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Effect of spraying levels of nano fertilizer (NPK) and biochar on the growth and yield of wheat

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Abstract

The study was carried out at the second research station of the College of Agriculture, Al-Muthanna University. The purpose was to investigate the impact of different amounts of nano-NPK fertilizer and biochar on the availability and concentration of NPK in wheat plants, as well as their growth and yield. The experiment was conducted using a mixed soil. The experiment involved the application of five different concentrations of nano-NPK fertilizer, which were labeled as follows: (A0) Control treatment,(A1) Full recommendation of traditional agrarian NPK, (A2) 2/1 recommendation of traditional agrarian NPK + 2/1 recommendation of nano-NPK, (A3) Full recommendation of nano-NPK + 2/1 recommendation of traditional agrarian NPK, (A4) Double recommendation of nano-NPK + 2/1 recommendation of traditional agrarian NPK. There are four levels of biochar represented by the symbols (B0:0%), (B1:1%), (B2: 2%), and (B3: 3%). The addition was based on the measurement of the volume of dry soil. A factorial experiment was conducted using a randomized complete block design (RCBD) with three repetitions. The averages were compared using the least significant difference (L.S.D) test. With a significance threshold of 0.05. The findings demonstrated substantial variations in the effects of incorporating different amounts of spraying with nano-NPK fertilizer and biochar, as well as their interaction, on plant height, flag leaf area, chlorophyll index, number of tillers, thousand grain weight, and grain yield.

Keywords: NPK nano, biochar, wheat crop

Introduction

Nano fertilizers, discovered by American scientist Richard Wittmann in 1959, partially mitigate fertilizer loss caused by washing, sedimentation, and fixation. Various methods exist for supplementing plants with nutrients, with each form of fertilizer having its own distinct approach. Nano fertilizers possess a diminutive size, exhibit elevated energy levels, demonstrate facile absorption by plants, and display remarkable efficacy. They augment the chlorophyll content, enhance plant growth, and boost crop efficiency (Abobatta, 2016). The study conducted by Rajemahaidik et al. (2018) examined nano fertilizers and compared them to conventional fertilizers. It was discovered that nano fertilizers are more efficient than regular fertilizers. The primary benefit of foliar nutrition, particularly with essential elements (NPK), is its ability to enhance the qualities of vegetative development by synthesizing the fundamental and secondary compounds of the plant, resulting in a plant with a robust vegetative and root system. The addition of nitrogen to the soil enhances the growth and productivity of plants, including wheat. Nitrogen plays a crucial role in the formation of compounds and amino acids, stimulates cell division, and increases the chlorophyll content (Naghmish, 2017). According to Abdel-Aziz's (2018) research, the application of nano-NPK fertilizer on wheat plants resulted in a 23.5% reduction in the plant's life cycle and an improvement in crop qualities. Biochar is the result of subjecting plant wastes to high temperatures in the absence of oxygen. Biochar is a substance that is produced by extracting water from plant waste and is manufactured without exposure to air. The botanical classification of a plant is a crucial determinant of the characteristics of biochar. Biochar is considered an eco-friendly substance due

