Effect of Biochar, Urea and Irrigation Determinants on the Growth and Yield of Maize *Zea mays* L.

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Abstract

The experiment was applied in the autumn season (2021 AD) to study the growth and yield of corn, the American variety 6664 DKC for two different levels of irrigation determinants A1 every four days and A2 every eight days and groups of urea fertilizer B1 no addition and B2 addition (200 kg/ha) and B3 addition (400 kg/ha) e) and different levels of Biochar (eucalyptus wood) C1 add no and C2 add (7 tons/ha), C3 add (14 tons/ha), and C4 add (21 tons/ha) using the (RCBD) design and with three replicates. The results of the experiment showed significant differences between the determinants of irrigation and urea fertilizer and Biochar and the interaction between them and for all the studied traits. The levels A1, B3 and C3 were characterized by giving the highest average over the rest of the classes for the characteristics of plant height (229.74, 235.68 and 243.59) cm and leaf area index (5.00 5.48, 5.64), chlorophyll content (43.45, 47.78, 47.88) CCI, the weight of 500 grains (134.31, 136.21, 138.22) g, total grain yield (9.48, 10.18, 10.81) ton/ha, and total dry weight (18.83, 19.72 and 21.39) tons/ha, according to the order. The interaction of the combination A1B3C3 gave the highest average in plant height, leaf area index, and weight of 500 grains amounted to (258.40 cm), (6.50) and (142.12 g) according to the order, which did not differ significantly from A1B2C3, A2B2C3 and A2B3C3. As for the chlorophyll content, the combination A1B3C3 excelled with the highest rate of (55.14) CCI and did not differ significantly from A2B3C3, while the combination A1B2C3 characterized the character of the total yield by giving it the best rate of (12.12 tons/ha), and it did not differ significantly from A1B3C3 and A2B2C3 and A2B3C3. In contrast, in the dry weight character A2B3, the two combinations, A1B3C3 and A2B3C3, were characterized by giving the best weight (23.50 ton/ha), and they did not differ significantly from A1B2C3. We conclude from the study that treating the soil with 14 tons/ha of biochar increased the urea fertilizer to 50% and increased the limits of irrigation to 8 days, meaning that the application of (14 tons/ha) biochar + (200 kg/ha) urea fertilizer and irrigation every eight days It was sufficient to meet the nutrient and moisture needs of the US 6664 DKC maize crop.

Keywords: Biochar, nutrients, irrigation determinants, maize

تأثير الفحم الحيوي واليوريا ومحددات الري على نمو وحاصل الذرة الصفراء *Zea mays* L.

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الخلاصة

طبقت التجربة في الموسم الخريفي (2021م) بهدف دراسة نمو وحاصل الذرة صنف DKC 6664 الأمريكي لمستويين مختلفين من محددات الري A1 كل 4 أيام وA2 كل 8 أيام ومستويات سماد اليوريا B1 عدم الإضافة وB2 إضافة (200 كغم/هـ) وB3 إضافة (400 كغم/هـ) ومستويات مختلفة من الفحم الحيوي (خشب شجر الكالبتوس) C1 عدم الإضافة وC2 إضافة (7 طن/هـ) وC3 إضافة (14 طن/هـ) وC4 إضافة (21 طن/هـ) باستخدام تصميم (R.C.B.D) وبثلاث مكررات. أظهرت نتائج التجربة وجود فروق معنوية بين محددات الري وسماد اليوريا وكذلك الفحم الحيوي والتداخل بينهما ولجميع الصفات المدروسة، إذ تميزت المستويات A1 وB3 وC3 بإعطائها اعلى معدل على بقية المستويات لصفات ارتفاع النبات (229.74 و235.68 و243.59) سم ودليل المساحة الورقية (5.00 و5.48 و5.64) ومحتوى الكلوروفيل (43.45 و47.78 و47.88) CCI ووزن 500 حبة (134.31 و136.21 و138.22) غم وحاصل الحبوب الكلي (9.48 و10.18 و10.81) طن/هـ والوزن الجاف الكلي (18.83 و19.72 و21.39) طن/هـ حسب الترتيب. أعطى التداخل للتوليفة A1B3C3 اعلى معدل في صفة ارتفاع النبات ودليل المساحة الورقية ووزن 500 حبة بلغ (258.40سم) و(6.50) و(142.12غم) حسب الترتيب والتي لم تختلف معنوياً عن A1B2C3 وA2B2C3 وA2B3C3. أما محتوى الكلوروفيل فقد تفوقت التوليفة A1B3C3 بأعلى معدل بلغ (55.14)CCI ولم تختلف معنوياً عن A2B3C3، اما صفة الحاصل الكلي تميزت التوليفة A1B2C3 بإعطائها أفضل معدل بلغ (12.12 طن/هـ) ولا تختلف معنوياً عن A1B3C3 وA2B2C3 وA2B3C3، بينما في صفة الوزن الجاف تميزت التوليفتين A1B3C3 وA2B3C3 بإعطائها أفضل وزن بلغ (23.50 طن/هـ) لكلاهما ولم تختلف معنوياً عن A1B2C3. نستنتج من الدراسة ان معالجة التربة بالفحم الحيوي 14 طن/هـ قد رشد سماد اليوريا الى 50% وزيد محددات الري الى 8 أيام، أي ان تطبيق (14 طن/هـ) فحم حيوي + (200 كغم/هـ) سماد يوريا والري كل 8 أيام كان كافياً لسد حاجة محصول الذرة صنف DKC 6664 الأمريكي من المغذيات والرطوبة.

