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Managing Biochar Application and Nitrogen Fertilization to Improve Wheat Production and Soil Nutrients Status under Clay Soil Conditions

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ABSTRACT

Biochar used lately as soil quality improver for nutritional, microbiological and physical properties. Under middle Nil delta alluvial clay soils conditions, during winter growing seasons of 2021/2022 and 2022/2023, a field experiment was conducted at El-Gemmeiza Agricultural Research Station, ARC, El-Gharbeya Governorate, Egypt located at (Lat. 30° 48′ 752" and Long. 31° 81 025"). This study looked at plant growth, leaf chlorophyll content, wheat productivity, nitrogen use efficiency (NUE), and grain quality of wheat cultivar Sakha 95 were affected by biochar (0 and 12.5 m^3/ha) and nitrogen fertilization levels i.e., 0, 50, 75 and 100 of the recommended rates (equals 0, 125, 187.5, and 250 kg N/ha) in the form of urea (46% N). Split-plot statistical design was applied, the biochar rates distributed in the main plots, whereas nitrogen fertilization levels randomized in the sub-plots. The obtained results showed that the combination between treated wheat plants grown in clay soil with biochar at 12.5 m^3/ha and fertilizing plants with 100% of recommended N fertilization rate (250 kg N/ha) was the best treatment for increasing**,** leaf chlorophyll content (LCC), i.e., chlorophyll a, b, and total a+b after 75 days from sowing, grain yield (GY), straw and biological yields (StY, BY), harvesting index (HI), and plant height (PH), nitrogen use efficiency (NUE), nitrogen, phosphorus and potassium contents in grain and straw (N, P and K %) and their uptake, the measured data includes total protein in grains as well as the available N, P, and K contents, and organic matter (OM %) in soils after harvesting of wheat in both growing seasons as soil quality parameters due to application of Biochar as unique soil improvement material. Treatments application produced improvement by 54.81%, 24.30%, and 36.5 % as relative increase in grain yield (GY), straw yield (StY), and biological yield (BY) ha^{-1}, respectively (as average of the two growing seasons) compared with unfertilized control wheat plots. On the other side, there were no significant differences for the interaction between 75 % of the recommended N rate combined with Biochar at application rate 12.5 m^3 ha^{-1} and 100 % of the recommended N fertilization rate without Biochar for all above mentioned data in both growing seasons.

Keywords: Wheat, Biochar, Nitrogen fertilizer, NPK, Soil quality

1. Introduction

After rice and maize, wheat (*Triticum aestivum* L.) is the world's most important food source for human nourishment and is required in one or more forms on a daily basis. It is Egypt's principal winter grain crop and a significant staple food crop. Due to its distinct protein qualities, wheat is the most extensively produced grain worldwide and is a vital source of both food and energy (Abedi *et al*., 2010). It is simple to process into a variety of foods, including desserts, macaroni, bread, and biscuits. Egypt grew wheat on 3.404 million feddans (one feddan is 4200 m^2) in the 2021–2022 growing season. The crop produced 9.700 million tons annually, with an average yield of 18.997 Ardab (one Ardab is 150 kg) per feddan (FAO, 2023).

The topic of biochar has received a lot of attention lately. The pyrolysis of biomass in low oxygen environments yields biochar, a stable, extremely porous, fine-grained carbon compound (Abbas *et al.,* 2018). Biochar is more effective than manure at lowering soil bulk density and increasing soil water-holding capacity (Malik *et al.,* 2018). Moreover, biochar is created and used to manage agricultural

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waste in the best possible way. Furthermore, biochar is essential for soil quality because of its role in enhancing aggregation, preventing leaching, balancing the pH of acidic soils, increasing soil carbon content, cation exchange capacity, and water holding capacity; additionally, it prepares the ground for additional microorganism activity (Ali *et al.,* 2017).

Treated wheat plants with biochar gave the best growth of plant, yield and grain quality of wheat (Olmo *et al*., 2014; Malik *et al*., 2018; Ibrahim, *et al*., 2019; Mahmoud *et al*., 2019; Sun *et al*., 2019; Hafez *et al*., 2020 ; El-Sayed *et al*., 2021;Khan *et al*., 2021; Seleiman, *et al*., 2021; Zaheer *et al.,* 2021; El-Sobky and Abdelsalam 2022; Li *et al*., 2022 and Essa *et al*., 2023).

As an important element, nitrogen (N) plays a prominent role in plant metabolism and enhances grain production, protein synthesis, and chlorophyll creation. According to Avlin *et al.,* (1999), N treatment during grain fill is necessary to maximize grain yield. When more nitrogen (N) is applied than the crop needs, it can immobilize the crop and make N inaccessible, which reduces the amount of N fertilizer that the crop can recover (King *et al.,* 2001). Split nitrogen (N) application is required because nitrogen (N) is lost through gaseous emission, soil volatilization, and leaching (Gad *et al*., 2018).

The application of nitrogen (N) fertilizer greatly enhanced the growth characteristics, grain, and straw yields of wheat. (Enayat *et al*., 2013; Dagash *et al*., 2014; Ali *et al*., 2016; El–Hag and Shahein, 2017 ; El-Seidy *et al*., 2017; Litke *et al.*, 2017 ; El-Dissoky and Attia, 2018; Gad *et al.*, 2018; Hefny and Mohammed, 2018; Shahin, 2020; Gheith *et al*., 2021; Saboon *et al.,* 2022; Marco *et al.*, 2021; Mohamed *et al*., 2022; El-Khamissy *et al*., 2023 and Abd El-Dayem *et al*., 2024).

Some authors showed that the combination between biochar and nitrogen fertilization improving plant growth, yield and grain quality of wheat (El-Sobky and Abdelsalam 2022; Li *et al*., 2022, Shaltout *et al*., 2022 and Liu *et al*., 2024).

Therefore, this work aims to know the extent of the response of wheat plants growing under alluvial clay soil conditions to treatment with biochar and nitrogen fertilizer, with the aim of improving soils quality properties and obtaining the best grain yield, improving nitrogen use efficiency and NPK elements uptake by the plants.

2. Materials and Methods

In the winter seasons of 2021/2022 and 2022/2023, a field experiment was conducted at El-Gemmeiza Agricultural Research Station, Agriculture research center (ARC) in El-Gharbeya Governorate (middle of nil delta), Egypt (longitude 31 7° E and latitude 30 43° N). This study looked at how growth, grains chemical composition, yield, and grain quality of wheat cultivar Sakha 95 under clay soil condition were affected by Biochar and nitrogen fertilization levels.

Some of the experimental soil's physical and chemical characteristics, as reported by Balck *et al.* (1981), are displayed in Table 1.a

Table 1.a: The experimental sites physical and chemical characteristics throughout the 2021–2022 and 2022–2023 growing seasons

Parameter	**Value**	
1. Physical properties	**2021/2022**	**2022/2023**
Corse sand (%)	3.88	4.50
Fine sand (%)	15.42	15.51
Silt (%)	40.47	40.90
Clay (%)	40.23	39.09
Textural class	**clayey loam**	**clayey loam**
2. Chemical properties		
EC dSm^{-1} (soil past extract)	2.41	2.29
pH (1: 2.5 soil: water suspension)	8.08	7.99
$CaCO_3$ (%)	2.51	2.46
Organic matter (%)	1.82	1.77
Available nitrogen ($\mu g\ g^{-1}$)	31	33
Available phosphorus ($\mu g\ g^{-1}$)	7.7	8.1
Available potassium ($\mu g\ g^{-1}$)	425	418

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In this experiment, two biochar rates (0 and 12.5 m^3 ha^{-1} equal to 9.4 tone ha^{-1}) and four nitrogen levels (0, 125, 187.5, and 250 kg/ha) were combined to create eight treatments. The main plot of the split-plot design used for these treatments contained the biochar rate, while the sub-plots with three replications contained the nitrogen levels.

The area of each sub-plot was 10.5 m^2 (3.0 m long ×3.5 m width). The wheat grains were sown manually in 20th and 22nd of November in both growing seasons, respectively with seeding rate at 150 kg grains /ha

According to the average of the two seasons, the biochar parameters utilized in this experiment were show in table 1.b.

Table 1.b: Some characteristic of Biochar.

Characteristic	Value	Characteristic	Value
Density, kg m^3	752.00	N, %	1.40
Moisture content, %	4.89	P, %	0.92
pH	8.90	K, %	1.48
EC, dS m^{-1}	0.52	Organic carbon (OC), %	27.21
Ca, %	1.50	Organic matter (OM), %	46.80
Mg, %	2.70	C/N ratio	33.40

ARC in Giza, Egypt provided the Biochar.

The soil was amended with biochar prior to the planting of wheat. Furthermore, two equal doses of nitrogen fertilization rates were applied: one before the first irrigation (21 days after sowing) and the second dose was applied before the second irrigation (45 days after sowing) in the form of urea (46 %N).