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to its production from natural resources and utilization of contemporary technologies (Gonzaga et al., 2018). Biochar promotes crop yield by enhancing the physical and chemical qualities of the soil, such as apparent density, soil structure, and dispersion of soil particles. Additionally, it enhances soil aeration. Biochar is crucial for land reclamation as it functions as a soil enhancer, preventing soil compaction caused by agricultural machinery and living organisms. Biochar has a carbon content ranging from 60% to 70%. Biochar enhances soil fertility by enriching it with nutrients, so promoting higher agricultural yields and improving the soil's capacity to retain these essential elements, consequently lowering reliance on synthetic fertilizers. Biochar offers environmental advantages by effectively sequestering CO2 from the atmosphere and preserving it for extended periods, typically spanning hundreds or even thousands of years. This is particularly significant considering that many farmers lack the knowledge to utilize plant waste effectively, necessitating its utilization. Iraqi soils are distinguished by their high content of carbonate minerals, specifically calcium carbonate, which comprises around 30-10% of the soil composition. This high concentration of carbonate minerals elevates the pH level of the soil, thereby lowering the accessibility of essential nutrients, such as phosphorus. Phosphorus in Iraqi soils undergoes adsorption interactions with calcium carbonate or calcium ions present in the soil solution, resulting in its loss and decreased availability in the soil. The majority of fertilizers applied to calcareous soil consist of calcium phosphate, which is rather stable and cannot be utilized by the plant until it undergoes a transformation into an ionic form that can be taken by the plant. The process of adsorption impacts the presence of phosphorus in the soil solution (Ali et al., 2014). Potassium is a vital nutrient that holds significant relevance, as it serves crucial functions within the plant. The plant hormone is accountable for numerous essential physiological functions, including enhancing the plant's immunity against pathogens and its ability to withstand challenging environmental circumstances such as high temperatures, salinity, and drought. Additionally, it possesses molecular capabilities that involve the regulation of carbohydrate transport and the activation of enzymes, proteins, and vitamins. The wheat crop belongs to the family of cereal grains. Triticum aestivum L. is a member of the Poaceae family and is highly significant as a staple crop for human consumption due to its rich content of carbs, proteins, vitamins, and lipids. The growth of the global population requires the advancement of contemporary technologies and approaches to enhance the productivity, excellence, and attributes of crops, as the demand for them is projected to expand by around 60% by 2050 (Asseng et al., 2018).

Materials and methods:

The study was conducted in the second research station in the Al-Bandar area of Al-Muthanna Governorate during the agricultural season of 2023. The objective was to investigate the impact of different levels of nano-fertilizer (NPK) and biochar spraying on the growth and production of wheat. Plowing activities were conducted perpendicularly and repeated twice. Subsequently, the field experiment was designed using the Randomized Complete Block Design (RCBD), and the area was divided into three sectors, each containing 20 experimental units. The planting procedure was executed on November 19, 2023. Subsequently, biochar was applied to a depth of 30-0 cm in each experimental unit, which had an area of 3 m and eight rows. The seed amount was 120 kg ha-1 at volume levels of 3%, 2%, 1%, and 0%, represented by the symbols B0, B1, B2, and B3, respectively.

The NPK fertilizer is categorized into five levels: (A0) Control treatment, (A1) Full recommendation of traditional agrarian NPK, (A2) 2/1 recommendation of traditional agrarian NPK combined with 2/1 recommendation of nano-NPK, (A3) Full recommendation of nano-NPK combined with 2/1 recommendation of traditional agrarian NPK, (A4) Double recommendation of nano-NPK combined with 2/1 recommendation of traditional agrarian NPK.

The manufacturer's prescribed dosage was 150 milliliters per hour, and the NPK ratio indicated on the packaging was 20 parts nitrogen to 20 parts phosphorus to 10 parts potassium.

Examined attributes:

1- Height of plants at the time of harvest (in centimeters). The height of plants was measured for five plants that were randomly picked from each experimental unit, from the soil surface to the top of the plant (Wiersma et al. 1986).

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2- Measurement of the area of the flag leaf in square centimeters. The flag leaf area of five plants from each experimental unit was randomly measured, following the method described by Thomas (1975).
The leaf area can be calculated by multiplying the length of the leaf by the width at its broadest point and then multiplying the result by 0.95.
3- Chlorophyll index, often known as Spad, is being referred to. The chlorophyll index was determined for five plants chosen at random using a portable Spad 502 Chlorophyll Meter (Felix et al., 2000).
4- Tiller density (number of tillers per square meter). The tiller count was determined at the stage of full maturity for all harvested plants in the two central rows of each experimental plot and then translated to square meters.
5- Mass of one thousand grains (grams). A total of one thousand grains were measured from each experimental unit and thereafter chosen at random for weighing using a very accurate balance.
6- The grain yield is measured in megagrams per hour (Mg h-1). The grain yield of two central rows was computed and subsequently translated to per hectare, and then further transformed to megagrams per hour.

Table No. (1) shows the chemical and physical properties of soil samples before planting.

