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Soil Application Impacts of Biochar, Compost, and Phosphorus Fertilization on Soybean Crop Productivity and Soil Fertility

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ABSTRACT

To examine the effects of compost, biochar, and different phosphorus rates on the growth, yield parameters, and seed quality of soybeans (*Glycine max* L.), c.v. Giza 111, two field experiments were conducted at EL-Gemmiza, Agricultural Research Station, Agricultural Research Centre, El-Gharbia Governorate, Egypt, during the summer seasons of 2022 and 2023. This experiment included 9 treatments as follows: control treatment without any addition, biochar at 5 ton/fed, biochar at 5 tons/fed +50 % of the recommended rate of phosphorus (RRP), biochar at 5 tons/fed+75 % RRP, biochar at 5 ton/fed +100 % RRP, compost at 5 tons/fed without phosphorus, compost at 5 tons/fed +50 % RRP, compost at 5 tons/fed +75 %RRP, compost at 5 ton/fed +100 % RRP. The tallest soybean plants and the highest number of pods/plant, weight of pods/plant, weight of 100 seeds, yield of seeds/plant, yield of seeds/fed, and straw yield/fed, as well as total protein in seeds, were produced by fertilizing soybean plants grown in clay soil with biochar at a rate of 5 tons/fed. + 75% recommended rate of phosphorus (RRP). This treatment also produced the highest values of N, P, and K uptake by seeds and straw and increased the amount of N, P, and K available in the soil after harvest. The increases in yield of seeds/fed. were about 45.08% and 53.78% for biochar at 5 tons/fed + 75 % RRP over the control in the 1st and 2nd seasons, respectively.

INTRODUCTION

As a member of the Fabaceae family, soybean (*Glycine max* L.) primarily provide oil and protein. According to Arif *et al.* (2010), its oil is thought to be the most abundant source of edible oils worldwide. Because of its high protein percentage (39-44%) and oil content (21%), soybeans are frequently referred to as "miracle plants" (Hamayun et al., 2010). Therefore, it truly lives up to the label of meat or oil on plants and is the best source of both protein and oil. Furthermore, soybean seed oil is high in unsaturated and essential fatty acids and low in cholesterol. Additionally, soybean oil is beneficial for diabetics, dieters, and those who are at risk for certain cancers (Agwu et al., 2009).The total of soybean devoted for production in 2022 year in Egypt, was 31200 fed, which produced 37939 tons with average 1.216 ton/fed (FAO 2023).

Because it improves aggregation, soil carbon content, cation exchange capacity, and water holding capacity, as well as prepares the ground for more microbial activity, inhibits leaching and balances the soil pH, biochar is crucial for soil quality (Ali *et al*. 2017). The application of biochar seeks to support both soil improvement characteristics and the nutritional requirements of plants. For dry terrain, biochar works well because it remains stable in the soil (Wu *et al*., 2022). Wood, straw, and other crop residues can be converted into biochar, a pyrolysis product (Kätterer *et al*., 2019). Biochar is made from organic components found in agricultural waste, including sugarcane waste, coconut shells, and husks.

Composting can be a practical, affordable, and ecological way to effectively use the nutrients from food scraps both before and after consumption. Applying compost can enhance soil fertility and boost yield output while providing the best possible support for plant growth and production (Rady *et al*. 2016). Additionally, compost is an alternative that can be used to lessen the need of mineral fertilizer (Bhadwal *et al*. 2022). Also, the use of organic fertilizers such as compost has received a lot of attention in an effort to improve soil fertility, decrease nutrient losses, and lessen plant and soil contamination from mineral fertilizers. Furthermore, organic fertilizers were thought to be good soil conditioners and providers of plant nutrients. Also, it include increased cation exchange capacity, soil aggregation, stability, and water-holding capacity. Moreover, organic fertilizers were used to increase the availability of macro and micro nutrients and lower the pH of the soil (Tahoun *et al*., 2000).

Numerous researches revealed the using of biochar or compost fertilizer produced optimal plant development productivity and seed quality of soybean (Jabborova *et al*., 2022, Wu *et al*., 2022, Elsherpiny *et al.* 2023, Nurmalasari *et al*., 2024 and Elshaboury *et al*., 2024).

Phosphorous (P) is essential for enhancing plant resistance to many diseases, flowering, pod setting, seed formation, protein synthesis, sugar translocation, growth, development, and reproduction, and seed quality (Brady, 2002). According to Tarekegn, and Kibret (2018), phosphorus is regarded as a major and necessary macronutrient that all plants need in order to contribute to a variety of metabolic processes, including cell division, tissue growth, photosynthesis, respiration, nucleic acids, glucose synthesis, N fixation, and the synthesis of phospholipids.

For healthy growth and nitrogen fixation, soybeans and all other nitrogen-fixing legumes require phosphorus. Because nitrogen addition need high quantities of phosphorous, beans are especially sensitive to low phosphorus availability. While, applying phosphorous solves this issue, its shortage may lessen the production of nodules (Carsky et al., 2001).

