ISSN NO: 2771-8840
Date of Publication: 26-05-2022

Test of the Effectiveness of Biochar and Mineral Fertilizer on The Growth and Yield of Two Broad Bean *Vicia Faba* L.

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Abstract : The experiment was applied in two successive winter seasons 2020 and 2021, with the aim of studying the growth and yield of two cultivars of bean, the Turkish variety A1 (Bakla sakiz) and the Spanish A2 variety (Histal), and three levels of NPK mineral fertilizer 20, 20, 20 and the total quantity was 200 kg.ha^{-1} S1 no addition and S2 adding 50% of the total fertilizer and S3 adding 100%, and three levels of biochar (corn stalks and poultry manure) H1 no addition and H2 adding 7 tons.ha^{-1} and H3 adding 14 tons.ha^{-1} and three replicates using a design. (R.C.B.D). The results of the study showed significant differences between cultivars, fertilizer and biochar and the interaction between them, and for all the studied traits two seasons, The Spanish cultivar was significantly superior to the Turkish cultivar in terms of plant height, leaf area, chlorophyll content in leaves, weight of 100 seeds and total seed yield, except that the number of branches per plant did not differ significantly two seasons, The S3 level was significantly distinguished in all growth traits, weight of 100 seeds two seasons and a recipe for yield for the 2021 season, While the level S2 was significantly superior in the trait of the achievement for the 2020 season, the level H3 was significantly superior in all the characteristics of the study two seasons, The binary interaction between cultivars, manure, cultivars and charcoal was significant, as the two combinations A2S3 and A2H3 excelled in all study characteristics two seasons, The triple interaction between cultivars, fertilizer and charcoal was significant, as the two combinations A2S2H3 and A2S3H3 were superior in plant height, chlorophyll and yield two seasons and 100-seed weight trait for the 2020 season, While the combinations A1S3H2, A1S3H3, A2S3H2 and A2S3H3 were significantly distinguished in the characteristics of number of branches on the plant and leaf area two seasons.

Key words: Plant Height, Branches, Leaf Area, Chlorophyll Content, Grain Yield.

Introduction

Vicia faba L. is a prehistoric winter legume crop that originated in the Middle East and was traditionally used as food for humans and animals, being a major source of protein (35). And its grains have a high percentage of carbohydrates, amino acids, potassium and calcium, and some necessary vitamins and important fatty substances (49). In recent years, the cultivation of the bean has received great attention from Europe, Canada and the United States of America (15), Its productivity in our country Iraq is about 25,711 tons, and the cultivated area is 17,727 acres (10). There are challenges that will face the agricultural sector due to the increase in hunger, by increasing the density of the world's population in 2050, it may reach 9 billion people (16) Among these challenges are climate change, environmental pollution and hunger, which have become one of the important issues in our modern age, and from here scientists set out to reduce or reduce greenhouse gas emissions (global warming), Improving the fertility, properties and quality of agricultural soil, and providing it with organic materials (1). The application of charcoal to agricultural soils by recycling plant residues (organic waste), is now one of the modern and environmentally friendly tools that are used throughout the year (18). Biochar (BC) received great attention when applied to the soil, for the sustainability and development of agriculture and the improvement of crop yield (4). BC has a large surface area and porosity and is negatively charged (38). Lehmann *et al* (30) reported that biochar provides macronutrients and releases them slowly. Moreover, biochar positively affects the growth of bacterial colonization within its pores by supplying them with air and nutrients (24). The mineral N.P.K is one of the important and basic nutrients for plant life, and one of the most important inputs to agriculture to increase the yield of agricultural production, especially nitrogen. There are environmental problems that accompany the application of nitrogen, as N is

ISSN NO: 2771-8840
Date of Publication: 26-05-2022

washed into groundwater, and then the pollution of that water, in addition to the economic losses resulting from washing N away from the absorption and eating of roots or volatilization or fixed between the layers of clay mineral (27). Nelissen *et al* (37) reported that biochar rapidly stabilizes NH4 by sorption, which reduces available nitrogen and thus reduces potential N losses in the soil. Phosphorous is an essential nutrient for plant growth, but only 10 to 25% of the P applied with mineral fertilizer is used by plants, and the rest is fixed in the soil or washed away (43). Experiments showed that the available P in the soil increased with the increase in the rate of biochar application (47). Potassium has a leading role in plant nutrition, photosynthesis, cell division, anti-lost, transporting processed materials from source to downstream (grain filling) and increases nutrient uptake (N, P). Usually biochar contains a large amount of (K), which ranges from (0.70 -116) g. kg^{-1} (23). Due to the large number of controversies and variables about the benefits of biochar (BC) and the applied treatments reported during the different studies, further experiments and ongoing studies on the quality of biochar for limited crops and soils are required. Therefore, the research aims to test the effect of biochar (BC) alone or in combination with mineral N.P.K fertilizer to regulate its levels, on the growth and yield of the bean plant.

