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Residual Effect of Wheat Previouly Grown on A Saline Soil Amended with Biochar and Sprayed with Nano-Materials on some of Its Indigenous Properties

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ABSTRACT

The wheat plant was previously cultivated on a salty soil treated with biochar and/or sprayed with K, either in its regular form or the nano one, with nanoparticles of Si and organic fertilizer dominated by amino acids in this experiment. Soil samples collected after harvesting wheat were utilized in this experiment to examine the effects of the aforementioned treatments on its qualities. Although biochar improved the soil pH, it had a substantial impact on lowering the soil salinity indicated as electrical conductivity, according to the results (EC in dSm^{-1}). However, the use of biochar might raise the soil organic matter (SOM) and, as a result, the cation exchange capacity of the soil (CEC). Adding to this, it seems that biochar may have increased the amount of N, P, and K that was accessible. This impact was amplified when biochar was administered together with the K. The application of K considerably lowered soil pH. The pH of the soil was significantly lowered by using K nanoparticles. K fertilizer, particularly when given in its nano-form, may help to reduce soil salinity a little. When K was combined with charcoal or nanoparticles, this impact was amplified. Although it increased the SOM, it also contributed to raising N, P, and K concentrations in the soil. In addition to N, P, and K, the nanoparticles put to the soil improved the CEC and increased the OM content.

Keywords: saline soil – biochar – nano-fertilization – CEC – N, P and K.

INTRODUCTION

Soil salinity stress is one of the major abiotic stresses affecting agricultural production in arid and semi-arid regions worldwide (Ali *et al*.,2016; Kamal *et al*., 2016; Helmi *et al*., 2018; Saifullah *et al*., 2018; Farid *et al*., 2019). Global agricultural yields are reduced by salinity, which has a severe influence on soil qualities and the ecological balance of large regions of land (Farid *et al*., 2014, Shrivastava and Kumar, 2015, Farid *et al*., 2020). It is possible that salinity issues in these places may be traced back to a number of factors, including fundamental sources such as the parent rock from which the soil was generated and salty water incursion from adjacent sea and ocean waves. The second source of soluble salts in soils is the secondary salinization. Secondary salinization of soils is caused in part by irrigation with sub-par water and poor drainage (Stavi *et al*., 2021). Secondary salinization degrades an estimated 1128 million hectares of soil (Wicke *et al*., 2011). There are several processes that salinity influences, including plant development and nutrient intake (Kumar *et al*., 2021, Singh, 2022). When plants are able to withstand salt stress and continue to thrive, this is known as salinity tolerance (Kumar *et al*. 2022). Soil and crop production may be adversely affected by salinity, making it a serious threat to long-term agricultural growth. Biochar has grown in popularity among scientists in the last several years (Abdelhafez *et al*., 2014 a and b; Abdelhafez *et al*., 2021).

Microorganisms have a hard time decomposing porous solid carbonaceous biochar (Abdelhafez *et al*., 2016; Mohamed *et al*., 2018; Farid *et al*., 2022). Pyrolysis is the heat breakdown of organic compounds in the absence or restricted presence of oxygen (Wang *et al*., 2017; Bassouny and Abbas, 2019; Tolba *et al*., 2021). Novac *et al*., (2009) found that biochar enhances soil physical, chemical, and biological properties (Saifullah *et al*., 2018; Elshony *et al*., 2019).

Additions of biochar to the soil led to a rise in pH, soil cation exchange capacity (CEC) as well as soil organic matter content (Singh *et al*.,2022), and soluble and available K (Amin, 2016). The second most abundant element in the Earth's crust after oxygen is silicon (Luyckx *et al*., 2017). Despite the fact that it is not needed for plant development, it is advantageous to particular crops, such as wheat. Boosted disease resistance increased wheat output. Abiotic stress, such as drought and salt, may be eased by the buildup of free amino acids and antioxidants in the plant, which improves the plant's ability to withstand the abiotic stress (Liu *et al*.,2009; Siddiqui and Al-Wihabi,2014; Kalteh *et al*.,2018; Ayman *et al*., 2020). When water is under severe saline stress, Si has been shown to boost water utilization efficiency (Parveen and Ashraf, 2010). Salinity stress may harm plant development because of its negative influence on cell stiffness and water content control, as well as its propensity to translocate along an electrochemical gradient (Marschner, 1995; Hajiboland and Joudmand, 2009).

Consequently, it may be concluded that both Si and K are critical for reducing plant oxidative damage and salt stress (Chen *et al*., 2016; Gomaa *et al*., 2021). Si and/or K treatment of the plant is likely to result in a higher biological yield. Thus, the amount of biomass remaining in the salty soil after harvesting will rise, and the organic leftovers may have

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possible consequences for the soil where the plant was growing. Therefore, the present study was conducted in order to shed light on the possible consequences that may arise in the qualities of a salty soil previously grown with wheat and treated with various amendments.

