Effect of mineral Fertilizer NPK and Biochar on some growth and Yield characteristics of Maize crop (*Zea mays* L.) in Calcareous soil in Northern Iraq

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Abstract

The study was conducted on calcareous soil in northern Iraq to study the effect of mineral fertilizer NPK and biochar on some growth and yield characteristics of yellow maize crop. A basic dose of N, P, and K nutrients was added according to the fertilizer recommendation (320 N - 200 P_2O_5 - 80 K_2O) kg h^{-1} by using urea fertilizer (46٪ N), tri-superphosphate fertilizer (47.5٪ P_2O_5) and potassium sulphate fertilizer (50٪ K_2O), as follows: Control treatment (F_0), 50% of the recommended NPK (F_1) and 100% of the recommended NPK (F_2). Biochar was added at three levels (0, 1, and 2%).Statistical analysis using Duncan's test indicated that 100% of recommended NPK + 2% biochar (F_2B_2) treatment had a significant effect on plant height (214.66 cm), grain yield (6525.00 kg h^{-1}), leaf area (8764.89 cm^2) and chlorophyll content (40.67 spad), dry weight of shoots (31848.67 kg h^{-1}), cob length (20.70 cm) and number of grains in the row (34.27 grain row^{-1}). Therefore, this treatment can be justified for the use these mixed fertilizers in the future to get a good quantity and quality yield of yellow maize crop in calcareous soils.

Keywords: Maize Crop, biochar, calcareous soil, NPK mineral fertilizer.

Introduction

Maize is one of the most important strategic crops and ranks third in terms of production and cultivated area (9). yellow maize grains are distinguished by their high content of vitamins. Despite this the maize crop in Iraq is low and insufficient to meet local needs, (13). (10) indicated that yellow maize production in Iraq for the year 2021 decreased by 10.7% compared to the year 2020. Calcareous soils are characterized by containing calcium carbonate at a high rate of not less than 15%, and this high percentage of calcium carbonate causes a decrease in the nutrients availability in the soil, and thus a decrease in the quantity and quality of crops, as well as a decrease in organic matter, nitrogen and the fixation of phosphorus and potassium (17).

NPK fertilizer is one of the most important fertilizers related to plant growth. The great importance of this fertilizer lies in the fact that it contains three nutrients for agriculture, which are nitrogen, phosphorous, and potassium which contribute to most of the vital and physiological processes within the plant, as well as its effect on enzymes important in the process of photosynthesis and building cell membranes.

The term biochar is applied to carbon-rich materials that result from burning crop residues in conditions of lack of oxygen and by using sealed containers for this purpose. This results in biochar, which is distinguished from fuel coal by containing some elements such as calcium, magnesium and carbon and can be used as an improver for soil properties (5).

(25) found that adding nitrogen fertilizer led to an increase in plant height, number of leaves, and leaf area of yellow maize. (15) also found that there was an increase in the height of yellow maize plants when adding the mineral fertilizer NPK. (14) found an increase in the percentage of chlorophyll in yellow maize with an increase in the level of added mineral fertilizer NPK. (6) found that adding NPK mineral fertilizer led to an increase in the area of yellow maize leaves. (26) found that adding biochar increased yellow maize grain yield.

(8) found that adding NPK mineral fertilizer with biochar gave higher grain yield in maizecompared to individual fertilization treatments of mineral fertilizer or biochar. (24) found that adding biochar led to an increase in chlorophyll content in maize plants. Therefore, the aim of this investigation is to study the effect of mineral fertilizer (NPK) with and without biochar on some growth characteristics of yellow maize crop in calcareous soils.

