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Enhancing Wheat Productivity by Adding Biochar and Plant Growth Promoting Bacteria (*Pseudomonas fluorescens*) under Sandy Soil Conditions

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ABSTRACT

The effects of biochar and plant growth promoting (*Pseudomonas fluorescens*) as biofertilizer on some sandy soil physical, chemical properties and wheat productivity were studied in two successive winter season (2021–2022 and 2022–2023). A field experiment was carried out at the Ismailia Agric.Res.Station, Ismailia Governorate, Egypt (latitude, 30° 35' 41.901" N and longitude, 32° 16' 45.834" E). Two rates of biochar (2.4 and 4.8 Mg ha^{-1}) and two techniques methods of biofertilization (*Pseudomonas fluorescens*) were applied as coating or soaking. The results showed that biochar rates and biofertilizer (*Pseudomonas fluorescens)* enhanced soil moisture content, bulk density, and total porosity. During both seasons under study; a significant decrease in (BD) values was observed, while an increase in (TP) and soil moisture content values (FC, WP, and AW) were observed compared to control. Furthermore, the biochar application has a greater impact on soil CEC and organic matter. The significant increase in soil nitrogen, phosphorus and potassium availability obtained with increasing rates of applied biochar combined with biofertilizer. Furthermore, the results showed that the application of a high rate of biochar (4.8 ha^{-1}) in conjunction with coating biofertilizer treatment recorded the highest values of macronutrient content and wheat yield components compared to control and other treatments. Also, there is no significant different detected between coating or soaking was observed.

Keywords*:* biochar, biofertilizer (*Pseudomonas fluorescens*), wheat, sandy soil.

INTRODUCTION

Wheat is a major crop worldwide. Considering wheat requires a lot of nutrients, growing production threatens its sustainability. Sustainable production goals may be fulfilled without sacrificing soil health or crop output with farm organic manure, chemical fertilizers, and biofertilizers (Kumar and Urmila 2018). Many studies have indicated that biochar increases soil organic carbon. Soil health, biological activity, nitrogen cycling and water retention depend on soil organic matter (SOM) (Kamali *et al*., 2022).

Biochar is a common soil amendment identified as "a fine-grained, porous, and carbonaceous solid substance that is created from waste biomass residuals by slow pyrolysis at low to medium temperatures (450–650 °C) under a low oxygen condition appropriate for the benign and continuing storage of carbon (Carter *et al*., 2013). Abdelhafez *et al*. (2014) reported that the use of sugar cane bagasse and orange peel biochar enhanced soil aggregate stability, water-holding capacity, cation exchange capacity, organic matter and nitrogen status. Hassan and Seddik (2018) mentioned that biochar application decreasing soil bulk density, and improving soil water retention, total porosity, increasing organic matter and nutrients as well as promoted plant nutrition absorption and yield productivity. According to several studies, Glaser *et al*. (2015) reported that, biochar affects soil pH, water storage and microbial activity. Glab *et al.* (2016) found that biochar improved sandy soil physical characteristics, increased soil porosity and lowered bulk density. Venkatesh *et al.* (2018) found direct and indirect soil health benefits from biochar. It affects bulk density, pore size distribution, aeration, soil structure and stability, water infiltration and water holding capacity. Furthermore, biochar improves soil fertility by increasing microbial activity, water holding capacity, soil pH, soil cation exchange capacity, water and fertilizer usage efficiency (Abel *et al*., 2013). Around fifty percent of nitrogen fertilizer is lost, affecting air, water, and soil quality. However, insufficient N fertilizer use has caused serious soil fertility loss, which hinders sustainable agriculture. Biochar-based N fertilizers help crops absorb N and prevent off-site loss (Gao *et al*., 2022).