MATERIALS AND METHODS

Site description:

The current experiment was conducted on a saline soil of field located at Al-Saniyah, Iraq (longitude 44º 55- 31.78– E and latitude 31º 59' 34.40″ N) in the winter seasons of 2018-2019 and 2019 -2020.

The experiment aimed at studying the residual effects of three factors i.e. biochar, K fertilization in both its ordinary and nanoforms, and nanoparticles of Si ,organic fertilizer dominated by amino acids and a combination of the aforementioned nanoparticles on yield of wheat grown on a saline soil (a paper published elsewhere) and consequently the changes that might occurred in some of the indigenous properties of the soil remained after harvesting of wheat owing to the aforementioned agricultural and fertilization treatment (the current investigation).Thus, the experimental design was a three factors randomized complete block. The first factor was biochar which was used at two rates 0 Mg ha^{-1} (control, Bo) and 10 Mg ha^{-1} (treatment, B1). The second factor was K fertilization whose treatments were no K addition K0, spraying with K in its ordinary form at a rate of 2gL^{-1} (K1), spraying the plant with nano K fertilizer at two rates i.e.1gL^{-1} and 2gL^{-1} (K2 and K3, respectively). The third factor was spraying the plant with nano-particles through a control treatment in which the plant received no nano-particles, (A0) , spraying with Si at a rate of 2 mL L^{-1} (A1) ,spraying with an organic fertilizer whose composition was dominated by amino acids (A2) and spraying the plant with a combination of the aforementioned nano-particles(A3).

Soil analyses

The physical and chemical analyses were performed according to Klute (1986) and Page *et al*., (1982) using representative soil samples from the previously cultivated plots, air dried, crushed, and sieved using a 2 mm sieve. It was found that the soil was of a silt clay loam texture, original pH of 7.7, an electrical conductivity of 4.4 dSm^{-1}, and OM content of 11.2g kg^{-1}.The available contents of N, P and K were 17, 11 and 199 mg kg^{-1}, respectively.

Following the harvest of the wheat, the chemical characteristics of the soils in the various plots were assessed using the conventional procedures outlined by Page *et al* (1982). Soil organic matter was determined by wet digestion method using 1N of $K_2Cr_2O_7$.Available N was determined using a solution of 2 M KCl according to Keeney and Nelson' (1982). Available P was determined using a solution of 0.5M $NaHCO_3$ pH 8.5 according to Watanabe and Olsen (1965). Available K was determined using a solution of 1N NH_4OAc pH 7. 0 according to Jackson (1967).

Statistical analysis:

The experimental plots were statistically arranged in completely randomized block design with three replicates .The analysis of variance for the final data set was conducted using ANOVA statistical analysis and the values of LSD at 0.05 level was carried out by SPSS (ver. 22) according to Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

Results

1. Soil acidity (pH):

For the first season, there was little variation in pH levels across treatments, according to data in Table 1. The treatment B0K0A0 resulted in the lowest pH value of 7.50, whereas the treatment B1K1A0 produced the highest pH value of 7.63. The soil's buffering capability is to blame for these low pH variations. However, it can be seen that the biochar application resulted in a modest rise in soil pH. The treatment B0K0A0, which did not get modification, had the lowest pH value (7.35) in the second season, whereas the treatment B1K0A0 had the highest pH value (7.48). There was, however, a considerable change in soil pH between the various treatments and the control treatment. Note that whether biochar was used alone or in combination with any of the other amendments, the pH values were higher than those obtained when biochar was not used. No noticeable influence was seen on soil pH levels from the nano treatments.

Table 1. Effect of some agricultural and fertilization treatments on soil pH value after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)	Nano materials (N) A0	A1	A2	A3	Mean
2018-2019 season						
B0	K0	7.50	7.50	7.50	7.50	7.50
	K1	7.50	7.53	7.53	7.53	7.52
	K2	7.50	7.50	7.50	7.50	7.50
	K3	7.50	7.53	7.50	7.53	7.52
	Mean	7.50	7.52	7.51	7.52	7.51
B1	K0	7.60	7.60	7.60	7.60	7.60
	K1	7.63	7.63	7.63	7.60	7.62
	K2	7.60	7.60	7.60	7.53	7.58
	K3	7.57	7.63	7.63	7.60	7.61
	Mean	7.60	7.62	7.62	7.58	7.60
General mean		7.55	7.57	7.56	7.55	
Mean of K						Mean
K0		7.55	7.55	7.55	7.55	7.55
K1		7.57	7.58	7.58	7.57	7.57
K2		7.55	7.55	7.55	7.52	7.54
K3		7.53	7.58	7.57	7.57	7.56
L.S.D. at	B K	N	BK	BN	NK	BKN
0.05	0.0006 0.0009	0.0009	0.0013	0.0013	0.0018	0.0025
2019-2020 seasons						
B0	K0	7.35	7.35	7.35	7.35	7.35
	K1	7.35	7.38	7.38	7.38	7.37
	K2	7.35	7.35	7.35	7.35	7.35
	K3	7.35	7.38	7.35	7.38	7.37
	Mean	7.35	7.37	7.36	7.37	7.36
B1	K0	7.45	7.45	7.45	7.45	7.45
	K1	7.48	7.48	7.48	7.45	7.47
	K2	7.45	7.45	7.45	7.38	7.43
	K3	7.42	7.48	7.48	7.45	7.46
	Mean	7.45	7.46	7.46	7.43	7.45
General mean		7.40	7.42	7.41	7.40	
Mean of K						Mean
K0		7.40	7.40	7.40	7.40	7.40
K1		7.42	7.43	7.43	7.42	7.42
K2		7.40	7.40	7.40	7.37	7.39
K3		7.38	7.43	7.42	7.42	7.41
L.S.D. at	B K	N	BK	BN	NK	BKN
0.05	0.0006 0.0009	0.0009	0.0013	0.0013	0.0018	0.0025