Materials and Methods

The study was carried out on calcareous soil of the field of College of Agriculture and Forestry/ Mosul University. The soil of the field was analyzed for some chemical and physical properties as shown in Table (1).The field was divided into three plots (each plot representing a replicate) and one plot was divided into nine experimental units using a randomized complete block design (RCBD).NPK mineral fertilizer was added according to the fertilizer recommendation (320N- 200P_2O_5- 80K_2O) approved by (4) (7) (1) with biochar and mixed with the soil, urea fertilizers, tri-

superphosphate and potassium sulfate, as sources of nitrogen, phosphorus and potassium, respectively. Nitrogen was added to the soil in two stages:The first was before planting and the second was a month after germination. Also, the activated biochar was also added to the soil at levels (0,1,2%).The following show the detailed treatments used in the experiment:

Control	F_0B_0
Zero NPK + 1% biochar	F_0B_1
Zero NPK + 2% biochar	F_0B_2
50% of the recommended NPK + 0% biochar	F_1B_0
50% of the recommended NPK + 1% biochar	F_1B_1
50% of the recommended NPK + 2% biochar	F_1B_2
100% of recommended NPK + 0% biochar	F_2B_0
100% of recommended NPK + 1% biochar	F_2B_1
100% of recommended NPK + 2% biochar	F_2B_2

Maize plant samples were taken at the harvesting stage to measure some traits of maize (plant height, grain yield, leaf area, chlorophyll content, dry weight of shoots, cob length and number of grains in the row). These traits of the maize crop were then statistically analyzed using Duncan's test to evaluate the effect and levels of significance of the treatment on the maize crop.

Table 1. Some Chemical and Physical properties of the studied calcareous soil.

Properties	Value	Unit
pH	7.8	
EC	0.9	dSm^{-1}
O.M.	17.5	$g\ kg^{-1}$
CEC	17.5	Centimol $kg\ soil^{-1}$
$CaCO_3$	250	$g\ kg^{-1}$
Sand	460	$g\ kg^{-1}$
Clay	215	$g\ kg^{-1}$
Silt	325	$g\ kg^{-1}$
Texture	Loam	

Results and Discussion

Plant height (cm):

Analysis of maize plant height as influenced by mineral fertilizer and biochar and the interaction between them is presented in Table (2). In general, the result showed that the plant height was increased significantly with increasing the rate of NPK fertilizer. The average increase in plant height ranged from 189.44 cm in the control treatment (F0) to 209.44 cm in the (F2) treatment, which had an increased rate of 10.56%, compared to the control treatment. This increase in plant height may be due to the increasing the level of nitrogen, phosphorus and potassium. The nitrogen element has an important role in increasing cell division, chlorophyll concentration and root penetration, while phosphorus increases the metabolism and formation of lipids and nucleic acids, whereas potassium element increases photosynthesis (22) Also, increasing the level of NPK fertilizer increases the availability of NPK elements in the soil and thus facilitates their absorption by the plant, and this reflects positively on growth indicators, including plant height (16). and this result is in agreement with the result that findings by (15) who found that there is an increasing in the height of maize plants when mineral fertilizer NPK was added.

Table 2. Effect of mineral fertilizers (NPK) and biochar on yellow maize plant height (cm).

Treatments	yellow maize plant height (cm) at			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	182.66 f	190.00 ef	195.66 de	189.44 c
50% of the recommended NPK (F_1)	199.66 cde	208.00 abc	198.66 cde	202.11 b
100% of the recommended NPK (F_2)	203.33 bcd	210.33 ab	214.66 a	209.44 a
Average biochar	195.22 b	202.77 a	203.00 a	200.33

The results also showed that there is a significant effect of all biochar treatments on plant height. The average plant height was increased from 195.22 cm in the control treatment (B0) to 203.00 cm in treatment (B2), where the percentage of increase was 3.99% compared to the control treatment. These results are consistent with a study (19) that concluded that the addition of biochar significantly increased the height of maize plants. The same results were found in the interaction treatment between NPK and biochar. It showed that the average plant height ranged from 182.66 cm in the control treatment (F0B0) to 214.66 cm in the treatment (F2B2).

