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EFFECT OF POLYACRYLAMIDE AND BIOCHAR ON CALCAREOUS SOIL MOISTURE CONTENT AND MAIZE PRODUCTION UNDER DRIP IRRIGATION

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Abstract

The field experiment was established in Nineveh nursey located in Mosul governorate, with silty loam texture, during summer season 2019. The study carried out the effect of polyacrylamide (PAMs) and biochar (BC-wheat straw pyrolysis at 400-500c) and the interaction between them on soil hydro-physical properties and productivity of maize crop under drip irrigation. The experiment laid-out in three application level of polyacrylamide (0, 160 and 320 kg ha^{-1}) and biochar (0, 4 and 8 t ha^{-1}) with three replications in a completely randomized block design (RCBD). The result showed polyacrylamide and biochar significantly affect the soil's physical properties (volumetric water content, bulk density, porosity, saturated hydraulic conductivity) and significantly affect plant parameters. The interaction between PAMs and BC showed more efficacy effect compared with control (CK) at ($p<0.005$). The lowest mean value for Bulk Density was in treatment P_2B_2 1.077 Mg m^{-3} compared with CK 1.407 Mg m^{-3}, total air porosity's highest mean value was in treatment P_2B_2 59.37% compared with CK 46.92% designate 12.45% increasing carryout significantly effect at level ($p<0.005$), The saturated hydraulic conductivity effected by PAMs and BC the highest mean value was in treatment P_2B_2 3.71 cm.hr^{-1} compared with CK 1.36cm.hr^{-1}. Also the Grain yield affected significantly the highest mean value was in treatment P_2B_2 10.75 ton ha^{-1} compared with CK 9 ton ha^{-1}. During the whole summer maize growing season the highest mean value of volumetric water content VWC was in treatment P_2B_2 45.301% compared with CK 35.058%.

Key words: Soil amendment, Polyacrylamide (PAMs), Biochar (BC), volumetric water content (VWC).

Introduction

Soil is a natural resource that plays a critical role in an environmental ecosystem; it's a dynamic living material and unrenewable. It also a basis of providing water and nutrients for plant growth, hence it's a source to incur a spread of food for the human life process (Smith, *et al.,* 2016). Soil management strategies change soil quality characteristics and play important roles in sustainable agriculture, In arid and semi-arid areas, the soil is naturally organized by low organic matter content cuase to the low of natural vegetation which causes low water holding capacity, essentially low fertility and perceptivity to erosion (Abdelfattah, Akhmet H., *et al.,* 2020). The dual important concern subjects the suitability of soils for productivity is soil moisture and nutrient holding capacity (Campos, Paloma, *et al.,* 2020). Additionally, the random land use and poorer management soil in arid and semi-arid areas over the past few decades have bare carrying on degradation and desertification, thus the condition is becoming even of lower quality with natural factors of global climate change. Also, low rainfall conditions and sequential distribution of rainfall are usually very unsuitable for plant growth. Previous research reported that the application of soil amendments is attitude strategies to improve the utilization of infrequent water resources for crop production and maintain proper soil properties within the arid and semi-arid regions (Bartkowski, Bartosz, *et al.,* 2020). Some natural water preservation soil amendments like biochar substance can increase macro aggregation, organic carbon and macronutrients and sustenance the microorganism activity, hence improve the soil properties and nutrient uptake by plants (Xu, Shengtao, *et al.,* 2018; Obia, Alfred, *et al.,* 2020).

Polyacrylamide (PAMs), a macromolecular cross-

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linked and environmentally responsive, the polymer had high dimensions of water adsorption and holding, which is obliging to improving seed growth and seedling continuance. PAMs might be degraded through physical or chemical progressions (Kim, Hyun Jung, 2020). thus, an increasing number of polymer commercial products are established to increase water use efficiency, improve drought stress, soil physical properties and increase crop yield also, supply higher soil moisture and seed germination rates, improve dry matter accumulation and water use efficiency of maize (Dorraji, Golchin & Ahmadi, 2010).

