b	148.69b	24.09b	22.43b	263.80b	219.81b
L.S.D 0.05		**1.8411**	**1.7877**	**0.2082**	**0.2697**	**1.9462**	**3.1314**
F. test		**	**	**	**	**	**
C- Interactions between soil amendments and antioxidants.							
ck	T	66.20k	56.71j	11.95k	10.68k	135.42k	129.10k
	SA	96.04j	83.53i	15.19j	13.37j	162.86j	152.11j
	Ksi	96.67g	106.99g	17.75h	16.55h	200.14h	191.78h
	SW	108.61i	96.02h	16.52i	15.23i	184.630i	174.227i
C	T	155.60d	136.28d	26.10d	24.15d	286.57e	261.28e
	SA	172.81d	156.00c	29.65c	27.77c	310.67c	288.62c
	Ksi	190.66a	183.59a	35.80a	32.14a	379.84a	332.77a
	SW	184.23b	167.24b	31.95b	29.50b	327.81b	302.38b
BC	T	125.05h	108.49g	18.50g	18.22g	210.77g	211.51g
	SA	134.62f	118.58f	21.78f	19.81f	252.39f	228.12f
	Ksi	173.15c	151.69d	25.93d	23.89de	299.56d	277.26d
	SW	162.85e	149.52e	24.89e	23.63e	287.16e	269.91d
L.S.D 0.05		**3.1890**	**3.0965**	**0.3607**	**0.4672**	**3.3710**	**5.4238**
F. test		**	**	**	**	**	**

ck: control (without soil amendements). C: compost. BC= biochar.
T: control (with water spray). SA: salicylic acids. Ksi: potassium silicate. SW: seaweeds.

rate of photosynthesis [101]. Enhance drought tolerance and improves root growth, decreases lodging and builds cellulose, activates at least 60 enzymes shared in growth, aids in photosynthesis and food formation, helps translocate sugars and starches, produces grains rich in starch, increases protein content of plants. nutrient translocation [102],energy transfer [103], stomatal opening mechanism [104],and stress resistance, i.e., heat [98].

Potassium is known to interact with nearly all of the important macro and micronutrients. Potassium uptake and utilization is closely associated to the availability and uptake of other nutrients. Abd El-Mageed et al. [105] said that the used potassium fertilized at 120 kg ha^{-1} in two equal split doses at the sowing and flowering stages, enhanced quality and yield of wheat.