Treatment designation:B0 and B1: no biochar and 10 Mgha^{-1}, respectively. K0, K1, K2 and K3: non, normal 2 gL^{-1}, nano 1 gL^{-1} and nano 2 gL^{-1} spray solution, respectively. A0, A1 A2 and A3: non treated, Si, amino acid and Si^+ amino acid, respectively. N.S: non-significant ($P \geq 0.05$)

2. Electrical conductivity (EC) in dSm^{-1} (soil salinity)

The treatment B1K3A3 had the lowest EC value (3.250 dSm^{-1}) in the first season, whereas treatment

B0K0A0 had the greatest EC value (4.44 dSm^{-1}) according to data in Table 2.An average of 0.67 dSm^{-1} of soil salinity was found in biochar (B) compared to control treatment B0K0A0, which was shown to be the least effective amendment. For K1, K2, and K3 treatments, potassium fertilizer (K) had average declines of 4.69; 5.68; and 10.37 percent when compared to the B0K0A0-treatments. This indicates that K addition might somewhat lower EC values when administered in its nano forms. There were no significant variations in EC values between the control treatment and any of the three other treatments, K1, K2, or K3. Treatments A1, A2, and A3 each reduced the major impact of nanomaterials (A) by 77.7, 2.30, and 7.93 percent. Generally, the average values of EC decreased significantly when biochar was added to K or A treatments, compared to the average values achieved without biochar. The use of agricultural organic fertilizer alone (A2) or in combination with nano silicon had no significant effect on soil salinity, although the EC value decreased dramatically as a result of the application of agricultural silicon alone (A2) (A1).

Table 2. Effect of some agricultural and fertilization treatments on soil EC (dS m^{-1}) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)	Nano materials (N) A0	A1	A2	A3	Mean
2018-2019 season						
B0	K0	4.44	4.42	4.40	4.30	4.39
	K1	4.26	4.24	4.20	4.10	4.20
	K2	4.27	4.25	4.11	4.06	4.17
	K3	4.06	4.01	3.90	3.80	3.94
	Mean	4.26	4.23	4.15	4.07	4.18
B1	K0	3.74	3.72	3.70	3.66	3.71
	K1	3.57	3.54	3.50	3.48	3.53
	K2	3.52	3.50	3.44	3.40	3.47
	K3	3.40	3.35	3.30	3.25	3.33
	Mean	3.56	3.53	3.49	3.45	3.51
General mean		3.91	3.88	3.82	3.76	
Mean of K						Mean
K0		4.09	4.07	4.05	3.98	4.05
K1		3.92	3.89	3.85	3.79	3.86
K2		3.90	3.88	3.78	3.73	3.82
K3		3.73	3.68	3.60	3.53	3.63
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0046	0.0066	0.0066	0.0093	0.0093	0.0131	0.0185
2019-2020 seasons						
B0	K0	4.70	4.68	4.67	4.56	4.65
	K1	4.51	4.50	4.46	4.35	4.45
	K2	4.53	4.51	4.35	4.30	4.42
	K3	4.30	4.25	4.14	4.03	4.18
	Mean	4.51	4.49	4.40	4.31	4.43
B1	K0	3.97	3.95	3.93	3.88	3.93
	K1	3.79	3.76	3.71	3.69	3.74
	K2	3.74	3.71	3.65	3.60	3.67
	K3	3.60	3.55	3.49	3.45	3.52
	Mean	3.77	3.74	3.70	3.66	3.72
General mean		4.14	4.11	4.05	3.98	
Mean of K						Mean
K0		4.34	4.31	4.30	4.22	4.29
K1		4.15	4.13	4.09	4.02	4.10
K2		4.13	4.11	4.00	3.95	4.05
K3		3.95	3.90	3.82	3.74	3.85
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0049	0.0069	0.0069	0.0098	0.0098	0.0139	0.0196

See footnotes of Table 1.