Materiais And Methods

This study was applied during two successive winter seasons, 2020 and 2021, and the field experiment was carried out in one location in Al-Sharqat district, Ashur district, which is located 125 km north of Salah Al-Din Governorate. The land of the experiment was plowed with the tipped plow and in an orthogonal manner, smoothed, torn and leveled with the knuckle and marked with a grooved distance (0.75) m between each two poles, and the land was cultivated for the first year on 5/10/2020, and the second year on 6/10/2021. Soil and crop servicing of all experimental units was carried out identically as needed. In this study (R.C.B.D) a randomized complete block design was implemented, With three factors, the first factor has two types of Beans A1 (Turkish Bakla sakiz), A2 (Spanish Histal), and the second factor has three levels of biochar H1, H2, H3 (zero, 7 tons.ha^{-1}, 14 tons.ha^{-1}) in order. Biochar BC (corn stalks and poultry dung) was made locally according to the old method (the pit), which is 2 m long, 1 m wide and 2 m deep. Sift it with a 2 mm sieve, and mix with the experiment soil. The third factor: Three levels of NPK mineral fertilizer S1, S2, S3 (zero, 50%, 100%) in order, the fertilizer was balanced 20-20-20, and the total amount of fertilizer was 200 kg ha^{-1}. This fertilizer was added in two first batches 30% of the total fertilizer after 15 days after germination, and the remaining 70% was added a month after the first batch. This experiment consisted of three replications, the replicator contains 18 harmonic factor treatments, the experimental unit consists of 4 spikes with a length of 3 m, the distance between the spikes and the experimental units is (0.75 m), the distance between the replicates is 2 m, and between one plant and another is 0.25 m, and the total area of the experimental unit is 9 m^2 Three seeds in one hole, then diluted to one plant in the hole. Measurements of all studied traits were taken for only ten plants from the middle goose, to study the following traits:

1- Plant height (cm): It was measured by measuring tape from the surface of the soil to the top of the plant.
2- The number of branches in the plant (branch. $Plant^{-1}$): The number of branches in the plant was calculated and then their average was extracted.
3- Chlorophyll content in leaves (CCI): The chlorophyll content was measured by (Chlorophyll Meter) and its type was (CCM_200), then its average was extracted.
4- Leaf area of the plant (cm^2.$plant^{-1}$): The ruler was used to measure the maximum length and maximum width of the leaf, then the leaf area was extracted by applying the equation reported (44).
Leaf Area= (Length× Width)0.04+0.45
5- Weight of 100 seeds (gm): 100 seeds were taken from each experimental unit at random, and were weighed with a sensitive scale (34).
6- Grain yield (tons. ha^{-1}): It was calculated by multiplying the seed yield of a single plant (which was extracted as the average weight of the seeds of all plants of the two middle lines) by the plant density, then converting it to a ton. ha^{-1}

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Table 1: The properties of the chemical and physical experiment soil for the years 2019-2020.

Chemical properties	2020	2021	Unit
PH	7.34	7.23	------
EC	2.23	2.95	ds.m $^{-1}$
Organic matter	3.75	4.23	g.kg^{-1} Soil
Nitrogen	30.3	28.4	mg.kg^{-1} Soil
Phosphor	6.92	8.74	
Potassium	6.2	7.6	
Physical properties			
Clay		324	g.kg^{-1} Soil
Silt		187	
Sand		489	
Texture		Sand Clay	

Results and Discussion:

1- Plant height (cm): The results of Table (2) indicate that there is a significant difference between the two cultivars in plant height characteristic two seasons, as Histal cultivar was distinguished by giving it the highest height (92.82 and 97.51) cm compared to Bakla Sakiz cultivar, which recorded the lowest height (92.46 and 93.38) cm two seasons, in order. The reason for the superiority of the Histal variety in plant height may be due to the genetic factors possessed by this variety that activate the division and elongation of stem cells and thus increase the height of the plant, and these results are in line with the result (7). The reason for the mineral NPK fertilization was a significant superiority when applying level S3 to the rest of the levels and two seasons by giving it the highest rate of (106.63 and 107.52) cm compared to level S1, which recorded the lowest rate (72.62 and 73.26) cm two seasons, in order, this was reported by Alsalim (5) when applying NPK fertilizer gave the best growth of the bean plant. Biochar levels (BC) achieved significant superiorities in plant height in two seasons, where the H3 level achieved the highest rate of (102.32 and 103.20) cm and an increase of (15.58% and 15.29%) compared to the level H1 which recorded the lowest height (88.82 and 89.51) cm, two seasons in order, The reason is due to the application of biochar, because BC coal in general is rich in minerals and organic carbon, and thus provided the soil with additional nutrients, which led to the development of plant growth (20), this result is consistent with (50). The results of Table (2) show that the interaction between cultivars, mineral fertilizers, cultivars, biochar, fertilizer and biochar was significant in this trait two seasons, as the combination A2S3 was significantly distinguished over the rest of the combinations by giving it the highest height of (109.38 and 110.29) cm compared to the combination A1S1 which gave Minimum height (71.15 and 71.78) cm, while the combination A2H3 recorded the highest height of (105.52 and 106.24) cm compared to the combination A1H1 which gave the lowest height of (87.49 and 88.14) cm. As for the interaction of fertilizer and charcoal, the two combinations S2H3 and S3H3 significantly outperformed the rest of the combinations by giving them the highest height of (114.97 and 115.98) cm and (114.67 and 115.76) cm compared to the combination S1H1, which recorded the lowest height (66.28 and 66.65) cm two seasons, in order, This result is in line with (33) and is consistent with what was reported (44) that the combined application of biochar and mineral fertilizer (P) led to an increase in crop growth efficiency. There is a significant difference between the interaction of cultivars, NPK fertilizer and biochar in the characteristics of plant height two seasons, Where the two combinations A2S2H3 and A2S3H3 significantly outperformed the other combinations by giving them the highest stem of (119.33 and 118.84) cm and (120.06 and 119.53) cm, with an increase of (85.43% and 84.67%) and (85.90% and 85.08%) compared to the combination A1S1H1, which gave the lowest height (64.35 and 64.58) cm two seasons, in order, The reason for the superiority of A2S2H3 at the highest height is attributed to the fact that biochar provided the bean plant throughout its life cycle with nutrients by improving the symbiotic relationship of legumes with Rhizobia bacteria, thus enhancing the plant with nitrogen and increasing growth (37), Biochar BC prevents plant stem cells from stresses (vital and abiotic), and this was confirmed by Alkheero *et al* (3) that charcoal retains water, so it