الكلمات المفتاحية: الفحم الحيوي، المغذيات، محددات الري، الذرة الصفراء

Introduction

Maize (*Zea mays* L.) is a distinguished cereal crop in the tropics. It is a source of oils and food for humans and fodder for animals and contains various raw materials for many agricultural-based industries (Zaidun *et al*., 2019). It is considered one of the vital crops in the world and grows in different soils and climates (Agegnehu *et al*., 2016). It is one of the most important nutritious crops that provide phytochemical compounds that prevent many diseases (Shah *et al*., 2016). The production for 2019 in Iraq of yellow corn for the summer season was about 473.1 thousand tons/ha, and the cultivated area is 515.2 thousand dunums for the spring and autumn seasons (Central Statistics Organization, 2020). There are many challenges facing agriculture globally, including climate change, water scarcity and hunger, which have become important issues in the current years. Hence, agricultural scientists set out to reduce greenhouse gas emissions (GHG) and improve agricultural soil fertility and quality with organic matter (Agegnehu *et al*., 2016; Mandol *et al*., 2016; Yoo *et al*., 2016). Adding Biochar to agricultural soils by diverting plant residues (organic waste) is now one of the modern environmentally friendly tools in all countries of the world (Gonzaga *et al*., 2018). Biochar is a porous, carbon-rich organic material produced by the pyrolysis process of organic matter without oxygen (Tenic *et al*., 2020). It is considered a biomass carbon, which improves soil fertility (El-Naggar *et al*., 2019). Biochar is receiving increasing attention when applied to soil to sustain agriculture and enhance crop productivity (Alotaibi *et al*., 2019). Biochar (BC) has been shown to improve soil's physical, biological, and chemical properties (Somerville *et al*., 2020). Biochar acts as a slow nutrient release source, providing macronutrients and improving soil properties such as water-holding capacity, air, and pH (Lehmann *et al*., 2011). Also called black carbon, not all black carbon is BiocharBiochar (Spokas *et al*., 2012). The C in Biochar remains unaffected for many years by microbial degradation (Lehmann *et al*., 2015). It has been proven that calcium and potassium are essential components of eucalyptus wood (Abdulah *et al*., 2010). It was reported (Dumroese *et al*., 2011) that BiocharBiochar increased the elements K, Fe, P, Na, B. It reduced Al, Mg, Mn, Ca, S. and increased the efficiency of fertilizer N (Biederman *et al*., 2013). Furthermore, BC contains Ca, Mg, and K (Deanik, 2011 & Rajkovich, 2012). Also, BiocharBiochar has a large surface area, is negatively charged, has a high density and is porous (Ahmad *et al*., 2014 and Rajapaksha *et al*., 2016). In addition, Biochar reduces the contamination of organic and inorganic materials, thus reducing or eliminating the uptake of pollutants by the plant (Park *et al*., 2015 and Rizwan *et al*., 2016). The BC system improves soil physicality, for example, water availability to plants by increasing the acidity of soil water holding capacity (WHC) (Liu *et al*., 2016). Also, Biochar accelerates water loss or water loss from clay soils and slows water movement in sandy soils (Major *et al*., 2010). Biochar alone does not have sufficient nutrients for optimal maize growth unless combined with fertilizers with adequate moisture (Sistani et al., 2019). But few field studies have evaluated the environmental and agricultural benefits of Biochar (BC) along with irrigation input technologists (Foster, 2016 and Kangoma, 2017). Due to the many controversies and variables in the benefits of Biochar and the treatments reported during the various studies, more ongoing research is required on biochar types for specific soils and crops. Therefore, this study aims to verify the effect of Biochar, alone or in combination with urea, on the growth and yield of maize and regulating the number of irrigations.

Materials and methods

This study was applied in the autumn season (2021 AD). In Kirkuk Governorate / Hawija District / Al Jubouriya Village, the American variety 6664 DKC was used in this study. The land was ploughed with the plough perpendicularly, and the ground was smoothed, broken up, and levelled with the knife and marked with a distance of (0.75) m between one mead and another, and land cultivated on 20/7/2021. In this study, (RCBD) used three factors, the first factor two levels of irrigation determinants A1, A2 (4 days and eight days) in order, and the second factor three levels of urea fertilizer B1, B2, B3 (0, 200 kg/ha, 400 kg/ha). According to the arrangement, and the third factor, four levels of biochar C1, C2, C3, C4 (zero, 7 tons/ha, 14 tons/ha, 21 tons/ha) according the arrangement. Biochar (eucalyptus wood) was made locally through the old method (the pit) with a depth of 2 m, 2 m and a width of 1 m. The eucalyptus wood was placed and burned in isolation from oxygen after covering the pot with a tight cover and then extracting biochar, grinding it and palm with a sieve of 2 mm and mixing it with the experiment soil. The experiment consisted of three replicates, each iterator containing 24 harmonic factor treatments. The experimental unit consisted of 4 Mesopotamia with a length of 3 m, the distance between the Mesopotamia and the experimental units was 0.75 m, the distance between the replicates was 2 m, and between one plant and another 20 cm, and the total area of the experimental unit was 9 square meters, three seeds planted in one hole. The data of growth characteristics and yield components of ten plants were taken as a sample from the middle goose to study the following traits:

1- Plant height (cm).

2- Leaf area index: It was obtained by dividing the quotient of the leaf area per plant by the space occupied by the plant in the land according to the equation (Birch et al., 1998).

3- Chlorophyll CCI content: measured by Opti-science device.

4- Weighing 500 grains/gm: 500 grains were randomly calculated from the stalks of ten plants for the experimental unit, and their weight was measured on a sensitive scale when their humidity was 15.5% (Al-Sahoki, 1990).

5- Total grain yield per unit area (tons/ha): Harvesting the middle grouse pods of the experimental unit and discarding their grains, then add to them the grains of the ten plants' erects that were taken previously, then according to the yield of all plants in the experimental unit and converting it to ton/ha at a humidity of 15.5% for seeds (Sahoki, 1990).

6- Total dry weight (tons/ha): Calculated for all the importance of the dry yield of the plant for stems, leaves, and stalks.

Table (1) The mineral content of biochar derived from eucalyptus wood.

Subject	EC 1:5 ds.m^{-1}	PH 1:5	O.M (g kg^{-1})	C/N Ratio	Mineral content mg.gm^{-1}		
Biochar	4.5	7.23	10.81	22	N	P	K
					13	3.3	30