4. CONCLUSION

The results of the current study investigated that the interaction effect of (compost and biochar) with plant spraying treatments had a positive effect in enhancing the soil physio-chemical properties via (BD, TP, HC, FC, WP, AW, EC, OM, pH and CEC) in addition for improving soil-available nitrogen, phosphorus and potassium. It might be attributed to the improvement of organic matter, but compost treatment has superior to biochar in these increments under climate change except biochar treatment was efficient in EC and P contents and this reflected an increment in wheat yield. Consequently, this combined application (soil amendments + foliar treatments) may be considered as a good strategy to tolerate climate change on biological yield, grain and straw yield, harvest index, yield efficiency, 1000 grain weight and grain quality (carbohydrates and protein). The applied of compost with all plant spraying treatments had more effective than biochar one.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Fauchereau N, Trzaska M, Rouault M, Richard Y. Rainfall variability and changes in Southern Africa during the 20th century in the global warming context. Nat Hazards. 2003;29(2):139-54.
DOI: 10.1023/A:1023630924100.
2. Pareek N. Climate change impact on soils: adaptation and mitigation. MOJ Eco Environ Sci. 2017;2(3):1-4.
DOI: 10.15406/mojes.2017.02.00026.
3. Li M, Zhang J, Yang X, Zhou Y, Zhang L, Yang Y et al. Responses of ammonia-oxidizing microorganisms to biochar and compost amendments of heavy metals-polluted soil. J Environ Sci (China). 2021;102:263-72.
4. Aksakal EL, Angin I, Oztas T. Effects of diatomite on soil physical properties. CATENA. 2012;88(1):1-5.
5. Singh M, Sarkar B, Biswas B, Churchman J, Bolan NS. Adsorption-desorption behavior of dissolved organic carbon by soil clay fractions of varying mineralogy. Geoderma. 2016;280:47-56.
6. Anwari G, Mandozai A, Feng J. Effects of biochar amendment on soil problems and improving rice production under salinity conditions. Adv J Grad Res. 2020;7(1):45-63.
7. Wang H, Gao B, Fang JY, Ok YS, Xue Y, Yang K et al. Engineered biochar derived from eggshell-treated biomass for removal of aqueous lead. Ecol Eng. 2018;121:124-9.
8. Adekiya AO, Agbede TM, Aboyeji CM, Dunsin O, Simeon VT. Effects of biochar and poultry manure on soil characteristics and the yield of radish. Sci Hortic. 2019;243:457-63.
9. Hussain M, Farooq M, Nawaz A, Al-Sadi AM, Solaiman ZM, Alghamdi SS et al. Biochar for crop production: potential benefits and risks. J Soils Sediments. 2017;17(3):685-716.
10. Xie SB, Cao XY, Liu JJ, Chen DG, Zhao ZD. Effects of high-temperature and hot-dry wind on wheat and preventative measures. Shandong Agric Sci. 2013;45:126-31.
11. Wang X, Cai J, Jiang D, Liu F, Dai T, Cao W. Pre-anthesis high-temperature acclimation alleviates damage to the flag leaf caused by post-anthesis heat stress in wheat. J Plant Physiol. 2011;168(6):585-93.
12. NOAA. State of the Climate: Global Climate Report for July 2020. National Centers for Environmental Information; 2020. Published online August 2020. Available online at: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202008
(accessed December 15, 2021).