Biochar is a creation of biomass pyrolysis for the assembly of renewable fuels and useful chemicals, improve soil properties corresponding nutrient accessibilities, porosity, water-holding capacity and bulk density (Busscher *et al.,* 2010; Novak *et al.,* 2012; Rogovska *et al.,* 2014) and improve plant growth and crop yield. Biochar is a type of charcoal formed from heating natural organic materials (plant biomass, manure, woodchips and other agricultural residues) during a heat 500-1000°C with low oxygen, the process known as pyrolysis. Biochar increase realizing carbon by active carbon adoption, improve soil structure and nutrients, decrease soil acidity, cation exchange capacity, nutrient use efficiency, improve water-holding capacity. In the last period biochar has been involved as great potential for climate change efficiency and its application to soil has appeared as an interesting approach for appropriating carbon, reducing greenhouse gas (GHG) releases, improving the quality of soil and possibly variable effects on soil properties, plant growth and crop yield (Pandit *et al.,* 2018; Sun *et al.,* 2019) and crop resistance to disease, also has an important and effective role in the remediation of soils with heavy metal and organic contaminants (Brennan *et al.,* 2014; Zama *et al.,* 2018), playing a serious achievement in decreasing ecological and human health risks correlated with heavy metal infection.

Corn (*Zea mays*), also called Indian corn or maize, a cereal crop of the grass family (*Poaceae*) and its edible (eatable) grain, Corn was first farmed by native publics in Mexico about 10,000 years ago. Native Americans educated European colonists to cultivate the original grains and since its introduction into Europe by Christopher Columbus and other travellers, corn has spread to overall areas of the world suitable to its cultivation. Maize is the most strategic cereal globally (Ashraf *et al.,* 2016). Different management practices are expected to spread and improve maize yields. for example, the use of organic-inorganic soil amendment regularly causes increased soil organic matter, soil structure, water-holding capacity and improved nutrient cycling and helps provide soil nutrient, cation exchange capacity (CEC) and improve biological activity in the soil (Saha *et al.,* 2008).

Materials and Methods

Field location

The experimental field is located in Nineveh (Mosul) Governor, at Nursery station, nursery department, ministry of agriculture, Iraq (36°21'49.55" N 43°08'11.79" E, elevation: 219 m). characterized by cool wet winters and hot dry summers, with very short springs and autumns, Rainfall and temperature are highly affected by the altitude, the average annual rainfall about 250-350 mm. The topography of sit location is flat to almost flat, land used for horticulture seedling activities.

Chemical analysis

The three soil samples collected at depth 0-30cm by auger-hall the dry aired ten sieved 2 mm dimeter to be ready for analyzing before sowing. Soil chemical analysis was achieved by standard methodologies (A.L. Page, R.H. Miller and D.R. Keeney, 1982), Soil extract taken 1:1 (Soil: water), electric conductivity is measured by EC meter (Hanna benchtop conductivity meter, Model EC214), the negative logarithm of the hydrogen ion concentration (pH) measured by (Hanna Instruments pH Meter HI 2211), Titration method was used for Soil organic matter (Nelson and Sommers, 1996), determination of total nitrogen was done conferring to the Kjeldahl method (Jackson, 1973) using (Kjeltec auto 1030 Analyzer), Available phosphor was determined as designated in (Olsen and Sommers 1982) using Ascorbic acid using spectrophotometer at 882 nm wavelength calculating P value form reading output, Available potassium was determined as defined in (Carson,1980) and was measured using flame photometer As shown in table 1.

Physical analysis

Soil texture was determined using the hydrometer method (Gee and Bauder, 1986), 40g of soil dried by oven were taken then treated with 60 mL of 6% H_2O_2, heated in a water bath at 80-90°c to remove the organic matter, the process was continued until frothing finished, then

Table 1: The Soil Chemical Analysis for site location (before adding soil amendment).

Soil sample	0-30 cm	Value
Electronic Conductivity	$dS.m^{-1}$	0.41
pH		7.6
Organic Matter	$g.kg^{-1}$	13.4
Total Nitrogen	$g.kg^{-1}$	1.1
Available Phosphor	$mg.kg^{-1}$	4.7
Available Potassium	$mg.kg^{-1}$	218

the contents were moved to an 800 ml beaker and diluted with 400 ml distilled water, 100 mL added of Calgon reagent (5% of sodium hexa-metaphosphate) (Fluka, Bochs, Switzerland), The suspensions were stimulated for 20 min with a magnetic stirrer, transferred into cylinder 1L shaken by plunger vertically for 1 min. The hydrometer put into the cylinder, after 40s hydrometer reading (a) taking with the temperature of suspensions recorded. Finally, 2h left the second reading of hydrometer (b) and the suspension temperature was re-recorded. The tow recorded hydrometer was corrected according to its calibration temperature. The particles size distributions were founded as follows:

Silt = (a-b)/c×100

Clay = (b/c) ×100

Sand % = 100-(Silt % + Clay %)

c is the weight of the oven-dry soil sample after removal of the weight of the oxidized OM. Lastly, the soil texture was founded using the textural triangle.