Biofertilizers have advantages over chemical fertilizers. They are essential for crop growth and soil fertility. Phosphorus is a crucial macronutrient for plant growth and development, but it naturally exists in an insoluble form, making it inaccessible to plants. Plant growth depends on the solubilization and remineralization of phosphorus. The growth-promoting bacteria generate organic acids like citric and gluconic acids are able to chelate phosphorus, making it adverbial to plants (Rathinasabapathi *et al*., 2018). Plant hormones are produced natural or abiotic stress can have an impact on how plants manage their hormones throughout their lives. Plant growth-promoting bacteria can control host plant growth by synthesizing large quantities of plant hormones. Indole 3-acetic acid, an auxin produced by *Pseudomonas spp*., is essential for cell division,

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differentiation, seed germination, vegetative growth control, induction of lateral and adventitious roots, pigments, photosynthesis, and secondary metabolite synthesis (Kumar *et al*., 2017). Egamberdieva *et al*., (2023) found that wheat grown in soil treated with biochar and *Pseudomonas putida* had considerably higher dry shoot and root biomass than plant control. Biochar and bacterial inoculants affected plant biomass, nitrogen (N) and phosphorus (P) content. On the other hand, biochar affected soil enzyme activity greater than the control soil. Danapriatna *et al*. (2023) reported that adding biochar to soil with nitrogen fixer and phosphate dissolver bacteria improves soil quality, fertilizer efficiency, nitrogen and phosphorus absorption as well as rice yield productivity.

The aim of the current study was to evaluate the impact of combined biochar and *Pseudomonas fluorescens* on the physical and chemical characteristics of sandy soil and the productivity of wheat yield.

MATERIALS AND METHODS

A factorial split-plot design was used in field studies at Ismailia Agricultural Research Centre, Egypt. The study examined the impact of biochar and plant growth promoting bacteria (*Pseudomonas fluorescens*) on wheat (*Triticum aestivum* L., CV. Sakha 98) production in sandy soil during two consecutive winter seasons (2021/2022 and 2022/2023). All treatments received the recommended wheat crop mineral fertilizer dosage. Before planting, superphosphate (15.5%P_2O_5) added incorporated with biochar at two rates (2.4 and 4.8 Mg ha^{-1}). Two equal dosages of potassium sulphate (50%K_2O) were applied at 10 and 30 days after seeding. Three equivalent dosages of ammonium nitrate (33.5%N) were sprayed at 10, 30, and 45 days after planting.

Some physical and chemical properties of the experiment soil are shown in Table (1).

Table 1. Some physical and chemical properties of the experimental soil.

Property	Value	Property	Value
Sand %	91.0	Soluble ions mmol l^{-1}	
Silt %	5.00	Ca^{++}	3.80
Clay %	4.00	Mg^{++}	3.00
Texture class	Sand	Na^{+}	6.80
O.M %	0.27	K^{+}	1.10
$CaCO_3$ %	2.75	HCO_3^{-}	1.20
pH	8.02	Cl^{-}	8.50
CEC (cmol kg^{-1})	4.23	SO_4^{-2}	5.00
EC dSm^{-1}	1.47	Available macronutrients (mg kg^{-1})	
Moisture % (w/w)			
Field capacity	6.20	N	27.2
Wilting point	2.88	P	5.23
Available water	3.32		
Bulk density (g cm^{-3})	1.64	K	93.5
Total porosity %	35.9		

The main characteristics of the used biochar for the two studied seasons are shown in Table 2.

Table 2. Some physical and chemical characteristics of the used biochar.