Fertilizing soybean plants, grown in clay soil, with different rates of phosphorus significantly enhanced growth, yield, and seed quality compared to the control treatment (Khatun, 2021, Gonyane, and Sebetha, 2022, Vanlalhmangaihi *et al*., 2023, Kabiru *et al*., 2024, Bebeley *et al*., 2024, Buernor *et al*., 2024.

Therefore, the objectives of the current study were: study the response of soybean productivity and quality to organic fertilization with biochar, compost, and different levels of phosphorus.

MATERIALS AND METHODS

Location:

During the summer seasons of 2022 and 2023, two field experiments were carried out at EL-Gemmiza, Agric. Res. Station, Agric. Res. Centre, (Lat. 30ᵎ 48´ 752" and Long. 31ᵎ 81 025"), El-Gharbia Governorate, Egypt.

Soil sampling:

Before seeding, a representative soil surface sample (0-15cm) was collected from the experimental location and prepared using the techniques outlined by A.O.A.C.(2012) to determine physical and chemical properties (Table 1).

Experimental layout:

This experiment included nine treatments as follows: control treatment without any addition, biochar at 5 tons/fed, biochar at 5 tons/fed +50 % of the recommended rate of phosphorus (RRP) equal 11.25 kg/fed P_2O_5, biochar at 5 tons/fed +75 % RRP equal 16.88 kg/fed P_2O_5, biochar at 5 tons/fed +100 % RRP equal 22.5 kg/fed P_2O_5, compost at 5 tons/fed without phosphorus, compost at 5 ton/fed +50 % RRP equal 11.25 kg/fed P2O5, compost at 5 tons/fed +75 %RRP equal 16.875 kg/fed P2O5, compost at 5 tons/fed +100 % RRP equal 22.5 kg/fed P2O5. These treatments were arranged in a randomized block design with three replicates.

All the treatments were added before sowing during the land preparation. Five rows, each measuring 3.5 meters in length and 60 centimeters apart, made up the 10.5 m^2 experimental unit area. Three soybean (C.v.Giza 111) seeds were planted after inoculation with okadein in each hill, spaced 10 cm apart on 14 and 17th May in both seasons, respectively and after 15 days, there were only two plants per hill. Fifteen kg/fed of nitrogen were added as a activating dose when sowing. Prior to the first and second irrigations, nitrogen fertilizer was administered to all experimental plots in two equal doses of ammonium sulphate (20.5%) at a rate of 20 kg N/fed. Additionally, potassium sulphate (48 percent K_2O) was applied as potassium fertilizer in one dose at a rate of 50 kg K_2O/fed. in the second irrigation.

The recommendations regarding soybean crops by the Ministry of Agriculture were adhered to according to the average of the two seasons, the biochar and compost characteristics utilized in this experiment were shown in Tables 2 and 3.

Plant sampling:

Ten randomly selected plants from each replicate were used to examine vegetative growth parameters, such as plant height. After that, the plants of each replicate were harvested and separated into seeds and straw.

Yield and its component characteristics:

At the maturity stage, yield and its constituent parts, including number of pods per plant, weight of pods per plant (g), weight of 100 seeds per plant (g), and yield of seeds per plant (g), as well as the yield of both seeds and straw, were measured also, biological yield (seed yield+ straw yield) (ton/fed) was calculated.

Nutrient contents and its uptake by seeds and straw:

To ascertain the N, P, and K contents, samples of seed and straw were randomly selected from each replicate's samples and oven-dried for 48 hours at 70°C. According to A.O.A.C. (2012), measurements were made of the amounts of nitrogen, phosphate, and potassium in seeds and straw during harvest time in both seasons. The N, P, and K uptake (kg/fed) was determined by multiplying the seeds or straw yields by the corresponding N, P, and K concentrations (%) using the method outlined by Craswell and Godwin (1984).

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

Parameter	Value	
Physical properties	**2022**	**2023**
Coarse sand (%)	4.98	5.11
Fine sand (%)	14.25	13.7
Silt (%)	40.22	41.36
Clay (%)	40.55	39.83
Textural class	clay loam	clay loam
Chemical properties		
EC dSm^{-1} (soil paste extract)	2.29	2.26
pH (1: 2.5 soil : water suspension)	8.06	8.08
$CaCO_3$ (%)	2.42	2.31
Organic matter (%)	1.91	1.88
Available nitrogen (mg/kg)	32.2	39.8
Available phosphorus (mg/kg)	7.26	7.31
Available potassium (mg/kg)	242	249

Table 2: Some characteristic of biochar used in the study.

Density ($kg\ m^{-3}$)	Moisture content (%)	pH	EC ($dS\ m^{-1}$)	Ca (%)	Mg (%)	Total nutrients(%)			OC (%)	OM (%)	C/N ratio
						N	P	K			
752.00	4.89	8.90	0.52	1.50	2.70	1.40	0.92	1.48	27.14	46.80	19:1

ARC in Giza, Egypt provided the Biochar.

Table 3: Some characteristic of compost used in the study.

OM (%)	OC (%)	C/N ratio	Total nutrients (%)		
			N	P	K
37.6	21.8	22:1	0.98	0.63	0.87

Protein content in the seeds:

Nitrogen % was multiplied by the 6.25 factor to get the protein content of the seeds (A.O.A.C., 2012).