Properties	**Unit**	**Value**
pH	7.70	___
Ece	8.12	ds|m
Organic matter	0.4	%
Available nitrogen	18.9	mg Kg^{-1} soil
Available phosphorus	14.7	mg Kg^{-1} soil
Available potassium	195	mg Kg^{-1} soil
Soil texture		Sandy loam
Silt	33.4	%
Sand	48.2	%
Clay	18.4	%
Calcium carbonate	250	g Kg^{-1} soil

Results and Discussion

Effect of spray levels of nano NPK fertilizer and biochar on:

1- Plant height (cm)

The findings from Table (2) demonstrate that there are notable variations in the impact of different quantities of nano-NPK fertilizer and biochar, as well as their combined effect, on the plant height trait (measured in centimeters). The findings from Table (2) indicate that treatment (A4) exhibited substantial superiority over all other treatments, with the greatest average measurement of 106.19 cm. In contrast, the comparison treatment had the lowest average measurement of 95.21 cm. The superiority of treatment A4 can be related to the role of nano-NPK fertilizer in nourishing and stimulating the vegetative group. This finding aligns with the research conducted by Al-Hassani (2021), which demonstrated that the addition of nano-fertilizer resulted in a rise in plant height. The findings from Table (2) demonstrate a positive correlation between the amount of biochar supplied and the growth of plant height. Notably, treatment B3 exhibited the greatest average height of 106.67 cm. The rise in plant height values can be attributed to the incorporation of biochar, which enhanced the soil's physical and chemical characteristics, hence influencing the accessibility of dissolved components. This finding aligns with the results obtained by Haider (2017), which demonstrated a significant growth in plant height when biochar was utilized. The findings from Table (2) indicate that there were notable variations in the interaction between the different quantities of nano-NPK fertilizer and biochar in relation to the plant height characteristic. Treatment A4B3 achieved the highest average height of 111.77 cm, surpassing all other

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treatments. Treatment A2B3 followed closely with an average height of 106.41 cm. In contrast, treatment A0B0 had the lowest average height of 83.48 cm.

Table (2) Effect of spraying levels of nano-NPK fertilizer and biochar and their interaction in the plant height trait at the harvest stage (cm).

B \ A	A0	A1	A2	A3	A4	Mean
B0	**83.48**	**98.70**	**100.58**	**101.51**	**103.47**	**97.55**
B1	**94.32**	**97.97**	**100.24**	**101.34**	**103.89**	**99.55**
B2	**99.52**	**101.71**	**102.41**	**102.98**	**105.64**	**102.45**
B3	**103.53**	**105.34**	**106.41**	**106.32**	**111.77**	**106.67**
Mean	**95.21**	**100.93**	**102.41**	**103.04**	**106.19**	
L.S.D	**A- 0.80**		**B- 0.72**		**AB- 1.60**	

2-Flag leaf area (cm2)

Table (3) reveals notable variations in the levels of nano NPK and biochar additions. Treatment A4 achieved the highest average of 53.09 cm2, whilst the comparison treatment had the lowest average of 45.41 cm2. The rise in the flag leaf area may be attributed to the involvement of NPK fertilizer, which entered the plant through the leaves and consequently resulted in an expansion of the flag leaf area. This aligns with the findings of Aziz (2020), who observed a rise in leaf area values upon the addition of a comprehensive nano fertilizer. The table indicates that treatment B3 exhibits a notable advantage, with the greatest average of 53.21 cm2, surpassing all other treatments. In contrast, the comparison treatment has the lowest average of 45.64 cm2. The addition of biochar influenced the root system by altering soil characteristics, hence impacting nutrient availability. This finding aligns with the conclusions drawn by Borha et al. (2019), who observed a positive correlation between the amount of additional charcoal and the expansion of leaf area. The findings from Table (3) demonstrate that there are notable variations in the interaction between the nano NPK and biochar levels. Treatment A4B3 had the greatest value of 57.21 cm2, whilst the comparison treatment had the lowest average of 42.62 cm2.

Table (3) Effect of spraying levels of nano-NPK fertilizer and biochar and their interaction on the average characteristic of flag leaf area (cm2).