ISSN NO: 2771-8840
Date of Publication: 26-05-2022

increases the performance and vitality of photosynthesis and the speed of the flow of its products to stem cells, which stimulates them to divide and elongate, and thus increased Stem rise, inorganic NPK nutrients are also necessary to ensure adequate supply of plant nutrients for increased growth, however, nutrient recovery from fertilizers is ineffective and occurs globally and is harmful to the crop (17), Sha *et al* (40) observed that when biochar (wood) was applied at rates of (5-15) tons.ha^{-1}, combined with nitrogen levels and at an amount of less than 200 kg.ha^{-1}, reduced the volatilization of NH3. This indicates that the addition of NPK fertilizer 50% with 14 tons. ha^{-1} of charcoal during our experiment was sufficient to fill the nutrient needs of the crop, causing it to form a higher stalk.

Table 2: Effect of cultivars, fertilizer and biochar and their interaction on plant height for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	3.41 C	5.45 B	5.82 A	4.31 C	5.00 B	5.36 A	4.89 A
A2	3.42 C	5.46 B	5.84 A	4.31 C	5.04 B	5.37 A	4.91 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	2.53 G	3.53 F	4.10 E	3.41 C	
		S2	5.10 D	5.36 C	5.83 B	5.45 B	
		S3	5.16 D	6.13 A	6.13 A	5.83 A	
		Biochar rate	4.31 C	5.02 B	5.36 A	**Mean rate** 4.90	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		2.46 H	3.53 G	4.06 F	2.60 H	3.53 G	4.13 F
S2		5.06 E	5.33 CD	5.80 B	5.13 E	5.40 C	5.86 B
S3		5.13 E	6.13 A	6.13 A	5.20 DE	6.13 A	6.13 A
Season 2021							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	3.68 C	5.53 B	5.88 A	4.53 C	5.08 B	5.48 A	5.03 A
A2	3.57 C	5.55 B	5.86 A	4.44 C	5.08 B	5.46 A	5.00 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	3.00 G	3.63 F	4.26 E	3.63 C	
		S2	5.23 D	5.43 C	5.96 B	5.54 B	
		S3	5.23 D	6.20 A	6.20 A	5.87 A	
		Biochar rate	4.48 C	5.08 B	5.47 A	**Mean rate** 5.01	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		3.06 G	3.66 F	4.33 E	2.93 G	3.60 F	4.20 E

ISSN NO: 2771-8840
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S2	5.26 CD	5.40 CD	5.93 B	5.20 D	5.46 C	6.0 AS
S3	5.26 CD	6.20 A	6.20 A	5.20 D	6.20 A	6.20 A

Similar numbers have no significant difference between them at the 5% probability level.

2- Number of branches plant^{-1}: Table (3) shows that there is no significant difference in the characteristics of the number of branches on the plant by the cultivar factor two seasons, this result is consistent with (6), while there is a significant difference between the levels of mineral fertilizer and biochar levels two seasons, The S3 level was distinguished by giving the highest rate of (5.83 and 5.87) branch .plant^{-1}, while level S1 achieved the lowest rate of (3.83 and 3.63) branch .plant^{-1} two seasons, in order. This result coincided with (12), As for the level H3, it was significantly superior by giving the highest rate (5.36 and 5.47) branch. plant^{-1}with an increase of (25.58% and 22.09%) compared to the H1 level, which recorded the lowest rate (4.26 and 4.48) branch. plant^{-1}two seasons in order, the interaction between cultivars, fertilizers, varieties and biochar showed a remarkable superiority in the number of branches over the plant two seasons, Where the combination A2S3 achieved the highest rate of (109.38 and 110.29) branch. plant^{-1}, while the combination recorded the lowest rate (71.15 and 71.78) branch. plant^{-1} in order, as for the A2H3 combination, it was significantly distinguished by giving it the highest rates of (105.52 and 106.24) branch. plant^{-1}, compared to the A1H1 combination, which recorded the lowest rate of (87.49 and 88.14) branch. plant^{-1} branches, in order. The results of our study indicate that there is a significant difference between the interaction of fertilizer and biochar in this trait and two seasons, as the two combinations S3H2 and S3H3 gave the best average number of branches that reached (6.13) branch. plant^{-1} and (6.20) branch. plant^{-1}, with an increase rate of (142.29%) and (106.66%) compared to the combination S1H1 that achieved the lowest rate (2.53 and 3.0) branch. plant^{-1} two seasons in order, this result is consistent with (33). There is a significant difference between the cultivars, NPK fertilizer and biochar in the characteristics of the number of branches per plant two seasons, the combinations A1S3H2, A1S3H3, A2S3H2 and A2S3H3 outperformed them by giving them the highest rate of (6.13) branch. plant^{-1} and (6.20) branch. plant^{-1} with an increase rate of (149.18%) and (111.60%) compared to the two combinations A1S1H1 and A2S1H1 which gave the lowest rate of (2.46). .93) branch. plant^{-1} two seasons in order.