Grain yield:

Table (3) shows the effect of mineral (NPK) and biochar and the interaction between them on the grain yield of maize crop. Data in this table show that the grain yield was 3177.77 kg h^{-1} in the control treatment (F0) and increased with increasing the added NPK to reach 5702.80 kg h^{-1} in (F2) treatment. This increase in grain yield of crop between F0 and F2 treatment represented about 79.46%. On the other hand, the addition of biochar also showed a significant increase in grain yield compared to the control treatment, as the average grain production ranged from 3952.77 kg h^{-1} in the control treatment (B0) to 5036.10 kg h^{-1} in (B2) treatment, which represented a percentage increasing about 27.41 % in comparison to the control treatment. The result also show that the interaction between mineral fertilizers and biochar treatment achieved a significant difference from the control treatment (F0B0), which recorded the lowest grain yield 2633.30 kg h^{-1}, while the highest grain yield 6525.00 kg h^{-1} was recorded in the treatment (F2B2).

Table 3. Interaction effect of NPK and biochar on yellow maize grain yield (kg h^{-1}).

Treatments	yellow maize grain yield (kg h^{-1})			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	2633.30 g	3050.00 g	3850.00 f	3177.77 c
50% of the recommended NPK (F_1)	4208.30 ef	4541.70 de	4733.30 cd	4494.43 b
100% of recommended NPK (F_2)	5016.70 c	5566.70 b	6525.00 a	5702.80 a
Average biochar	3952.77 c	4386.13 b	5036.10 a	4458.33

The superiority of the treatment (F2B2) in grain yield is due to the role of biochar in improving the physical and chemical traits of the soil, increasing the soil's ability to retain water, and increasing the availability of nutrients (2)

The increase in grain yield of maize crop may be due to an increase in the availability of NPK nutrients, which in turn increase the dry matter accumulation, and grain weight and thus increase grain yield (3).

These results are confirmed by the result of (21), who noticed that there is a significant increase in the yield of yellow maize grain with increasing the added mineral fertilizer (NPK). Also, the results are confirmed with results of (8) who found that adding mineral fertilizer NPK with biochar to the soil gave the highest value of grain yield compared to mineral fertilization alone or biochar alone.

leaf area (cm^2):

The results (the effect of NPK and biochar on the leaf area of maize) are shown in Table (4) which indicate that there is a significant increase in the leaf area per plant in the yellow maize crop with increasing the mineral fertilization. This increase ranged from 4322.35 cm2 in the control treatment (F0) to 8334.56 cm2 in the treatment (F2), which achieved an increase rate of 92.82 % compared to the comparison treatment.

The results also showed that all the biochar treatments significantly affect leaf area over the control treatment (B0), which recorded the lowest value amounted to 5829.61 cm2, in comparison with (B2) treatment which achieved the highest value for the average leaf area amounted to 7050.06 cm2, with increasing percentage equal to 20.94% compared to the control treatment

Table 4. The effect of NPK and biochar on the leaf area of maize (cm^2).

Treatments	leaf area of maize (cm^2)			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	3520.65 h	4156.69 g	5289.72 f	4322.35 c
50% of recommended NPK (F_1)	5887.54 e	6337.01 d	7095.56 c	6440.04 b
100% of recommended NPK (F_2)	8080.63 b	8158.15 b	8764.89 a	8334.56 a
Average biochar	5829.61 c	6217.28 b	7050.06 a	6365.65

The interaction treatments between mineral fertilizer and biochar also achieved a significant increase in the leaf area of maize crop compared to the control treatment. This increase ranged from 3520.65 cm2 in the control treatment (F0B0) to 8764.89 cm2 in the treatment (F2B2), which gave an increase percent equal to 148.96 % compared to the control treatment.The increase in leaf area with an increase in mineral fertilizer level and biochar is due to the role of nitrogen in

increasing plant growth and prolonging the period during which the leaves remain green, and thus the duration of the photosynthesis process increase and increase accordingly leaf area, in addition to the role of biochar in increasing the vegetative growth of plants, which lead to an increase in leaf area (11) The obtained results are consistent with the results obtained by (6), which showed an increase in the leaf area of the yellow maize crop with an increase in the added amount of NPK mineral fertilizer for all growth stages, as it is consistent with the results of (8) who observed an increase in the leaf area of maize when biochar was added.

chlorophyll content (spad):

Table (5) shows the effect of mineral fertilization and biochar and the interaction between them on the chlorophyll percentage of the yellow maize crop. It shows that there is a significant effect of all mineral fertilizer treatments on the chlorophyll percentage. It ranged from 33.93 spad in (F0) treatment to 43.16 spad in (F2) treatment, with an increasing percent of 27.20 % in comparison to the control treatment. This increase in chlorophyll content may be due to the high content of NPK nutrients present in the plant of (F2) treatment. This result is in agreement with (13), who found that there is an increase in chlorophyll content in maize when the level of mineral fertilizer NPK was increased.