B \ A	A0	A1	A2	A3	A4	Mean
B0	**42.62**	**47.45**	**44.30**	**45.90**	**47.94**	**45.64**
B1	**44.10**	**50.98**	**48.97**	**50.98**	**53.04**	**49.61**
B2	**46.58**	**52.12**	**50.24**	**52.30**	**54.19**	**51.09**
B3	**48.34**	**53.41**	**52.42**	**54.68**	**57.21**	**53.21**
Mean	**45.41**	**50.99**	**48.98**	**50.96**	**53.09**	
L.S.D	**A- 0.47**		**B- 0.42**		**AB- 0.94**	

3-Chlorophyll index (Spad).

The findings from Table (4) indicate that the A4 nano-fertilizer treatment outperformed the others, with an average Spad value of 48.88. This value was not significantly different from the A3 treatment, which had an average Spad value of 48.65. In comparison, the treatment being compared had the lowest average Spad value of 43.43. The findings align with the conclusions drawn by Abbasi and Rezaei (2014), who observed a rise in the chlorophyll levels of wheat plants when exposed to nano-fertilizer. Table (4)

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indicates that treatment B3 exhibits a substantial advantage over all other treatments, with the greatest average Spad value of 48.43. In contrast, the comparative treatment (without any addition) has the lowest value of 45.23 Spad. The addition of biochar resulted in an increase in chlorophyll content. This was owing to biochar's ability to lower the soil pH, which in turn enhanced the availability of nutrients. Additionally, biochar had a role in preserving and gradually releasing nutrients into the soil solution. This aligns with the findings of Junaidu (2021), who observed a positive correlation between the concentration of applied biochar and the percentage of chlorophyll. The findings from Table (4) demonstrate that there are notable variations in the interaction between the NPK fertilizer levels and biochar in relation to the chlorophyll content values in the plant. Treatment A4B3 achieved the greatest average Spad value of 50.30, surpassing all other treatments. In contrast, the comparison treatment had the lowest average Spad value of 45.32. This demonstrates the function of nano fertilizer combined with biochar in delivering and releasing nutrients at the precise time and location, resulting in an augmentation of chlorophyll levels in the leaves.

Table (4) Effect of spraying levels of NPK fertilizer and biochar and their interaction on chlorophyll content in the flowering stage (Spad).

B \ A	A0	A1	A2	A3	A4	Mean
B0	**42.48**	**44.22**	**45.99**	**46.71**	**46.78**	**45.23**
B1	**43.11**	**48.15**	**46.10**	**48.20**	**48.51**	**46.81**
B2	**43.47**	**49.15**	**47.13**	**49.84**	**49.94**	**47.90**
B3	**44.66**	**49.60**	**47.70**	**49.87**	**50.30**	**48.43**
Mean	**43.43**	**47.78**	**46.73**	**48.65**	**48.88**	
L.S.D	**A- 0.42**		**B- 0.37**		**AB- 0.84**	

4-Number of tillers (m2).

The findings from Table (5) indicated that treatment A4 exhibited superior performance compared to all other treatments, with the exception of treatment A3. Treatment A4 had the highest average of 449.1 tillers per square meter, whereas the comparison treatment had the lowest average of 298.4 tillers per square meter. The cause can be ascribed to the nano-fertilizer, which supplied an ample quantity to the plant, thereby diminishing the amount absorbed from the soil and delivering the fertilizer directly to the root system. This finding aligns with the conclusions drawn by (Armin et al., 2014), who observed a rise in the quantity of tillers in response to nano-fertilizer treatments. The findings from Table (5) indicate that treatment B3 had superior performance in terms of the number of tillers, with an average of 420.4 m2. In contrast, the comparison treatment had the lowest average of 374.8 m2. The possible cause could be attributed to the progressive release of nutrients by biochar during the initial stages of plant growth, which aligns with the findings of Al-Musa (2020). Table (5) indicates a significant interaction between the levels of nano NPK and biochar. Treatment A4B3 had the highest average of 470.3 tillers m2, which represents a 67% increase compared to the lowest average of 281.5 tillers m2 in the comparison treatment. The proliferation of tillers can be attributed to the influence of nano fertilizer, which enhances the plant's ability to absorb and utilize nutrients, as well as the effect of biochar in preserving and gradually releasing nutrients to the plant.