Bulk density (g cm^{-1})	EC (dsm^{-1})	pH	CEC (cmol kg^{-1})	OC%	N%	P%	K%	C/N
1.18	2.86	8.9	28.5	47.27	0.78	0.37	0.68	60.61

Plant growth promoting rhizobacteria {*Pseudomonas fluorescens*(*ps.f*)}was obtained from Biofertilizer Production Unit, Soils, Water and Environment Research Institute, ARC, Giza, Egypt. *Pseudomonas fluorescens* strain was grown on king's medium (King *et al*., 1954), incubated for 48 h at 28°C and added to sterilized vermiculite to prepare the biofertilizer (1.2x 10^8 cell of. *Pseudomonas fluorescens* per g of inoculated vermiculite). The bio fertilizer was applied at rate 2kg of inoculated vermiculite /150 kg of wheat seeds. Two techniques and methods of biofertilization were applied (Seed coating or Seed-soaking). In the first technique, the seeds were coated with the Biofertilizer by Preparing the biofertilizer slurry by adding the biofertilizer (*ps.f*)to water and Arabic gum wich was added to help biofertilizer to stick on the wheat seeds then, seeds were left to air-dry before sowing .In the second technique, Seed-soaking in Biofertilization (*Pseudomonas fluorescens*)solution : Biofertilizer (*ps.f*) (2kg of inoculated vermiculite) mixed with water and the amount of wheat seeds required per hectare (150 kg) were soaked into the solution for 24 h, after then, seeds were left to air-dry before sowing.

Treatments were as follows:

Control. (without biochar and biofertilizer)

BcI (biochar at rate 2.4 Mg ha^{-1})

BcII (biochar at rate 4.8 Mg ha^{-1})

Ps.f-C {seed-coating with *Pseudomonas fluorescens* (*Ps.f*)}.

Ps.f-S {seed- soaking with *Pseudomonas fluorescens* (*Ps.f*)}.

BcI + Psf -C {biochar at rate 2.4 Mg ha^{-1}+ seed-coating with *Pseudomonas fluorescens (Ps.f)*}

BcI + Ps.f -S {biochar at rate 2.4 Mg ha^{-1}+ seed- soaking with *Pseudomonas fluorescens (Ps.f)*}

BcII+ Ps.f -C {biochar at rate 4.8 Mg ha^{-1}+ seed-coating with *Pseudomonas fluorescens (Ps.f)*}

BcII+ Ps.f -S {biochar at rate 4.8 Mg ha^{-1}+ seed- soaking with *Pseudomonas fluorescens (Ps.f)*}

Soil samples were collected after harvesting, air-dried, and analyzed for chemical and physical properties according to Klute (1988) and Sparks *et al*. (2020). Yield components of wheat, i.e., weights of grain and straw were recorded and dried at 70° C, ground, and digested with H_2SO_4 and H_2O_2 for N, P and K determinations using Kjeldahl, Spectrophotometer and Flame Photometer apparatus, respectively according to Cottenie *et al*. (1982).

Statistical analysis:

The experiment was in a factorial split-plot design with three replications using L.S.D. at 0.05 was performed to estimate the significant differences among treatments according to Snedecor and Cochran (1982).

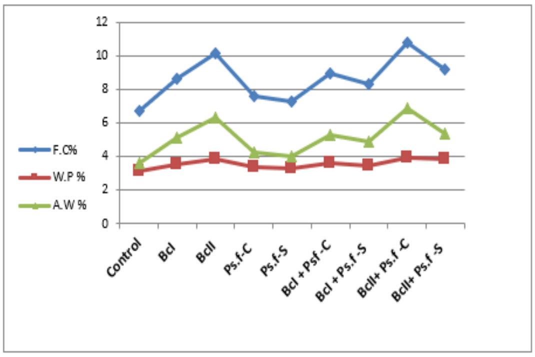
RESULTS AND DISCUSSION

Effect of different biochar rates and biofertilizer on some soil physical parameters include field capacity, wilting point, availability water, bulk density and total porosity.

Soil moisture contents as the field capacity (FC), wilting point (WP), and available water (AW) of soil are excellent indicators of soil physical characteristics improvement under different treatments. Data in fig. (1) and fig. (2) indicated that application of both biochar rates alone or combined with biofertilizer *(Pseudomonas fluorescens*) to the soil had a general positive impact on the total porosity(TP), bulk density and soil moisture content.