Phosphorus was applied as single super-phosphate (15.5% P_2O_5) at a rate of 75 kg P_2O_5/ha during the soil preparation process. Potassium fertilizer was provided in the second irrigation at a rate of 125 kg K_2O/ha as potassium sulphate (48% K_2O). In the final week of April, harvesting took place (156 days after planting). Further farming practices for wheat fields were adopted based on recommendations from the Field Crops Research Institute.

Recorded data

Vegetative growth: The percentage of dry matter (DMP) in the shoots was calculated by randomly selecting 10 plants from each plot.

Photosynthetic Pigments: Leaf chlorophyll contents (LCC) a, b and total chlorophyll (a+b) were extracted and determined at 75 days after sowing according to Moron (1982).

Yield and its components

When the wheat plants reaches physiological maturity were harvested and the height of plants (PH) in centimeters was measured, ten randomly selected spikes in each experimental plot were used to determine the 100-grain weight (g) (100-GW). By harvesting 2.0 m^2 from each plot and converting it to a hectare, the grain yield (GY), straw yield (StY), and biological yield (BY) (grain yield + straw yield) as expressed in tons per hectare were calculated. The harvest index (HI, %) was calculated using the grain (GY) to biological yield (BY) ratio and reported as a percentage.

Nitrogen use efficiency (NUE)

NUE was calculated according to Delogu *et al.* (1998) by the following equation:

$$NUE = \frac{\text{Grain yield at N treatment} - \text{Grain yield at zero N}}{\text{Applied N rate at N treatment}}$$

Nutrients contents: According to A.O.A.C. (2012), the nitrogen, phosphorus, and potassium contents of grains were determined at harvest time in both seasons. Grain yield was multiplied by the corresponding N, P, and K concentrations (%) to compute the N, P, and K uptake (kg ha^{-1}), according to method of per Craswell and Godwin (1984).

Grains quality
Protein % (Pr%): According to A.A.C.C. (2012), the crude protein % was calculated by multiplying the N% by 5.7.

Total carbohydrate percentage (TChP)**:** The total carbohydrate percentage in the whole wheat grains was analyzed using the method described by Dubois *et al.* (1956).

Statistical analysis: For all data that was gathered, a statistical analysis was done according to Snedecor and Cochran (1980) were used to calculate the analysis of variance, and Duncan (1958) method was used to separate the means at the 0.05 probability level.

3. Results and Discussion

3.1. Vegetative growth

3.1.1. Effect of Biochar

Data in Table 2 indicated that there were significant differences between the two Biochar application rates concerning dry matter shoots of wheat plants at 75 days after sowing in both seasons. Treated soil with Biochar at application rate 12.5 m^3 ha^{-1} recorded the highest values of dry matter accumulation (DM) of shoots (14.08 and 13.56%) against untreated soil (12.81 and 12.95%) in the both growing seasons, respectively. The relative increases in DM % due to application of Biochar was about 9.91 and 4.71 % over untreated soil in the two growing seasons, respectively.

The porosity of the biochar, which allowed more water to be retained in the soil, may have contribution to the plants treated with biochar growing more than control plants. Another idea holds that plants treated with biochar have increased access to nutrients, particularly phosphorus, due to the ash concentration of the charcoal (Das *et al*., 2018). Improvements in soil fertility and other characteristics may indicate the positive effects of adding biochar on vegetative growth (Sohi *et al*., 2010). Furthermore, Joba *et al.,* (2022) confirmed that the addition of biochar had an impact on soil nutrients. Additionally, due of its large surface area, and a good sources of nitrogen using biochar improves soil fertility and promotes plant growth (Li *et al*., 2022).

Similar results were reported by several investigators Olmo *et al*. (2014); Malik *et al*. (2018); Ibrahim, *et al*. (2019); Mahmoud *et al*. (2019); Sun *et al*. (2019). They indicated that vegetative growth characteristics of wheat were significantly increased by application of biochar as compared to untreated.

3.1.2. Effect of nitrogen rates

Dry matter of wheat shoots increased significantly with increasing nitrogen fertilizers rates 75 days after sowing in both growing seasons (Table 2). Fertilizing wheat plants grown in clay soil with different levels of nitrogen significantly enhanced dry matter of shoots as compared to the control treatment in both growing seasons, in addition nitrogen at 250 kg ha^{-1} (100% of recommended N fertilization rates) gave the best results for dry matter of shoots (15.93 and 15.85%) in the 1st and 2nd growing seasons, respectively, followed by 187.5 kg N ha^{-1} (75% of recommended N rates). The relative increases in DM % due to fertilizing with 250 kg N ha^{-1} were about 47.50 and 50.81 % over unfertilized plots in the 1st and 2nd growing seasons, respectively.

Shoot was increased by increasing N fertilization rate through increased cell elongation and vegetative development. These results corroborate those of Enayat *et al.* (2013); Dagash *et al.* (2014); Ali *et al.* (2016); El-Hag and Shahein (2017); El-Seidy *et al.* (2017); and Litke *et al.* (2017), which also showed that DM of shoots rose as N application rates increased.

3.1.3. Effect of the interaction

All the interaction treatments significantly increased wheat shoots DM after 75 days from sowing as compared to the control treatment (no addition of biochar or nitrogen) in both growing seasons (Table 2).

The favorable interaction treatment for increasing shoot dry matter (DM) was Biochar at 12.5 m^3 ha^{-1} and N at 250 kg N/ha, which produced the highest shoot DM values (16.92 and 16.50 %) in each of the two growing seasons. On the other side, there were no significant differences between the combination between Biochar at 0 m^3 ha^{-1} and N at 250 kg N ha^{-1} and the combination between biochar at 12.5 m^3 ha^{-1} and N at 187.5 kg N/ha (75% of recommended N fertilization rate) in both growing seasons.

The relative increases in DM % of the interaction between Biochar at 12.5 m^3 ha^{-1} and N at 250 kg N ha^{-1} were about 57.72 and 63.04 % over unfertilized control plots in the two growing seasons, respectively.

In the same line, El-Sobky and Abdelsalam (2022) was located similar results on wheat.

Table 2: Effect of Biochar and N fertilization rate and their interaction on wheat shoots (dry matter) DM at 75 days after sowing in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rate (kg ha^{-1})				Mean (biochar)
	0	125	187.5	250	
			2021/2022 season		
Without	10.10 g	12.50 e	13.70 cd	14.95 b	**12.81 b**
12.5m3 ha^{-1}	11.50 f	13.41 d	14.50bc	16.92 a	**14.08 a**
Mean (N)	**10.80 d**	**12.95c**	**14.10 b**	**15.93 a**	
			2022/2023 season		
Without	10.12 f	12.70 d	13.80 c	15.20 b	**12.95 b**
12.5m^3 ha^{-1}	10.90 e	12.95 d	13.90 c	16.50 a	**13.56 a**
Mean (N)	**10.51 d**	**12.82 c**	**13.85 b**	**15.85 a**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

3.2. Leaf chlorophyll content (LCC)

3.2.1. Effect of Biochar

Leaf photosynthetic pigments, i.e., chlorophyll a, b, and total a+b (LCC) in leaves of wheat after 75 days from sowing were significantly affected by adding biochar to soil in both seasons (Table 3).

Treating soil with Biochar at rate 12.5 m^3 ha^{-1} recorded the highest values of LCC a (3.51 and 3.59 mg dm^2), LCC b (1.09 and 1.13 mg/dm^2), and total LCC a+b (4.03 and 4.12 mg/dm^2) for untreated soil in each of the two growing seasons.

The relative increases in total LCC a+b due to application of biochar at 12.5 m^3 ha^{-1} were about 14.39 and 14.80% over untreated plants in each of the two growing seasons.

These results are in agreement with those stated by Hafez *et al*. (2020) and El-Sobky and Abdelsalam (2022) and Essa *et al*. 2023. They indicated that treating soil of wheat plants with biochar significantly increased total LCC a and LCC b as compared to untreated plants.

3.2.2. Effect of N rates

Fertilizing wheat plants grown in clay soil with N using different rates (125, 187.5, and 250 kg ha^{-1}) had affected all leaf of photosynthetic pigments (LCC), i.e., leaf chlorophyll content (LCC) a, b, and total LCC a+b in leaves of wheat after 75 days from sowing as compared to control treatments (no fertilizer) in both growing seasons (Table 3).

The maximum concentrations of LCC a (3.78 and 3.89 mg/dm^2), LCC b (1.33 and 1.38 mg $dm^{2)}$, and LCC a+b (5.11 and 5.28 mg dm^2) were scored with N at 250 kg ha^{-1} in the 1st and 2nd growing seasons, respectively, followed by those plants that were fertilized with 187.5 kg ha^{-1} (75% of N recommended fertilization rate). On the other hand, control plants (no N fertilizer) scored the minimum concentrations in all leaf pigments of wheat in both seasons.