Results and discussion

1-Plant height (cm): The results of Table (2) indicate that there is a significant difference in the characteristic of the size of the crop at the determinants of irrigation, as level A1 distinguished by giving it the highest rate of height (229.74 cm) compared to the level A2, which achieved the lowest elevation (221.51 cm), as well as The results, indicated that B3 level of urea fertilizer significantly distinguished from the rest of the classes by giving it the highest height (235.68 cm) and an increase of (12.95%) compared to the B1 rate, which is the lowest height of (208.65 cm), Table (2) also shows a significant difference in the same characteristic with biochar, as the level C3 was distinguished over the rest of the levels, as it achieved the best height (243.59 cm) and an increase of (14.14%) compared to the level C1 which gave the lowest height (213.40 cm). It shows a significant interaction between the determinants of irrigation and the combinations of urea fertilizer, as the combination A1B3 was characterized by giving it the highest height (241.04 cm) and an increased rate of (16.83%) compared to the combination A2B1, which gave the lowest height (206.30 cm). In contrast, the interaction of biochar and irrigation, which is the other, was significant in The characteristic of the height of the crop, as the two combinations, A1C3 and A2C3, achieved the best rate of 243.64 and 243.54 cm, with an increase of (17.18% and 17.13%), respectively, compared to the combination A2C1 which gave the lowest height (207.91 cm). There is a significant difference between the interaction of biochar and urea fertilizer, where the two combinations, B2C3 and B3C3, outperformed all varieties by giving them the highest best rate (258.35 and 258.38) cm and an increased rate of (29.51% and 29.52%) compared to the combination B1C1 (199.48 cm), which is the lowest height of the yield. The results of the Table made a significant difference in the yield height when the determinants of irrigation, urea fertilizer and biochar were overlapped. The combination A1B3C3, which did not differ significantly from the combinations A1B2C3, A2B2C3, and A2B3C3, was distinguished by giving it the highest rate of (258.40 cm) with an increase of (34.40%) compared to A2B1C1 (192.25 cm), this is the lowest height. The high yield is that biochar supplies the crop throughout its growth period with nutrients and growth increases. Biochar prevents plant stem cells from biotic and abiotic stresses; This increases photosynthesis activity and the speed of transmission of its products to the stem cell, which prompted it to divide and elongate, which was positively reflected in the height of the stem. Biochar also has effects on CEC capacity (Fowles, 2007). Greatly conserves nutrients and slowly makes them available to the plant, increasing fertilizer use efficiency (N) (Glaser *et al*., 2002 and Biederman *et al*., 2013).

Urea / Irrigation	**Overlap of irrigation and urea fertilizer AB**			**Overlap Irrigation and biochar AC**				**Irrigation rate**
	B1	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	
A1	211.00E	237.20B	241.04A	218.89D	225.50C	243.64A	230.95B	229.74A
A2	206.30F	227.92D	230.32C	207.91F	216.02E	243.54A	218.57D	221.51B
Urea rate	208.65C	232.56B	235.68A	213.4 D	220.76C	243.59A	224.76B	Mean 225.63

Bio / Urea	**Overlap of urea and biochar BC**			
	C1	**C2**	**C3**	**C4**
B1	199.48 J	209.17I	214.03G	211.91H
B2	217.45F	223.93E	258.35A	230.51C
B3	223.28E	229.19D	258.38A	231.85B

Overlap of irrigation, urea and biochar ABC

	A1				**A2**			
Bio / Urea	**C1**	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
B1	206.71N	210.40L	214.16J	212.73K	192.25O	207.95M	213.90J	211.09L
B2	220.05G	230.08D	258.36A	240.31B	214.85J	217.77H	258.34A	220.72G
B3	229.92D	236.04C	258.40A	239.81B	216.65I	222.35F	258.37A	223.90E

Table (2) The effect of irrigation determinants, urea fertilizer and biochar and the interaction between them on plant height (cm).

Similar letters have no significant difference between them at a probability of 5%

In addition, the structure of coal increases water retention, soil aeration and bulk density (Ali *et al*., 2017 and Zafar *et al*., 2018). (Njoku *et al*., 2016) reported a significant increase in maize height when biochar was applied compared to the control; this is what was said (Ibrahim *et al*., 2020) when using biochar, 5% and 10% increased the sorghum yield by (20.1% and 13.7%), respectively, compared to the control. Some studies reported that adding biochar in large quantities will freeze N and thus reduce the concentration of N in the tissues of cowpea *Vigna unguiculata* (Lehmann *et al*., 2003).

2-Leaf area index: The results of Table (3) indicated that the determinants of irrigation had a significant effect on the character of the leaf area index, as level A1 was distinguished by giving it the highest rate (5.00) compared to level A2, which achieved the lowest rate (4.53). The results also indicate that level B3 of urea fertilizer recorded the highest rate. Significant (5.48) compared to level B1 (3.55), which is the lowest average for the area index.

Urea / Irrigation	**Overlap of irrigation and urea fertilizer AB**			**Overlap Irrigation and biochar AC**				**Irrigation rate**
	B1	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	
A1	3.72 D	5.49 B	5.79 A	4.32 D	4.75 C	5.66 A	5.27 B	5.00 A
A2	3.38 E	5.05 C	5.16 C	3.77 E	4.36 D	5.63 A	4.36D	4.53 B
Urea rate	3.55 C	5.27 B	5.48 A	4.05 D	4.55 C	5.64 A	4.82 B	Mean 4.76

Bio / Urea	**Overlap of urea and biochar BC**			
	C1	C2	C3	C4
B1	3.01 H	3.49 G	3.96 E	3.73 F
B2	4.28 D	4.91 C	6.48 A	5.40 B
B3	4.85 C	5.26 B	6.48 A	5.32 B

Overlap of irrigation, urea and biochar ABC								
	A1				**A2**			
Bio / Urea	**C1**	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
B1	3.39 G	3.53 G	4.00 F	3.96 F	2.64 H	3.45 G	3.92F	3.50G
B2	4.56 E	4.96CD	6.47 A	5.96 B	4.01 F	4.86CD	6.49A	4.85CD
B3	5.02 C	5.76 B	6.50 A	5.91 B	4.67DE	4.76CDE	6.46A	4.74CDE

Table (3) The effect of irrigation determinants, urea fertilizer and biochar and the overlap between them on the characteristic of leaf area index. Similar letters have no significant difference between them at a probability of 5%