13. Rojas M, Lambert F, Ramirez-Villegas J, Challinor AJ. Emergence of robust precipitation changes across crop production areas in the 21st century. Proc Natl Acad Sci U S A. 2019;116(14):6673-8. DOI: 10.1073/pnas.1811463116
14. Lemmens E, Moroni AV, Pagand J, Heirbaut P, Ritala A, Karlen Y; et al. Impact of cereal seed sprouting on its nutritional and technological properties: A critical review. Compr Rev Food Sci Food Saf. 2019;18(1):305-28. DOI: 10.1111/1541-4337.12414.
15. Sattar A, Sher A, Ijaz M, Ul-Allah S, Rizwan MS, Hussain M; et al. Terminal drought and heat stress alter physiological and biochemical attributes in flag leaf of bread wheat. PLOS ONE. 2020;15(5):e0232974. DOI: 10.1371/journal.pone.0232974
16. Biju S, Fuentes S, Gupta D. Silicon improves seed germination and alleviates drought stress in lentil crops by regulating osmolytes, hydrolytic enzymes and antioxidant defense system. Plant Physiol Biochem. 2017;119:250-64. DOI: 10.1016/j.plaphy.2017.09.001.
17. Abu-Muriefah SS. Effect of sitosterol on growth, metabolism, and protein pattern of pepper (*Capsicum annum* L.) plants grown under salt stress conditions. Int J Agric Sci. 2015;8:94-106.
18. Qin GZ, Tian SP. Enhancement of biocontrol activity of Cryptococcus laurentii by silicon and the possible mechanisms involved. Phytopathology. 2005;95(1):69-75.
19. Saudy HS, El-Metwally IM. Nutrient utilization indices of NPK and drought management in groundnut under sandy soil conditions. Commun Soil Sci Plant Anal. 2019;50(15):1821-8
20. Carneiro-Carvalho A, Anjos R, Pinto T, Gomes-Laranjo J. Stress oxidative evaluation on SiK®-supplemented *Castanea sativamill*. Plants growing under high temperature. J Soil Sci Plant Nutr. 2021;21(1):415-25.
21. Hameed Z. Effect of salicylic acid on the activity of enzymatic antioxidants and proline in vegetative growth of maize plant under NaCl stress. Diyala Agric Aciences J. 2015;7:143-52.
22. Fan Y, Lv Z, Li Y, Qin B, Song Q, Ma L et al. Salicylic acid reduces wheat yield loss caused by high temperature stress by enhancing the photosynthetic performance of the flag leaves. Agronomy. 2022; 12(6):1386. DOI: 10.3390/agronomy12061386.
23. Cabo S, Morais MC, Aires A, Carvalho R, Pascual-Seva N, Silva AP; et al. Kaolin and seaweed-based extracts can be used as middle and long-term strategy to mitigate negative effects of climate change in physiological performance of hazelnut tree. J Agron Crop Sci. 2020;206(1):28-42. DOI: 10.1111/jac.12369.
24. El Boukhari MEME, Barakate M, Bouhia Y, Lyamlouli K. Trends in seaweed extract based biostimulants: manufacturing process and beneficial effect on soil-plant systems. Plants (Basel). 2020;9(3):359. DOI: 10.3390/plants9030359
25. Almaroai YA, Eissa MA. Role of marine algae extracts in water stress resistance of onion under semiarid conditions. J Soil Sci Plant Nutr. 2020;20(3):1092-101. DOI: 10.1007/s42729-020-00195-0.
26. Mukherjee A, Patel JS. Seaweed extract: biostimulator of plant defense and plant productivity. Int J Environ Sci Technol. 2020;17(1):553-8. DOI: 10.1007/s13762-019-02442-z.
27. McLean EO. Soil pH and lime requirement. In: Methods of soil analysis, part 2, chemical and microbiological properties, A. L. Page, (eds.) American Soc. Agron. Inc, Madison, w1, USA. 1982;199- 224.
28. Page AL, Miller RH, Keeney DR. Methods of Soil Analysis. In Soil Science Society of America; American Society of Agronomy: Madison, WI, USA; 1982. ISBN 0891180729.
29. Kim YW, Petrov I, Greene JE, Rossnagel SM. Development of 111 texture in Al films grown on SiO_2/Si (001) by ultrahigh-vacuum primary-ion deposition. J Vac Sci Technol A. 1996;14(2):346-51. DOI: 10.1116/1.579899.
30. Bhattacharyya T, Chandran P, Ray SK, Mandal C, Tiwary P, Pal DK; et al. Walkley-Black recovery factor to reassess soil organic matter: Indo-gangetic plains and black soil region of India case studies. Commun Soil Sci Plant Anal. 2015;46(20):2628-48.
31. Matsumoto S, Ae N, Yamagata M. The status and origin of available nitrogen in soils. Soil Sci Plant Nutr. 2000;46(1):139-49.
32. Tian H, Qiao J, Zhu Y, Jia X, Shao MA. Vertical distribution of soil available phosphorus and soil available potassium in