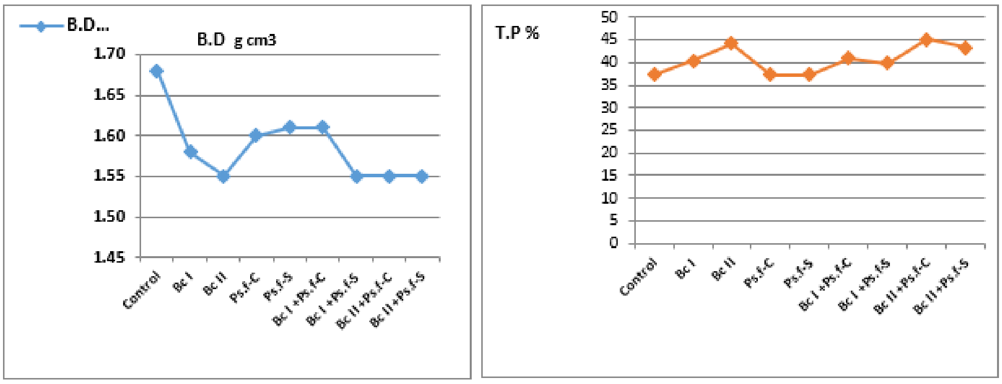
Concerning the effect of biochar rates based on the results, the (BD) values were considerably decreased, while the (TP) and soil moisture contents values (FC, WP, and AW) were increased in comparison to the control at both studied seasons and the biochar high rate was more beneficial. This agree with resultant of El-Habashy *et al.*, (2021) who reported that, soil bulk density (BD) declined whereas field capacity, wilting point, available water, and total porosity increased with increasing biochar rates. The mechanisms responsible for the enhancement of soil physical properties through the application of biochar may be due to the high micro porosity, porous surface structure of biochar which affects soil microorganisms, and improving soil water content, and soil aggregates (Huang K.,et.al 2023).

Regarding the interaction of biochar and biofertilizer (*Pseudomonas fluorescens*) results revealed that biochar at the rate of (4.8 Mg h^{-1}) with the application of bio fertilizer as a coating was recorded the best values of (BD), (TP) and soil moisture content at both seasons followed by biochar (4.8 Mg h^{-1}) combined with (*Pseudomonas fluorescens*) as soaking. However, the least values were recorded in case of biochar (2.4 Mg h^{-1}) combined with *(Pseudomonas fluorescens*) as soaking treatment. This agreement with Tammeorg *et al.*, (2014) who reported that The lower bulk density of biochar-amended soil may be indicative of soil structure, aggregation enhancement, and aeration. Furthermore, (Uzoma *et al.*, (2011) revealed this response to presence a hydrophilic functional groups on biochar's graphene sheet and pores that promote water availability. Also, Pages-Dumroese (2018) observed that biochar increased soil moisture content.



Significance		F.C	W.P	A.W
	Biochar (BC)	*	*	*
	Biofertilizer (Ps.f)	ns	ns	ns
	Interaction BC x Ps.f	*	*	*

Fig. 1. Soil moisture contents, field capacity (FC), wilting point (WP) and available water (AW) as affected by different biochar rates and biofertilizer during wheat cultivation.



Significance		B.D	T.P
	Biochar (B)	*	**
	Biofertilizer (Ps.f)	ns	ns
	Interaction B x Psf	*	**

Fig. 2. Soil bulk density (B.D) and Total porosity (T.P) as affected by different biochar rates and biofertilizer during wheat cultivation.

Effect of different biochar rates and biofertilizer on some soil chemical characteristics:

Effect of biochar and biofertilizer (*Pseudomonas fluorescens*) on electrical conductivity (EC), soil reaction (pH), cation exchange capacity (CEC), soil organic matter (O.M) and availability of N, P and K are shown in Table (3).