EC values ranged from 3.45 dSm^{-1} for treatment B1K3A3 to 4.70 dSm^{-1} for treatment B0K0A0 in season two. Without nano or K fertilizer, biochar's (B) primary impact on decreasing EC averaged 0.71 dSm^{-1}. In comparison to the control treatment, potassium fertilizer (K) had an average impact of 4.43 percent, 5.59 percent, and 10.26 percent on EC value. Only when treated in nano K form and at a greater rate of 2g L^{-1} did the applied K have a substantial impact on soil salinity. Regardless of whether or not biochar was used in conjunction with the administration of K, this resulted. In contrast, the major impact of nanomaterials (A) resulted in declines of 0.72, 2.17 and 3.86 percent, respectively, attributed to A1 and A2. Thus, the combination of A1 and A2 had a significant impact in lowering the EC value. EC values decreased significantly when biochar was applied in combination with treatments A1, A2 or A3 compared to their average values. Although the control treatment and the corresponding one with nano Si alone had no significant differences in the mean EC value, there was a significant decrease in EC value attained due to the treatment A2 whether alone or with A1.

3. The soil cation exchange capacity (CEC) (cmolckg-1)

CEC values were lowest (23.60 and 22.89 cmolckg-1, respectively) for treatment B0K0A0 but greatest (27.40 and 26.58 cmolckg- 1, respectively) for treatment B1K3A3 in both seasons of the experiment, according to data in Table 3.

Table 3. Effect of some agricultural and fertilization treatments on soil CEC ($cmol_c kg^{-1}$) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)	Nano materials (N) A0	A1	A2	A3	Mean
2018-2019 season						
B0	K0	23.60	23.60	23.60	23.60	23.60
	K1	23.60	23.60	23.60	23.60	23.60
	K2	23.60	23.60	23.60	23.60	23.60
	K3	23.60	23.60	23.60	23.60	23.60
	Mean	23.60	23.60	23.60	23.60	23.60
B1	K0	27.40	27.40	27.40	27.40	27.40
	K1	27.40	27.40	27.40	27.40	27.40
	K2	27.40	27.40	27.40	27.40	27.40
	K3	27.40	27.40	27.40	27.40	27.40
	Mean	27.40	27.40	27.40	27.40	27.40
General mean		25.50	25.50	25.50	25.50	
Mean of K						Mean
K0		25.50	25.50	25.50	25.50	25.50
K1		25.50	25.50	25.50	25.50	25.50
K2		25.50	25.50	25.50	25.50	25.50
K3		25.50	25.50	25.50	25.50	25.50
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	N.S	N.S	N.S	N.S	N.S	N.S	N.S
2019-2020						
B0	K0	22.89	22.89	22.89	22.89	22.89
	K1	22.89	22.89	22.89	22.89	22.89
	K2	22.89	22.89	22.89	22.89	22.89
	K3	22.89	22.89	22.89	22.89	22.89
	Mean	22.89	22.89	22.89	22.89	22.89
B1	K0	26.58	26.58	26.58	26.58	26.58
	K1	26.58	26.58	26.58	26.58	26.58
	K2	26.58	26.58	26.58	26.58	26.58
	K3	26.58	26.58	26.58	26.58	26.58
	Mean	26.58	26.58	26.58	26.58	26.58
General mean		24.74	24.74	24.74	24.74	
Mean of K						Mean
K0		24.74	24.74	24.74	24.74	24.74
K1		24.74	24.74	24.74	24.74	24.74
K2		24.74	24.74	24.74	24.74	24.74
K3		24.74	24.74	24.74	24.74	24.74
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	N.S	N.S	N.S	N.S	N.S	N.S	N.S

See footnotes of Table 1.

B0K0A0 increased CEC values by 3.80 and 3.69 cmolckg-1on average, whereas biochar (B) had no influence on CEC values. Treatments K1, K2, and K3 had no influence on the major effect of potassium fertilizer (K), as measured by the CEC. This study found no significant changes in CEC values amongst the treatments that got K in either the conventional or nano form, regardless of whether biochar was used in the process. The control treatment. However, when K was applied in conjunction with biochar, CEC values were generally higher than when it was applied solely. Although the CEC values of the nanomaterials (A) may be raised, no substantial changes were seen in these values.

4. The soil organic matter (O.M) (g kg^{-1})

Table 4 shows that the organic matter content varied by treatment during both seasons of the experiment. The treatment B0K0A0 had the lowest values, while the treatment B1K3A3 had the highest values. This result was consistent over the course of the two research seasons.

Organic matter content was increased by average values of 0.41 and 0.39, respectively, in the two seasons of the experiment when biochar (B) was used instead of the treatment B0K0A0.