Soil fertility:

After soybean plant harvesting, surface soil samples were taken randomly from each plot to determine soil available N, P and K according to A.O.A.C (2012).

Statistical analysis:

Snedecor and Cochran (1980) were used to compute the analysis of variance for all collected data, and the Duncan (1958) approach was taken to separate the means at the 5% probability level.

RESULTS AND DISCUSSION

Plant growth

Data presented in Table 4 indicated that fertilizing of soybean plants grown in clay soil with organic fertilizers (biochar or compost at 5 ton /fed of each) and phosphorus (0, 50, 75 and 100% of the recommended (RRP)) significantly increased plant height in both seasons as compared to control treatment (without any addition).

Table 4: Effect of biochar, compost, and phosphorus levels on plant height.

Treatments	plant height (cm)	
	2022 season	**2023 season**
0 organic + 0 P (control)	88.3 e	85.0 g
Biochar 5 ton /fed + 0 P	98.00 d	95.00 f
Biochar 5 ton /fed +50 % RRP	113.07 c	110.00 d
Biochar 5 ton /fed+75 %RRP	127.33 a	125.00 a
Biochar 5 ton /fed+100% RRP	125.00 ab	123.00 b
Compost 5 ton /fed+0 P	96.67 d	94.00 f
Compost 5 ton /fed+50 % RRP	112.67 c	108.00 e
Compost 5 ton /fed+75 %RRP	126.00 ab	125.00 a
Compost 5 ton /fed+100% RRP	123.67 b	120.00 c
LSD at 5 % level	2.88	1.73

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Fertilizing with biochar at 5 tons/fed + 75 % RRP or with compost at 5 tons/fed + 75 % RRP resulted in the tallest plants, followed by biochar or compost at 5 tons/fed of each + 100 % RRP in both seasons.

This means that biochar at 5 ton /fed + 75 % RRP, which equals 16.88 kg /fed P_2O_5, increased plant height, followed by biochar or compost at 5 ton /fed. of each + 100 % RRP, which equals 22.5 kg/fed P_2O_5. The increases in plant height were about 44.2 and 47.1 % for biochar at 5 tons/fed. + 75 %RRP and 42.6 and 47.1 % for compost at 5 ton /fed + 75 % RRP, 41.5 and 44.7 % for biochar at 5 ton /fed + 100 % RRP over the control in the 1st and 2nd seasons, respectively.

The nutrients in the soil were affected by the addition of biochar. Furthermore, applying biochar enhances soil fertility and encourages plant growth because of its wide surface area and high nitrogen content (Li *et al*., 2022). According to another theory, plants treated with biochar have better access to nutrients, especially phosphorus, because of the charcoal's high ash content (Das *et al*., 2018). In the other sides, increases in plant growth characteristics, like height, brought on by high phosphorus fertilizer application may be related to the fact that phosphorus is a macronutrient that all soybean plants need for a variety of metabolic processes, including cell division, tissue formation, photosynthesis, respiration, the synthesis of glucose and nucleic acids, N fixation, and the synthesis of phospholipids (Servani *et al*., 2014).

These outcomes align with the findings published by Liana *et al*., 2021 and Jabborova *et al*., 2022 for the effect of organic fertilizers and Abdel lateef, 2017 and Abido, 2018 on the response of soybean to phosphorus fertilizer levels. In this regard, Yusuf and Mulyono (2018) found that the outcomes of soybean plant height were not substantially different from the control treatment (100% urea) when 100% compost, 25% compost + 75% urea, 50% compost + 50% urea, and 75% compost + 25% urea were used.

Yield and its components

Data in Tables 5 and 6 indicated that biochar or compost at 5 ton /fed of each with all different rates (0, 50,75 and 100 % RRP) significantly increased number of pods/plant, weight of pods/ plant, weight of 100 seeds, yield of seeds/plant, yield of seeds /fed. and straw yield /fed. compared to the control treatment (0 organic + 0 P) in both seasons. Fertilizing with biochar at 5 ton /fed + 75 % RRP increased number of pods/plant (112.33 and 111.00), weight of pods/ plant (50.80 and 51.20 g), weight of 100 seeds (20.69 and 20.35 g), yield of seeds/plant (40.60 and 41.40 g), yield of seeds /fed (1.77 and 1.83 ton) and straw yield /fed (4.24 and 4.47) in the each of both seasons, respectively, followed by biochar at 5 ton /fed + 100 RRP and compost at 5 ton/fed + 75 % RRP. The increases in number of pods/ plant, weight of pods/plant, weight of 100 seeds, yield of seeds/ plant, yield of seeds /fed and straw yield /fed were about 56.01 and 58.57; 73.56% and 79.65; 38.80 and 44.94 %; 95.95 and 101.95 %, 45.08 and 53.78 % and 51.97 and 68.68 % for biochar at 5 ton /fed. + 75 % RRP over the control in the 1st and 2nd seasons, respectively.