the critical zone on the Loess Plateau, China. Sci Rep. 2021;11(1):3159.
33. Campbell DJ. Determination and use of soil bulk density in relation to soil compaction. Dev Agric Eng. 1994;11:113-39. ISBN 0167-4137.
34. Klute A, Dirkoson C. Hydraulic conductivity and diffusivity: Laboratory methods. Methods of soil analysis: part 1—physical and mineralogical methods. 1986;687-734.
35. Walinga I, Van Der Lee JJ, Houba VJ, Van Vark W, Novozamsky I. Plant analysis manual. Springer Science+Business Media; 2013.
36. Anonymous. Official Methods of Analysis of the Association of Official Analytical Chemists. 15th Ed. Helrich (Ed.) Assoc. off. Ana. Chemists. Inc., Virginia, USA. 1990;11.
37. Cipollini DF, Newell SJ, Nastase AJ. Total carbohydrates in nectar of *Sarracenia purpurea* L. (northern pitcher plant). Am Midl Nat. 1994;131(2):374-7. DOI: 10.2307/2426265.
38. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research, IRRI. 2nd Ed. John Wily and Sons, New York, US. 1984;680.
39. Post WM, Emanuel WR, Zinke PJ, Stangenberger AG. Soil carbon pools and world life zones. Nature. 1982;298(5870):156-9.
40. Singh BP, Cowie AL, Chan KY. (eds.). Soil health and climate change, Soil Biology, Springer-Verlag Berlin Heidelberg. 2011;1-414.
41. Rosenzweig C, Hillel D. Potential impacts of climate change on agriculture and food supply. Consequences. 1995;1:24-31.
42. Tejada M, Gonzalez JL, García-Martínez AM, Parrado J. Effects of different green manures on soil biological properties and maize yield. Bioresour Technol. 2008;99(6):1758-67.
43. Liu B, Gumpertz ML, Hu S, Ristaino JB. Long-term effects of organic and synthetic soil fertility amendments on soil microbial communities and the development of southern blight. Soil Biol Biochem. 2007;39(9):2302-16. DOI: 10.1016/j.soilbio.2007.04.001.
44. Brown S, Cotton M. Changes in soil properties and carbon content following compost application: results of on-farm sampling. Compost Sci Util. 2011;19(2):87-96.
45. Ondrasek G, Rengel Z. Environmental salinization processes: detection, implications & solutions. Sci Total Environ. 2021;754:142432.
46. Baghbani-Arani A, Modarres-Sanavy SAM, Poureisa M. Improvement the soil physicochemical properties and fenugreek growth using zeolite and vermicompost under water deficit conditions. J Soil Sci Plant Nutr. 2021;21(2):1213-28.
47. Rey A. Mind the gap: non-biological processes contributing to soil CO_2 efflux. Glob Change Biol. 2015;21(5):1752-61.
48. Sun F, Lu S. Biochars improve aggregate stability, water retention, and pore-space properties of clayey soil. J Plant Nutr Soil Sci. 2014;177(1):26-33.
49. Yang X, Igalavithana AD, Oh SE, Nam H, Zhang M, Wang CH, et al. Characterization of bioenergy biochar and its utilization for metal/metalloid immobilization in contaminated soil. Sci Total Environ. 2018;640-641:704-13.
50. Cheng CH, Lehmann J, Thies JE, Burton SD. Stability of black carbon in soil across a climatic gradient. J. Geophys. Res. 2008;126.
51. Gallardo-Lara F, Nogales R. Effect of the application of town refuse compost on the soil-plant system: a review. Biol Wastes. 1987;19(1):35-62.
52. El-Sharkawy M, El-Naggar AH, AL-Huqail AA, Ghoneim AM. Acid-modified biochar impacts on soil properties and biochemical characteristics of crops grown in saline-sodic soils. Sustainability. 2022;14(13):1-21. DOI: 10.3390/su14138190.
53. Yao R, Li H, Zhu W, Yang J, Wang X, Yin C et al. Biochar and potassium humate shift the migration, transformation and redistribution of urea-N in salt-affected soil under drip fertigation: soil column and incubation experiments. Irrig Sci. 2022;40(2):267-82.
54. Sun J, He F, Shao H, Zhang Z, Xu G. Effects of biochar application on Suaeda salsa growth and saline soil properties. Environ Earth Sci. 2016;75(8):630.
55. Brevik EC. An introduction to soil science basics. In soils and human health: Brevik, E.C., Burgess, L.C.,Eds.; CRC Press: Boca Raton, FL, USA. 2013;3-28.
56. Lützow MV, Kögel-Knabner I, Ekschmitt K, Matzner E, Guggenberger G, Marschner B et al. Stabilization of organic matter in temperate soils: mechanisms and their relevance under different soil conditions—

a review. Eur J Soil Sci. 2006;57(4):426-45.