The relative increases in (LCC) a+b due to fertilization with N at 250 kg ha^{-1} were about 43.13 and 50.85% over unfertilized plants in each of the two growing seasons.

The right amount of nitrogen varies based on the characteristics of the soil and the surrounding environment. This is explained by the part N, a crucial macronutrient, plays in dry matter production and plant growth. It also encourages photosynthesis, which aids in the accumulation of additional biomass. These findings concur with those reported by Zhen *et al*. (2021). It has been demonstrated that increasing N application increases leaf chlorophyll content, which flushes growth and raises dry matter.

3.2.3. Effect of the interaction

There were significant differences between all the interaction treatments and the interaction between zero biochar and zero nitrogen as for leaf pigments in wheat after 75 days from sowing in both growing seasons (Table 3).

The best interaction treatment for increasing the concentrations of LCC a (3.92 and 4.09 mg dm^2), LCC b (1.44 and 1.52 mg dm^2), and total LCC a+b (5.36 and 5.61 mg dm^2) were produced with the interaction between 12.5 m^3 ha^{-1} Biochar and N at 250 kg ha^{-1} in the two growing seasons, respectively. While, the lowest concentrations of all leaf pigments were produced with unfertilized biochar and nitrogen in both seasons. On the other side, there were no significant differences with all leaf pigments of wheat with the interaction between nitrogen at 250 kg ha^{-1} only and the combination between N at 187.5 kg ha^{-1} and treated soil with biochar at 12.5 m^3 ha^{-1} in both growing seasons.

The relative increases in total chlorophyll a+b due to the interaction between fertilization with N at rate 250 kg/ha and treated soil with Biochar at rate 12.5 m^3 ha^{-1} were about 68.02 and 77.53% over unfertilized plants in the both growing seasons, respectively.

Table 3: Effect of Biochar, N fertilization rates and their interaction on leaf chlorophyll content (LCC) (mg/dm^2) in leaves of wheat after 75 days after sowing in 2021/22 and 2022/23 growing seasons

Treatments		Chlorophyll a		Chlorophyll b		Total chlorophyll a+b	
		2021/2022 season	2022/2023 season	2021/2022 season	2022/2023 season	2021/2022 season	2022/2023 season
				Effect of Biochar (m^3 ha^{-1})			
Without		3.10 b	3.15 b	0.93 b	0.96 b	4.03 b	4.12 b
12.5		3.51 a	3.59 a	1.09 a	1.13 a	4.61 a	4.73 a
				Effect of N Fertilization rate (kg ha^{-1})			
0.0		2.78 d	2.71 d	0.79 d	0.79 d	3.57 d	3.50 d
125		3.15c	3.31 c	0.90 c	0.93 c	4.05 c	4.24 c
187.5		3.52b	3.59 b	1.01 b	1.09 b	4.53 b	4.68 b
250		3.78 a	3.89 a	1.33 a	1.38 a	5.11 a	5.28 a
Biochar	**N rates**			Effect of interaction			
Without	**0**	2.51f	2.43 e	0.68 f	0.73 d	3.19 f	3.16 e
	125	2.90e	3.10 cd	0.84e	0.89 c	3.74 e	3.99 d
	187.5	3.34d	3.40 bc	0.98cd	0.99 c	4.32 cd	4.39 c
	250	3.6bc	3.70 ab	1.22b	1.25 b	4.87 ab	4.95 b
	0	3.05e	2.99 d	0.91de	0.85 cd	3.96 de	3.84 d
12.5	**125**	3.40 cd	3.52 b	0.97cde	0.98 c	4.37bcd	4.50 c
	187.5	3.70 b	3.78 ab	1.05bc	1.20 b	4.75 bc	4.98b
	250	3.92 a	4.09 a	1.44 a	1.52 a	5.36 a	5.61 a

According to Duncan's multiple range tests, values with the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance.

3.3. Yield and its components

3.3.1. Effect of Biochar

Data in Tables 4 to 8 showed that yield and its components, i.e., 100 grains weight (100-GW), grains yield (GY), straw yield (StY), and biological yield (BY), harvest index (HI) had significant affect by Biochar application in both growing seasons.

Treating soil with Biochar at rate 12.5m^3 ha^{-1} gave the highest values of 100-GW (4.99 and 4.93g), GY (6.468 and 6.588 ton/ha), (8.736 and 8.606 ton ha^{-1}), BY (15.204 and 15.194 ton ha^{-1}) and HI(42.54and43.36%) against control treatment (4.30 and 4.24g), (5.968 and 6.075 ton ha^{-1}), (8.269 and 8.293 ton ha^{-1}), (14.237 and 14.368 ton ha^{-1}) and (41.92 and 42.28 %) for 100-GW, GY, StY, BY and HI in the 1^{st} and 2^{nd} growing seasons, respectively.

The relative increase in GY due to application of Biochar at 12.5 m^3/ha were about (8.37 and 8.44 %), StY were about (5.64 and 3.77%) and BY were about (6.79 and 5.74 %) over untreated plants during the first and second growing seasons, respectively.

Regarding PH, in the first and second growing seasons, respectively, treated soil with 12.5 m^3 ha^{-1} of Biochar provided the highest values of PH (112.50 and 114.50 cm) compared to untreated soil (105.75 and 108.75 cm) as shown in (Table 9).

Applying biochar as a soil amendment promotes plant development and yield (Naeem *et al*., 2017). Additionally, biochar can increase the amount of carbon and organic matter in the soil as well as the microbial activity in the soil, which increases the availability of nutrients in the soil and ultimately increases overall yield (Ahmed *et al*., 2019). Furthermore, biochar increases plant development by making nutrients like P, K, Ca, and Mg readily available and absorbable, which enhances plant photosynthesis. Higher rates of photosynthetic energy and the generation of carbohydrates lead to increased plant height, weight at 100 grains, grain yield, and straw yield (Khan *et al*., 2021).

Our findings are in agreement with previous researchers as Hafez *et al*. (2020) ; El-Sayed *et al*. (2021); Khan *et al*. (2021); Seleiman, *et al*. (2021); Zaheer *et al.* (2021); El-Sobky and Abdelsalam (2022); Li *et al*. (2022) and Essa *et al*. (2023). They showed that application of biochar to wheat plants superior yield and its components than unapplied biochar.

3.3.2. Effect of N rates

Data tabulated in Tables 4-8 show that all nitrogen fertilizer rates had significantly affected yield and its components as compared to unfertilized plants in both seasons. Yield and its components, such as 100-GW, GY, StY and BY, as well as HI, significantly gradually increased with increasing N fertilization rates up to the highest levels in both growing seasons, except 100-GW significantly gradually decreased.

Fertilizing wheat plants with 250 kg N ha^{-1} scored the maximum values of GY (7.500 and 7.650 tons ha^{-1}), StY (9.298 and 9.231 ton ha^{-1}), BY (16.798 and 16.881 ton /ha) and HI (44.65 and 45.32%) in the 1^{st} and 2^{nd} seasons, respectively, followed by fertilizing with 187.5 kg ha^{-1} and then 125 kg /ha. while, control plants recorded the highest values of 100-GW (5.17 and 5.21g) in the both two growing seasons, respectively.

The relative increase in GY, StY, and BY due to fertilizing with 100% of recommended N rates were about (46.34 and 45.71%), (19.38 and 19.26%), and (30.08 and 29.95%) over unfertilized (control) wheat plants in the two growing seasons, respectively.

Increasing nitrogen levels increased total number of grains, but reduced rate of grain filling (Mosalem *et al*., 1999).

Regarding PH at harvesting time (Table 9), fertilizing wheat plants grown in clay soil with different N rates significantly enhanced PH as compared to the control treatment in both seasons, in addition N at 250 kg /ha scored the highest values (121.0 and 126.0 cm) in each of the two growing seasons, followed by 187.5 kg N ha^{-1} (75% from recommended fertilization rates). The relative increases in PH due to fertilizing with 250 kg N/ha were about 27.37 and 29.90% over unfertilized in each of the two growing seasons.

Plant height (PH) was increased by nitrogen through increasing cell elongation and vegetative development (Ali *et al*., 2016).

The increases in wheat yield and its components with increasing N level up to an acceptable N dose can be attributed to the dynamic role of N as a required component of dry matter buildup (Table 2), LCC (Table 3), and higher GY (Table 5).

Additionally, the fact that N fertilizer is regarded as one of the key nutrients for wheat growth and, consequently, the yield of grains and straw, may account for the beneficial effect of raising N fertilizer levels on the DM. Furthermore, being a crucial macronutrient, N aids in the development of dry matter and plants. It also enhances photosynthesis, which helps to accumulate more biomass and improves yield components (Ali *et al.,* 2016).