Table 4. Effect of some agricultural and fertilization treatments on soil OM (g kg^{-1}) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)		Nano materials (N) A0	A1	A2	A3	Mean
			2018-2019 season				
	A0		13.0	13.1	13.2	13.3	13.2
	K1		13.2	13.4	13.4	13.6	13.4
B0	K2		13.3	13.5	13.6	13.7	13.5
	K3		13.5	13.6	13.7	13.9	13.7
	Mean		13.3	13.4	13.5	13.6	13.4
	A0		17.0	1..2	17.3	17.5	17.3
	K1		17.2	1..4	17.5	17.6	17.4
B1	K2		17.3	1..4	17.6	17.7	17.5
	K3		17.5	1..6	17.7	18.0	17.7
	Mean		17.3	1..4	17.5	17.7	17.5
General mean			15.3	15.4	15.5	15.7	
Mean of K							Mean
A0			15.0	15.1	15.3	15.4	15.2
K1			15.2	15.4	15.5	15.6	15.4
K2			15.3	15.5	15.6	15.7	15.5
K3			15.5	15.6	15.7	16.0	15.7
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.025	0.036	0.036	0.051	0.051	N.S	N.S
			2019-2020 season				
	K0		12.7	12.8	12.9	13.1	12.9
	K1		13.0	13.1	13.1	13.3	13.1
B0	K2		13.1	13.2	13.4	13.5	13.3
	K3		13.2	13.4	13.5	13.6	13.4
	Mean		13.0	13.1	13.2	13.4	13.2
	K0		16.7	16.9	17.0	17.2	16.9
	K1		16.9	17.0	17.2	17.2	17.1
B1	K2		17.0	17.1	17.2	17.4	17.2
	K3		17.2	17.3	17.4	17.6	17.4
	Mean		16.9	17.1	17.2	17.4	17.1
General mean			15.0	15.1	15.2	15.4	
Mean of K							Mean
K0			14.7	14.8	14.9	15.1	14.9
K1			14.9	15.1	15.2	15.3	15.1
K2			15.0	15.1	15.3	15.4	15.2
K3			15.2	15.3	15.4	15.6	15.4
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.025	0.035	0.035	0.050	N.S	N.S	0.099

See footnotes of Table 1.

The main effect of potassium fertilizer (K) was to increase organic matter content by an average of 1.32, 1.97, and 3.29 percent in the first season, and by 1.34, 2.01 and 3.36 percent in the second season.

A1 and A2 treatments increased organic matter content by 0.65, 1.31, and 2.61 percent respectively in the first season, while A3 treatments increased the organic matter content by 0.67, 1.33, and 2.67 percent.

Regardless of whether K was applied in its normal or nano form, or whether it was applied with or without biochar, the applied K had no significant effect on the organic matter content. When biochar was used in conjunction with other treatments, the organic matter content values were generally higher. Also, regardless of whether or not biochar was used in all nano-fertilization treatments, there was a significant increase in OM content. Although there were no significant differences in the OM content due to biochar or K addition, there were significant increases in the OM content due to organic fertilizer application (dominated by amino acids) whether applied alone (K2) or mixed with nano silicon in the treatment that received only K1 but no significant differences in OM content due to nano silicon application (K1) (K3)

Comparing the OM content of biochar (B) to that of the control treatment (B0K0A0), an increase of 0.39 percent was observed on average.

As compared to the OM of the control treatment, potassium fertilizer (K) has an average impact of 1.34, 2.01 and 3.36 percent in terms of the OM content in K1, K2 and K3, respectively.

For treatments A1, A2 and A3 compared with treatment B0K0A0: Si, amino acid and Si^{+} amino acid, OM content increases by 0.67, 1.33, and 2.67 percent, respectively.

OM (percent) increased non-significantly between the control treatment and the treatments containing 2 g L^{-1} of normal potassium (K1) or 1 g L^{-1} of nano-potassium (K2), but the OM content increased significantly due to the application of 2 g L^{-1} of nano potassium (K3), whether it was used alone or in conjunction with biochar. However, it was shown that the organic matter (OM) content obtained by the various treatments was typically greater when the biochar was used in conjunction with the comparable treatment without biochar.

Nitrogen (N) concentration in soil(mg kg^{-1})

All of the nano-fertilization treatments included the use of biochar, which resulted in a significant increase in OM content on average according to data in Table 5. In addition, the OM content increased significantly, regardless of whether biochar was used, as a result of all treatments including nanoparticles. Organic fertilizer (A2) treatment alone resulted in significant increases, as did the addition of nano silicon mg kg-1 of soil nitrogen content.

Both the first and second seasons yielded soils with the lowest levels of N after harvest, while the first season yielded soils with highest levels of N.

More than 13% more N was found in the biochar (B) treatment compared to the control treatment, which did not receive any of the amendments under study (B0K0A0). Due to K1, K2 and K3, N content decreased by 2.01, 4.41, and 5.83 percent, respectively, as a result of potassium fertilizer (K).