Bulk density was m determinate using the core method (Blake and Hartge, 1986). A core of known volume was pressed in the soil, then removed attentively to reserve and un-distribute the structure, the core with the soil were represent wet weight of the soil sample, put it in an oven-dry at 105^0C 24 h, weight the dry soil sample, bulk density was determinate according to the equation: : Dry bulk density (ρb) = Oven dry mass of soil/volume of soil (wet). Particle density is the real density, it's the ratio of the mass of soil via the volume of the specific mass (Flint and Flint, 2002), the pycnometer method was used by the equations:

Particle density (ρs) = *Ms/Vs*

The total porosity of the soil was calculated from the values of the dry bulk density and particle density using the equation given by Chancellor (1994).

Table 2: The soil physical analysis for site location (before adding soil amendment).

Soil sample	0-30 cm	Value
Sand %		19.9
Silt %		56.0
Clay %		24.1
Soil texture		Silty loam
Bulk density	Mgm^{-3}	1.48
Particle density	Mgm^{-3}	2.63
Porosity	%	43.7
Aggregate Stability Rate	mm	382
Volumetric Water Content VWC	%	52.6
Saturated Hydraulic Conductivity	$cm.min^{-1}*10^{-2}$	7.2
Infiltration Rate	$cm.min^{-1}*10^{-2}$	7.5

Porosity % = 1- (bulk density/ particle density)* 10
Saturated hydraulic conductivity (Ks) was measured by falling head method technique in the laboratory were founded on the direct of Darcy's equation to a saturated soil column of un-disturbed soil, A hydraulic head variance was compulsory on the soil column, the out flux of water was measured, saturated Ks can be calculated as an equation:

$$Ks = \frac{al}{At} In\left(\frac{H1}{H2}\right)$$

where Ks is the saturated hydraulic conductivity ($cm.h^{-1}$), a is the area of column cm^2 ($a = r^2 * \pi$), l is the length of the soil column cm, A is the cross sectional area of the soil sample cm^2, t is the time required for the volume of water h, H1 is the length of water head before measuring cm, H2 is the length of water head after measuring and the Ks values were resulting using Darcy's law.

Treatments and experiment design

The field experiment established in the end of Juley 2019, which laid in a randomize complete block design (RCBD), with three application level of BC, PAMs and interaction or mix between them, nine treatments and three replications were performed. The total field area $592m^2$ measured 15m wide by 37m length, with 27 experimental units measured 4.0×3.0m with 1m alley. The PAMs treatments are symbolled with P and biochar treatments with BC and interaction PB.

Statistical Analysis

Statistical analysis was achieved using SAS program version 9.2. The overall linear model (GLM) was used to complete statistical analysis to evaluate the impact of the PAMs and Biochar as a soil amendment on some physical and yield parameters, treatment means were divided by the least significant difference (Duncan) test at $p<0.05$.

Results and Discussion

Effect on soil Bulk density and Porosity

The effects of PAMs (P) and Biochar (B) on soil bulk density are shown in table 3.

The lowest mean value was in treatment P2B2 1.077 $Mg.m^{-3}$ compared with CK 1.407 $Mg.m^{-3}$, PAMs significantly affected of bulk density which decreased to 1.25, 1.14 $Mg.m^{-3}$ for P1B0, P2B0 respectively, additionally biochar significantly decreased bulk density to 1.23. 1.16 $Mg.m^{-3}$ for treatment P0B1, P0B2 respectively, the results of this study indicated that application of biochar reduced soil bulk density during the cultivation season, interaction of PAMs and BC

Table 4: Duncan's Multiple Range Test for Volumetric Water Content during 15 weeks, starting from planting until maturation, means with the same letter is not significantly different.