Table 5. The effect of NPK and biochar on the chlorophyll content of maize crop

Treatments	chlorophyll content (spad)			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	31.03 f	33.96 e	36.80 d	33.93 c
50% of the recommended NPK (F_1)	39.30 c	39.50 bc	40.56 bc	39.78 b
100% of recommended NPK (F_2)	41.13 b	43.70 a	44.66 a	43.16 a
Average biochar	37.15 c	39.05 b	40.67 a	38.96

The results also showed a significant effect of biochar on the percentage of chlorophyll compared to the control treatment. The increase ranged from 37.15 spad in the control treatment (B0) to 40.67 spad in (F2B2) treatment. This result indicates the role and importance of biochar in increasing the chlorophyll content of maize leaves. These results are confirmed with the results obtained by (24) who observed that biochar has a significant effect in increasing the chlorophyll content of maize plants. Also, the result in Table (5) shows that the interaction between mineral fertilizers and biochar had a significant effect on the percentage of chlorophyll in

maize crop. It, ranged from 31.03 spad in the control treatment (F0B0) to 44.66 spad in the treatment (F2B2).

The increase in chlorophyll content with the increase in mineral fertilizer level is due to increased availability of nitrogen, phosphorus, and potassium that cause increased activity of vital processes and increased chlorophyll content.

Dry matter weight of the vegetative part (kg h^{-1}):

Table (6) shows the effect of mineral fertilizer (NPK) and biochar and the interaction between them on dry matter weight of the vegetative part of maize crop. The results showed a significant effect of all mineral fertilizer treatments on the average dry matter weight, which ranged from (18375.26) kg ha^{-1} in the comparison treatment (F0) to (29335.06) kg ha^{-1} in the (F2) treatment. The percentage increase was (59.64%) in treatment (F2) compared to the control treatment.

Table 6. The effect of NPK and biochar on the Dry matter weight of the vegetative part (kg h^{-1})

Treatments	Dry matter weight (kg h^{-1})			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	15816.2 h	18187.33 h	21122.17 g	18375.26 c
50% of the recommended NPK (F_1)	23657.67 f	24688.00 e	25393.04 d	24579.57 b
100% of recommended NPK (F_2)	26963.6 c	29192.83 b	31848.67 a	29335.06 a
Average biochar	22145.8 c	24022.72 b	26121.29 a	

The results also showed a significant effect of all biochar treatments on the weight of the dry matter, as the average weight of the dry matter ranged from (22145.88) kg ha^{-1} in the comparison treatment (B_0) to (26121.29) kg ha^{-1} in the treatment (B_2), which reached a percentage The increase in it is (17.95%) compared to the comparison treatment (B_0). There was also an effect of the interaction between mineral fertilizer and biochar on the weight of dry matter, as its lowest value was recorded (15816.29) kg ha^{-1} in the comparison treatment (F_0B_0) and its highest value was (29335.06) kg ha^{-1} in the treatment (F_2). The reason for the increase in the dry matter weight of the plant is due to the increase absorption of NPK nutrients, as nitrogen and phosphorus contribute to building the plant's membranes and thus help the plant in increasing the efficiency of the photosynthesis process, which helps in increasing the dry weight of the vegetative part. In addition to the role of potassium in increasing dry weight through its role in increasing leaf area and building

chlorenchyma cells that work to increase stem thickness (18).

Cob length (cm):

Table (7) show the effect of mineral fertilizers and biochar and their interaction on the cob length of yellow maize crop. The results showed significant differences in all mineral fertilizer treatments compared to the control treatment, as the average cob length ranged from 16.52 cm in the control treatment (F0) to 19.98 cm. In treatment (F2), which achieved an increase of 20.94% over the comparison treatment.