The stimulative effect of biochar at 5 ton /fed. + 75 % RRP on seed yield /fed may be due to that treatment increased number of pods / plant , weight of pods/ plant, weight of 100 seeds, yield of seeds / plant as shown in Tables 5 and 6. Also, biochar at 5 ton /fed + 75 % RRP treatment simulative effect on straw yield may be due to that this treatment increased plant height (Table 4).

Organic fertilizers, such compost or biochar, are crucial because they improve the soil's physical, chemical, and biological qualities, while also meeting the nutritional needs of plants and enhancing pH, Ca, Mg, K, and P, thereby enhancing soybean growth and yields.

Table 5: Effect of biochar, compost and phosphorus levels on yield components.

Treatments	Number of pods / plant		Weight of pods / plant (g)		Weight of 100 seeds (g)	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
0 organic + 0 P (control)	72.00i	70.00 g	29.27 f	28.50f	14.90 f	14.04 e
Biochar 5 ton /fed + 0 P	87.00 g	84.00 f	39.00 e	38.40 e	15.61 e	15.54 d
Biochar 5 ton /fed +50 % RRP	96.67 e	94.00 d	43.55 d	42.20 d	18.11 c	18.09 c
Biochar 5 ton /fed+75 %RRP	112.33 a	111.00 a	50.80 a	51.20 a	20.69 a	20.35 a
Biochar 5 ton /fed+100% RRP	106.33 c	105.00 c	47.91 b	47.70 b	18.89 b	18.27 bc
Compost 5 ton /fed+0 P	84.00 h	83.00 f	38.52 e	38.10 e	15.21 ef	15.12 d
Compost 5 ton /fed+50 % RRP	94.33 f	92.00 e	43.10 d	42.70 d	16.56 d	15.34 d
Compost 5 ton /fed+75 %RRP	108.33 b	107.00 b	48.40 b	48.10 b	18.84 b	18.84 b
Compost 5 ton /fed+100% RRP	105.00 d	106.00 bc	47.08 c	46.60 c	17.96 c	17.63 c
LSD at 5 % level	1.15	1.73	0.34	0.86	0.69	0.64

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

Table 6: Effect of biochar, compost and phosphorus levels on yield parameters.

Treatments	Yield of seeds / plant (g)		Yield of seeds (ton/fed.)		Yield of straw (ton/fed.)		Biological yield (ton /fed)	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
0 organic + 0 P (control)	20.72f	20.50g	1.22 h	1.190 f	2.79 f	2.65 e	4.01 f	3.84 f
Biochar 5 ton /fed + 0 P	30.71 e	30.32 f	1.50 e	1.50 cd	3.67 d	3.45 d	5.17 d	4.95 d
Biochar 5 ton /fed +50 % RRP	32.92 d	32.70 d	1.52 d	1.50 cd	3.72 d	3.87 c	5.24 d	5.37 bc
Biochar 5 ton /fed+75 %RRP	40.60 a	41.40 a	1.77 a	1.83 a	4.24 a	4.47 a	6.01 a	6.30 a
Biochar 5 ton /fed+100% RRP	37.67 bc	37.45 bc	1.60 c	1.42 de	3.99 bc	4.10 b	5.59 c	5.52 b
Compost 5 ton /fed+0 P	30.06 e	30.10 f	1.41g	1.35 e	3.47 e	3.30 d	4.88 e	4.65 e
Compost 5 ton /fed+50 % RRP	32.34 d	31.80 e	1.44 f	1.40 de	3.70 d	3.80 c	5.14 d	5.20 c
Compost 5 ton /fed+75 %RRP	38.03 b	37.90 b	1.62 b	1.62 b	4.12 ab	3.95 bc	5.74 b	5.57 b
Compost 5 ton /fed+100% RRP	37.10 c	36.85 c	1.61 bc	1.54 bc	3.88 c	3.90 c	5.49 c	5.44 b
LSD at 5 % level	0.92	0.86	0.01	0.11	0.14	0.17	0.138	0.213

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

(Altaee and Alsawaf, 2021). The increases in seed and straw yields brought about by phosphorus fertilization may be explained by the element's function in negotiation.

processes, abundant nodulation, and as a component of ribonucleic acid, deoxyribonucleic acid, and ATP, which control essential plant metabolic processes. Additionally, it aids in root development and nitrogen fixation, which benefits photosynthetic organs and rate and promotes improved crop growth and production (Basak, 2006). Additionally, Servani *et al.* (2014) found that phosphorus fertilization regulates the growth, leaf area, yield, and other characteristics of legume plants and plays a significant role in their life cycle.

These findings concur with those suggested by Sandrakirana and Arifin, 2021, Jabborova *et al*., 2022, and Elshaboury *et al*., 2024 as for the response of organic fertilizers and Abido, 2018, Khatun, 2021, Gonyane, and Sebetha, 2022 and Vanlalhmangaihi *et al*., 2023 as for the effect of phosphorus levels on soybean.

In this concern, Ruth *et al.* (2017) indicated that the use of compost at the rate of 2.5 t per ha combined with 50% of NPK was able to create higher production per hectare of soybean plants as compared control treatment (100% NPK). According to Yusuf and Mulyono (2018), the yield of soybean production variables (number of pods per plant, percentage of filled pods per plant, number of seeds per plant, weight of seeds per plant, and seed production per hectare) did not differ significantly from the control treatment (100% urea) when 100% compost, 25% compost + 75% urea, 50% compost + 50% urea, and 75% compost + 25% urea were used.