Table (5) The effect of spraying levels of nano NPK fertilizer and biochar and the interaction between them on the number of tillers (m2)

B \ A	A0	A1	A2	A3	A4	Mean

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B0	**281.5**	**353.6**	**381.5**	**445.2**	**412.3**	**374.8**
B1	**289.4**	**412.0**	**396.3**	**430.0**	**448.3**	**395.2**
B2	**296.4**	**388.5**	**438.4**	**438.9**	**465.4**	**405.5**
B3	**326.3**	**431.6**	**437.0**	**437.0**	**470.3**	**420.4**
Mean	**298.4**	**396.4**	**413.3**	**437.8**	**449.1**	
L.S.D	**A- 16.98**		**B- 15.19**		**AB- 33.96**	

5-Weight of 1000 grains (g).

Table (6) indicates that treatment A4 exhibited superior performance compared to all other treatments, with the greatest average of 50.37 g. In contrast, the comparison treatment had the lowest average of 45.88 g. The high amount of potassium is responsible for transferring the results of photosynthesis from the flag leaf to the seeds, hence enhancing the plumpness of the grains. This finding aligns with the conclusions drawn by Al-Zubaidi and Al-Naqeeb (2017), who demonstrated that the rise in the weight of a thousand grains can be attributed to the expansion of the flag leaf's surface area. Table (6) results indicate that treatment B3 demonstrated superior performance, with the greatest average of 52.16 g, whereas the comparison treatment had the lowest value of 45.42 g. The explanation can be ascribed to the action of biochar in providing nutrients to the plant during its growth cycle. This, in turn, promotes the production of chemicals like sugars and carbs, which are then transported to the grains, resulting in their fullness. This aligns with the findings of (Hosseini, 2021), which indicated that the weight of the grains increased as the levels of additional charcoal increased. The findings from Table (6) demonstrated that treatment A4B3 exhibited superiority, as it achieved the highest average of 54.45 g. The rise can be attributed to its superiority in several growth parameters, which directly or indirectly resulted in an increase in grain weight.

Table (6) Effect of spraying levels of NPK nano fertilizer and biochar and their interaction on the weight of 1000 grains (g).

A / B	A0	A1	A2	A3	A4	Mean
B0	45.31	45.71	45.67	45.69	44.74	45.42
B1	45.32	50.08	50.06	50.08	49.81	49.07
B2	46.34	51.22	51.20	51.22	52.51	50.50
B3	46.57	53.33	53.30	53.18	54.45	52.16
Mean	45.88	50.08	50.06	50.04	50.37	
L.S.D	A- 0.10		B- 0.09		AB- 0.21	

6-Grain yield: Megagram ha-1

The data presented in Table (7) demonstrates that treatment A4 exhibited superiority, with the highest average yield of 6.37 megagrams ha-1. In contrast, the comparison treatment yielded the lowest value of 4.63 megagrams ha-1. This discrepancy can be attributed to the elevated concentration of elements in the plants, which stimulated the fertilization process, fruit set, and grain filling.

The data shown in Table (7) indicates that treatment B3 outperformed the other treatments, achieving the highest average yield of 6.14 megagrams per hectare. In contrast, the comparison treatment had the lowest average yield of 4.91 megagrams per hectare. These values were in agreement with those obtained by Harsini in 2014.
The table results indicated that treatment A3B3 exhibited superiority, recording the highest average of

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6.70 megagrams ha-1. This treatment significantly outperformed all other treatments, primarily due to the inclusion of nano-fertilizer and biochar. These additives played a crucial role in enhancing growth components and yield, resulting in an increase in grain yield.

Table (7) Effect of spraying levels of nano-NPK fertilizer and biochar and their interaction on the grain yield trait (megagram h-1).

A / B	A0	A1	A2	A3	A4	Mean
B0	**4.13**	**4.74**	**4.92**	**4.92**	**5.86**	**4.91**
B1	**4.52**	**5.08**	**5.74**	**5.72**	**6.41**	**5.49**
B2	**4.90**	**5.61**	**6.32**	**6.54**	**6.53**	**5.98**
B3	**4.99**	**5.91**	**6.42**	**6.70**	**6.68**	**6.14**
Mean	**4.63**	**5.33**	**5.85**	**5.97**	**6.37**	
L.S.D	**A- 0.021**		**B- 0.018**		**AB- 0.042**	

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