Regarding pH values

Data in Table (3) revealed that application of biochar and biofertilizer at two rates (2.4 and 4.8 Mg h^{-1}) show a slightly changes in (pH) values at two studied seasons. Despite the insignificant effect of the treatments on soil pH, which is due to the regulating ability of the soil to change pH values. The results showed a slight increase in the average pH values for the biochar treatments, possible explanation for increases in soil pH due to biochar application is that basic cations (Ca2+, Mg2+ and K+) in biochar could be altered to alkaline substances during pyrolysis (Singh *et al.*, 2022). In contrast the biofertilization treatments, which led to a slight decrease in the average soil pH values compered to control probably to synthesizing organic acids (Rathinasabapathi*et al.*, 2018) indicated that plant growth promote Bactria can synthesizing organic acids).

Concerning electrical conductivity (EC)

Data presented indicated that, biochar and biofertilizer increased soil EC value as compared to control treatment. The biochar (4.8 Mg h^{-1}): proved to be highly effective combined with biofertilizer as coating This may be due to application of biochar and soluble salt-containing ash accumulation that increased EC (Usman et.al.2016).

Respect to CEC

Data presented in Table (3) show a significant increase in soil CEC due to adding biochar as a soil amendment which can raise soil CEC and enhance soil capacity to hold nutrients. All treatments led to an increase in soil CEC values, but it appeared with significant values only in the biochar treatments, whether alone or combined with biofertilizer. Also, increasing the biochar rate had a significant increase in the soil CEC values were increased to 11%, 19%, 14, 12%, 24%, and 21% for the Bc I, Bc II ,(Bc I +*Ps.f*-C) ,(Bc I +*Ps.f*-S) , (Bc II +*Ps.f*-C) and (Bc + *Ps.f*-S) treatments respectively compared to control treatment. Biochar treatment at all rates enhanced soil CEC more than the control that is due to biochar coating a negative charge, cations are electrostatically. So, applying biochar should result increase in cations adsorption (Singh *et al*., 2022).

The impact of biochar and biofertilizers on soil organic matter (O.M).

Table (3) shows that biochar alone or with biofertilizer has a beneficial effect when compared to control. Increase biochar rates boosted these values. The organic matter (O.M) increased significantly possibly due to the fact that high organic carbon percent of biochar (47.27%) as appear in Table (2), this may be due to biochar generated through pyrolysis comprise aromatic carbon (C) as well as the amounts of other elements essential for plant growth, such as N, P and K. In soils with lower levels of naturally occurring OM, applying biochar has resulted in a favorable impact on soil C stability (Alkharabsheh *et al*., 2021). Soil organic matter inceased due to the treatments followed the descending order of (Bc II +*Ps.f*-C)> (Bc II +*Ps.f*-S) > Bc II>(Bc I +*Ps.f*-C)> (Bc I +*Ps.f*-S) > Bc I > *Ps.f*-C > Ps.f-S > control .

Concerning the effect of (biochar and bio fertilizers) on nitrogen, phosphorus and potassium availability in soil.

The results in Table (3) showed that biochar and bio fertilizer significant increased soil nitrogen, phosphorous and potassium availability compared to control treatments. Considering to NPK biochar contains as mentioned previously in Table (2), the results demonstrated that soil N, P, and K availability increased significantly by increasing biochar rates. Biochar possibly increase and improves cation exchange capacity (CEC), which is helpful in binding nutrient cations and reducing their movement within the soil profile. Biochar improves soil physical quality, water retention, cation exchangeable capacity and nutrient cycling microbial biodiversity that involved in nutrient availability (Khan *et al*., 2021). Also, our results in agreement with Page-Dumroese (2018) who found that, enhancement in soil nutrient availability due to biochar application, which reduce nitrogen fertilizer leaching. Morover, Statistical interaction analysis showed that biochar and biofertilizer enhanced soil N, P, and K availability. The amount of nutrients that leach from the soil can be greatly reduced by biochar through enhancing fertility of the soil, (Cao *et al*.,2018) biochar reduced the NO_3^-, NH_4^+, and depletion of nitrogen, reducing ammonia volatilization, or nitrifying it into NO_3^-,the biochar addition to the soil will significantly lower N losses.(Major *et al*., 2009) . Increase in retaining of nutrients as well as other organic molecules by the characteristics of biochar include: porosity, large surface area, CEC and charge density. Moreover, results showed that biochar at rate of (4.8Mg h^{-1}) combined with coating biofertilizer was more pronounced. Rathinasabapathi*et al*., (2018) indicated that PGPB solubilizes and demineralizes phosphorus by synthesizing organic acids (citric and gluconic acids) that chelate and help assimilate it.