The obtained data in Table 6 indicate that fertilizing soybean plants with organic fertilizer (biochar and compost at 5 ton /fed of each with different rates of phosphorus significantly increased biological yield compared to control treatment (0 organic + 0 P) fertilizing with biochar at 5 ton /fed + 75 % RRP increased biological yield, followed by biochar at 5 ton /fed + 100 % RRP in both seasons. This means that biochar and compost at 5 ton /fed of each + 75 % RRP which equals 16.88 kg /fed P_2O_5 enhances biological yield.The increases in biological yield were about 19.40 and 27.45 % for biochar at 5 ton /fed + 75 %RRP, 17.39 and 26.44% for compost at 5 ton /fed. + 75 % RRP, 14.14 and 22.52 % for biochar at 5 ton /fed. + 100 %RRP over the control (Zero organic fertilizer + Zero phosphorus) in the both seasons, respectively.

By improving soil nutrient loss, fertilization effectiveness, and water-holding capacity, biochar can boost plant growth and biological yield (Torane *et al*., 2017). Phosphorous (P), plays a pivotal role in improving growth, development and reproduction, flowering, pod setting, seed formation, protein synthesis, sugars translocation, and then increased biological yield (Brady, 2002). More grain yield may also result from phosphorus's positive effects on plant fruiting and improved translocation of desirable metabolites to the plant sections that contribute to yield. Because phosphorus improves the nutritional environment of the rhizosphere and plant system, which raises plant metabolism and photosynthetic activity, it may contribute to greater growth and development in terms of plant height, branches, and dry matter, which could explain the increase in straw production (Yadav *et al*., 2017). In this regard, Nurmalasari *et al*., 2024 came the similar results for biochar and organic fertilizers on biological yield of soybean.

N, P and K contents and total protein in seeds

Data in Table 7 illustrate that biochar at 5 ton /fed + 75 % RRP and compost at 5 ton /fed + 75 % RRP significantly increased total protein, N, P and K contents in seeds with no significant differences with biochar at 5 ton /fed + 100 % RRP with respect to K content in seeds in both seasons.

As for total protein in seeds, under all treatments, the values of total protein were ranged between 34.50 to 41.19 % in the 1st season and between 31.88 to 40.63 % in the 2nd season. Biochar at 5 ton /fed + 75 % RRP or compost at 5 ton/fed + 75 % RRP recorded maximum values of total protein in seeds (41.19 and 40.63 and 40.50 and 40.31 % in both seasons, respectively). The increases in nitrogen, and potassium in seeds due to treated soybean plants with biochar at 5 ton /fed + 75 % RRP were about 19.40 and 27.45%; 32.14 and 31.82% for biochar at 5 ton /fed + 75 % RRP over the control in the 1st and 2nd seasons, respectively.

N, P and K contents in straw

Treating soybean plants with biochar at 5 ton /fed + 75 or 100 % RRP and compost at 5 ton /fed + 75 or 100 % RRP significantly increased N and K contents in straw, whereas biochar at 75 % RRP significantly increased P content in straw (Table 8). This means that biochar or compost at 5 ton /fed of each + 75 % RRP increased N and K content in straw. As for P contents in straw, treating plants with biochar at 5 ton /fed, + 100 % RRP produced the highest P contents (0.209 and 0.205 %) in the each of the two seasons.The increases in nitrogen, and potassium in straw due to treated soybean plants with biochar at 5 ton /fed + 75 % RRP were about 31.67 and 34.29% ; 32.83 and 37.25 % for biochar at 5 ton /fed + 75 % RRP over the control in the 1st and 2nd seasons, respectively.

These results are in harmony with those obtained by Bebeley *et al*., 2024, and Buernor *et al*., 2024 they indicated that highest concentrations of N, P and K in seeds and straw on soybean were produced from the plants which fertilized with the moderate levels of phosphorus.

N, P and K uptake by seeds

Fertilizing soybean plants which grown in clay soil with biochar at 5 ton /fed. + 75 % RRP produced the highest values of N, P and K uptake by seeds in both seasons (Table 9).

The simulative effect of biochar at 5 ton /fed. + 75 % RRP on N, P and K uptake by seeds may be due to that this treatment increased yield of seeds per plant and per fed (Table 6) and N, P and K contents in seeds (Table 7).

The increases in nitrogen, phosphorus and potassium uptake by seeds due to treated soybean plants with biochar at 5 ton /fed. + 75 % RRP were about 173.21 and 196.0 % ; 290.39 and 389.73% and 91.80 and 165.40% and 75 % RRP over the control in the 1st and 2nd seasons, respectively.

N, P and K uptake by straw

The obtained results in Table 10 show that treating soybean plants with biochar at 5 ton /fed + 75 % RRP significantly produced the highest values of N, P and K uptake by straw, with no significant differences with biochar at 5 ton /fed + 100 % RRP with respect to P uptake by straw in both seasons (Table 10) .