57. Moradi S, Rasouli-Sadaghiani MH, Sepehr E, Khodaverdiloo H, Barin M. Soil nutrients status affected by simple and enriched biochar application under salinity conditions. Environ Monit Assess. 2019;191(4):257.
58. Jiang Z, Lian F, Wang Z, Xing B. The role of biochars in sustainable crop production and soil resiliency. J Exp Bot. 2020;71(2):520-42.
59. Lu W, Ding W, Zhang J, Li Y, Luo J, Bolan N et al. Biochar suppressed the decomposition of organic carbon in a cultivated sandy loam soil: A negative priming effect. Soil Biol Biochem. 2014;76:12-21.
60. Caravaca F, Lax A, Albaladejo J. Organic matter, nutrient contents and cation exchange capacity in fine fractions from semiarid calcareous soils. Geoderma. 1999;93(3-4):161-76.
61. Blanco-Canqui H. Biochar and soil physical properties. Soil Sci Soc Am J. 2017;81(4):687-711.
62. Ali MM. Effect of plant residues derived biochar on fertility of a new reclaimed sandy soil and growth of wheat (*Triticum aestivum* L.). Egypt. J. Soil Sci. 2018;58:93–103.
63. Lavee H, Imeso AC, Sarah P. The impact of climate change on geomorphology and desertification along a Mediterranean-arid transect. Land degradation and development. 1998;9:407- 422.
64. Zupanc V, Justin MZ. Changes in soil characteristics during landfill leachate irrigation of Populus deltoids. Waste Manag. 2010;30(11):2130-6.
65. Reich PB, Hobbie SE, Lee T, Ellsworth DS, West JB, Tilman D et al. Nitrogen limitation constrains sustainability of ecosystem response to CO_2. Nature. 2006;440(7086):922-5.
66. Mullen RW. Nutrient cycling in soils: Nitrogen in soil management: Building a stable base for agriculture; Hatfield, J.L., Sauer, T.J., Eds.; soil science society of America: Madison, WI, USA. 2011;67-78.
67. Hungate BA, Dukes JS, Shaw MR, Luo Y, Field CB. Atmospheric science. Nitrogen and climate change. Science. 2003;302(5650):1512-3.
68. Barnes RT, Gallagher ME, Masiello CA, Liu Z, Dugan B. Biochar-induced changes in soil hydraulic conductivity and dissolved nutrient fluxes constrained by laboratory experiments. PLOS ONE. 2014;9(9):e108340.
69. Saleh ME, Mahmoud AH, Rashad M. Peanut biochar as a stable adsorbent for removing N (H. sub. 4)-N from wastewater: a preliminary study. Adv Environ Biol. 2012:2170-7.
70. Spokas KA, Novak JM, Venterea RT. Biochar’s role as an alternative N-fertilizer: ammonia capture. Plant and Soil. 2012;350(1- 2):35- 42.
71. Nigussie A, Kissi E, Misganaw M, Ambaw G. Effect of biochar application on soil properties and nutrient uptake of lettuces (*Lactuca sativa*) grown in chromium polluted soils. Am Eurasian J Agric Environ Sci. 2012;12:369-76.
72. Yuan JH, Xu RK, Zhang H. The forms of alkalis in the biochar produced from crop residues at different temperatures. Bioresour Technol. 2011;102(3):3488-97.
73. Zhang P, Xue B, Jiao L, Meng X, Zhang L, Li B et al. Preparation of ball-milled phosphorus-loaded biochar and its highly effective remediation for Cd- and Pb-contaminated alkaline soil. Sci Total Environ. 2022;813:152648.
74. Liu S, Meng J, Jiang L, Yang X, Lan Y, Cheng X et al. Rice husk biochar impacts soil phosphorous availability, phosphatase activities and bacterial community characteristics in three different soil types. Appl Soil Ecol. 2017;116:12-22.
75. Germida J, Siciliano J. Microbially Mediated Process. In: Handbook of Soil Science (Sumner, M.E., Ed.), CRC Press, Boca Raton, Florida. 2000;C95-C117.
76. Rao S, Subba Rao A, Takkar PN. Changes in different forms of K under earthworm activity. National Seminar on Organic Farmingand Sustainable Agriculture, India. 1996;9-11.
77. Olk DC, Cassman KG. Reduction of potassium fixation by organic matter in vermiculitic soils. Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. 1993;307-315.
78. Verma VK, Setia RK, Sharma PL, Charanjit S, Kumar A. Pedospheric Variations in distribution of DPTA – extractable micronutrients in soils developed on different physiographic units in central parts of Punjab, India. Int J Agric Biol. 2005;7(2):243-6.
79. Silber A, Levkovitch I, Graber ER. PH-dependent mineral release and surface

properties of corn straw biochar: agronomic implications. Environ Sci Technol. 2010;44(24):9318-23.