N content is reduced by 0.34 and 1.55 percent, respectively, as a result of the main effect of nano materials (A). N content in soil was not significantly reduced by fertilization with K1 (K1), while N content in soil was significantly reduced by the nano-potassium treatment (K2). Nano-fertilization treatments (A) also show no significant decrease in N content when compared to the control group (B). It was compared to results obtained without biochar, it was found that the N contents were consistently higher when biochar was used in all treatments. It was shown that employing biochar significantly increased N content compared to using just nano-fertilization treatments without applying any biochar at all. This treatment got biochar and a greater rate of sprayed nano-K, as well as the combined application of nano Si+ the organic fertilizer, which resulted in an increase of 71.0 percent compared to the control treatment in the second season's N content (36.97 gkg-1). The primary impact of biochar (B) was an increase in nitrogen content of 23.96 percent on average when compared to the control.

There is a 7.42, 16.48, and 22.99 percent increase in N content owing to K1, K2, and K3 potassium fertilizer, respectively. Due to the treatments A1, A2, and A3, nanomaterials (A) result in a 3.93, 7.00, and 10.36 percent increase in N content.

Table 5. Effect of some agricultural and fertilization treatments on soil N content (mgkg^{-1}) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)		Nano materials (N) A0	A1	A2	A3	Mean
			2018-2019 season				
B0		K0	22.60	22.50	22.40	22.20	22.42
		K1	22.00	22.00	21.90	21.80	21.93
		K2	21.60	21.50	21.40	21.20	21.43
		K3	21.20	21.10	21.00	19.90	20.80
		Mean	21.85	21.78	21.68	21.27	21.64
B1		K0	25.55	25.40	25.20	25.00	25.29
		K1	25.00	24.90	24.80	24.60	24.83
		K2	23.60	24.50	24.40	24.30	24.20
		K3	24.30	24.20	24.10	24.00	24.15
		Mean	24.61	24.75	24.63	24.48	24.62
General mean			23.23	23.26	23.15	22.87	
Mean of K							Mean
K0			24.08	23.95	23.80	23.60	23.86
K1			23.50	23.45	23.35	23.20	23.38
K2			22.60	23.00	22.90	22.75	22.81
K3			22.75	22.65	22.55	21.95	22.47
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0199	0.0282	0.0282	0.0399	0.0399	0.0564	0.0797
			2019-2020 season				
B0		K0	21.62	22.56	23.50	24.44	23.03
		K1	23.50	24.75	25.69	26.32	25.07
		K2	26.32	27.26	28.51	29.14	27.81
		K3	28.20	29.45	30.08	30.08	29.45
		Mean	24.91	26.01	26.95	27.50	26.34
B1		K0	28.20	29.45	30.08	31.33	29.77
		K1	30.39	31.33	31.96	32.90	31.65
		K2	31.96	32.90	33.84	36.03	33.68
		K3	33.84	35.09	36.03	36.97	35.48
		Mean	31.10	32.19	32.98	34.31	32.65
General mean			28.00	29.10	29.96	30.90	
Mean of K							Mean
K0			24.91	26.01	26.79	27.89	26.40
K1			26.95	28.04	28.83	29.61	28.36
K2			29.14	30.08	31.18	32.59	30.75
K3			31.02	32.27	33.06	33.53	32.47
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0506	0.0715	0.0715	0.1011	0.1011	0.1430	0.2023

See footnotes of Table 1.

Phosphorus (P) concentration in soil (mg kg^{-1})

Following wheat plant removal, soil P content increased to13.63 g kg^{-1} due to treatment B1K0A0 according to data in Table 6.. When compared to the control, biochar (B) had an average effect of 32.21 percent on boosting the P content of the soil.

Potassium fertiliser (K) had the greatest impact, with average drops of 2.79, 5.15, and 7.26 percent attributable to K1, K2, and K3.

Treatments A1, A2, and A3 all exhibit reductions of 0.69, 1.48, and 2.43 percent in the major impact of nanomaterials (A). There was a significant drop in P content with the application of organic fertilizer A1.