There are substantial differences between the levels of biochar, as the level C3 was distinguished over the rest of the classes by giving it the best evidence of (5.64) and an increase of (39.25) compared to the level of C1 (4.05), which is the lowest average for the trait. The results show that the interaction of the combinations of determinants of irrigation and urea fertilizer was significant; the combination A1B3 outperformed by giving it the best evidence of (5.79) and with an increased rate of (71.30) compared to the combination A2B1, which gave the least proof (3.38). Also, the interaction of irrigation with biochar was significant in the same trait, as the two combinations A1C3 and A2C3 were distinguished by the highest leaf area index (5.66 and 5.63) with an increased rate of (50.13% and 49.33%), respectively, compared to the combination A2C1 which recorded the lowest rate (3.77) As for the interaction of urea with biochar in the same character, it was significant, as the two combinations B2C3 and B3C3 recorded the best evidence of (6.48) for both, with an increase of (114.61%) compared to the combination B1C1 which gave the lowest rate (3.01) for the leaf area. The reason is that the biochar has retained a sufficient amount of nutrients, thus providing the plant with the nutrients it needs during its life, which prompted the crop to form a large leaf area that increased the leaf area index. Confirmed (Lehmann *et al*., 2011) that biochar is a large store of nutrients and releases them slowly and improves soil properties.The results of Table (3) also showed a significant difference when the determinants of irrigation, urea fertilizer and biochar were overlapped. The combination A1B3C3, which did not differ significantly from A1B2C3, A2B2C3 and A2B3C3, was distinguished by giving it the highest rate (6.50) and an increase of (146.21%) compared to the speed of combination A2B1C1 (2.64). The lowest rate of the adjective. The reason for the rise in (paper area index for corn crop 6664 DKC) is due to the increase in moisture and nutrients, especially N produced from biochar in addition to urea and its absorption by the crop, which stimulated growth buds and then the development and division of leaf cells and their expansion, nitrogen increases vegetative growth, especially in the stages of growth. Early plant (Fageria *et al*., 2010). When the leaf area is increased, the photosynthetic activity (NAR) and the speed of the flow of its products increased, which prompted the plant stem cell to divide and elongate the stem to obtain the highest branch reported in Table (2) and this is reflected positively by the increase in the leaf area index LAI. Herein lies the importance of biochar, as it changes the water-repellent properties of the soil and makes it more water and nutrient-retaining through the increase in cation exchange (Yost *et al*., 2019). Several studies have reported that biochar reduces nitrogen leaching (Nguyen *et al*., 2017).

3-Chlorophyll content CCI: The results of Table (4) showed that the determinants of irrigation had a significant effect on the character of chlorophyll content, as level A1 was characterized by giving it the highest range (43.45) compared to level A2, which recorded the lowest range (40.13). The results also indicate that level B3 of urea achieved the highest effective content. For chlorophyll, it reached (47.78) compared to level B1 (31.81), which is the lowest content of chlorophyll; there are significant differences between the levels of biochar, as the level C3 was distinguished over the rest of the classes by giving it the highest content of chlorophyll (47.88) and an increase of (35.36%) compared to the level C1, which was recorded (35.37), and this is what was reported by (Rizwan et al., 2019) increases Chlorophyll content when biochar is applied. The results indicate that the interaction of the determinants of irrigation and urea fertilizer combinations was significant, as the combination A1B3 outperformed it by giving it the highest content (49.94) with an increased rate of (61.82%) compared to the combination A2B1, which was recorded the lowest content (30.86). Also, the interaction of irrigation with biochar was significant in chlorophyll content. The two combinations, A1C3 and A2C3, were characterized by giving them the highest range (47.92 and 47.83) with an increased rate of (48.22% and 47.94%), respectively, compared to the A2C1 combination, which recorded the lowest content (32.33).

Urea / Irrigation	Overlap of irrigation and urea fertilizer AB			Overlap Irrigation and biochar AC				Irrigation rate
	B1	B2	B3	C1	C2	C3	C4	
A1	32.75E	47.66B	49.94A	38.42E	41.68D	47.92A	45.79B	43.45A
A2	30.86F	43.92D	45.61C	32.33G	36.81F	47.83A	43.56C	40.13B
Urea rate	31.81C	45.79B	47.78A	35.37D	39.24C	47.88A	44.68B	Mean 41.79

Bio / Urea	Overlap of urea and biochar BC			
	C1	C2	C3	C4
B1	27.93K	31.31 J	34.73 H	33.26 I
B2	37.45G	41.44 E	53.79 B	50.48 C
B3	40.74F	44.98 D	55.11 A	50.28 C

Overlap of irrigation, urea and biochar ABC								
	A1				A2			
Bio / Urea	C1	C2	C3	C4	C1	C2	C3	C4
B1	30.31 P	32.22 O	34.83 L	33.64 M	25.55 Q	30.40 P	34.63 L	32.89 N
B2	39.76 I	44.94 G	53.80 B	52.14 C	35.14 L	37.94 J	53.78 B	48.83 E
B3	45.18 G	47.88 F	55.14 A	51.58 D	36.29 K	42.09 H	55.08A	48.98 E

Table (4) Effect of irrigation determinants, urea fertilizer and biochar and the interaction between them on chlorophyll content CCI.

Similar letters have no significant difference between them at a probability of 5%

At the same time, the interaction of urea fertilizer with biochar in the same trait was Significant, where the combination B3C3 recorded the highest chlorophyll amounted to (55.11) with an increased rate of (97.31%) compared to the combination B1C1, which achieved the lowest chlorophyll amounted to (27.93).), the results of Table (4) reported that there were significant differences in this trait (chlorophyll content) when the determinants of irrigation, urea fertilizer and biochar were overlapped. 115.81% and 115.57%), respectively, compared to the combination A2C1B1, which recorded less chlorophyll (25.55). The reason for the increase in chlorophyll in the leaves of *Zea mays* L is due to biochar, which retains water, and changes the chemistry of the soil, i.e. increases the capacity of cation exchange, which provides nutrients and makes them ready for plants, and this increases soil fertility (Igalavithana *et al*., 2016). (Al-Zubaidi,2019), when biochar was applied with 30 tons/ha + 180 tons/ha nitrogen, gave the best nitrogen concentration of (39.62 g N kg-1) in the vegetative total of the maize crop. The N produced from biochar, and urea fertilizer increased the vegetative capacity, especially the length of the leaf, which made the young leaves green, unlike the old ones, because N is fast-moving inside the plant and moves to the plastids of modern leaves, which increases the content of chlorophyll (Tollenar Lee., 2007). The lower N Causes Demolition and ageing of leaves (Thomas and Smart, 1993).