REP	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10	week 11	week 12	week 13	week 14	week 15	mean
P0B0	60.13	33.23	26.70	25.83	30.37	26.63	26.80	27.77	30.47	47.40	46.70	30.70	27.40	29.37	56.37	35.06b
P0B1	66.70	35.88	34.30	32.73	33.97	31.53	28.87	30.10	32.83	48.40	48.63	32.97	30.63	30.40	42.40	37.36ab
P0B2	73.23	36.40	31.60	38.10	38.97	36.17	32.47	30.83	32.93	48.50	51.17	34.60	30.90	35.37	44.13	39.69ab
P1B0	76.97	37.17	29.40	32.43	35.83	33.43	29.73	30.83	34.20	49.23	52.97	31.50	29.87	36.93	44.17	38.98ab
P1B1	78.83	42.73	34.30	32.20	38.33	38.03	34.90	31.63	34.73	52.17	52.67	35.40	30.97	37.20	41.70	41.05ab
P1B2	82.23	40.47	34.30	33.60	42.70	32.93	37.13	33.60	38.67	54.57	53.73	37.87	30.77	39.53	43.63	42.38ab
P2B0	77.87	41.43	31.40	31.70	43.43	36.97	35.63	32.67	38.27	50.03	54.77	38.73	32.50	38.87	43.83	41.87ab
P2B1	73.67	39.53	32.90	34.00	42.70	35.83	37.93	35.07	38.63	53.80	54.40	37.70	33.00	39.73	54.03	42.86ab
P2B2	81.77	40.73	35.50	35.40	43.20	37.90	38.07	37.30	40.30	59.07	56.50	39.33	34.10	41.57	58.77	45.30a

significantly reduced bulk density from 1.4 $Mg.m^{-3}$ as a CK to 1.07, 1.13, 1.16, $1.16g.cm^{-3}$ for treatment P2B2, P1B2, P2B1, P1B1 respectively and significantly affected.

Total air porosity's highest mean value was in treatment P2B2 59.37% compared with CK 46.92% designate 12.45% increasing total air porosity carryout significantly effect at level ($p<0.005$) table 5. PAMs treatment P1B0, P2B0 increased 10.06, 5.78% total porosity compared with CK additionally significantly affect, also biochar treatment increased 9.31, 6.54% for treatment P0B2, P0B1 respectively, in Addison the interaction between treatment PAM, + BC increased mean value of porosity 12.46, 10.43, 9.30, 9.18% for P2B2, P1B2, P2B1, P1B1 severally Figure13, all treatments with soil amendment significantly affected to bulk density and total air porosity. (J. Abedi, koupaei And Kazemi Jafar Asad. 2006) showed soil amendment PAMs affects the bulk density of soil, compaction, soil texture, crust hardness and evaporation rates, also (W. Bai, *et al.,* 2010) reported that soil bulk density decreases with increasing PAMs amendment rates. Basically the soil

Table 5: Duncan's Multiple Range Test for saturated hydraulic conductivity, means with the same letter are not significantly different (Alpha =0.05).

Treatment	Hydraulic Conductivity			
	R1 $cm.hr^{-1}$	R2 $cm.hr^{-1}$	R1 $cm.hr^{-1}$	Mean $cm.hr^{-1}$
P0B0	1.38	1.28	1.44	1.36e
P0B1	2.46	2.42	2.33	2.40d
P0B2	2.35	2.42	2.39	2.39d
P1B0	2.53	2.63	2.50	2.55cd
P1B1	2.63	2.56	2.79	2.66c
P1B2	2.42	2.79	2.57	2.59cd
P2B0	2.89	2.57	3.11	2.86
P2B1	3.23	3.56	3.53	3.44b
P2B2	3.57	3.67	3.88	3.71a