Table 3. Effects of different biochar rates and biofertilizer on some chemical properties of the soil for both seasons.

Treatment		pH	EC (dsm^{-1})	CEC (cmol kg^{-1})	O.M %	Available Macronutrients (mg kg^{-1}) N	P	K
Control		7.98	1.56	4.31	0.30	37.23	5.16	89.28
Bc I		8.05	1.80	4.78	0.38	48.16	6.90	190.20
Bc II		8.12	1.88	5.11	0.48	55.93	7.30	197.73
Ps.f-C		7.91	1.74	4.43	0.34	63.98	7.84	105.10
Ps.f-S		7.91	1.66	4.40	0.34	63.49	7.42	102.51
Bc I +*Ps.f*-C		7.93	1.85	4.88	0.43	74.13	8.35	233.72
Bc I +Ps.f-S		7.91	1.83	4.83	0.44	67.58	8.48	211.58
Bc II +*Ps.f*-C		7.96	1.90	5.32	0.55	80.62	9.20	252.88
Bc II +*Ps.f*-S		7.93	1.88	5.18	0.52	79.13	9.30	225.63
Significance	Bc	n. s	*	*	*	*	*	*
	Psf	n. s	n. s	n. s	n. s	*	*	*
	Interaction (Bc * *Psf*)	n. s	*	*	*	**	**	**

Effect of different biochar rates and biofertilizer on total contents of N, P and K for wheat grains and straw .

Table (4) shows the average of the total nitrogen, phosphorus, and potassium contents of wheat grain and straw for both seasons. Genaraly, the application of biochar combined with *Pseudomonas fluorescens* increased the rate of nutrient accumulation in wheat crops in comparison to control regarding to their effects on soil nutrients availability.

With respect to the application rate of biochar, results revealed that high rate as compared low rate was increased higher for (N, P and K) total contents for wheat grains and straw at both seasons. In this respect (Bakhat *et al*., 2021) found that applied biochar to agricultural land boosted its ability to store water and nutrients and minimize evaporation. Also, Shetty *et al*. (2021) observed the consumption of nutrients by plants increased by application of rice husk biochar.

Table 4. Effects of different biochar rates and biofertilizer on total contents of macronutrients for wheat grains and straw.

		Grains (kg h^{-1}) N	P	K	Straw (kg h^{-1}) N	P	K
Control		93.50	10.6	26.62	36.96	5.43	102.1
Bc I		114.0	13.6	36.96	55.90	8.08	155.4
Bc II		126.8	16.6	46.68	68.10	10.9	172.3
Ps.f-C		124.8	19.7	46.04	66.38	10.77	149.7
Ps.f-S		116.2	18.1	42.71	74.42	9.44	142.1
Bc I +*Ps.f*-C		153.5	24.2	55.30	84.40	13.9	190.2
Bc I +*Ps.f*-S		145.4	21.7	52.12	77.10	12.87	173.5
Bc II +*Ps.f*-C		185.0	28.2	68.90	91.10	16.6	216.6
Bc II +*Ps.f*-S		175.7	24.1	62.70	88.50	16.4	208.8
Significance	Bc	**	**	**	**	*	*
	Psf	**	**	*	**	*	*
	Interaction (Bc * *Psf*)	***	**	**	**	*	**