4-Weight of 500 grain/gm: The 500-grain weight trait is an essential key yield component that enhances maize yield (Yigermal *et al*., 2019). The results of Table (5) indicate that the determinants of irrigation had a significant effect on the characteristic of the weight of 500 grains, as level A1 was distinguished by giving it the highest weight (134.31 g) compared to the level A2, which achieved the lowest weight (132.42 g). The results also indicated that the levels B2 and B3 of urea fertilizer Which did not differ significantly among them, outperformed the level B1, which gave the lowest weight (127.74 g); there is a significant difference between the levels of biochar, as the level C3 was distinguished over the rest of the levels by giving it the best weight for the trait amounted to (138.22 g) with an increased rate of (7.08%) compared to the level C1, which gave the lowest weight amounted to (129.08 g). Furthermore, the results show that the overlapping combinations of irrigation determinants Urea fertilizer was significant, as the combination A1B3 significantly outperformed the rest of the varieties by giving it the highest weight of (137.40 g) and an increase rate of (8.53%) compared to the combination A2B1 which showed a low rate of (126.60 g), It was also significant that the interaction of irrigation with biochar in the weight of

500 grains, as the combination A1C3 outperformed the rest of the combinations by giving them the best consequence (139.15 g) and an increase of (8.90%) compared to the combination A2C1 which showed the lowest weight (127.77 g), while the interaction of fertilizer Urea with biochar was significant in the same character, as the two combinations B2C3 and B3C3 were distinguished and were significantly superior to the rest of the combinations by giving them the highest rate (142.11 g and 142.12 g) with an increase of (12.96% and 12.97%) respectively compared to the combination B1C1 which gave the lowest weight (125.80 g).Urea fertilizer and biochar were overlapped. The combinations A1B2C3, A1B3C3, A2B2C3, and A2B3C3, were significantly distinguished by giving them the best weight for the trait (142.11, 142.12, 142.12 and 142.11) g, respectively. On the other hand, the combination A2B1C1 (125.29g) is the lowest rate for the feature. The reason for the increase in the trait of 500 grains is attributed to the effect of biochar, which was the main store for nutrients and good moisture at the same time, which prompted the crop to form a large leaf area, which increased the leaf area index Table (3) and increased the content of chlorophyll in Table (4). led to a longer and larger reception of Solar rays, thus increasing photosynthetic activity, flow speed, and the accumulation of vital matter downstream (grains). Also, urea fertilizer has a positive effect on the preparation of nitrogen, which delays the ageing of leaves and prolongs the period of grain filling (Al-Badrany, 2013).

Urea / Irrigation	Overlap of irrigation and urea fertilizer AB			Overlap Irrigation and biochar AC				Irrigation rate
	B1	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	
A1	128.88 E	136.65 B	137.40 A	130.38 G	133.33 D	139.15 A	134.39 C	134.31 A
A2	126.60 F	135.65 C	135.01 D	127.77 H	132.54 E	137.30 B	132.07 F	132.42 B
Urea rate	127.74 B	136.15 A	136.21 A	129.08 D	132.93 C	138.22 A	133.23 B	Mean 133.36

Bio / Urea	Overlap of urea and biochar BC			
	C1	**C2**	**C3**	**C4**
B1	125.80 G	127.17 F	130.44 E	127.55 F
B2	130.09 E	135.78 C	142.11 A	136.61 B
B3	131.34 D	135.85 C	142.12 A	135.52 C

Overlap of irrigation, urea and biochar ABC	A1				A2			
Bio / Urea	**C1**	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
B1	126.30 L	127.54 K	133.21 G	128.46 J	125.29 M	126.79 L	127.67 K	126.64 L
B2	131.55 H	136.05DE	142.11 A	136.88 C	128.64 J	135.51EF	142.12 A	136.34 CD
B3	133.29G	136.38CD	142.12 A	137.82 B	129.40 I	135.32 F	142.11 A	133.22 G

Table (5) The effect of irrigation determinants, urea fertilizer and biochar, and the interaction between them on the weight of 500 grains (gm).

Similar letters have no significant difference between them at a probability of 5%

Muhammad *et al*., (2021), when applying Bio 9 ton/ha + 140 kg n/ha, the maximum weight of 1000 grains was reached (271.33 g).

5-Total grain yield per unit area (tons/ha): Table (6) shows that there are significant differences in the characteristic of the total grain yield per unit area at the determinants of irrigation, as level A1 was distinguished by giving the best yield (9.48 tons/ha) compared to level A2, which was recorded the lowest yield (8.80 tons/ha), as the results indicated. The levels B2 and B3, which did not differ significantly, achieved the best yield per unit area (10.16 and 10.18) ton/ha, respectively, compared to level B1 (7.07 ton/ha), which is the lowest yield. There are significant differences between the levels of biochar, as it significantly exceeded the level C3 by giving it the best rate (10.81 tons/ha) with an increased rate of (42.80%) compared to the level C1, which recorded the lowest yield (7.57 tons/ha). Urea was significant in this trait, as the mixture A1B3 was distinguished over the rest of the varieties by giving it the best rate (10.55 tons/ha) with an increased rate of (59.60%) compared to the mixture A2B1, whose yield was (6.61 tons/ha), which is the lowest yield. The interaction of irrigation with biochar was also significant in this trait, as the combination A1C3 was significantly distinguished over the rest of the varieties by giving it (11.11 tons/ha) the highest grain yield and an increase in yield of about (57.81%) compared to the combination A2C1 which recorded the lowest rate (7.04 tons). /e), found that the interaction of urea fertilizer and biochar was significant, as the two combinations of B2C3 and B3C3 were significantly superior to the rest of the combinations by giving them the best yield of (12.10 and 12.07) tons/ha, with an increase of (109.70% and 109.18%) compared to the combination B1C1 Which recorded the lowest rate (5.77 tons/ha), The results also showed a significant difference between the interaction of the determinants of irrigation, urea fertilizer and biochar, as the combinations A1B2C3, A1B3C3, A2B2C3, and A2B3C3

were significantly distinguished over the rest of the varieties. No significant difference appeared between them, as it recorded an average of (12.12, 12.07, 12.08 and 12.06) tons/ha. With an increase of (132.62%, 131.66%, 131.86% and 131.46%), according to the order, compared to the combination A2B1C1 (5.21 tons/ha), which is the lowest yield of grains. We note from these results that the biochar reduced the urea fertilizer to 50%, meaning that half the dose (200 kg/ha) was sufficient to meet the crop's need.

Urea / Irrigation	Overlap of irrigation and urea fertilizer AB			Overlap Irrigation and biochar AC				Irrigation rate
	B1	B2	B3	C1	C2	C3	C4	
A1	7.54 E	10.34 B	10.55 A	8.09 F	9.06 D	11.11 A	9.65 C	9.48 A
A2	6.61 F	10.03 C	9.77 D	7.04 G	8.88 E	10.51 B	8.77 E	8.80 B
Urea rate	7.07 B	10.16 A	10.18 A	7.57 D	8.97 C	10.81 A	9.21 B	Mean 9.14

Bio / Urea	Overlap of urea and biochar BC			
	C1	C2	C3	C4
B1	5.77 H	6.98 G	8.27 E	7.28 F
B2	8.36 E	9.92 C	12.10 A	10.37 B
B3	8.58 D	10.00 C	12.07 A	9.99 C

Overlap of irrigation, urea and biochar ABC

	A1				A2			
Bio / Urea	**C1**	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
B1	6.32 K	7.09 J	9.14 F	7.61 HI	5.21 L	6.88 J	7.40 I	6.95 J
B2	8.85 F	9.95 E	12.12 A	10.45 C	7.87 GH	9.88 E	12.08 A	10.29 CD
B3	9.11 F	10.13 DE	12.07 A	10.91 B	8.06 G	9.88 E	12.06 A	9.08 F

Table (6) The effect of the determinants of irrigation, urea fertilizer and biochar and the interaction between them on the character of the total grain yield (tons/ha).