80. Hasanuzzaman M, Alam MM, Rahman A, Hasanuzzaman M, Nahar K, Fujita M. Exogenous proline and glycine betaine mediated upregulation of antioxidant defense and glyoxalase systems provides better protection against salt-induced oxidative stress in two rice (*Oryza sativa* L.) varieties. Biomed. Res. Int., 2014;2014:757219.
Available: http:// doi: 10.1155/2014/757219.Epup2014 Jun 3.

81. Babar S, Siddiqi EH, Hussain I, Hayat Bhatti K, Rasheed R. Mitigating the effects of salinity by foliar application of salicylic acid in fenugreek. Physiol J. 2014;2014:1-6.
DOI: 10.1155/2014/869058.

82. Kizilgeci F, Yildirim M, Islam MS, Ratnasekera D, Iqbal MA, Sabagh AE. Normalized difference vegetation index and chlorophyll content for precision nitrogen management in durum wheat cultivars under semi-arid conditions. Sustainability. 2021;13(7):3725.
DOI: 10.3390/su13073725.

83. Maghsoudi K, Emam Y, Ashraf M, Arvin MJ. Alleviation of field water stress in wheat cultivars by using silicon and salicylic acid applied separately or in combination. Crop Pasture Sci. 2019;70(1):36-43.
DOI: 10.1071/CP18213.

84. Sharma A, Kumar V, Shahzad B, Ramakrishnan M, Singh Sidhu GPS, Bali AS et al. Photosynthetic response of plants under different abiotic stresses: a review. J Plant Growth Regul. 2020a;39(2):509-31
DOI: 10.1007/s00344-019-10018-x.

85. Sattar A, Cheema MA, Sher A, Ijaz M, Ul-Allah S, Nawaz A et al. Physiological and biochemical attributes of bread wheat (*Triticum aestivum* L.) seedlings are influenced by foliar application of silicon and selenium under water deficit. Acta Physiol Plant. 2019;41(8):146.
DOI: 10.1007/s11738-019-2938-2.

86. Salem EMM, Kenawey MKM, Saudy HS, Mubarak M. Influence of silicon forms on nutrient accumulation and grain yield of wheat under water deficit conditions. J Soil Sci Plant Nutration. 2022;74(3):539-48.
DOI: 10.1007/s10343-022-00629-y.

87. Mubarak MU, Zahir M, Ahmad S, Wakeel A. Sugar beet yield and industrial sugar contents improved by potassium fertilization under scarce and adequate moisture conditions. J Integr Agric. 2016; 15(11): 2620-6.
DOI: 10.1016/S2095-3119(15)61252-7.

88. Packirisamy P, Chinniah C, Baskaran Kanagaraj M, Manickavasagam K, Krishnasamy S, Senthilnayagam K. Biochemical alternation and silicon accumulation in groundnut (*Arachis hypogaea* l.) in response to root and foliar application of two sources of silicon. J Phosphorus Sulfur Silicon Relat Elem. 2019;194(9):9917-921.
DOI: 10.1080/10426507.2019.1576679.

89. DoGramaci, Mahmut, Arthurs, Steven P, Chen, et al. Silicon applications have minimal effects on scirtothrips dorsalis (thysanoptera: thripidae) populations on pepper plant, capsicum annum l. Florida Entomologist An International J. for the Americas. 2013;96(1):48-54.
Available:https://doi.org/10.1653/024.096.0106.

90. Puppe D, Sommer M. Experiments, uptake mechanisms, and functioning of silicon foliar fertilization—a review focusing on maize, rice, and wheat. Adv Agron. 2018;152:1-49.
DOI: 10.1016/bs.agron.2018.07.003.

91. Ghouri F, Ali Z, Naeem M, Ul-Allah S, Babar M, Baloch FS et al. Effects of silicon and selenium in alleviation of drought stress in rice. Silicon. 2021;14:5453-61.
DOI: 10.1007/s12633-021-01277-z.