Table 3: Effect of cultivars, fertilizer and biochar and their interaction on Number of branches on the plant for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	3.41 C	5.45 B	5.82 A	4.31 C	5.00 B	5.36 A	4.89 A
A2	3.42 C	5.46 B	5.84 A	4.31 C	5.04 B	5.37 A	4.91 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	2.53 G	3.53 F	4.10 E	3.41 C	
		S2	5.10 D	5.36 C	5.83 B	5.45 B	
		S3	5.16 D	6.13 A	6.13 A	5.83 A	
		Biochar rate	4.31 C	5.02 B	5.36 A	**Mean rate** 4.90	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		2.46 H	3.53 G	4.06 F	2.60 H	3.53 G	4.13 F
S2		5.06 E	5.33 CD	5.80 B	5.13 E	5.40 C	5.86 B
S3		5.13 E	6.13 A	6.13 A	5.20 DE	6.13 A	6.13 A
Season 2021							

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Fertilizer × varieties	Interaction of varieties and fertilizer			Interaction of varieties and biochar			varieties rate
	S1	S2	S3	H1	H2	H3	
A1	3.68 C	5.53 B	5.88 A	4.53 C	5.08 B	5.48 A	5.03 A
A2	3.57 C	5.55 B	5.86 A	4.44 C	5.08 B	5.46 A	5.00 A
		Biochar × fertilizer	Interaction of fertilizer and biochar			Fertilizer rate	
			H1	H2	H3		
		S1	3.00 G	3.63 F	4.26 E	3.63 C	
		S2	5.23 D	5.43 C	5.96 B	5.54 B	
		S3	5.23 D	6.20 A	6.20 A	5.87 A	
		Biochar rate	4.48 C	5.08 B	5.47 A	Mean rate 5.01	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		A1			A2		
		H1	H2	H3	H1	H2	H3
S1		3.06 G	3.66 F	4.33 E	2.93 G	3.60 F	4.20 E
S2		5.26 CD	5.40 CD	5.93 B	5.20 D	5.46 C	6.0 AS
S3		5.26 CD	6.20 A	6.20 A	5.20 D	6.20 A	6.20 A

Similar numbers have no significant difference between them at the 5% probability level.

3- Leaf area (cm^2 $plant^{-1}$): The results of Table 4 showed that the cultivars differed in the characteristics of leaf area two seasons, as the Spanish variety was distinguished by giving the highest leaf area (7119.2 and 7131.1) cm^2 $plant^{-1}$, while the Turkish variety recorded the lowest leaf area amounted to (7079.2 and 7080.7) cm^2 $plant^{-1}$ two seasons in order, this result is in line with (7 and 11). The levels of NPK fertilizer and biochar levels significantly affected the leaf area two seasons, as level S3 achieved the highest leaf area of (7583.3 and 7584.0) cm^2 $plant^{-1}$with an increase of (20.77% and 20.43%) compared to level S1, which was the lowest the leaf area was (6278.9 and 6297.4) cm^2 $plant^{-1}$two seasons in order, and this result was consistent with (12). As for the levels of charcoal, the level of H3 was significantly superior by giving it the highest area of (7680.5 and 7681.4) cm^2 $plant^{-1}$, compared to the level of H1, which was the lowest level of (6499.1 and 6517.2) cm^2 $plant^{-1}$ two seasons in order, The reason for the increase is due to the application of BC, which provided the plant with nutrients by increasing the efficiency of rhizobia (14 and 45), which supplied the plant with nitrogen, and thus increased the plant height Table (2) and the number of leaves (observed in the field) and this reflected positively on the increase in the area of leaves, this result was in line with (47), the effect of interaction between cultivars, fertilizers, varieties and biochar on leaf area character two seasons, the two combinations A2S3 and A2H3 were distinguished over the rest of the combinations, as they gave the widest leaf area of (7587.9 and 7588.3) cm^2 $plant^{-1}$ compared to the combination A1S1, which had the lowest area of (6255.2 and 6257.6) cm^2 $plant^{-1}$ two seasons, in order, also the combination A2H3 excelled by giving it the widest leaf area of (7712.8 and 7713.5) cm^2 $plant^{-1}$ compared to the combination A1H1, which had the lowest area of (6486.2 and 6488.0) cm^2 $plant^{-1}$ two seasons, in order. The results indicate a significant difference at a probability of 5% between the interaction of fertilizer and biochar in this trait and two seasons, as the two combinations S2H3 and S3H3 were distinguished by giving them the widest area of (8251.1 and 8251.7) cm^2 $plant^{-1}$ and (8250.9 and 8251.33) cm^2 $plant^{-1}$ While the lowest area of S1H1 was achieved (6050.7 and 6103.1) cm^2 $plant^{-1}$ two seasons in order, The reason for the increase is due to the plant height Table (2) and the number of leaves seen in the field, as well as the role of both charcoal and fertilizer in preparing the leaf cells with nutrients, which prompted them to divide and expand, thus creating a wide leaf area. This result was in line with (32 and 51) on the Soybean plant.