These results coincide with those reported Shahin, (2020); Gheith *et al*. (2021); Saboon *et al.* (2022); Marco *et al.* (2021); Mohamed *et al*. (2022); El-Khamissy *et al*. (2023); Abd El-Dayem *et al*. (2024) and Rashwan *et al*. (2024). They indicated that yield attributed of wheat significantly increased by increasing N fertilization rates.

3.3.3. Effect of the interaction

The interaction between biochar and N fertilizer rates significantly affected yield and its attributes in the 2021/2022 and 2022/2023 growing seasons (Tables 4-8).

Generally, increasing the N fertilizer rates from zero to 250 kg N ha^{-1} under Biochar application showed maximum values of all yield attributes than all N rates under zero Biochar only in both growing seasons. Whereas, the interaction between Biochar at 12.5 m^3 ha^{-1} and N at 250 kg ha^{-1} recorded the

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highest values of GY (7.750 and 7.925 tones ha^{-1}), StY (9.558and 9.327tones ha^{-1}), BY (17.308 and 17.252 tons ha^{-1}), and HI (44.78 and 45.94%) in the 1^{st} and 2^{nd} growing seasons, respectively. In the same time, there were no significant differences with the interaction between nitrogen at 250 kg ha^{-1} only and the interaction between nitrogen at 187.5 kg ha^{-1} and treated soil with Biochar at 12.5 m^3 ha^{-1}, with the most parameters of wheat yield in both growing seasons. On the other hand, the plants of wheat grown under Biochar and zero nitrogen gave the highest values of 100-GW (5.42 and 5.59g) in both growing seasons.

The relative increase in of GY, StY and BY (55.00 and 54.63%), (24.25 and 24.36%) and (36.36 and 36.64%) over unfertilized wheat plants in the 1^{st} and 2^{nd} growing seasons, respectively.

Concerning, the response of PH to the interaction treatment, (Table 9) indicated that all the interaction treatments significantly increased PH of wheat as compared to the control treatment (no addition of biochar or nitrogen) in both growing seasons. The best interaction treatment for enhancing PH was Biochar at 12.5 m^3 ha^{-1} and N at 250 kg N ha^{-1}, which produced the highest values (122.0 and 128.0 cm) in each of the two growing seasons.

These results are in harmony with those obtained by El-Sobky and Abdelsalam (2022); Li *et al*., (2022); Shaltout *et al*. (2022) and Liu *et al*. 2024).

Table 4: Effect of Biochar and N rates and their interaction on100 grains weight 100-GW (g) of wheat at harvesting time in 2021/22 and 2022/23 growing seasons

Biocahr rates	**N levels (kg/ha)**				**Mean (Biochar)**
	0	**125**	**187.5**	**250**	
			2021/2022 season		
Without	4.92 b	4.59 c	4.26 d	3.42 e	**4.30 B**
12.5m³/ha.	5.42a	5.09 b	4.96 b	4.50c	**4.99A**
Mean (N)	**5.17 A**	**4.84B**	**4.61 C**	**3.96D**	
			2022/2023 season		
Without	4.83 c	4.50 de	4.25 f	3.37 g	**4.24B**
12.5m³/ha.	5.59a	5.13 b	4.59 d	4.42 e	**4.93A**
Mean (N)	**5.21A**	**4.81 B**	**4.42 C**	**3.90D**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 5: Effect of Biochar and N rates and their interaction on grain yield (GY tone ha^{-1}) of wheat at harvesting time in 2021/22 and 2022/23 growing seasons

Biocahr rates	**N fertilization rates (kg ha^{-1})**				**Mean (Biochar)**
	0	**125**	**187.5**	**250**	
			2021/2022 growing season		
Without	5.000f	5.375 e	6.250 c	7.250 b	**5.968 B**
12.5m³ ha^{-1}	5.250ef	5.875 d	7.00 b	7.750 a	**6.468 A**
Mean (N)	**5.125D**	**5.625 C**	**6.625 B**	**7.500 A**	---
			2022/2023 growing season		
Without	5.125e	5.500d	6.300c	7.375b	**6.075B**
12.5m³ ha^{-1}	5.375de	5.925c	7.125b	7.925a	**6.588A**
Mean (N)	**5.250D**	**5.713C**	**6.713B**	**7.650A**	--

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 6: Effect of Biochar and N rates and their interaction on straw yield (StY tone/ha) of wheat at harvesting time in 2021/22 and 2022/23 seasons

Biocahr rates	N levels (kg/ha)				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 season		
Without	7.692d	7.885d	8.462c	9.038b	**8.269B**
12.5m³/ha.	7.885d	8.462c	9.038b	9.558a	**8.736A**
Mean (N)	**7.788D**	**8.173C**	**8.750B**	**9.298A**	
			2022/2023 season		
Without	7.500f	7.981e	8.558c	9.135a	**8.293B**
12.5m³/ha.	7.981ed	8.269d	8.846b	9.327a	**8.606A**
Mean (N)	**7.740D**	**8.125C**	**8.702B**	**9.231A**	

Table 7: Effect of Biochar and N rates and their interaction on biological yield (BY tone/ha) of wheat at harvesting time in 2021/22 and 2022/23 growing seasons

Biocahr rates	N levels (kg/ha)				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 season		
Without	12.692d	13.26d	14.712c	16.288b	**14.237B**
12.5m³/ha.	13.135d	14.337c	16.038b	17.308a	**15.204A**
Mean (N)	**12.913D**	**13.798C**	**15.375B**	**16.798A**	
			2022/2023 season		
Without	12.625f	13.481e	14.858c	16.51b	**14.368B**
12.5m³/ha.	13.356e	14.194d	15.971b	17.252a	**15.194A**
Mean (N)	**12.99D**	**13.838C**	**15.415B**	**16.881A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 8: Effect of Biochar and N rates and their interaction on harvest index (HI%) of wheat at harvesting time in 2021/22 and 2022/23 growing seasons

Biocahr rates	N levels (kg/ha)				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 season		
Without	39.39 g	40.54 e	42.48 c	44.51 a	**41.92 B**
12.5m³/ha.	39.97 f	40.98 d	43.65 b	44.78a	**42.54 A**
Mean (N)	**39.69 D**	**40.77 C**	**43.09 B**	**44.65 A**	
			2022/2023 season		
Without	40.59 ef	40.80 e	42.40 c	44.67b	**42.28B**
12.5m³/ha.	40.24 f	41.74d	44.61b	45.94a	**43.36A**
Mean (N)	**40.42 D**	**41.28 C**	**43.55B**	**45.32A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 9: Effect of Biochar and N rates and their interaction on plant height (pH cm) of wheat at harvesting time in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1})				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 growing season		
Without	90.00 e	100.00 d	113.00 c	120.00 ab	**105.75 B**
12.5m³ ha^{-1}	100.00 d	110.00 c	118.00 b	122.00 a	**112.50 A**
Mean (N)	**95.00 D**	**105.00 C**	**115.50 B**	**121.00 A**	
			2022/2023 growing season		
Without	92.00 f	109.00 d	110.00 d	124.00 b	**108.75 B**
12.5m³ ha^{-1}	102.00 e	109.00 d	119.00 c	128.00 a	**114.50 A**
Mean (N)	**97.00 D**	**109.00 C**	**114.50 B**	**126.00 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

3.4. Nitrogen use efficiency (NUE)

3.4.1. Effect of Biochar

There were significant differences between the two Biochar levels on NUE in both growing seasons (Table 10). Treating wheat plants with Biochar at 12.5 m^3 ha^{-1} pre-sown gave the highest values of NUE (8.11 and 7.98 kg grains /kg N) against (6.22 and 6.09 kg grains kg^{-1} N) for contrail treatment in each of the two growing seasons.

These results are in harmony with those reported by Sun *et al*. 2019. They indicated that NUE was the highest when treated wheat plants with Biochar at 20 ton/ha as compared to other rates (0, 5, 10, 30, 40 and 50 ton ha^{-1}).

3.4.2. Effect of N rates

All N fertilization rates (125, 187.5, and 250 kg ha^{-1}) had a significant effect on NUE by wheat plants grown in clay soil as compared to unfertilized plants in both growing seasons (Table 10). NUE was gradually increased by increasing N levels up to the highest levels. The maximum values of NUE were found with fertilizing wheat plants by 250 kg/ha (9.50 and 9.60 kg grain kg^{-1} N), respectively, followed by N at 187.5 kg ha^{-1} (7.99 and 7.80 kg grain kg^{-1} N) and (4.0 and 3.70 kg grain kg^{-1} N) for nitrogen at 125 kg ha^{-1} in each of the two growing seasons.

These results coincide with those reported by Shahin (2020). They showed that NUE in wheat plants were significantly improved by application of N at 120 kg /fad as compared to other levels (0, 30, 60 and 90 kg N /fad).

3.4.3. Effect of the interaction

The combination between Biochar and N rates had a significant effect on NUE in wheat plants in both growing seasons (Table 10).