The simulative effect of biochar at 5 ton /fed + 75 % RRP on N, P and K uptake by straw may be due to that this treatment increased yield of straw / fed (Table 3) and N, P and K contents in straw (Table 8).

The increases in nitrogen, phosphorus and potassium uptake by straw due to treated soybean plants with biochar at 5 ton/fed + 75 % RRP were about 100.10 and 126.50 % ; 108.84 and 128.84 % and 101.85 and 131.50 % over the control in the 1st and 2nd seasons, respectively.

Table 7: Effect of biochar, compost and phosphorus levels on nitrogen, phosphorus and potassium contents and total protein (%), in seeds.

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Total protein (%)	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
0 organic + 0 P (control)	5.52 e	5.10 f	0.19 g	0.19 f	1.12 d	1.10 d	34.50 f	31.88 f
Biochar 5 ton /fed + 0 P	5.76 d	5.80 e	0.22 f	0.22 e	1.24 c	1.20 c	36.00 e	36.25 d
Biochar 5 ton /fed +50 % RRP	6.00 c	6.10 cd	0.36 d	0.35 c	1.34 b	1.30 b	37.50 d	38.13 c
Biochar 5 ton /fed+75 %RRP	6.59 a	6.50 a	0.51 ab	0.50 b	1.48 a	1.45 a	41.19 a	40.63 a
Biochar 5 ton /fed+100% RRP	6.30 b	6.25abc	0.51 a	0.51 a	1.46 a	1.44 a	39.38 c	39.06 b
Compost 5 ton /fed+0 P	5.70 d	5.65 e	0.22 f	0.21 e	1.23 c	1.21 c	35.63 e	35.31 e
Compost 5 ton /fed+50 % RRP	5.95 c	5.90 de	0.34 e	0.34 d	1.31 b	1.30 b	37.19 d	36.88 d
Compost 5 ton /fed+75 %RRP	6.48 a	6.45 ab	0.50 c	0.50 b	1.43 a	1.43 a	40.50 b	40.31 a
Compost 5 ton /fed+100% RRP	6.23 b	6.20 bc	0.50 bc	0.50 b	1.42 a	1.41 a	38.94 c	38.75 bc
LSD at 5 % level	0.13	0.25	0.01	0.01	0.06	0.05	0.68	0.65

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤.0.05

Table 8: Effect of biochar, compost and phosphorus levels on nitrogen, phosphorus and potassium contents in straw.

Treatments	**Nitrogen** (%)		**Phosphorus** (%)		**Potassium (%)**	
	2022 season	**2023 season**	**2022 season**	**2023 season**	**2022 season**	**2023 season**
0 organic + 0 P (control)	1.80 d	1.75 d	0.16 d	0.16 de	2.98 c	2.95 c
Biochar 5 ton /fed + 0 P	1.98 c	1.95 c	0.18 c	0.18 c	3.25 b	3.20 b
Biochar 5 ton /fed +50 % RRP	2.20 b	2.15 b	0.20 b	0.19 b	3.52 a	3.50 a
Biochar 5 ton /fed+75 %RRP	2.37 a	2.35 a	0.21 a	0.21 a	3.49 a	3.48 a
Biochar 5 ton /fed+100% RRP	2.35 a	2.30 a	0.16 d	0.16 e	2.96 c	2.92 c
Compost 5 ton /fed+0 P	1.95 c	1.93 c	0.17 c	0.17 cd	3.22 b	3.20 b
Compost 5 ton /fed+50 % RRP	2.17 b	2.10 b	0.19 b	0.19 b	3.47 a	3.45 a
Compost 5 ton /fed+75 %RRP	2.35 a	2.31 a	0.19 b	0.19 b	3.44 a	3.42 a
Compost 5 ton /fed+100% RRP	2.32 a	2.30 a	0.17 d	0.16 de	2.98 c	2.95 c
LSD at 5 % level	0.09	0.11	0.01	0.01	0.12	0.11

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

Table 9: Effect of biochar, compost and phosphorus levels on nitrogen, phosphorus and potassium uptakes (kg /fed) by seeds.

Treatments	**Nitrogen uptake (kg /fed)**		**Phosphorus uptake (kg /fed)**		**Potassium uptake (kg /fed)**	
	2022 season	**2023 season**	**2022 season**	**2023 season**	**2022 season**	**2023 season**
0 organic + 0 P (control)	67.34 g	60.69 g	2.29 e	1.85 f	13.66 f	10.00 h
Biochar 5 ton /fed + 0 P	86.40 e	87.00 de	3.33 d	3.00 e	18.60 d	18.00 f
Biochar 5 ton /fed +50 % RRP	91.20 d	91.50 cd	5.44 c	5.25 d	20.37 c	19.50 de
Biochar 5 ton /fed+75 %RRP	116.64 a	118.95 a	8.94 a	9.06 a	26.20 a	26.54 a
Biochar 5 ton /fed+100% RRP	100.80 c	88.75 de	8.16 b	7.24 c	23.36 b	20.45 cd
Compost 5 ton /fed+0 P	80.37 f	76.28 f	3.03 de	2.88 e	17.34 e	16.34 g
Compost 5 ton /fed+50 % RRP	85.68 e	82.60 ef	4.92 c	4.76 d	18.86 d	18.20 ef
Compost 5 ton /fed+75 %RRP	104.98 b	104.49 b	8.04 b	8.02 b	23.17 b	23.17 b
Compost 5 ton /fed+100% RRP	100.30 c	95.48 c	8.02 b	7.68 bc	22.86 b	21.71 c
LSD at 5 % level	2.15	6.56	0.76	0.72	1.25	1.41