ISSN NO: 2771-8840
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Table 4: Effect of cultivars, fertilizer and biochar and their interaction on leaf area (cm^2 $plant^{-1}$) for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	6255.2 F	7403.6 D	7578.7 B	6486.2 F	7103.0 D	7648.3 B	7079.2 B
A2	6302.6 E	7467.2 C	7587.9 A	6512.0 E	7133.0 C	7712.8 A	7119.2 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	6050.7 H	6246.5 G	6539.5 F	6278.9 C	
		S2	6628.1 E	7427.0 C	8251.1 A	7435.4 B	
		S3	6818.6 D	7680.5 B	8250.9 A	7583.3 A	
		Biochar rate	6499.1 C	7118.0 B	7680.5 A	**Mean rate** 7099.2	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		6102.7 O	6218.3 N	6444.6 L	5998.8 P	6274.6 M	6634.4 J
S2		6541.5 K	7419.1 F	8250.1 B	6714.6 I	7434.9 E	8252.0 A
S3		6814.5 H	7671.6 D	8250.0 B	6822.6 G	7689.4 C	8251.8 A
Season 2021							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	6257.6 F	7404.7 D	7579.7 B	6488.0 F	7104.6 D	7649.4 B	7080.7 B
A2	6337.3 E	7467.8 C	7588.3 A	6546.4 E	7133.5 C	7713.5 A	7131.1 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	6103.1 H	6247.9 G	6541.3 F	6297.4 C	
		S2	6629.3 E	7427.8 C	8251.7 A	7436.2 B	
		S3	6819.2 D	7681.4 B	8251.3 A	7584.0 A	
		Biochar rate	6517.2 C	7119.0 B	7681.4 A	**Mean rate** 7105.9	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		6105.3 N	6220.2 M	6447.3 K	6100.9 O	6275.7 L	6635.3 I
S2		6543.2 J	7420.3 E	8250.6 A	6715.3 H	7435.2 D	8252.8 A
S3		6815.5 G	7673.3 C	8250.3 A	6823.0 F	7689.5 B	8252.3 A

Similar numbers have no significant difference between them at the 5% probability level.

Significant differences were observed between the three-cultivar interaction, NPK fertilizer and biochar in the characteristic of leaf area two seasons, where the two combinations A2S2H3 and A2S3H3 outperformed by giving them the widest leaf area of (8252.0 and 8251.8) cm^2 $plant^{-1}$ compared to the combination A2S1H1, which formed the lowest area of (5998.8) cm^2 $plant^{-1}$ for the 2020 season, as for the season of 2021, the combinations A1S2H3, A1S3H3, A2S2H3 and A2S3H3 were significantly distinguished by giving them the widest area of (8250.6 and 8250.3) and (8252.8 and 8252.3) cm^2 $plant^{-1}$ compared to the combination A2S1H1 which formed the least leaf area (6100.9) cm^2 $plant^{-1}$, the reason for the increase in leaf area is attributed to

ISSN NO: 2771-8840
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the application of charcoal, which equipped the plant with nutrients, especially nitrogen, which plays a prominent role in the physiological processes of the legume crop, which helped it to divide and expand leaf cells, because charcoal positively affects the growth of bacterial colonization and its supply of air and nutrients, thus fixing nitrogen in a way. High (13), also mineral nutrients NPK plays a vital role, especially P, in improving the performance of bacterial ganglia (2), but high amounts of mineral nitrogen prevent bacterial ganglia from fixing nitrogen (9).

4- Chlorophyll content in leaves CCI: The results of Table (5) indicated that the cultivars differed significantly in the character of the chlorophyll content in leaves for both seasons, as the Histal variety was distinguished by giving the highest chlorophyll content of (38.87 and 38.94) CCI compared to the variety Bakla Sakiz, which had the lowest chlorophyll content of (38.70 and 38.88). CCI two seasons in order, the reason for this is due to the different nature of the varieties in their genetic composition and their influence on environmental factors, or the nature of growth and its morphological shape that allowed the largest amount of sunlight to be exposed to a larger area of leaves, and this is a major factor in the formation of chlorophyll, this result was consistent with (11). The levels of NPK and BC levels significantly affected the chlorophyll content in leaves two seasons, as S3 was distinguished over the rest of the levels as it gave the highest chlorophyll content of (42.42 and 42.45) CCI compared to level S1, which was the lowest chlorophyll content of (32.46 and 32.66) CCI, this result is consistent with (50) obtained when applying mineral fertilizer to Soybean plant. While the H3 level of charcoal was superior by giving it the best chlorophyll content of (42.26 and 42.35) CCI, while the H1 level recorded the lowest chlorophyll content of (33.70 and 33.82) CCI two seasons in order. This result was in line with (50) when biochar was applied 10% Increase the chlorophyll content in the leaves of the Soybean plant, the results indicate that the binary interaction between cultivars, fertilizer, cultivars and biochar was significant for this trait and two seasons,