All N fertilization treatments subjected to Biochar had significant increases in NUE than those subjected under control (no Biochar application). The maximum NUE by wheat plants grown in clay soil was recorded with the interaction between Biochar at 12.5 m^3 ha^{-1} and fertilizing with N at 250 kg ha^{-1} (10.0 and 10.2 kg grain kg^{-1} N in each of the two growing seasons.

There were no significant differences with the combination between Biochar at 0 and N at 250 kg ha^{-1} and the interaction between biochar at 12.5 m^3 ha^{-1} and N at 187.5 kg ha^{-1}. However, the maximum values (9.33 kg grain kg^{-1} N) in both growing seasons were recorded with the interaction between biochar at 12.5 m^3 ha^{-1} and N at 187.5 kg ha^{-1} against (9.00 kg grain kg^{-1} N) in both growing seasons for the interaction between Biochar at 0 and N at 250 kg ha^{-1}.

Table 10: Effect of Biochar and N fertilization rates and their interaction on nitrogen use efficiency NUE (kg grains kg^{-1} N) of wheat in 2021/22 and 2022/23 growing seasons.

Biocahr rates	N fertilization rates (kg ha^{-1}) 0	125	187.5	250	Mean (Biochar)
			2021/2022 growing season		
Without	0.00 f	3.00 e	6.66 c	9.00 b	**6.22B**
12.5m^3 ha^{-1}	0.00 f	5.00 d	9.33 b	10.0 a	**8.11A**
Mean (N)	**0.00 D**	**4.00 C**	**7.99 B**	**9.50 A**	
			2022/2023 growing season		
Without	0.00 g	3.00 f	6.27 d	9.00 c	**6.09B**
12.5m^3 ha^{-1}	0.00 g	4.40 e	9.33 b	10.2 a	**7.98A**
Mean (N)	**0.00 D**	**3.70 C**	**7.80 B**	**9.60 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

3.5. Nutrients Content and their uptake in Wheat Grains

NPK nutrients content and their uptake by grain are shown in Tables 11-13).

3.5.1. Effect of Biochar

The contents of N, P and K and their uptake by grain were significantly affected by Biochar application to soil pre sowing in both growing seasons. Treated wheat plants with Biochar at 12.5 m^3 ha^{-1} gave the maximum contents of N (2.10 and 2.14%), P (0.271 and 0.275%) and K (1.625 and 1.634%) against control treatment (1.90 and 1.92%), (0.232 and 0.236%) and 1.311and 1.378%) for N, P and K contents in grain in the 1st and 2nd growing seasons, respectively (Tables 11-13).

In terms uptake of NP and K, kg/ha is the data showed the same trend as the grain content of NP and K in both growing seasons (Tables 14-16). Application of Biochar to wheat plants produced the highest values of N uptake (137.53 and 140.05 kg /ha), P (20.35 and 21.09 kg ha^{-1}) and K (105.11 and 107.65 kg ha^{-1}) comparing with control treatment (no Biochar addition) (116.15 and 118.12 kg ha^{-1}) (15.95 and 16.32 kg ha^{-1}) and (78.24 and 83.71kg ha^{-1}) for N, P and K uptake by grain ha^{-1} in the 1st and 2nd growing seasons, respectively.

The superiority of Biochar may be explained by its ability to prevent nutrient losses lead to an increase in the amount of nutrients available in soil. It's interesting to note that biochar amendment has a good impact on plant nutrition; this conclusion is supported by an increase in the concentration of resin-extractable phosphate that was observed following biochar amendment (Atkinson *et al*., 2010). Some of the characteristics of biochar that significantly contribute to its beneficial effects are high porosity, which explains its great capacity to retain water, and high cation exchange capacity, which encourages nutrient retention and inhibits its loss (Ghazi and El-Sherpiny, 2021).

These results are in harmony with those obtained with Hafez *et al.* (2020) and Shaltout *et al.* (2022). They showed that the highest N, P and K contents and their uptake were obtained with Biochar application than control treatment.

3.5.2. Effect of N rates

All nitrogen levels had significant effect on N, P and K contents in wheat grains as well as N, P and K uptake by grain as compared control treatment in both seasons (Tables 11-16).

N, P and K contents in grain (Tables 11-13) as well as N, P and K uptake (Tables 14-16) significantly increased with increasing N rates up to the highest level equal to 100% of the recommended fertilization N rate (250 kg N ha^{-1}) which recorded the highest values (2.30 and 2.33 %), (0.314 and 0.320 %) and (1.767 and 1.824 %) for N, P and K contents in the 1st and 2nd growing seasons, respectively and (170.69 and 174.11 kg ha^{-1}), (23.62 and 24.53 kg ha^{-1}) and (105.74 and139.54 kg ha^{-1}) for N, P and K uptake in the 1st and 2nd growing seasons, respectively. On the other side, fertilizing with 187.5 kg ha^{-1} (75% of recommended N fertilizer) came in the second for N, P, and K contents and their uptake in both growing seasons. Control treatment (zero N) recorded the lowest values of all abovementioned parameters in both growing seasons.

These results coincide with those reported by Shahin (2020) and El-Sobky and Abdelsalam (2022). They showed that, fertilizing wheat plants with 120 N kg fed^{-1}. gave the highest values of N, P and K contents in grains and their uptake as compared to other levels (0,30,60 and 90kg fad^{-1}).

3.5.3. Effect of the interaction

The combination between biochar and N rates had a significant effect on N, P and K contents in wheat grain and their uptake in both seasons (Tables 11-16).

The combination between Biochar application at 12.5 m^3 ha^{-1} and fertilizing wheat plants with N at 250 kg ha^{-1} significantly increased the contents of N (2.30 and 2.33%), P (0.330 and 0.340%) and K (1.900 and 1.976 %) in each of the two growing seasons, (Tables 11-13), without significant differences with Biochar at 12.5 m^3 ha^{-1} and fertilizing with 187.5 kg ha^{-1} (75% of recommended N fertilization) in both growing seasons.

N, P and K uptake gave the similar trend for N, P and K contents in both growing seasons (Tables 14-16). The maximum values of N uptake (173.25 and 182.28), P (25.57 and 26.95) and K (147.25 and 156.60) kg ha^{-1} in each of the two growing seasons were recorded under the combination between Biochar at 12.5 m^3/ha and fertilizing wheat plants with N at 250 kg ha^{-1}.

Regarding N, P, and K contents as well as N, P, and K uptake in both growing seasons, there were no significant differences between the interaction between nitrogen at 250 kg ha^{-1} solely and the interaction between nitrogen at 187.5 kg ha^{-1} and treated soil with Biochar at 12.5 m^3 ha^{-1}.

These results are in harmony with those obtained with Shaltout *et al*. (2022). They showed that the highest N, P and K contents and their uptake were obtained with Biochar and highest levels of N.

Table 11: Effect of Biochar and N fertilization rates and their interaction on grains N concentration in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1})				Mean (Biochar)
	0	125	187.5	250	
	2021/2022 growing season				
Without	1.31 d	1.89 c	2.15 ab	2.25 ab	**1.90 B**
12.5m^3 ha^{-1}	1.80 c	2.10 b	2.20 ab	2.30 a	**2.10 A**
Mean (N)	**1.55 C**	**1.99 B**	**2.17 A**	**2.27 A**	
	2022/2023 growing season				
Without	1.39 d	1.90 c	2.10 b	2.29 a	**1.92 B**
12.5m^3/ha	1.85 c	2.15 ab	2.25 ab	2.33 a	**2.14 A**
Mean (N)	**1.62 D**	**2.02 C**	**2.17 B**	**2.31 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 12: Effect of Biochar and N fertilization rates and their interaction on grains P concentration in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1})				Mean (Biochar)
	0	125	187.5	250	
	2021/2022 growing season				
Without	0.180 e	0.220 d	0.230 cd	0.299 b	**0.232 B**
12.5m^3 ha^{-1}	0.209 d	0.247 c	0.300 b	0.330 a	**0.271 A**
Mean (N)	**0.194 D**	**0.233 C**	**0.265 B**	**0.314 A**	
	2022/2023 growing season				
Without	0.190 e	0.219 d	0.235 c	0.300 b	**0.236 B**
12.5m^3 ha^{-1}	0.211 d	0.240 c	0.310 b	0.340 a	**0.275 A**
Mean (N)	**0.200 D**	**0.229 C**	**0.272 B**	**0.320 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 13: Effect of Biochar and N fertilization rates and their interaction on grains K concentration in 2021/22 and 2022/23 growing seasons

Biocahr rates	N levels (kg/ha)				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 season		
Without	1.026 e	1.140e	1.444d	1.634bc	**1.311B**
12.5m³/ha.	1.368 d	1.482cd	1.748b	1.900a	**1.625A**
Mean (N)	**1.197 D**	**1.311 C**	**1.596B**	**1.767A**	
			2022/2023 season		
Without	1.064 f	1.178e	1.596cd	1.672bc	**1.378B**
12.5m³/ha.	1.292e	1.520d	1.748b	1.976a	**1.634A**
Mean (N)	**1.178D**	**1.349C**	**1.672B**	**1.824A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