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

Table 10: Effect of biochar, compost and phosphorus levels on nitrogen, phosphorus and potassium uptakes by straw

Treatments	**Nitrogen uptake (kg /fed)**		**Phosphorus uptake (kg /fed)**		**Potassium uptake (kg /fed)**	
	2022 season	**2023 season**	**2022 season**	**2023 season**	**2022 season**	**2023 season**
0 organic + 0 P (control)	50.22 h	46.38 e	3.96 e	3.71 e	73.94 g	67.58 f
Biochar 5 ton /fed + 0 P	72.67 f	67.28 d	6.06 cd	5.52 d	109.37 e	101.78 e
Biochar 5 ton /fed +50 % RRP	81.84 e	83.21 c	6.62 c	6.77 bc	120.90 d	123.84 d
Biochar 5 ton /fed+75 %RRP	100.49 a	105.05 a	8.27 a	8.49 a	149.25 a	156.45 a
Biochar 5 ton /fed+100% RRP	93.77 c	94.30 b	8.34 a	8.41 a	139.25 b	142.68 b
Compost 5 ton /fed+0 P	67.67 g	63.69 d	5.62 d	5.22 d	102.71 f	96.36 e
Compost 5 ton /fed+50 % RRP	80.29 e	79.80 c	6.44 c	6.46 c	119.14 d	121.60 d
Compost 5 ton /fed+75 %RRP	96.82 b	91.25 b	7.83 ab	7.39 b	142.96 b	136.28 c
Compost 5 ton /fed+100% RRP	90.02 d	89.70 b	7.49 b	7.41 b	133.47 c	133.38 c
LSD at 5 % level	2.43	5.43	0.73	0.65	5.33	6.26

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

The superiority of biochar can be attributed to its capacity to stop nutrient losses, which raises the quantity of nutrients in the soil. An increase in the concentration of resin-extractable phosphate after biochar amendment supports the intriguing finding that biochar amendment has a positive effect on plant nutrition (Atkinson *et al*., 2010). High porosity, which explains its remarkable ability to hold water, and high cation exchange capacity, which promotes nutrient retention and prevents its loss, are some of the properties of biochar or compost that greatly contribute to its positive benefits (Ghazi and El-Sherpiny, 2021).

In this regard, phosphorus application may have a nutritional environment in the rhizosphere and in plants, which could promote nutrient uptake and translocation, particularly of N, P, and K in reproductive structures, resulting in higher content and intake. Additionally, a strong and favorable relationship between yield and nutrients was demonstrated for higher nutritional content. Since the uptake of N, P, and K depends on the yield and content of grain and straw, the overall uptake of N, P, and K was improved by the notable increase in these nutrients' concentrations as well as by higher grain and straw yield. In essence, grain's protein content is an indication of its N content. Therefore, a higher N concentration may have resulted in a higher protein content (Yadav *et al*., 2017).

These results are in harmony with those obtained by Hafez *et al*. (2020) Liu et al., 2022 and Shaltout *et al*. (2022). They showed that the highest N, P and K uptake by seeds and straw were obtained with biochar application than control treatment. In the other line, Abd El-Rahman *et al*. (2019) showed that fertilizing soybean plants with 22.5 kg P_2O_5 per fed produced the highest values of N, P and K uptake by grains and straw as compared to zero P_2O_5 Awaad *et al*. (2020) on faba bean indicated that the highest values of N, P and K contents and their uptake by seeds were obtained by using (30 kg P_2O_5 per fed) as compared with the other levels.

N, P and K in the soil after harvesting

Fertilizing soybean plants with biochar and compost at 5 ton /fed. of each with 0., 50, 75 + 100 % RRP increased available N, P and K in the soil after harvesting compared to control treatment (without any addition) and biochar at 5 ton /fed and + 75 or 100 % RRP or compost at 5 ton /fed. + 75 or 100 % RRP gave the highest values of both seasons (Table 11).

This means that biochar and compost at 5 ton /fed of each + 75 % RRP (16.875 kg P_2O_5/fed) of each were the best treatments for enhancing the available of N, P and K in the soil after harvesting. Available of N, P and K in the soil after harvesting for all treatments in both seasons were around from 35.10 to 45.57 for available N, from 8.07 to 10.27 ppm for available P and from 290.0 to 375.0 for available K.

Soil organic carbon, pH, total nitrogen, accessible nitrogen, available potassium, and available phosphorus were all markedly raised by the use of organic fertilizers like compost or biochar (Du *et al.*, 2020).