ISSN NO: 2771-8840
Date of Publication: 26-05-2022

Table 5: Effect of cultivars, fertilizer and biochar and their interaction on Chlorophyll content in leaves (CCI) for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	32.29 E	41.41 C	42.41 A	33.66 D	40.36 C	42.09 B	38.70 B
A2	32.62 D	41.56 B	42.43 A	33.73 D	40.44 C	42.43 A	38.87 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	31.15 H	32.47 G	33.75 F	32.46 C	
		S2	34.63 E	43.31 C	46.52 A	41.48 B	
		S3	35.32 D	45.42 B	46.51 A	42.42 A	
		Biochar rate	33.70 C	40.40 B	42.26 A	**Mean rate** 38.79	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		31.17 J	32.42 I	33.29 H	31.13 J	32.52 I	34.22 G
S2		34.50 F	43.23 C	46.51 A	34.75 E	43.39 C	46.53 A
S3		35.32 D	45.43 B	46.49 A	35.32 D	45.42 B	46.54 A
Season 2021							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	32.59 D	41.61 B	42.45 A	33.83 E	40.60 C	42.21 B	38.88 B
A2	32.73 C	41.64 B	42.46 A	33.80 E	40.54 D	42.49 A	38.94 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	31.0 H	32.70 G	34.02 F	32.66 C	
		S2	34.78 E	43.58 C	46.52 A	41.62 B	
		S3	35.41 D	45.44 B	46.52 A	42.45 A	
		Biochar rate	33.82 C	40.57 B	42.35 A	38.91	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		31.37 K	32.76 I	33.65 H	31.10 L	32.64 J	34.39 G
S2		34.71 F	43.61 C	46.51 A	34.85 E	43.56 C	46.53 A
S3		35.42 D	45.43 B	46.49 A	35.39 D	45.44 B	46.55 A

Similar numbers have no significant difference between them at the 5% probability level.

as the combinations A1S3, A2S2 and A2H3 were significantly distinguished at a probability of 5% over the rest of the combinations by giving them the highest content of chlorophyll (42.41 and 42.45) CCI and (42.43 and 42.46). CCI and (42.43 and 42.49) CCI as measured by the combinations A1S1, A1H1 and A2H1 that made the lowest chlorophyll content of (32.29 and 32.59) CCI and (33.66 and 33.80) CCI two seasons in

ISSN NO: 2771-8840
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order, also there was a significant interaction between NPK and charcoal in the chlorophyll content in leaves two seasons, where the two combinations S2H3 and S3H3 achieved the best chlorophyll content of (46.52 and 46.52) CCI and (46.51 and 46.52) CCI, with an increase of (49.34% and 50.06%). and (49.30% and 50.06%) compared to the combination S1H1, which had the lowest chlorophyll content of (31.17 and 31.0) CCI two seasons in order, the reason for the increase in chlorophyll in leaves may be due to the increase in the percentage of nitrogen in the leaves, which plays a key role in the production of chlorophyll pigment, in the leaves of the plant, moreover, that 70% of N enters into the formation of leaf chlorophyll (8). This result is consistent with (50). The results showed a significant interaction between cultivars, NPK fertilizer and BC charcoal in this trait two seasons, the combinations A1S2H3, A1S3H3, A2S2H3, and A2S3H3 were significantly superior to the rest of the combinations, as they gave the best chlorophyll that reached (46.51 and 46.49) CCI and (46.54 and 46.55) CCI Compared to the combination A2S1H1, which formed the lowest chlorophyll content, it was (31.13 and 31.10) CCI two seasons in order.

5- Weight of 100 seeds (g): Table (6) shows that there are significant differences between the two cultivars in the characteristics of 100-seed weight for both seasons, as the Spanish variety was distinguished by giving the best weight of (136.32 and 136.44) g compared to the Turkish cultivar, which had the lowest weight of (135.40 and 135.49) g two seasons in order, the superiority of the Spanish variety in this trait may be due to its superiority in leaf area and leaf content of chlorophyll, thus increasing the efficiency of photosynthesis and increasing its outputs that flow into the fullness of the grains. This result is consistent with (6), the levels of NPK and biochar significantly affected the weight of 100 seeds in two seasons, where the level S3 significantly outperformed the other levels by producing the highest weight of (141.23 and 141.33) g, compared to the level S1 which produced the lowest weight of (126.40 and 126.48) g two seasons in order, As for the H3 level of coal, it achieved the highest weight of (144.81 and 144.86) g compared to the H1 level, which produced the lowest weight of (130.75 and 130.83) g two seasons in order, The results indicate that there are significant differences between the interaction of cultivars, fertilizer, varieties and biochar in this trait and for both seasons,