bulk density affects by PAMs application refers to the shrinkage and swelling results in higher soil and causes a decrease in the hardness of surface, same result reported by (R.T. Brandsma, M.A. Fullen and T.J. Hocking 1999) the effect of PAM statistically significant decreases in soil bulk density values and increases in soil porosity and aggregate stability. The high porosity of biochar and highly stable carbon due to decrease in soil bulk density (Gwenzi, Willis, *et al.,* 2015), low bulk density refers to high porosity when integrated to the soil in satisfactory application can reduce the total bulk density of the soil. Similarly (Mukherjee, Atanu and Rattan Lal. 2013) agreed that biochar utilization decreased bulk density because porosity of biochar is high and when it is in soil significantly decreases bulk density by increasing the pore volume. This was confirmed by (Downie, Adriana, Alan Crosky and Paul Munroe. 2009; Lehmann, Johannes, *et al.,* 2011; and Alburquerque, José Antonio, *et al.,* 2014; Laird *et al.,* 2010; Zhang *et al.,* 2010; Chen *et al.,* 2011, Jones *et al.,* 2011; Mankansingh *et al.,* 2011; Case *et al.,* 2012; Liu *et al.,* 2017) they showed that bulk density of soil might decrease through addition of biochar especially at high application rates, due to its lower bulk density compared to particle size of the mineral, also the effect of soil bulk density after biochar application was refers to the enhanced soil aggregate size, the particle of biochar has a porous and an envelope density (0.64 1.13 g.cm-3 significantly lower than that of typical soil aggregates 1.4 1.5 $g.cm^{-3}$. Biochar's made it from grasses and crop residues are lower in bulk density and generally cause greater decreases in soil bulk density than biochar made from (Novak, Jeffrey M., *et al.,* 2012). Many other studies (Zhang *et al.,* 2010; Jones *et al.,* 2011; Case *et al.,* 2012) reported soil porosity increased through biochar amendment with soil increased the porosity of sandy soil from 56.1% (control) to 57.6 and 62.1%, respectively. The porosity of a silt loam in field plots was increase from 50.9 to 52.8% when a biochar applied at 9 $t.ha^{-1}$

(Karhu, Kristiina, *et al.,* 2011).

The decrease of bulk density and increasing total air porosity more in mixing PAM+ BC refers to that the interaction between PAMs and Biochar contains organic materials, which may increase the soil porosity, thereby reducing the soil bulk density and providing beneficial conditions for the growth of crops.

Soil Volumetric Water Contain (VWC). The soil volumetric water content (VWC) for top soil (0-15 cm) soil layer for all treatment during the summer maize growth period after the application of different amounts of PAMs and BC under the drip irrigation measured by TDR300. In this way, readings of the volumetric soil moisture have been taken at specified depths from undisturbed soil.

During the entire summer maize growing season, the highest VWC mean value was in treatment P2B2 45.30% compared with CK 35.06% table 4.

PAMs increased VWC 6.8, 3.94% for treatments P2B0, P1B0 respectively and its significantly affected at level ($p<0.005$), however BC increase VWC 4.633, 2.29% for P0B2, P0B1 significantly affected, the interaction of PAMs+ BC increases 10.243, 7.803, 7.324, 6.472% for treatments P2B2, P2B1, P1B2, P1B1 respectively and significantly affect under same stander level Fig. 1.

The soil amendments may additionally decrease unproductive water losses from the soil surface and enhance soil water status, which play an effective role in field water management and crop growth. The result of volumetric water content of our study, under soil amendment treatments were higher than the water contents under no soil amendment treatment figure 15, which refers that the increased levels of PAMs and BC applications caused the soil to effectively hold soil water possibly through reduced evaporation, starting the early growth stage (0–60 day after sowing), the treatments significantly increased the soil water contents over the irrigation levels. This result was agreed with (Farrell, Mark, *et al.,* 2013; R. Paradelo, R. Basanta and M.T. Barral 2019) who reported improved water holding capacity with PAMs and BC. During this early growth stage, the small maize plants consumed less water and the BC treatments allowed the soil to retain more soil