Table 14: Effect of Biochar and N fertilization rates and their interaction on grains N uptake kg /ha in 2021/2022 and 2022/2023 seasons

Biocahr rates	N fertilization rates (kg ha^{-1})				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 growing season		
Without	65.50 h	101.59 f	134.38 d	163.13 b	**116.15 B**
12.5m³ ha^{-1}	94.50 g	123.38 e	154.00 c	178.25 a	**137.53 A**
Mean (N)	**80.00 D**	**112.49 C**	**144.19 B**	**170.69 A**	
			2022/2023 growing season		
Without	67.14 h	103.95 f	135.45 d	165.94 b	**118.12 B**
12.5m³ ha^{-1}	96.75 g	124.43 e	156.75 c	182.28 a	**140.05 A**
Mean (N)	**81.95 D**	**114.19 C**	**146.10 B**	**174.11 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

Table 15: Effect of Biochar and N fertilization rates and their interaction on grains P uptake (kg /ha) in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1})				Mean (Biochar)
	0	125	187.5	250	
			2021/2022 growing season		
Without	9.00e	11.82cd	14.37c	21.67b	**15.95B**
12.5m³ ha^{-1}	10.97de	14.50c	21.00b	25.57a	**20.35A**
Mean (N)	**9.98D**	**13.16C**	**17.68B**	**23.62A**	
			2022/2023 growing season		
Without	9.75d	12.05cd	14.80c	22.12b	**16.32B**
12.5m³ ha^{-1}	11.35cd	14.22c	22.10b	26.95a	**21.09A**
Mean (N)	**10.55D**	**13.13C**	**18.45B**	**24.53A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

Table 16: Effect of Biochar and N fertilization rates and their interaction on grains K uptake (kg /ha) in 2021/22 and 2022/23 growing seasons

Biocahr rates	N levels (kg/ha) 0	125	187.5	250	Mean (Biochar)
			2021/2022 season		
Without	51.30f	61.28e	90.25c	118.47b	**78.24B**
12.5m³/ha.	71.82d	87.07c	122.36b	147.25a	**105.11A**
Mean (N)	**61.35D**	**73.74C**	**105.74B**	**132.53A**	
			2022/2023 Season		
Without	54.53f	64.79e	100.55c	123.31b	**83.71B**
12.5m³/ha.	69.45d	90.06c	124.55b	156.60a	**107.65A**
Mean (N)	**61.85D**	**77.07C**	**112.24B**	**139.54A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

3.6. Grains quality

3.6.1. Effect of Biochar

Data in Tables 17 and 18 shows that, there were significant differences between two Biochar rates on wheat grains total protein (TPr) and total carbohydrates (TCh) in both growing seasons. Treated wheat plants with Biochar at 12.5 m^3 ha^{-1} pre sowing gave the highest values of TPr (11.97 and 12.23%) and TCh (67.66 and 67.62%), that the control treatment produced (10.83 and 10.94%) and (67.07 and 66.84%) for TPr and TCh in the 1st and 2nd growing seasons, respectively.

Many researchers have found that the percentage of protein and total carbohydrates in the grain yield of wheat has increased with increasing Biochar rates (Khan *et al*., 2021; Essa *et al*., 2023).

3.6.2. Effect of N rates

Fertilizing wheat plants grown in clay soil with 125, 187.5, and 250 kg ha^{-1} significantly increased TPr and decreased TCh in grains during the 2021/2022 and 2022/2023 growing seasons (Tables 17 and 18).

TPr significantly increased with increasing N rates up to the highest levels, and the highest values were produced with 250 kg ha^{-1} (12.96 and 13.16%) in the 1st and 2nd growing seasons, respectively, without significant differences with 187.5 kg ha^{-1} as in the 1st season. As for TCh in grains, the highest values (68.70 and 68.30%) were produced form the control N treatment in the tow growing seasons.

The results obtained are consistent with the findings published by Rashwan *et al.* (2024) and Seleiman *et al.* (2021). They demonstrated that the maximum percentage of protein in grains was produced when wheat plants were fertilized with 100% mineral N.

3.6.3. Effect of the interaction

All interaction treatments significantly increased TPr and TCh as compared to zero Biochar and zero N in both seasons (Tables 17 and 18).

The best interaction treatment for increasing TPr (13.11 and 13.38%) was scored with 250 kg N ha^{-1} under Biochar at 12.5 m^3 ha^{-1} in the 1st and 2nd growing seasons, respectively. In this regard, there were no significant differences with the interaction between Biochar at 12.5 m^3 ha^{-1} and fertilizing with 75% of recommended N rate at 187.5 kgN ha^{-1} and the interaction between Biochar zero and N at 250 kg/ha in both growing seasons. While, the interaction between Biochar at 12.5 m^3/ha and unfertilized N plots gave the best results for wheat grains TCh (69.10 and 68.70%) in each of the two growing seasons.

Table 17: Effect of Biochar and N fertilization rates and their interaction on grains total protein (TPr %) in 2021/2022 and 2022/2023 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1}) 0	125	187.5	250	Mean (Biochar)
			2021/2022 growing season		
Without	7.47 d	10.77 c	12.26 ab	12.82 ab	**10.83 B**
12.5 m^3 ha^{-1}	10.26 c	11.97 b	12.54 ab	13.11 a	**11.97 A**
Mean (N)	**8.86 C**	**11.37 B**	**12.40 A**	**12.96 A**	
			2022/2023 growing season		
Without	7.92 d	10.83 c	11.97 b	13.05 a	**10.94 B**
12.5 m^3 ha^{-1}	10.55 c	12.26 ab	12.83 ab	13.28 a	**12.23 A**
Mean (N)	**9.23 D**	**11.54 C**	**12.40 B**	**13.16 A**	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

Table 18: Effect of Biochar and N fertilization rates and their interaction on grains total carbohydrates (TCh%)in 2021/22 and 2022/23 growing seasons

Biocahr rates	N fertilization rates (kg ha^{-1}) 0	125	187.5	250	Mean (Biochar)
			2021/2022 growing season		
Without	68.30 b	67.10 c	66.80 cd	66.10 e	67.07 b
12.5 m^3 ha^{-1}	69.10 a	68.10 b	67.10 c	66.37 de	67.66 a
Mean (N)	68.70 a	67.60 b	66.95 c	66.23 d	
			2022/2023 growing season		
Without	67.91 b	67.25 c	66.50 d	65.70 e	66.84 b
12.5 m^3 ha^{-1}	68.70 a	68.20 b	67.40 c	66.20 d	67.62 a
Mean (N)	68.30 a	67.72 b	66.95 c	65.95 d	

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range test.

3.7. Some Soil Chemical Characteristics after Harvesting

3.7.1. Effect of Biochar rates

Available soil N, P, K and OM content after harvesting of wheat were significantly affected by Biochar application as compared to untreated soil (Table 19). In addition, treated soil with Biochar pre sowing at 12.m^3/ha produced the highest values (73.73 and 73.70 mg kg^{-1}) for N, (11.06 and 11.43 mg kg^{-1}) for P, (363.51 and 363.61 mg kg^{-1}) for K, and (2.51 and 2.45 %) for OM compared to untreated soil which produced (51.0 and 51.50 mg kg^{-1}) for N, (8.54 and 7.97 mg kg^{-1}) for P, (225.48 and 225.87 mg kg^{-1}) for K, and (1.76 and 1.76 %) for organic matter in the 1st and 2nd seasons, respectively.

According to Ali *et al.* (2017), biochar plays a crucial role in soil quality because of its capacity to hold more water, exchange cations, increase soil carbon content, improve aggregation, prevent leaching, balance the pH of acidic soils, and create an environment that is favorable for additional microbial activity. Mukherjee *et al.* (2014) provided evidence of the significant influence of biochar on the elemental cycle and the mitigation of carbon, nitrogen, and phosphorus waste in soil. They claimed that biochar has a wide variety of nutrients that were released at various rates and had a significant impact on soil fertility.

3.7.2. Effect of N fertilization rate

Fertilizing wheat plants grown in clay soil with different rates of nitrogen had significantly affected available NPK, and OM content in soils after harvesting as compared to unfertilized control plots in both growing seasons (Table 19).

The highest values of available three NPK elements beside OM% in soil after harvesting wheat plants, such as available N (66.09 and 65.59 mg kg^{-1}), P (11.97 and 11.87 mg kg^{-1}), K (298.40 and

299.62 mg kg^{-1}), and organic matter (2.39 and 2.29%), were produced from the highest, which fertilized with N at 250 kg/ha, followed by 187.5 kg/ha (demonstrated 100% and 75% of N fertilization recommended rates) in both growing seasons.