ISSN NO: 2771-8840
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Table 6: Effect of cultivars, fertilizer and biochar and their interaction on weight of 100 seeds (g) for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	125.63 F	139.73 D	140.86 B	130.24 F	131.68 D	144.29 B	135.40 B
A2	127.17 E	140.17 C	141.61 A	131.27 E	132.35 C	145.33 A	136.32 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	123.78 H	126.61 G	128.82 F	126.40 C	
		S2	133.37 E	133.68 D	152.79 A	139.95 B	
		S3	135.12 C	135.76 B	152.83 A	141.23 A	
		Biochar rate	130.75 C	132.01 B	144.81 A	**Mean rate** 135.86	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		122.45 N	126.00 L	128.43 J	125.10 M	127.21 K	129.20 I
S2		133.33 H	133.65 G	152.20 B	133.41 H	133.72 G	153.38 A
S3		134.94 F	135.40 D	152.24 B	135.30 E	136.11 C	153.42 A
Season 2021							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	125.68 E	139.84 C	140.95 B	130.25 E	131.87 CD	144.34 B	135.49 B
A2	127.28 D	140.33 BC	141.71 A	131.40 D	132.53 C	145.38 A	136.44 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	123.76 F	126.82 E	128.86 D	126.48 C	
		S2	133.51 C	133.87 C	152.88 A	140.09 B	
		S3	135.22 B	135.92 B	152.85 A	141.33 A	
		Biochar rate	130.83 C	132.20 B	144.86 A	**Mean rate** 135.96	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		122.36 I	126.21 GH	128.46 EF	125.15 H	127.43 FG	129.27 E
S2		133.37 D	133.85 CD	152.30 A	133.66 D	133.88 CD	153.45 A
S3		135.03 BC	135.54 B	152.26 A	135.40 B	136.29 B	153.44 A

Similar numbers have no significant difference between them at the 5% probability level.

where the two combinations A2S3 and A2H3 outperformed the rest of the combinations because they produced the best weight of (141.61 and 141.71) g and (145.33 and 145.38) g compared to the two combinations A1S1 and A1H1 Which produced the lowest weight of (125.63 and 125.68) g and (130.24 and 130.25) g two seasons in order. The binary interaction between manure and charcoal had a significant effect on the character of 100 seeds two seasons, as the two combinations S2H3 and S3H3 were distinguished over the rest of the combinations by producing the best weight of (152.79 and 152.88) g and (152.83 and 152.85)

ISSN NO: 2771-8840
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g compared to the combination S1H1 which produced the lowest weight of (123.78 and 123.76) g two seasons in order, this result matches with (33). The results showed that there was a significant interaction between cultivars, manure and charcoal in this trait for both seasons, as the two combinations A2S2H3 and A2S3H3 were distinguished for their production with the best weight of (153.38 and 153.45) g and (153.42 and 153.44) g, with an increase of (25.25% and 25.40%). and (25.29% and 25.40%) compared to the mixture A1S1H1, which produced the lowest weight of (122.45 and 122.36) g two seasons in order, The reason for the increase in the character of 100 seeds is due to the effect of fertilizer and charcoal on increasing the leaf area Table (4) and the content of chlorophyll Table (5), and this increased the reception of the largest and the longest light period, which increased the efficiency of photosynthesis and increased its products and accumulation in the downstream (grains), in addition Moreover, NPK fertilizer positively affected the bean plant through the nitrogen element that delays leaf senescence and this extends the duration of the grain filling (36), the bean responds to nitrogen in the soil, and often refuses to coexist with the roots when the nitrogen in the soil is sufficient (41) , Phosphorous plays a prominent role in the process of photosynthesis and nitrogen holding and fixation (19,31), while potassium increases the efficiency of photosynthesis, transport rate and accumulation of products, and delays the aging of leaves (26).