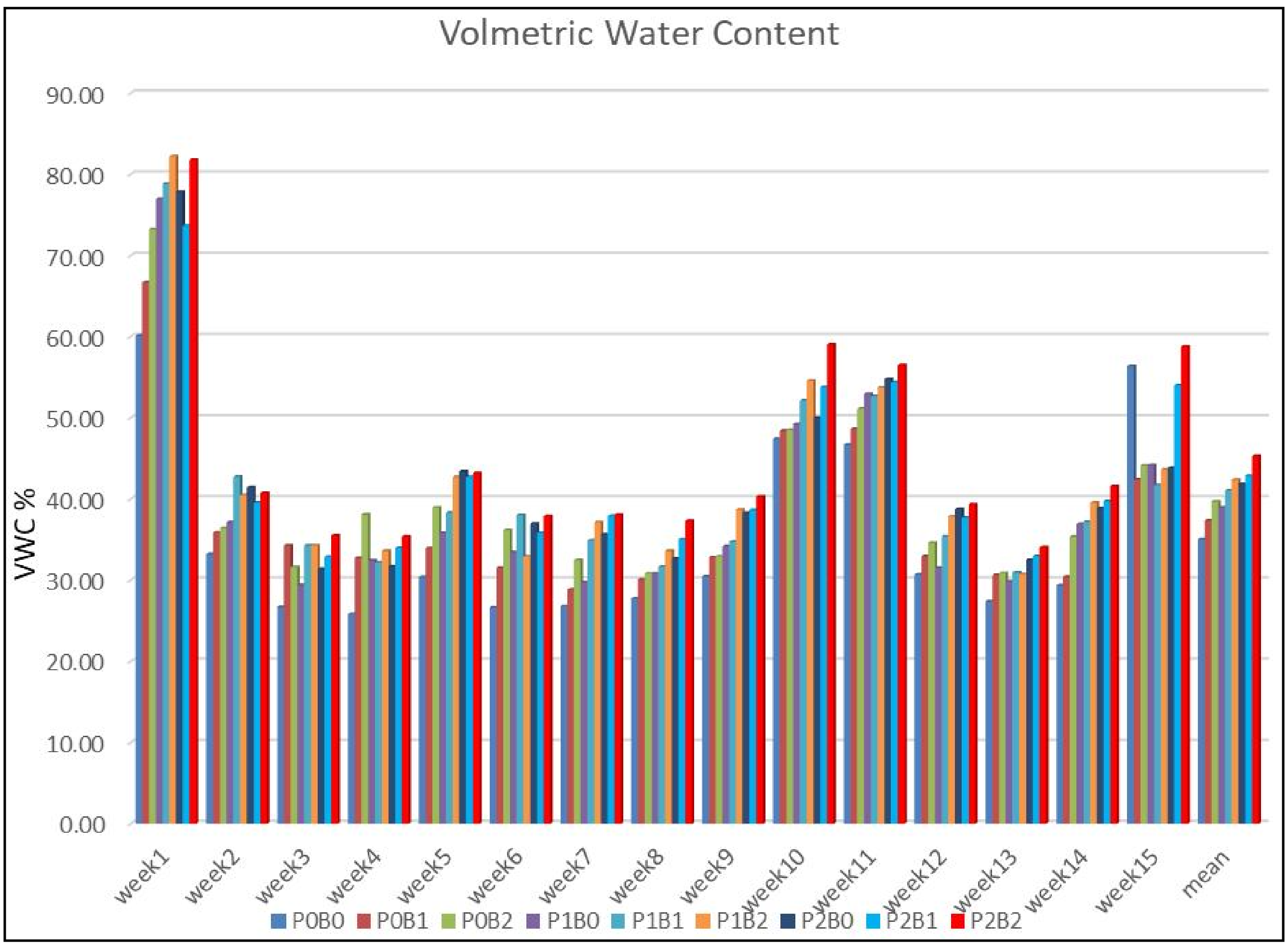

Fig. 1: The Volumetric Water Content measured by Time Domain Reflectometer TDR300.

water than the effects of the no soil amendment. former studies agreed with that the application of PAMs and BC were lead important role for maintaining water content and can increase water retention directly or indirectly because of a relatively large surface area of BC or a high WHC of PAM molecules (Mukherjee, Atanu and Rattan Lal. 2013; R.E. Sojka, *et al.,* 2007; Van Zwieten, Lukas, *et al.,* 2010). (S. Kishimoto 1985) found that BC has had larger surface area (200-400 m^2 g^{-1}) by pyrolysis at 100–200°C, which the BC which used for this study pyrolysis at 400-500°C. Indirectly, the BC interacts with soil OM, minerals and microorganisms and improves soil aggregate and structure, thereby maintaining water retention in soils (F. Verheijen, *et al.,* 2010). PAM additionally contributes preservation of water retention or conservation in soils through buffering the root area causes water loss, especially in the region occurs by drought. However, PAM does not affect water demand by plants but increase soil water storage in soils. Based on our findings, the mixture of BC and PAM is expected to be an excellent strategy for improving water retention or storage capacity of soils. (Hüttermann, Aloys, Moitaba Zommorodi and Kim Reise. 1999) reported that the increase of PAMs amendment from 0.04, 0.08, 0.12, 0.2 to 0.4% caused an exponential to expand in the WHC of sandy soil. This response of WHC on the attention of hydrogel additionally reported when sandy loam soils had been amended with 0.1, 0.2 and 0.3% PAM, the WHC elevated by way of 17, 26 and 46%, respectively, (J. Akhter, *et al.,* 2004). In our study Biochar effected of volumetric water content less than PAMs, some studies agreed that fine grained biochar radically affected retention properties of soil (C.T. Petersen, *et al.,* 2016). Furthermore, hydrophobic biochar may be turned hydrophilic and become shortly after application to field soils as a result of rainfall washing and microbial decomposition of the coating compounds. Biochar amendment also darkens soil color and may increase the temperature of surface soils (Ventura, Francesca, *et al.,* 2012). The benefit by biochar is dependent on biochar quality, soil type and biochar rate. In general, coarse-textured soils (e.g., sandy loam) are more sensitive than fine-textured soils (e.g., silty clay) to biochar amendment in WHC improvement (L. Ouyang, *et al.,* 2013). The improvement decreased with time, as further leaching increased gradually the bulk density of the amended soils (Laird, David, *et al.,* 2010). (F.A.N. Ruqin, *et al.,* 2015) reported the interaction of biochar and PAM significantly increased the virtual water content, this was consistent with the increased water content and porosity as well as acceptable pH and EC levels under the combined effects of biochar and PAMs amendments which created a preferable circumstance for seed emergence al., (2012).