Also Viger *et al*. (2015) suggested that, biochar application is a key for growth stimulation by increasing the activity of membrane transporters for nutrients, and sugar, to facilitate the uptake of water and nutrients and the movement of carbohydrates for metabolism in plant parts. The interactions between, biochar and biofertilizers (*Pseudomonas fluorescens*), boichar (4.8 Mg h^{-1}) with biofertilizers as coating recorded the highest total nitrogen, phosphorus, and potassium contents of straw and wheat grain during both seasons.. It increases root mass and volume, which is an important factor in nutrient uptake. Genaraly, the application of biochar combined with *Pseudomonas fluorescens* increased the accumulation of nutrients in wheat crop as compared to control.

Effect of different biochar rates and biofertilizer on yield components of wheat.

Data shown in Table (5) revealed that wheat yield components (straw, grains, biomass and weight of 1000-grain) of both studied growing seasons were significantly increased due to the different applied treatments of both boichar and biofertilizers (*Pseudomonas fluorescens*) each alone and or a combination compared to control (without boichar or biofertilizers). However, the high rate of biochar (4.8 Mg h^{-1}) being better as compared to low rate (2.4 Mg h^{-1}) for productivity (Glaser *et al*., 2015). Moreover, applying of biochar on agricultural land boosted its capacity to conserve water and nutrients and reduce evaporation which affected in yield productivity (Bakhat *et al*., 2021). Page *et al*. (2020) explained the positive effect of biochar application is possibly due to the correlation with bulk density decreasing and soil porosity increasing on improving water, nutrient status and improved soil aeration. Moreover, the biochar have many pores which storage available water for plant use. Thus, the productivity of crops is positively influenced by an increase in soil porosity, as it increases the quantity of available water and creates more favorable conditions for root growth (Lu and Zong 2018). The CEC of soil was increased when it was amended with biochar, which is an essential indicator of soil quality. A soil with a higher CEC demonstrates a greater capacity for nutrient fixation, which is crucial for the growth of plants (Karthik *et al*.,2020) Biochar application also increased leaf cell expansion, stimulation of development, with minimal effects on the genes that regulate photosynthesis (viger *et al*.,2015) .

Regarding the interaction effect, data showed that the greatest value of wheat yield components were recorded by the application of boichar (4.8 Mg h^{-1}) combined with biofertilizers as coating in comparison to other treatments. Increases in yield components of wheat as compared to control, recorded 41.0%, 39.0% and 24.0% for grains, straw and 1000-grains, respectively. The synergistic interaction effects of *Pseudomonas fluorescens* with biochar are analogous to those finding of (Egamberdieva *et al*., 2023) who identified that dry biomass of wheat roots and shoots greatly increased in soil mixed with biochar and *P. putida* compared to the control. Also, (Hadiawati *et al*., 2019) revealed that the utilization of biochar combined with biological fertilizers, increased significantly yield productivity. The positive impact of biofertilizers (*Pseudomonas fluorescens*) on biological yield attributed to Phytohormone production. According to Kumar *et al.* (2017), PGPB produce many plant hormones which increase plant growth. On the other hand, the most inferior treatments for yield components were recorded for the application of biofertilizers as soaking. This increase recorded 10.8%, 9.0% and 12.0% for grains straw, and 1000-grains, as compared to control, respectively.

Table 5. Effect of different biochar rate and biofertilizer on yield components of wheat crop (Mg ha^{-1}) for an average of two season 2021/2022 and 2022/2023.