These results are agreement with Wu *et al*. (2022) who indicated that treated soil with biochar significantly increased available of N, P and K in the rhizosphere soil of soybean than untreated plants. Similarly, Awaad *et al*. (2020) showed that fertilizing faba bean plants with 30 kg P_2O_5/ fed increase the availability of nitrogen, phosphorus and potassium in soil as compared to control.

Table 11: Effect of biochar, compost and phosphorus levels on available nitrogen, phosphorus and potassium in soil after harvesting

Treatments	Nitrogen (ppm)		Phosphorus (ppm)		Potassium (ppm)	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
0 organic + 0 P (control)	35.20 d	35.10 c	8.08 e	8.07 c	292.00 d	290.00 d
Biochar 5 ton /fed + 0 P	40.18 bc	40.10 b	9.15 cd	9.10 b	315.00 c	310.00 c
Biochar 5 ton /fed +50 % RRP	40.80 b	40.70 b	9.70 abc	9.65 ab	343.00 b	340.00 b
Biochar 5 ton /fed+75 %RRP	45.57 a	45.40 a	10.15 ab	10.10 a	375.00 a	370.00 a
Biochar 5 ton /fed+100% RRP	45.47 a	45.35 a	10.27 a	10.25 a	372.33 a	360.00 a
Compost 5 ton /fed+0 P	40.08 c	40.00 b	9.05 d	8.95 b	314.00 c	311.00 c
Compost 5 ton /fed+50 % RRP	40.61 bc	40.55 b	9.60 bcd	9.55 ab	340.00 b	338.00 b
Compost 5 ton /fed+75 %RRP	45.07 a	44.90 a	10.03 ab	9.95 a	372.00 a	370.00 a
Compost 5 ton /fed+100% RRP	44.96 a	44.90 a	10.15 ab	10.10 a	366.67 a	365.00 a
LSD at 5 % level	0.68	1.35	0.62	0.72	8.65	11.53

Means of each criterion followed by the different letters within each column are significantly different using Duncan's Multiple Range Test at P- value of ≤ 0.05

CONCLUSIONS

In the same circumstances, it could be said that fertilizing soybean plants grown in clay soil with 5 tons of biochar per fed. + 75% RRP resulted in the tallest plants and higher yield and its components, including straw and biological yield, N, P, and K concentrations, as well as their uptake by seeds and straw and the amount of N, P, and K in the soil thereafter plant harvest.

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الملخص العربي

تأثير استخدام البيوشار والكمبوست والتسميد الفوسفاتى على إنتاجية محصول فول الصويا وخصوبة التربة

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معهد بحوث الاراضى والمياه والبيئة – مركز البحوث الزراعية

لدراسة تأثير سماد الكومبست العضوي والفحم الحيوي ومعدلات الفوسفور المختلفة على نمو فول الصويا (صنف جيزة ١١١) والمقاييس الانتاجيه وجودة بذوره، تم أُجرأء تجربتان حقليتان في محطة البحوث الزراعية بالجميزة، التابعة لمركز البحوث الزراعية، محافظة الغربية، مصر، خلال صيفَي ٢٠٢٢ و٢٠٢٣. وكانت المعاملات كمايلي:

بدون تسميد عضوي او فوسفاتي، ٥ طن بيوشار/فدان، ٥ طن بيوشار/فدان + ٥٠٪ من التسميد الفوسفاتي الموصي به ٥ طن بيوشار/فدان + ٧٥٪ من التسميد الفوسفاتي الموصي به، ٥ طن بيوشار/فدان + ١٠٠٪ من التسميد الفوسفاتي الموصي به، ٥ طن كمبوست/ فدان، ٥ طن كمبوست/فدان + ٥٠٪ من التسميد الفوسفاتي الموصي به، ٥ طن كمبوست/فدان + ٧٥٪ من التسميد الفوسفاتي الموصي به، ٥ طن كمبوست/فدان + ١٠٠٪ من التسميد الفوسفاتي الموصي به. تم الحصول على أطول نباتات لفول الصويا وأعلى عدد من القرون/نبات، ووزن القرون/نبات، ووزن ١٠٠ بذرة، وإنتاجية البذور/نبات، وإنتاجية البذور/فدان، وإنتاجية القش/فدان، وكذلك البروتين الكلي في البذور، وذلك بتسميد نباتات فول الصويا المزروعة في الارض الطينية بالفحم الحيوي بمعدل ٥ أطنان لكل فدان مع ٧٥٪ من المعدل الموصى به للفوسفور، والذي يعادل ١٦.٨٧٥ كجم/فدان من خامس اكسيد الفوسفور، كما أنتجت هذه المعاملة أعلى قيم لامتصاص النيتروجين والفوسفور والبوتاسيوم بواسطة البذور والقش وزادت من كمية النيتروجين والفوسفور والبوتاسيوم المتاح في التربة بعد الحصاد. وكانت الزيادات في إنتاجية البذور/فدان حوالي ٤٥.٠٨٪ و٥٣.٧٨٪ لمعامله الفحم الحيوي عند ٥ أطنان/فدان و٧٥٪ من المعدل الموصى به للفوسفور عن معامله المقارنه في الموسمين الأول والثاني على التوالي. وكذلك أدت هذه المعامله علي تحسين النيتروجين الميسر في التربة بعدالحصاد.