Similar letters have no significant difference between them at a probability of 5%

The irrigation limits were increased to 8 days because it retained moisture within its nano-sized particles and provided the plant with water during its lifespan. Corn variety 6664 DKC American biochar is similar to endosperm with its high efficiency in nutrient retention and moisture retention in addition to the ready N of urea. All of this led to a significant increase in the leaf area index (LAI) trait (table 3), chlorophyll content (table 4), and the weight of 500 grains (table 5). Applying biochar (20 and 40 tons/ha) with nitrogen fertilizer, corn yields 8.8% and 12.1%, respectively. It was discovered (Njoku *et al*. 2016) that the higher the biochar levels, the higher the grain yield of maize. (Van Zweiten *et al*. 2010), an approximately 300% increase in yield was obtained when biochar was applied in sufficient quantities.

6-Total dry weight (tons/ha) : The results of Table (7) showed a significant difference in the characteristic of the total dry weight of the vegetative group at the irrigation determinants, as the level A1 was distinguished by giving it the best dry weight (18.83 tons/ha) compared to the level A2, which recorded the lowest weight (18.15 tons/ha), and also showed Results that B3 level urea fertilizer was significantly distinguished from the rest of the levels by giving it the best dry weight (19.72 tons/ha) with an increase of (22.40%) compared to the B1 level, which is the lowest dry weight (16.11 tons/ha). The Table also indicates that there is a significant difference in the same characteristic with biochar, as the level C3 was distinguished over the other levels, where it achieved the best dry weight (21.39 tons/ha) with an increased rate of (29.63%) compared to the level C1, which gave the lowest weight (16.50 tons/ha), there was a significant interaction between irrigation determinants and urea fertilizer levels. The combination A1B3 was significantly distinguished over the rest of the blends by giving it the best dry weight (20.15 tons/ha) and with an increase in dry weight (29%) compared to the combination A2B1, which gave the lowest weight (15.62 tons/ha). The interaction of biochar and irrigation was also significant in this trait. The A1C3 blend achieved the best rate of (21.65 tons/ha) with an increase of (34.72%) compared to the A2C1 combination, which gave the lowest rate (16.07 tons/ha). There is a significant difference between the interaction of biochar and urea fertilizer, where the B3C3 blend significantly outperformed all combinations by giving it the highest rate (23.50 tons/ha) and an increase of (58.56%) compared to the B1C1 mix, which gave the lowest rate (14.82 tons/ha), the results achieved a difference Significant in the characteristic of dry weight when overlapping determinants of irrigation, urea fertilizer and biochar, of the mixtures by giving them the best rate (23.38, 23.50 and 23.50) ton/ha, with an increased rate of (52.51%, 53.29% and 53.29%) according to the order compared to the combination A2B1C1 which gave the lowest rate (15.33 tons/ha). The increase in the total dry weight (stems, leaves and stalks) is attributed to the treatment with biochar, which improved the physical properties of the soil and urea fertilizer and sufficient moisture. All this has a positive effect on increasing dry weight. (Zhu *et al*., 2018) stated that BC amended soils increase dry weight by absorbing nutrients that maintain growth and root/stem ratio. Biological yield increased when the earth was treated with 9 tons/ha of biochar + 140 kg N/ha (Muhammad *et al*., 2021).

Urea / Irrigation	**Overlap of irrigation and urea fertilizer AB**			**Overlap Irrigation and biochar AC**				**Irrigation rate**
	B1	**B2**	**B3**	**C1**	**C2**	**C3**	**C4**	
A1	16.61 E	19.72 B	20.15 A	16.94 G	18.18 D	21.65 A	18.54 C	18.83 A
A2	15.62 F	19.53 C	19.28 D	16.07 H	17.82 E	21.13 B	17.56 F	18.15 B
Urea rate	16.11 C	19.63 B	19.72 A	16.50 D	18.00 C	21.39 A	18.05 B	Mean 18.49

Bio / Urea	**Overlap of urea and biochar BC**			
	C1	**C2**	**C3**	**C4**
B1	14.82 K	15.99 J	17.31 G	16.35 I
B2	17.14 H	18.93 D	23.37 B	19.07 C
B3	17.55 F	19.09 C	23.50 A	18.73 E

Overlap of irrigation, urea and biochar ABC								
	A1				**A2**			
Bio / Urea	**C1**	**C2**	**C3**	**C4**	**C1**	**C2**	**C3**	**C4**
B1	15.33 P	16.25 M	18.08 G	16.79 K	14.32Q	15.73 O	16.53 L	15.91 N
B2	17.43 I	19.00 E	23.38 AB	19.09 E	16.85 K	18.86 F	23.36 B	19.06 E
B3	18.06 G	19.31 D	23.50 A	19.75 C	17.05 J	18.87 F	23.50 A	17.72 H

Table (7) Effect of irrigation determinants, urea fertilizer and biochar and the interaction between them on the characteristic of total dry weight (tons/ha).

Similar letters have no significant difference between them at a probability of 5%

REFERENCES

- **Abdullah, H., Mediaswanti, K.A., Wu, H. (2010).** Biochar as a fuel: 2. Significant differences in fuel quality and ash properties of biochars from various biomass components of mallee trees. Energy Fuels 24, 1972–1979.

- **Agegnehu, G., Adrian, M.B., Paul, N.N., and Michael, I.B. (2016).** Benefits of biochar, compost and biochar– compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. Science of the Total Environment 543:295-306. **Ahmad, M.;**

- **Rajapaksha, A.U.; Lim, J.E.; Zhang, M.; Bolan, N.; Mohan, D. (2014).** Vithanage, M.; Lee, S.S.; Ok, Y.S. Biochar as a sorbent for contaminant management in soil and water: A review. Chemosphere, 99, 19–33.