The results also showed a significant difference for all biochar treatments compared to the comparison treatment, as the average length of the cob in the biochar treatments ranged from 17.97 cm in the comparison treatment (B0) to 18.50 cm in the comparison treatment (B2), which achieved an increase of 2.95%.

Table 7. Effect of mineral fertilizer and activated charcoal on the cob length of yellow maize plants (cm)

Treatments	Cob length (cm)			
	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	15.90 f	16.70 ef	16.96 def	16.52 c
50% of the recommended NPK (F_1)	17.83 cde	18.40 bcd	18.46 bc	18.23 b
100% of recommended NPK (F_2)	19.63 ab	19.63 ab	20.70 a	19.98 a
Average biochar	17.97 a	18.26 a	18.50 a	

As for the interaction between mineral fertilizer and biochar, the lowest value for the cop length was recorded in the comparison treatment (F_0B_0), which reached 15.90 cm, while the treatment (F_2B_2) achieved the highest value, reaching 20.70 cm an increase of 30.19% over the comparison treatment.The increase in cop length may be due to the high efficiency of the photosynthesis process, as well as the availability of nutrients in sufficient quantities, especially nitrogen and potassium, which transport the products of this process to the seeds (12). These results are consistent with the results of (20), who observed an increase in the cob length of yellow maize plants when adding the mineral fertilizer NPK.

Number of grains in the row (grain row^{-1}):

The results shown in table (8) indicate a significant effect of all treatments of mineral fertilizer and biochar on the number of grains per row of yellow maize

crop. The average number of grains per row in the mineral fertilizer treatments ranged from 25.86 grain row^{-1}, in the control treatment (F_0) to 32.95 grain row^{-1} in the treatment (F_2) which achieved an increase of 27.42% compare with control treatment. The results also showed a significant increase for all biochar treatments in terms of the number of grains per row, as the average number of grains per row ranged from 28.48 grain row^{-1} in the control treatment (B_0) to 30.78 grain row^{-1} in the treatment (B_2) which was a percentage the increase is 8.08% compare with control treatment. As for the effect of the interaction between mineral fertilization and biochar, it achieved a significant difference for all treatments in the number of grains per row, the lowest value of which was recorded at 24.05 grains row^{-1} in the comparison treatment (F_0B_0), while the treatment (F_2B_2) recorded the highest value for the average number of grains in the row, which it amounted to 34.27 grains row^{-1}, and this treatment gave the highest percentage increase of 24.49% compared to the control treatment.

Table 8. Effect of mineral fertilizer and activated charcoal on the Number of grains in the row (grain row^{-1})

Treatments	0% biochar B_0	1% biochar B_1	2% biochar B_2	Average NPK
Control (F_0)	24.05 e	26.35 de	27.18 ce	25.86 c
50% of the recommended NPK (F_1)	29.49 bd	29.91 bc	30.88 b	30.09 b
100% of recommended NPK (F_2)	31.88 ab	32.70 ab	34.27 a	32.95 a
Average biochar	28.48 b	29.65 ab	30.78 a	

The reason for the increase in grains in the row may be due to the increase concentration of nutrients, which in turn increased the length of the plant and the area of the leaves and thus increased the process of photosynthesis and its products that are transferred to the grains, which in turn increase the processes of fertilization, pollination, and the number of grains (23).

Finally, it can be concluded from the results of the study, that the interaction between mineral fertilizers NPK and biochar (F2B2) treatment had a significant effect in the improvement of all maize crop properties and can increase the productivity of calcareous soils when cultivated with this crop.

Conclusion

The study showed that increasing the level of biochar added led to a noticeable increase in plant height, grain productivity, leaf area, chlorophyll content, dry matter weight of the vegetative part, cob length and number of grains in the row in yellow maize plants. Also, increasing the level of added mineral fertilizer NPK led to an increase in plant height, grain productivity, and leaf area. Adding biochar with NPK mineral fertilizer achieved better results in plant height, grain yield, leaf area, chlorophyll content, dry matter weight, cob length and number of grains in the row compared to adding biochar alone or mineral fertilizer alone.

Conflict of interest

The authors declare no conflict of interest.

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