3.7.3. Effect of the interaction

Results in Table 20 indicate that available NP and K, as well as OM (%) in soil after harvesting the wheat plants, were significantly affected by the interaction between Biochar and N fertilizer application rate in both growing seasons. The best results for increasing N (77.53 and 76.61 mg kg^{-1}), P (13.30 and 13.31 mg kg^{-1}), K (368.57 and 369.57 mg kg^{-1}), and organic matter (2.83 and 2.72%) were obtained with the interaction between Biochar at 12.5 m^3 ha^{-1} and N at 250 kg/ha in the 1st and 2nd growing seasons, respectively. On the other hand, the lowest values of all soil available NPK and OM% after harvesting of plants were produced from control treatment (0 Biochar and 0 N) in both growing seasons.

Table 19: Soil analysis after harvesting as affected by Biochar and N fertilization rates in 2021/2022 and 2022/2023 growing seasons

Treatments	N mg kg^{-1}		P mg kg^{-1}		K mg kg^{-1}		Organic matter (OM %)	
	S1	S2	S1	S2	S1	S2	S1	S2
	Effect of Biocahr rates							
Without	51.00 b	51.50 b	8.54 b	7.97 b	225.48b	225.87b	1.76 b	1.76 b
12.5m³ ha⁻¹	73.73 a	73.70 a	11.06 a	11.43 a	363.51a	363.61a	2.51 a	2.45 a
	Effect of N fertilization rates (kg ha^{-1})							
0	55.59 c	56.53 c	7.19 d	7.73 d	291.08b	286.34b	1.89 d	1.89 d
125	62.89 b	63.02 b	9.15 c	8.90 c	293.37b	294.44ab	2.00 c	2.07 c
187.5	64.90 a	65.28 a	10.91 b	10.29 b	295.14 ab	298.57a	2.28 b	2.17 b
250	66.09 a	65.59 a	11.97 a	11.87 a	298.40a	299.62a	2.39 a	2.29 a

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

Table 20: Soil analysis after harvesting as affected by the interaction between Biochar and N fertilization rates in 2021/2022 and 2022/2023 growing seasons

Treatments		N mg kg^{-1}		P mg kg^{-1}		K mg kg^{-1}		Organic matter (OM %)	
Biocahr rates	**N rates kg ha^{-1}**	**2021/22**	**2022/23**	**2021/22**	**2022/23**	**2021/22**	**2022/23**	**2021/22**	**2022/23**
Without	**0**	45.50 f	46.10 f	6.11 f	6.20 g	221.65 c	219.68 c	1.61 f	1.60 f
	125	50.57 e	51.10 e	8.14 e	7.19 f	225.43 c	226.58 c	1.65 f	1.76 e
	187.5	53.30 d	54.26 d	9.30 d	8.05 e	226.60 c	227.85 c	1.86 e	1.81 e
	250	54.65 d	54.57 d	10.64 c	10.44 c	228.23 c	229.36 c	1.95 e	1.87 e
12.5m³ ha⁻¹	**0**	65.69c	66.96 c	8.27 e	9.27 d	360.50 b	353.00 b	2.17 d	2.19 d
	125	75.21 b	74.95b	10.16 cd	10.61 c	361.30 b	362.29ab	2.36 c	2.39 c
	187.5	76.50ab	76.30ab	12.53 b	12.53 b	363.67ab	369.29 a	2.71 b	2.53 b
	250	77.53a	76.61a	13.30a	13.31a	368.57 a	369.87 a	2.83 a	2.72 a

Values sharing the same alphabetical letter(s) did not substantially differ at the 0.05 level of significance, according to Duncan's multiple range tests.

Finally, under conditions similar to conducting this research, it can be recommended to fertilize wheat growing in clay soil at a rate of 100% of the recommended rate, which is 250 kg of nitrogen/ha, in the form of urea, with the use of biochar at a rate of 12.5 m^3/ha during soil preparation, as this treatment recorded the best results for increasing the yield of grain, straw and biological yield as well as grain chemical composition. It is also possible to reduce a quarter of the amount of nitrogen used by fertilizing wheat growing in clay soil at a rate of 75% of the recommended rate, which equals 187.5 kg of nitrogen/ha, with the use of Biochar at a rate of 12.5 m^3/ha, as this treatment recorded results similar to all the characteristics that were studied with fertilization using the recommended rate of 100%, which is equivalent to 250 kg/ha without adding biochar.

References

Abbas Z., Ali S., M. Rizwan, I.E. Zaheer, A. Malik, M.A. Riaz, M.R. Shahid, M.Z.U. Rehman and M.I. Al-Wabel, 2018. A critical review of mechanisms involved in the adsorption of organic and inorganic contaminants through biochar. Arab. J. Geosci 11:448. https://doi.org/10. 1007/s12517-18-3790-1

Abd El-Dayem S.M.A., U.A. Abdel-Razek and M.A.M. El-Dahrawy, 2024. Effect of some nitrogen fertilization rates on the yield and its components for some new Egyptian bread wheat cultivars. J. Sustain. Agric. Environ. Sci., 3 (1): 35-46.

Abedi, T., A. Alemzadeh and S.A Kazemeini, 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Australian J. Crop Sci., 4: 384-389.

Ahmed, R., Y. Li, L. Mao, C. Xu, W. Lin, S. Ahmed and W. Ahmed**,** 2019**.** Biochar effects on mineral nitrogen leaching, moisture content and evapotranspiration after 15N urea fertilization for vegetable crop. Agronomy, 9: 331.

Ali S., M. Rizwan, M.F. Qayyum, Y.S. Ok, M. Ibrahim, M. Riaz, M.S. Arif, F. Hafeez, M.I. Al-Wabel and A.N. Shahzad, 2017. Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review. Environ. Sci. Pollut. Res., 24:12700–12712.

Ali A. M., A. M. Omar, A. Nawar and S. El-Tabbakh, 2016. Effect of sowing date and nitrogen fertilization level on growth and productivity of some durum and bread wheat varieties. Alexandria Science Exchange J., 37(4): 541-549**.**

AOAC, 2012. Official method of analysis: association of analytical chemists. 19th Edition, Washington DC, USA.

Atkinson, C.J., J.D. Fitzgerald and N.A. Hipps, 2010. Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant and soil, 337 (1): 1-18.

Avlin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson,1999. Function and Forms of N in Plants. In Soil Fertility and Fertilizers. 6th Ed. Prentice Hall, Upper Saddle River, New Jersey.

Black, C.A., D.D. Evans, L.E. Ensminger, G.L. White and F. E. Clark, 1981.Methods of Soil Analysis. Part 2: 1-100. Agron. Inc. Madison. WI., USA.

Craswell, E.T. and D.C. Godwin,1984. The efficiency of nitrogen fertilizers applied to cereals in different climates. In Tinker, P.B. and A. Luchli (ed). Advances in Plant Nutrition, Vol.1.praeger.

Dagash, Y.M.I., I.S. Ahmed and N.A. Khalil, 2014. Effect of nitrogen fertilization, sowing methods and sowing dates on yield and yield attributes of wheat (*Triticum aestivum* L). Universal J. Plant Sci., 2(6): 108-113.

Das, S.K., R.K. Avasthe, M. Singh and A. Yadav, 2018. Soil health improvement using biochar application in Sikkim: A success story. Innov. Farming, 3: 48–50.

Delogu, G., L. Cattivelli, N. Pecchioni, D. De Falcis, T. Maggiore, and A.M. Stanca, 1998. Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat. Eur. J. Agron., 9: 11–20.

Dubois, M., K.A. Gilles, J. Hamillon, P.A. Rebers, and F. Smith, 1956. Colorimeteric methods for determination of sugars and related substances. Anal. Chem., 28:350.

Duncan, D.B., 1958. Multiple Range and Multiple F-Test. Biometrics, 11, 1-5.

El-Dissoky, R.A. and A.M. Attia, 2018. Influence of nitrogen, biofertilizer, compost addition and sowing dates on wheat grown in upper Egypt. J. Soil Sci. and Agric. Eng., Mansoura Univ., 9 (4): 155 – 164.

EL-Hag, A.A. and, M.E.A. Shahein , 2017. Effect of different nitrogen rates on productivity and quality traits of wheat cultivars. Egypt. J. Agro., 39(3): 321 - 335.

El-Khamissy S.H., A.Y. El Bana, A.E. Omar and A.S. El-Kholy,2023. Effect of nitrogen fertilization on yield and its attributes of some bread wheat (*Triticum aestivum* L.) cultivars. Inter. J. Chem. Biochem. Sci., 24(12): 685-693.

El-Sayed, M.E.A., M. Hazman, A.G. Abd El-Rady, L. Almas, M. M. Shams El Din and S. Burian, 2021. Biochar reduces the adverse effect of saline water on soil properties and wheat production profitability. Agriculture, 11, 1112. https://doi.org/10.3390/ agriculture 11111112.