92. Bhambhani S, Kondhare KR, Giri AP. Diversity in chemical structures and biological properties of plant alkaloids. Molecules. 2021;26(11):3374.
DOI: 10.3390/molecules26113374

93. Kousar R, Qureshi R, Din JU, Munir M, Shabbir G. Salicylic acid mediated heat stress tolerance in selected bread wheat genotypes of pakistan. Pak J Bot. 2018;50(6):2141-3146.

94. Mahmoud SH, Salama DM, El-Tanahy AMM, Abd El-Samad EH. Utilization of seaweed (*Sargassum vulgare*) extract to enhance growth, yield and nutritional quality of red radish plants. Ann Agric Sci. 2019;64(2):167-75.
DOI: 10.1016/j.aoas.2019.11.002.

95. Gupta S, Stirk WA, Plačková L, Kulkarni MG, Doležal K, Van Staden J. Interactive effects of plant growth-promoting rhizobacteria and a seaweed extract on the growth and physiology of onion (*Allium*

cepa L.). J Plant Physiol. 2021; 262:153437.
DOI: 10.1016/j.jplph.2021.153437

96. El-Metwally IM, Geries L, Saudy HS. Interactive effect of soil mulching and irrigation regime on yield, irrigation water use efficiency and weeds of trickle-irrigated onion. Arch Agron Soil Sci. 2022; 68(8):1103-16.
DOI: 10.1080/03650340.2020.1869723.
97. Kocira S, Szparaga A, Kuboń M, Czerwińska E, Piskier T. Morphological and biochemical responses of *Glycine max* (L.) Merr. To the use of seaweed xtract. Agronomy. 2019;9(2):93.
DOI: 10.3390/agronomy9020093.
98. Singh KM, Singh HK. Effect of foliar application of potassium nitrate on late sown wheat (*Triticum aestivum* L.) in mitigating terminal heat stress. J Pharmacogn Phytochem. 2020;9(6):492-5.
99. Hasanuzzaman M, Bhuyan MHMB, Zulfiqar F, Raza A, Mohsin SM, Al Mahmud JA et al. Reactive oxygen species and antioxidant defense in plants under abiotic stress: revisiting the crucial role of a universal defense regulator. Antioxidants (Basel). 2020;9(8):1-52.
DOI: 10.3390/antiox9080681
100. Sahi N, Mostajeran A, Ghanadian M. Altering amino acid profile in *Catharanthus roseus* (L.) G. Don using potassium and ascorbic acid treatments. Open Biochem J. 2021;15(1):53-60.
DOI: 10.2174/1874091X02115010053.
101. Siddiqui MH, Khan MN, Mukherjee S, Alamri S, Basahi RA, Al-Amri AA et al. Hydrogen sulfide (H_2S) and potassium (K^+) synergistically induce drought stress tolerance through regulation of H^+-ATPase activity, sugar metabolism, and antioxidative defense in tomato seedlings. Plant Cell Rep. 2021; 40(8): 1543-64.
DOI: 10.1007/s00299-021-02731-3.
102. Xu X, Du X, Wang F, Sha J, Chen Q, Tian G et al. Effects of potassium levels on plant growth, accumulation and distribution of carbon, and nitrate metabolism in apple dwarf rootstock reedlings. Front Plant Sci. 2020;11:1-13.
103. Sardans J, Peñuelas J. Potassium control of plant functions: ecological and Agricultural Implications. Plants (Basel). 2021;10(2):419.
DOI: 10.3390/plants10020419.
104. Anokye E, Lowor ST, Dogbatse JA, Padi FK. Potassium application positively modulates physiological responses of cocoa seedlings to drought stress. Agronomy. 2021;11(3):563.
DOI: 10.3390/agronomy11030563.
105. Abd El-Mageed TA, Semida WM, Abdou NM, Abd El-Mageed SA. Coupling effects of potassium fertilization rate and application time on growth and grain yield of wheat (*Triticum aestivum* L.) plants grown under Cd-contaminated saline soil. J Soil Sci Plant Nutration. 2023;23:1070-84.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101374