Table 6. Effect of some agricultural and fertilization treatments on soil P content (mg kg^{-1}) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)		Nano materials (N) A0	A1	A2	A3	Mean
			2018-2019 season				
B0		K0	10.20	10.20	10.10	10.00	10.13
		K1	10.00	9.87	9.87	9.80	9.88
		K2	9.80	9.73	9.67	9.63	9.71
		K3	9.63	9.60	9.50	9.40	9.53
		Mean	9.91	9.85	9.78	9.71	9.81
B1		K0	13.63	13.63	13.53	13.43	13.56
		K1	13.40	13.27	13.00	12.87	13.13
		K2	12.90	12.77	12.73	12.60	12.75
		K3	12.63	12.47	12.43	12.20	12.43
		Mean	13.14	13.03	12.92	12.78	12.97
General mean			11.52	11.44	11.35	11.24	
Mean of K							Mean
K0			11.92	11.92	11.82	11.72	11.84
K1			11.70	11.57	11.43	11.33	11.51
K2			11.35	11.25	11.20	11.12	11.23
K3			11.13	11.03	10.97	10.80	10.98
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0201	0.0285	0.0285	0.0402	0.0402	0.0569	0.0805
			2019-2020 season				
B0	K0		10.00	10.00	9.90	9.80	9.92
	K1		9.80	9.67	9.67	9.60	9.69
	K2		9.60	9.54	9.47	9.44	9.51
	K3		9.44	9.41	9.31	9.21	9.34
	Mean		9.71	9.65	9.59	9.51	9.62
B1	K0		13.36	13.36	13.26	13.17	13.29
	K1		13.13	13.00	12.74	12.61	12.87
	K2		12.64	12.51	12.48	12.35	12.50
	K3		12.38	12.22	12.19	11.96	12.18
	Mean		12.88	12.77	12.67	12.52	12.71
General mean			11.29	11.21	11.13	11.02	
Mean of K							Mean
K0			11.68	11.68	11.58	11.48	11.61
K1			11.47	11.34	11.20	11.11	11.28
K2			11.12	11.03	10.98	10.89	11.00
K3			10.91	10.81	10.75	10.58	10.76
L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.0197	0.0279	0.0279	0.0395	0.0395	0.0558	0.0789

See footnotes of Table (1).

The standard potassium treatment (K1) resulted in a negligible drop in phosphorus content, but the nano-potassium treatments, whether used in conjunction with or without biochar, resulted in a considerable decrease in phosphorus content. Due to nano-particle treatments, there was a negligible drop in the P content of the samples compared to the control samples. It was found that the P contents were greater when biochar was mixed with the other amendments than when the same amendments were used without the addition of biochar. Biochar and nanoparticles together resulted in a significant increase in the average P content, compared to the average P value that would have been obtained had the nanoparticles been added without the use of biochar. Almost to the same amount as in the first season, the applied amendments influenced soil P concentration in the second season.

Potassium (K) concentration in soil (mg kg^{-1})

According to the first season's data in Table 7, the lowest (174.33 g kg-1) and greatest (207.33 g kg-1) concentrations of K in soil were found in the treatment B0K0A2 and the treatment B1K3A0, respectively.

Biochar (B) had an average impact on soil K content of 11.38 percent.

Soil potassium concentration increased by 0.99, 1.84, and 3.86 percent on average as a result of applying K1, K2, and K3, respectively.

Due to treatments A1, A2, and A3, the soil content of accessible K decreased by 1.02, 2.13, and 3.41 percent in comparison to the control.

Table 7. Effect of some agricultural and fertilization treatments on soil K content (mg kg^{-1}) after harvest of wheat grown in a salt-affected soil.

Biochar (B)	K fertilizer (K)	Nano materials (N) A0	A1	A2	A3	Mean
2018-2019 seasons						
B0	K0	177.33	176.33	174.33	177.33	176.33
	K1	177.33	177.33	174.33	172.00	175.25
	K2	180.00	178.33	178.33	176.00	178.17
	K3	186.00	185.00	184.33	180.33	183.92
	Mean	180.17	179.25	177.83	176.42	178.41
B1	K0	198.00	196.00	194.00	190.33	194.58
	K1	203.00	200.00	198.00	196.33	199.33
	K2	204.67	202.33	197.33	194.00	199.58
	K3	207.33	202.67	200.33	195.00	201.33
	Mean	203.25	200.25	197.42	193.92	198.71
General mean		191.71	189.75	187.62	185.17	
Mean of K						Mean
K0		187.67	186.17	184.17	183.83	185.46
K1		190.17	188.67	186.17	184.17	187.29
K2		192.34	190.33	187.83	185.00	188.87
K3		196.67	193.84	192.33	187.67	192.62

L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.1362	0.1926	0.1926	0.2723	0.2723	0.3851	0.5446

Biochar (B)	K fertilizer (K)	A0	A1	A2	A3	Mean
2019-2020 season						
B0	K0	195.07	193.97	191.77	195.07	193.97
	K1	195.07	195.07	191.77	189.20	192.78
	K2	198.00	196.17	196.17	193.60	195.99
	K3	204.60	203.50	202.77	198.37	202.31
	Mean	198.19	197.18	195.62	194.06	196.26
B1	K0	217.80	215.60	213.40	209.37	214.04
	K1	223.30	220.00	217.80	215.97	219.27
	K2	225.13	222.57	217.07	213.40	219.54
	K3	228.07	222.93	220.37	214.50	221.47
	Mean	223.58	220.28	217.16	213.31	218.58
General mean		210.88	208.73	206.39	203.69	
Mean of K						Mean
K0		206.44	204.79	202.59	202.22	204.01
K1		209.19	207.54	204.79	202.59	206.02
K2		211.57	209.37	206.62	203.50	207.76
K3		216.34	213.22	211.57	206.44	211.89

L.S.D. at	B	K	N	BK	BN	NK	BKN
0.05	0.1498	0.2118	0.2118	0.2995	0.2995	0.4236	0.5990

See footnotes of Table 1.