6- Grain yield (tons ha^{-1}): Table (7) shows that the two cultivars differed significantly in the characteristics of seed yield for both seasons, as the Spanish variety was distinguished by giving the highest yield of (4.03 and 4.04) tons ha^{-1} compared to the Turkish variety, which produced the lowest yield of (3.58 and 3.60) tons ha^{-1}. The reason for the superiority of the Spanish variety is due to its superiority in weight and 100 seeds Table (6). This result is consistent with (7, 12). The levels of NPK and charcoal significantly affected the trait of seed yield two seasons, as the S2 level in the 2020 season was characterized by giving the highest yield of 4.66 tons ha^{-1}compared to the S1 level, which was the lowest yield of 2.28 tons ha^{-1} while in the 2021 season the level S3 exceeded By giving it the best yield of 4.68 tons ha^{-1} compared to level S1, which had the lowest yield of 2.29 tons ha^{-1}, Ibrahim (22) mentioned that mineral fertilizer improves agricultural production, and Khaled (28) reported that mineral fertilizer is fast decomposing and compensates for the lack of nutrients in the soil and contributes to raising crop production. Coal levels were significantly superior to H3 by giving it the best yield of (5.04 and 5.06) tons ha^{-1} compared to the level of H1, which recorded the lowest yield of (2.49 and 2.51) tons ha^{-1} two seasons in order, the reason for the increase is attributed to the supply of nutrients throughout the life of the crop, so the growth characteristics increased, and thus the surface of photosynthesis increased, its products increased and the speed of its flow to the flowers to meet their needs of nutrients to increase the percentage of fertilization in them, so abortion decreases and the number of pods on the plant increases and thus increase the yield, In this regard, Issa (25) reported that the plant has the ability to hold pods and can be equipped with the products of photosynthesis only. This result is in line with (24 and 29) and this was confirmed by Yeboah *et al* (49) in his experiment on the Cowpea plant, and Egamberdieva *et al* (14) reported by applying biochar in their Soybean experiment. The results showed that there were significant differences between the interaction of cultivars, manure, cultivars and charcoal in this trait two seasons, the two combinations A2S3 and A2H3 were distinguished by giving them the best yield per unit area of (5.04 and 5.05) tons ha^{-1} and (5.27 and 5.27) tons ha^{-1} compared to the combination A1S1 which recorded the lowest yield of (2.19 and 2.21) tons ha^{-1} two seasons in order. Also, a significant difference was found between the interaction of fertilizer and biochar in the trait of seed yield for both seasons, as the combination S2H3 was significantly distinguished over the rest of the combinations, by giving it the best yield of (6.53 and 6.55) tons ha^{-1} compared to the combination S1H1 which recorded the lowest yield of (2.04 and 2.05) tons ha^{-1} two seasons in order, this result is in line with (33). We note from the results of Table (7) that biochar reduced the NPK fertilizer to 50%, meaning that half the amount of applied fertilizer was sufficient to meet the needs of the plant. What was reported (21) that the charcoal prevents the loss of nutrients from the soil, in addition to the applied NPK, and thus this led to a significant increase in the growth characteristics and the weight of 100 seeds, Table (6), all of this reflected positively on the increase in yield. The results indicated that there was a significant interaction between the cultivars, manure and charcoal in this trait two seasons, as the combination A2S2H3 was characterized by giving the best yield of (7.09 and 7.07) tons ha^{-1} compared to the combination A1S1H1 which recorded the lowest yield of (1.95 and 1.96) tons ha^{-1}.

ISSN NO: 2771-8840
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Table 7: Effect of cultivars, fertilizer and biochar and their interaction on grains yield (tons ha^{-1}) for the 2020-2021 seasons.

Season 2020							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	2.19 E	4.28 C	4.28 C	2.44 F	3.50 D	4.81 B	3.58 B
A2	2.37 D	5.04 A	4.67 B	2.55 E	4.26 C	5.27 A	4.03 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	2.04 I	2.25 H	2.55 G	2.28 C	
		S2	2.77 E	4.67 D	6.53 A	4.66 A	
		S3	2.67 F	4.72 C	6.03 B	4.47 B	
		Biochar rate	2.49 C	3.88 B	5.04 A	**Mean rate** 3.80	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		1.95 P	2.15 N	2.48 L	2.13 O	2.35 M	2.63 K
S2		2.73 H	4.13 F	5.97 C	2.82 G	5.22 D	7.09 A
S3		2.65 J	4.21 E	5.98 C	2.70 I	5.22 D	6.09 B
Season 2021							
Fertilizer × varieties	**Interaction of varieties and fertilizer**			**Interaction of varieties and biochar**			**varieties rate**
	S1	**S2**	**S3**	**H1**	**H2**	**H3**	
A1	2.21 E	4.30 C	4.30 C	2.46 F	3.51 D	4.84 B	3.60 B
A2	2.38 D	5.05 A	4.68 B	2.57 E	4.27 C	5.27 A	4.04 A
		Biochar × fertilizer	**Interaction of fertilizer and biochar**			**Fertilizer rate**	
			H1	**H2**	**H3**		
		S1	2.05 I	2.27 H	2.56 G	2.29 C	
		S2	2.80 E	4.68 D	6.55 A	4.49 B	
		S3	2.69 F	4.73 C	6.06 B	4.68 A	
		Biochar rate	2.51 C	3.89 B	5.06 A	**Mean rate** 3.82	
		Interaction of varieties and fertilizer and biochar					
Varieties × Biochar × fertilizer		**A1**			**A2**		
		H1	**H2**	**H3**	**H1**	**H2**	**H3**
S1		1.96 P	2.17 N	2.49 L	2.14 O	2.36 M	2.64 K
S2		2.74 H	4.14 F	6.03 C	2.85 G	5.22 D	7.07 A
S3		2.67 G	4.22 E	6.01 C	2.72 I	5.24 D	6.10 B

Similar numbers have no significant difference between them at the 5% probability level.

This indicates that the addition of NPK fertilizer 50% with 14 tons' ha^{-1} of charcoal during our experiment was sufficient to meet the crop's need of nutrients, which prompted it to form the highest yield, and this was reported by Robb *et al* (39) that biochar combined with the fertilizer The mineral, at lower levels, is more effective for general crops and less expensive in many countries.

ISSN NO: 2771-8840
Date of Publication: 26-05-2022

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ISSN NO: 2771-8840
Date of Publication: 26-05-2022

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