Treatments		Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Biological yield (Mg ha^{-1})	weight 1000 seed (g)
Control		5.28	5.43	10.17	28.8
Bc I		6.16	6.21	12.37	31.02
Bc II		6.62	6.81	13.43	31.80
Ps.f-C		5.94	5.98	11.92	33.50
Ps.f-S		5.81	5.91	11.72	32.06
Bc I +Ps.f-C		6.89	7.05	13.94	33.80
Bc I +Ps.f-S		6.76	6.94	13.70	32.03
Bc II +Ps.f-C		7.4	7.52	14.92	35.62
Bc II +Ps.f-S		7.29	7.43	14.72	34.50
Significance	Bc	*	*	*	*
	Ps.f	*	*	*	*
	Interaction (Bc * Psf)	**	**	**	**

CONCLUSION

Based on the results obtained, it is possible to infer that biochar and biofertilizers (*Pseudomonas fluorescens*) increased availability of macronutrients, and improved soil moisture content .As well as increased wheat yield component and total content of macronutrients. Moreover, the wheat yield components, as well as the N, P, and K compositions of grain and straw wheat, were recorded at the highest levels and the soil moisture content of sandy soil was improved addition to enhancing macronutrients availability by application of biochar (4.8 Mg h^{-1}) combined with biofertilizers as coating techniques.

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تحسين إنتاجية القمح النامى فى الأراضى الرملية باستخدام البيوشار والبكتريا المشجعة للنمو *Pseudomonas Fluorescens*

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الملخص

تمت دراسة تأثير البيوشار والبكتريا المحفزة لنمو النبات (*Pseudomonas fluorescens*) والمستخدمة كسماد حيوي على بعض الخواص الفيزيائية والكيميائية للتربة الرملية وإنتاجية القمح ،أجريت تجربة حقلية في محطة البحوث الزراعية- مركز البحوث الزراعية ،محافظة الإسماعيلية، مصر خلال موسمين شتويين متتاليين (2021-2022 و2022-2023). تم تطبيق معدلين من البيوشار (2,4 و4,8 ميجا جرام للهكتار) وطريقتين لتطبيق التسميد الحيوي (*Pseudomonas fluorescens*) الأ ولى تغطية تقاوى حبوب القمح بالسماد الحيوى والثانية بنقع تقاوى حبوب القمح فى محلول مائى يحتوى على السماد الحيوى . أظهرمتوسط النتائج بالنسبة للموسمين أن تطبيق معدلات البيوشار منفردة أو مختلطة مع السماد الحيوى (*Pseudomonas fluorescens*) فى التربة الرملية ادى إلى تحسين بعض الخواص الطبيعية للتربة موضع الدراسة مقارنة بمعاملة الكنترول مثل حدوث زيادة معنوية فى المحتوى الرطوبى للتربة {السعةالحقلية(FC%)، معامل الذبول(WP%)، والماء الميسر (AW%) } و انخفاض في قيم الكثافة الظاهرية (BD) كما أوضحت النتائج زيادة معنوية فى نسبة المسامية الكلية (TP%) . بالنسبة لطريقة تطبيق التسميد الحيوي خلال الموسمين قيد الدراسة؛بالرغم من أن طريقة التغطية كانت أفضل من طريقة النقع إلا أن الأختلاف لم يكن معنويا. كذلك، تشير البيانات إلى أن إضافة البيوشار خاصة بالمعدل4.8 ميجا جرام للهكتار أدى إلى زيادة معنوية فى قيم السعة التبادلية الكاتيونية ونسبة المادة العضوية فى التربة كما أظهرت النتائج زيا دة فى تيسر النيتروجين والفوسفور والبوتاسيوم فى التربة لجميع المعاملات مقارنة بالكنترول خاصة بزيادة معدلات البيوشار المضاف مع الأسمدة الحيوية. علاوة على ذلك، أظهرت النتائج أن إضافة البيوشار بمعدل 4.8 ميجا جرام للهكتار مع معاملة تقاوى القمح بالسماد الحيوى بطريقة التغطية أعطى أعلى قيم لمحتوى العناصر الغذائية(النيتروجين والفوسفور والبوتاسيوم) ومكونات محصول القمح من الحبوب والقش وكذلك وزن الألف حبة مقارنة بالكنترول بالمعاملات الأخرى .