El-Seidy, E.H., A.A. Morad , R.A. El-Refaey and Nehal Kh.El-Hadidy, 2017. Effect of nitrogen fertilizer levels on some wheat varieties belonging two species. Menoufia J. Plant Prod., (2): 207 – 217.

El-Sobky El-Sayed E.A. and A. Abdelsalam, 2022. Improving grain yield and nitrogen use efficiency in two wheat cultivars by biochar and nitrogen application timing. SINAI J. Appl. Sci.,11 (5): 859-878.

Enayat, A., S. Lack and A. Modhej, 2013. Effect of different nitrogen rates on grain yield and grain growth of bread and durum wheat genotypes. Inter. J. Agron. Plant Prod., 4(11):3076-3082.

Essa R.E., A.A. Afifi, S.M. El-Ashry and M.F. Mohamed, 2023. Productivity of some winter wheat (*Triticum aestivum* L.) varieties through integrated application of vermicompost and biochar in sandy soil. Egypt. J. Agron., 45(2): 201-212.

FAO, 2023. Food and Agriculture Organization. Faostat, FAO Statistics Division, April, 2023. http://www.fao.org/faostat/en/#data /QC.

Gad, B.H., E.M.M. Shalaby, H.G. Hassanein, E.A. Aliand and M.T. Said, 2018. Effect of preceding crop, rates and splitting of nitrogen fertilizer on bread wheat production and nitrogen use efficiency, J. Plant Prod., Mansoura Univ., 9 (8): 663-669.

Ghazi, D.A. and M.A. El-Sherpiny, 2021.Improving performance of maize plants grown under deficit water stress. J. Soil Sci. and Agric. Eng., 12 (11): 725-734.

Gheith, E.S., S.A. Safina, O.Z. EL-Badry and M.A.A. Saboon, 2021. Response of the wheat varieties to different nitrogen levels, seeding rates and their combination: 4- Yield and quality. Plant cell Biotech. Molecular Bio., 22(71-72): 296–306.

Hafez E.M., A.M.S. Kheir, S.A. Badawy, E. Rashwan, M. Farig and H.S. Osman, 2020. Differences in physiological and biochemical attributes of wheat in response to single and combined salicylic acid and biochar subjected to limited water irrigation in saline sodic soil. Plants, 9: 1346; doi:10.3390/plants9101346.

Hefny Y.A.M. and N.E. Mohammed, 2018. Behavior of some bread wheat genotypes under different planting dates and nitrogen fertilizer levels in Sohag Governorate. Assiut J. Agri. Sci., 49, 1-14.

Ibrahim, M., E. Mahmoud, L. Gad and A. Khader, 2019. Effects of biochar and phosphorus fertilizer rates on soil physical properties and wheat yield on clay textured soil in middle Nile Delta of Egypt. Communications in Soil Sci. Plant Analysis, 50 (21): 2756–2766.

Joba, P., P. Shif, A. Muhamed and D. Jaskran, 2022. Wheat straw biochar amendment significantly reduces nutrient leaching and increases green pepper yield in a less fertile soil. Environ. Technol. Innovation, 28.

Khan, Z., M. Habib and G. Haider, 2021. Chemical and biological enhancement effects of biochar on wheat growth and yield under arid field conditions. Sustainability, 13: 5890-5899.

King, J.A., R. Sylvester-Bradley and A.S.H. Rochford, 2001. Availability of nitrogen after fertilizer applications to cereals. J. Agric. Sci., 136 (2): 141-157.

Li, Y., F. Hao, C. Ji, L. Junsheng and W. Wenjie, 2022. Biochar incorporation increases winter wheat (*Triticum aestivum* L.) production with significantly improving soil enzyme activities at jointing stage. Catena, 211.

Litke. L., Z. Gaile and A. Ruža, 2017. Nitrogen fertilizer influence on winter wheat yield and yield compo-nents depending on soil tillage and forecrop. Agric. Sci. (Crop Sci., Animal Sci.,) DOI:10.22616/rrd.23.2017.049.

Liu, J., Z. Chen, S. Wu, H. Sun, J. Xing and Z. Zhang, 2024. Interaction of biochar addition and nitrogen fertilizers on wheat production and nutrient status in soil profiles. Plants, 13,614. https://doi.org/10.3390/plants 1305 06 14.

Mahmoud, E., M. Ibrahim, L. Abd El-Rahman and A. Khader, 2019. Effects of biochar and phosphorus fertilizers on phosphorus fractions, wheat yield and microbial biomass carbon in *Vertic Torrifluvents*. Communications in Soil Sci. Plant Analysis, 50 (3): 362–372.

Malik, Z., Z. Yutong, L. ShengGao, G.H. Abassi and A. Shafaqat, 2018. Effect of biochar and quicklime on growth of wheat and physicochemical properties of Ultisols. Arab J Geosci 11:496. https://doi.org/10. 1007/ s 12517-018-3863-1.

Marco M.K., C.T. Aristotelis, C. Nataša and B. Dragana, 2021. The effect of N fertilizer application timing on wheat yield on chernozem. Soil, Agron., 11(7): 1413.

Mohamed, I.S., M. Mohiy and M.M. Mohamed, 2022. The impact of sowing date and nitrogen fertilization on Yield in four bread wheat cultivars. Egypt. J. Agric. Res., 100(1): 1-10

Moron, R., 1982. Formulae for Determination of Chlorophyllous Pigments Extracted with *N,N*-Dimethyl formamide.Plant Physiol., 69(6):1376–1381.

Mosalem, M.M.E., M. Zahran, M. El-Menofi and A.M. Moussa, 1999. Effect of sowing date, seeding rate and nitrogen level on wheat production. 2-Yield and yield components. Products, Symp. of the Egypt. Soc. of plant Nutrition and Fertilization, September 1997, Cairo, 83-96.

Mukherjee, A., R. Lal and A.R. Zimmerman, 2014. Effects of biochar and other amendments on the physical properties and greenhouse gas emissions of an artificially degraded soil. Sci. Total Environ., 487:26–36.

Naeem, M.A., M. Khalid, M. Aon and G. Abbas, 2017. Effect of wheat and rice straw biochar produced at different temperatures on maize growth and nutrient dynamics of a calcareous soil. Arch. Agron. Soil Sci., 63: 2048–2061.

Olmo, M., J.A. Alburquerque, V. Barrón and M.C. del Campillo,2014. Wheat growth and yield responses to biochar addition under Mediterranean climate conditions. Bio. Fert. Soils, 50: 1177-1187.

Rashwan E.A., Z.E. Waleed and M.I. Elgendy, 2024. Response productivity and grain quality of new wheat cultivars to seeding rates and nitrogen levels under different sowing dates. Egypt. J. Agron., 46 (1): 61 - 73.

Saboon, M.A.A., E.M.S. Gheith, S.A. Safina and O.Z. El-Badry, 2022. Response of three wheat varieties to nitroge n levels, seeding rates and their combination; 2: spike characters. Indian J. Res., 11(04): 144-147.

Seleiman M.F., M.E. Ibrahim, I.H. Darwish and A.N.M. Hardan, 2021. Effect of mineral and organic fertilizers on yield and quality of some egyptian and omani wheat cultivars. Menoufia J. Plant Prod., 6: 351 – 372.

Shahin, M.G., 2020. Nitrogen recovery efficiency and grain yield response index of some wheat varieties as affected by nitrogen fertilizer rates. Middle East J. Agric. Res., 9(4): 1101-1113.

Shaltout, N.H., A.H. Ibrahim, M.K. Abdel-Fattah and A.I. Abdo, 2022. Effects of mineral fertilization, biochar and fulvic acid on sandy soil properties and nutrients uptake by wheat plants. Zagazig J. Agric. Res., 49(6): 815-823.

Snedecor, G.W. and W.G. Cochran,1980. Statistical Methods. 7th ed. Ames, Iowa U.S.A: Iowa State Univ. Press, pp. 507.

Sohi, S.P., E. Krull, E. López-Capel and R. Bol, 2010. A review of biochar and its use and function in soil. Adv. Agron., 105: 47-82.

Sun, H., H. Zhang, W. Shi, M. Zhou and X. Ma, 2019. Effect of biochar on nitrogen use efficiency, grain yield and amino acid content of wheat cultivated on saline soil. Plant, Soil and Environ., 65 (2): 83–89.

Zaheer, M.S., H.H. Ali, W. Soufan and R. Iqbal, 2021. Potential effects of biochar application for improving wheat (*Triticum aestivum* L.) growth and soil biochemical properties under drought stress conditions. land, 10, 1125. https://doi.org/ 10.3390/land10111125

Zhen, Z., Y. Zhenwen, Z. Yongli and H. Yus, 2021. Split nitrogen fertilizer application improved grain yield in winter wheat (*Triticum aestivum* L.) *via* modulating antioxidant capacity and 13C photosynthate mobilization under water-saving irrigation conditions. Ecol. Proc., 10 (1): 1-13.