- **Ali, S., Rizwan, M., Qayyum, M.F., Ok, Y.S., Ibrahim, M., Riaz, M., Arif, M.S., Hafeez, F. Al-Wabel, M.I., Shahzad, A.N. (2017).** Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review. Environmental Science and Pollution Research, 24(14), 12700–12712. http://doi.org/10.1007/s11356-017-8904-x.
- **Al-Badrani, Waheeda Ali Ahmed Ibrahim Ahmed Al-Roumi .(2013**). The effect of different levels of nitrogen fertilization (urea) on some growth characteristics of the two wheat cultivars (*Ttriticum spp*.). Journal of Basic Education Research Vol. 12, No. 3, 723-732.

- **Alotaibi, K.D.; Schoenau, J.J. (2019).** Addition of Biochar to a Sandy Desert Soil: Effect on Crop Growth, Water Retention and Selected Properties. Agronomy, 9, 327.

- **Al-Sahuki, Medhat Majid (1990).** maize productivity and quality. Ministry of Higher Education and Scientific Research. Baghdad University.

- **Al-Zubaidi, Haider Mohsen Jaber .(2019**). The effect of biochar on some soil properties and nitrogen availability for maize crop zea mays L. Master's thesis, College of Agriculture. h Albasrah university.

- **Biederman, L.A.; Harpole, W.S. (2013).** Biochar and its effects on plant productivity and nutrient cycling: A meta-analysis. GCB Bioenergy, 5, 202–214.

- **Birch, C. J.; G. L. Hammer and K. G. Rickert .(1998).** Improved methods for predicting individual leaf area and leaf senescence in maize (*Zea mays* L.). Australian Journal of Agricultural Research, 49(2) :249-262
.
- **CSO. (2020).** Directorate of Agricultural Statistics - Central Bureau of Statistics / Iraq.

- **Deenik, J.L., Diarra, A., Uehara, G., Campbell, S., Sumiyoshi, Y., Antal Jr., M.J.(2011).** Charcoal ash and volatile matter effects on soil properties and plant growth in an acid Ultisol. Soil Sci. 176, 336–345.

- **Dumroese, R.K., J. Heiskanen, K. Englund, and A. Tervahauta. (2011).** Pel-leted biochar: Chemical and physical properties show potential use as a substrate in container nurseries. Biomass Bioenergy 35:2018–2027. doi: 10.1016/j.biombioe.2011.01.053.

- **El-Naggar, A.; Lee, S.S.; Rinklebe, J.; Farooq, M.; Song, H.; Sarmah, A.K.; Ok, Y.S. (2019).** Biochar application to low fertility soils: A review of current status, and future prospects. Geoderma, 337, 536–554
.

- **Fageria., N.K., V.C. Baligar and R. Clark. (2010).** Growth and Mineral Nutrition of Field Crops, 3rd edition (Books in Soils, Plants, and the Environment). Publisher: CRC Press PP: 586.

- **Foster, E.J., Hansen, N., Wallenstein, M., Cotrufo, M.F. (2016).** Biochar and manure amendments impact soil nutrients and microbial enzymatic activities in a semi-arid irrigated maize cropping system. Agriculture, Ecosystems and Environment,233, 404–414. http://doi.org/10.1016/j.agee.2016.09.029

- **Fowles, M. (2007).** Black carbon sequestration as an alternative to bioenergy. Biomass Bioenergy, 31, 426–432.

- **Glaser, B.; Lehmann, J.; Zech, W. (2002).** Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal-a review. Biol. Fertil. Soils, 35, 219–230.

- **Gonzaga, M.I.S., Mackowiak, C., Almeida, A.Q., Carvalho, J.I.T., and Andrade, K.R. (2018).** Positive and negative effects of biochar from coconut husks, orange bagasse and pine wood chips on maize (*Zea mays* L.) growth and nutrition. CATENA 162:414-420.

- **Ibrahim, M.E.H., Ali, A.Y.A., Zhou, G., Elsiddig, A.M.I., Zhu, G., Nimir, N.E.A. (2020).** Biochar application affects forage sorghum under salinity stress. Chilean Journal of Agricultural Research 80:317- 325. doi.org/10.4067/S0718-58392020000300317.

- **Igalavithana, A.D.; Ok, Y.S.; Usman, A.R.A.; Al-Wabel, M.I.; Oleszczuk, P.; Lee, S.S. (2016).** The Effects of Biochar Amendment on Soil Fertility. In Agricultural and Environmental Applications of Biochar: Advances and Barriers; Guo, M., He, Z., Uchimiya, M., Eds.; SSSA Special Publication 63; Soil Science Society of America, Inc.: Madison, WI,USA, pp.123-144

- **Kangoma, E., Blango, M.M., Rashid-noah, A.B., Sherman-kamara, J., Moiwo, J.P., Kamara, A. (2017).** Potential of biochar-amended soil to enhance crop productivity under deficit irrigation. Irrigation and Drainage,614(June), 600–614. http://doi.org/10.1002/ird.2138.

- **Lee, E.A. and M.Tollenaar .(2007).** Physiological basis of successful breeding strategies for maize grain yield. Crop Sci. 47: 202- 215.

- **Lehmann, J.; Rillig, M.C.; Thies, J.; Masiello, C.A.; Hockaday, W.C.; Crowley,**

D.(2011). Biochar effects on soil biota—A review. Soil Biol. Biochem. 43, 1812–1836.

- **Lehmann, J.; Abiven, S.; Kleber, M.; Pan, G.; Singh, B.P.; Sohi, S.P.; Zimmerman, A.R. (2015).** Persistence of biochar in soil. In Biochar for Environmental Management: Science, Technology and Implementation, 2nd ed.; Lehmann, J.L., Joseph, S., Eds.; Earthscan: London, UK, pp. 235–282.

- **Lehmann, J., J. Pereira da Silva, Jr., C. Steiner, T. Nehls, W. Zech, and B. Glaser. (2003).**Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: Fertilizer, manure and charcoal amendments. Plant Soil 249:343–357.

- **Liu, C.; Wang, H.; Tang, X.; Guan, Z.; Reid, B.J.; Rajapaksha, A.U.; Ok, Y.S. (2016).** Sun, H. Biochar increased water holding capacity but accelerated organic carbon leaching from a sloping farmland soil in China. Environ. Sci. Pollut. Res, 23, 995–1006.

- **Mandal, S., Sarkar, B., Bolan, N., Novak, J., Ok, Y.S., Van Zwieten, L. (2016).** Designing advanced biochar products for maximizing greenhouse gas mitigation potential. Critical Reviews in Environmental Science and Technology 46:1367-1401.