Saturated Hydraulic Conductivity

The saturated hydraulic conductivity effected by PAMs and BC, the highest mean value was in treatment P2B2 3.71 cm.hr^{-1} compared with CK 1.36 cm.hr^{-1}, PAMs treatments P2B0, P1B0 significantly affected by increasing saturated hydraulic conductivity to 2.86, 2.40 cm.hr^{-1} respectively, BC also significantly increased Ks to 2.39, 2.4 cm.hr^{-1} for treatments P0B2, P0B1 with not effecting by increasing the rate of biochar. Generally, the values for saturated hydraulic conductivity affected by (PAMs+ BC) It can be arranged as follows P2B2>P2B1> P2B0> P1B1> P1B2>P1B0>P0B1>P0B2>P0B0 as shown in table 5.

In our results, the Ks significantly increased with an increase in the PAM applications, Some studies have shown positive effects of PAM on Ks (R.E. Sojka, *et al.,* 1998) as a reaction of the high soil pores, which the PAM physically bung by its flocculating effect, which increased with increasing applications of PAM, other studies reported incompatible effects on the Ks (D. Lentz, Rodrick 2003; Young, H. Michael, *et al.,* 2009). PAM was slimier than the end formed a thin layer with low conductivity that can delay the liquid flow in the soil. (Lentz, 2003; Young *et al.,* 2009; M. Tadayonnejad, M.R. Mosaddeghi and Sh Ghorbani Dashtaki 2017) reported that PAM significantly increased the water retention capacity. The PAMs is synthetic polymers with a large capacity to absorb and prevent water many times by their weight, others studies which showed opposite opinion the addition of PAM can improve water storage in porous of soils by enlarge the retention pores, which decrease hydraulic conductivity and decrease evaporation (M.I. Choudhary, A.A. Shalaby and A.M. Al Omran 1995; O.A. El-Hady and S.A. Abo-Sedera 2006). PAMs molecules raise flocculation and soil aggregate stability, reducing soil loss, at the same time, the existence of long linear chains of PAM in solution refers to an increase of the solution viscosity ;consequently, an increase in viscosity of the percolating solution can cause a decrease in the IR due to the reduction of the soil hydraulic conductivity (Ajwa, A. Husein and Thomas J. Trout 2006; Young *et al.,* 2009; C.A. Seybold 1994).

Biochar can be produced from many agricultural wastes such as olive mill solid waste, wheat straw and animal waste (Demirbas, Ayhan. 2004). Some researchers (Hseu, Zeng-Yei, *et al.,* 2014) reported the addition of biochar Compared with un-amended increase in saturated hydraulic conductivity, biochar with < 2 mm at 2% (w/w) increased the Ks of a sandy loam from 64.3 to 67.2 cm d^{-1} and silty clay from 53.2 to 57.6 cm d^{-1}