Researchers' findings reveal no change in potassium content between the control and normal potassium treatments, but that applying the latter led to large increases in potassium content. Nano-potassium treatments compared to the control treatment, whether the administered nano-potassium was coupled with biochar or not. "Also, the use of nanoparticle treatments resulted in considerable declines in soil K availability (A). Noteworthy is the fact that, across all treatments, biochar used increased soil K contents relative to soil K values obtained via the same procedures without adding biochar. When nanoparticles (A) were added, the K content was lower than in the control treatment, regardless of the presence of biochar. During the second growing season, the impact of the various amendments utilised on the Kin soil differed according on the treatment. However, these results were much in line with those obtained in the first season after the same set of changes.

Discussion

It is worth noting that all of the fertilizer treatments evaluated were applied to the leaves rather than directly to the soil. It is thus not possible to trace some of the changes in soil characteristics to spraying treatments on the soil itself, but rather, to the influence of these treatments on plants growing on the saline soil and the effects of the removed plant on soil properties. Saline soils may benefit from biochar's capacity to reduce the harmful effects of salt stress, making it an ideal supplement. The findings obtained in this study are nearly identical to those found in previous studies, which showed that biochar application reduced soil electrical conductivity. According to Artiola *et al*., (2012), Lashari *et al*., (2013), applied biochar may improve the chemical and biological characteristics of the saline soils, which is why this impact was seen. As a consequence of its high aromaticity, biochar has the potential to store carbon in soil for a long length of time (Fang *et al*., 2014). Consequently, the findings of this research suggest that biochar has a significant role to play in the enrichment of soil organic matter (OM). As a practical matter, biochar may help maintain the soil's organic carbon content and fertility (Kimetu and Lehmann, 2010). This research demonstrated that adding biochar to the soil increased its cation exchange capacity (CEC). According to the findings of an earlier experiment, applying biochar together with K fertilizers increased both the soil's ability to reduce salt and its level of organic matter (OM). Biochar and K fertilizers, notably K nano form, may be seen as a final product of these outcomes on crop development and, subsequently, on the accumulation of its residues as the primary source of organic matter in soil. Potassium, as previously stated, reduces the negative effects of soil salinity (Garg and Gupta, 1998). Soil organic matter may also be found in root exudates.

Plant tolerance to abiotic stress may have been increased by nano silicon and organic fertilizer (dominated by amino acids) that was applied. Consequently, an increase in the crop's dry matter production on saline soil was anticipated. Thus, the OM's soil content and its CEC increased as a consequence of these treatment methods.

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الأثر المتبقي للقمح السابق نموه في أرض ملحية معاملة بالبيوشار والمواد النانونية علي بعض من خواصها الأصلية

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الملخص

تم زراعة نبات القمح في أرض ملحية معاملة بالبيوشار و/أو تم رش النبات بالبوتاسيوم سواء في صورته المعتادة أو الصورة النانونية بالاضافة إلى الجزئيات النانونية للسليكون و سماد عضوي مكونه السائد الأحماض الأمينية وأجري إعادة تحليل لخواص التربة بعد حصاد القمح لتقييم تداعيات المعاملات سالفة الذكر علي هذه الخواص .وقد أوضحت النتائج أن معاملة التربة بالبيوشار قد أدى إلى زيادة محدودة وإن كانت معنوية في رقم حموضتها وعلي الجانب الآخر ادي إلي نقص واضح و معنوى في مستوي ملوحتها (التوصيل الكهربي بوحدات الديسي سيمنز/متر). وقد ادي إضافة البيوشار إلي زيادة محتوي التربة من المادة العضوية و بالتبعية زيادة سعتها التبادلية الكاتيونية.اكثر من ذلك فإن البيوشار قد ادي إلي زيادة محتوي التربة الميسر من النيتروجين والفوسفور والبوتاسيوم. أدي الرش بالبوتاسيوم إلي نقص محدود و لكن معنوي في رقم حموضة التربة وكان هذا النقص أكثر وضوحاً عندما أضيف البوتاسيوم وخاصة في صورته النانونية متصاحبا مع البيوشار و/أو الجزئيات النانونية. وقد ادي الرش بالبوتاسيوم إلي تشجيع تراكم المادة العضوية في التربة كما أنه شارك في زيادة محتواها الميسر من النيتروجين والفوسفور والبوتاسيوم. . لوحظ أيضا أن الرش بالجزئيات النانونية قد ادي إلي زيادة سعة التربة التبادلية الكاتيونية وزيادة محتواها من المادة العضوية بالإضافة إلى النيتروجين والفوسفور والبوتاسيوم.