- **Major, J.; Lehmann, J.; Rondon, M.; Goodale, C.L. (2010).** Fate of soil-applied black carbon: downward migration, leaching and soil respiration. Glob. Chang. Biol, 16, 1366–1379.

- **Muhammad,A.A.,Irfan.A.,Sabir.H.S.,Sher.M.,Muhammad.L.Azeem.KH. (2021).**Effects of biochar and zeolite integrated with nitrogen on soil characteristics, yield and quality of maize (*zea mays* L).Pak.J.Bot.,53(6):2047-2057.

- **Nguyen, T.T.N., Xu, C.Y., Tahmasbian, I., Che, R., Xu, Z., Zhou, X., Wallace, H.M., Bai, S.H. (2017).** 671 Effects of biochar on soil available inorganic nitrogen: A review and meta-analysis. Geoderma, 288, 672 79–96. http://doi.org/10.1016/j.geoderma.2016.11.004

- **Njoku, C., Uguru, B.N., and Chibuike, C.C. (2016).** Use of biochar to improve selected soil chemical properties, carbon storage and maize yield in an Ultisol in Abakaliki Ebonyi State, Nigeria. International Journal of Environmental and Agriculture Research 2(1):15-22.

- **Park, J.H.; Ok, Y.S.; Kim, S.H.; Kang, S.W.; Cho, J.S.; Heo, J.S.; Delaune, R.D.; Seo, D.C. (2015).** Characteristics of biochars derived from fruit tree pruning wastes and their effects on lead adsorption. J. Korean Soc. Appl. Biol. Chem, 58, 751–760.

- **Rajapaksha, A.U.; Chen, S.S.; Tsang, D.C.W.; Zhang, M.; Vithanage, M.; Mandal, S.; Gao, B.; Bolan, N.S.; Ok, Y.S. (2016).** Engineered/designer biochar for contaminant removal/immobilization from soil and water: Potential and implication of biochar modification. Chemosphere, 148, 276–291.

- **Rajkovich, S., Enders, A., Hanley, K., Hyland, C., Zimmerman, A.R., Lehmann, J. (2012).** Corn growth and nitrogen nutrition after additions of biochars with varying properties to a temperate soil. Biol. Fertil. Soils 48, 271–284.

- **Rizwan, M.; Ali, S.; Qayyum, M.F.; Ibrahim, M.; Rehman, M.Z.; Abbas, T.; Ok, Y.S. (2016).** Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: A critical review. Environ. Sci. Pollut. Res, 23, 2230–2248.

- **Rizwan, M.; Ali, S.; A, M.; Ali, L.; Hussain, A.; Rehman, M. Z.; A, M.; Qayyum, M.F.; Chatha, S.A.S. (2019).** Alleviation of cadmium accumulation in maize (*zea mays* L.) by foliar spray of zinc oxide nanoparticles and biochar to contaminated soil. Environmental pollution.248, 358-367.

- **Shah, T.R., Prasad, K., and Kumar, P. (2016).** Maize - A potential source of human nutrition and health: A review. Cogent Food & Agriculture 2(1):1166995.

- **Sistani.K.R.; S.R.J.; Jn-Baptiste.M.;N.J.M. (2019).** Poultry Litter, Biochar, and Fertilizer Effect on Corn Yield, Nutrient Uptake, N2O and CO2 Emissions. Environments, 6, 55,1-14.

- **Spokas, K.A.; Cantrell, K.B.; Novak, J.M.; Archer, D.A.; Ippolito, J.A. (2012**). Collins, H.P.; Boateng, A.A.; Lima, I.M.; Lamb, M.C.; McAloon, A.J.; et al. Biochar: A synthesis of its agronomic impact beyond carbon sequestration. J. Environ. Qual, 41, 973–989.

- **Somerville, P.D.; Farrell, C.; May, P.B.; Livesley, S.J. (2020)**. Biochar and compost equally improve urban soil physical and biological properties and tree growth, with no added benefit in combination. Sci. Total Environ, 706, 135736.

- **Tenic, E.; Ghogareh, R.; Dhingra, A. (2020).** Biochar—A Panacea for Agriculture or Just Carbon? Preprints. Horticulturae, 6, 37.

- **Thomas, H. and C.M. Smart. (1993).** Yield improvement in temperate maize is attributed to greater stress tolerance. Crop Sci. 39: 1597-1604.

- **Van Zwieten L., S. Kimber, S. Morris, K.Y. Chan, A. Downie, J. Rust, S. Joseph and A. Cowie. (2010).** Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant & Soil, 327: 235-246.

- **Yigermal, H., Nakachew, K., and Assefa,F. (2019).** Effects of integrated nutrient application on phenological, vegetative growth, and yield-related parameters of maize in Ethiopia: A review. Cogent Food & Agriculture 5:1567998. https://doi.org/10.1080/23311932.2019.1567998.

- **Yoo, J., Woo, S.H., Park, K.D., and Chung, K.Y. (2016).** Effect of no-tillage and conventional tillage practices on the nitrous oxide (N2O) emissions in an upland soil: soil N2O emission as affected by the fertilizer applications. Applied Biological Chemistry 59(6):787-797. doi:10.1007/s13765-016-0226-z.

- **Yost, J.L.; Hartemink, A.E. (2019).** Soil organic carbon in sandy soils: A review. Adv. Agron. 217, 217–310.

- **Zafar, U., Akmal, M., Ahmed, M., Ali, M., and Jamali, A.Z. (2018).** Effect of biochar on soil chemical properties and nutrient availability in sandstone and shale derived soils. Journal of Biodiversity and Environmental Sciences 12(5):272-277.

- **Zaidun, S.W., Jalloh, M.B., Awang, A., Sam, L.M., Besar, N.A., Musta, B. (2019).** Biochar and clinoptilolite zeolite on selected chemical properties of soil cultivated with maize (*Zea mays* L.) Eurasian Journal of Soil Science 8(1):1-10.

- **Zhang, A., Liu, Y., Pan, G., Hussain, Q., Li, L., Zheng, J. (2011).** Effect of biochar amendment on maize yield and greenhouse gas emissions from a soil organic carbon poor calcareous loamy soil from Central China Plain. Plant and Soil 351(1-2):263-275.

- **Zhu, Q., Kong, L., Xie, F., Zhang, H., Wang, H., and Ao, X. (2018).** Effects of biochar on seedling root growth of soybeans. Chilean Journal of Agricultural Research 78:549-558. doi:10.4067/S0718-58392018000400549.