after 90 day. The soil evaporation rate reflects soil hydraulic conductivity. Thus, soil hydraulic conductivity at low water content decreased with the increase in biochar application rate, particle size and pyrolysis temperature. Other studies (Cantrell, B. Keri, *et al.,* 2012; Gray, Myles, *et al.,* 2014; Blanco-Canqui, Humberto 2017) reported the effects of biochar application on saturated hydraulic conductivity of coarse textured soil and most of the studies agreed that biochar application decreased saturated hydraulic conductivity of sandy soil with the increase in biochar application rate, it refers the embodiment of biochar in sandy soil increased the asymmetry of the porous of soil and reduced pore pharynx size. The result of those studies suggest that the hydraulic conductivity of sandy soil in dry or wet conditions would decrease with increasing by the rate of biochar, Biochar particle size had an effect on the saturated hydraulic conductivity of sandy soil. (Liu, Zuolin, *et al.,* 2016) reported that at 2% (w/w) biochar amendment rate, the saturated hydraulic conductivity of a sand and biochar mixture reduced by 72% when biochar particles were greater than the sand particles, reduced by 15% when the biochar particles were coarser than the sand particles, when biochar and sand grain sizes were similar. minced biochar reduced the saturated hydraulic conductivity of sandy soil more than biochar with large particles with the same biochar's application rate. Some studies have reported that better hydraulic properties were detected for the biochar-amended soils, as a consequence of improvements in both the structure and the porosity of the amended soil (Tomczyk, Agnieszka, Zofia Soko³owska and Patrycja Boguta. 2020).

Yield characteristics

The grain yield affected significantly with BC, PAMs and BC+PAMs, the highest mean value was in P2B2 treatment 10.75ton hectare^{-1} compared with CK 9ton hectare^{-1} table 6. PAMs treatments P2B0, P1B0 significantly increase grain yield to 10.57, 10.28ton hectare^{-1} sequentially, BC increase yield for treatments P0B2, P0B1were the mean value was 9.94, 9.43 ton hectare^{-1}, but only treatment P0B2 significantly affected and the interaction between (PAMs+BC) significantly increased grain yield to 10.75, 10.57, 10.09, 10.53ton.hectare^{-1} for treatments P2B2, P2B1, P1P2, P1B1 respectively.

Table 6: Duncan's Multiple Range Test for Yield parameter, means with the same letter are not significantly different (Alpha = 0.05).

TRT	Grain YieldTon. hectare^{-1}	500-Grain weightGram
P0B0	9.00d	121.00d
P0B1	9.43d	126.83c
P0B2	9.94c	133.68b
P1B0	10.28abc	138.25ab
P1B1	10.53ab	141.55a
P1B2	10.09cb	143.32a
P2B0	10.57ab	142.05a
P2B1	10.57ab	141.11a
P2B2	10.75a	140.34a

The treatment P1B2 recorded the highest mean value for 300-garin weight 143.32 gr, with significantly effecting, all treatments significantly increased mean vale of 300-grain weight compared with CK at level (P>0.005), It can be arranged as follows: (P1B2 > P2B0> P1B1> P2B1> P2B2> P1B0> P0B2> P0B1>P0B0).

The application of BC and PAMS improved the physical properties of soil; increased the hydraulic conductivity, increased the water-holding capacity, released water slowly through soil reduced the waste of water and prevented leaching of nutrients from soils, subsequently increased water and fertilizer use efficiency, causing the better growth of plants under normal irrigation and drought stress conditions, additionally releasing of Potassium from the PAMs (O.A. El-Hady, M.Y. Tayel and A.A. Lotfy 1985). The study was in agreement with (Nazarli, Hossein, *et al.,* 2010) and (Islam, Atif, *et al.,* 2011) who had tested the effectiveness of PAMs on different species and yielded similar results which is associated with higher water retention capacity and available water, other researchers reported the Soil amendments increased the yield, mainly due to the reduce irrigation water consumption and improve fertilizer retention in the soil (M.Y. Guo, M.Z. Liu, F.L. Zhan and L. Wu 2005).

Conclusion

The PAMs uses in agriculture to improve the soil hydro-physical properties, crop yield and the irrigation efficiency. Moreover, PAMs are offered at the market with a cheap value (one kilogram costs between 2 and 4 USD). The technique of BC manufacturing for this study is ideal for a small scale farmers in Iraq, they can consider as an investment and utilize the local agriculture residence products that and can obtain for small to no cost to make a material that can enhancement productivity on their land, if they understand the benefits that can succeed through using specific amendments, thus will be an abundant demand for these. Furthermore the soil VWC significantly improved which refers to increase maize grain yield characteristics.

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