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INFLUENCE OF N-FERTIGATION STRESS AND AGRO- ORGANIC WASTES (BIOCHAR) TO IMPROVE YIELD AND WATER PRODUCTIVITY OF SWEET PEPPER UNDER SANDY SOILS CONDITIONS

Abdelraouf R.E.[1*], Abdou S.M.M.[2], Mahmoud Abbas M.M.[3], Mohamed Hafez[4], Alexander I. Popov[5] and L.M.M. HAMED[6]

[1]Water Relations and Field Irrigation Department , Agricultural and Biological Division, National Research Centre, 33 EL Bohouth St., Dokki, Giza, Egypt, Postal Code: 12622.

[2]Water requirements and Field irrigation department, Soils, water and environmental research institute, Agriculture Rresearch Center, Egypt.

[3]Plant Nutrition Department, Agricultural and Biological Division, National Research Centre, 33 EL Bohouth St., Dokki, Giza, Egypt, Postal Code: 12622.

[4]Land and Water Technologies Department, Arid Lands Cultivation Research Institute, City of Scientific Research and Technological Applications, New Borg El-Arab, 21934, Alexandria, Egypt.

[5]Department of Soil Science and Soil Ecology, Institute of Earth Sciences, Saint Petersburg State University, Embankment, 7/9, Saint Petersburg, 199034, Russia.

[6] Soil and water Department, Faculty of Agriculture, Cairo University.12613,Giza, Egypt

*Corresponding Author E-mail: abdelrouf2000@yahoo.com

Abstract

Many recent studies interest on biochar application as the soil amendment and water management system due to its potential to soil nutrient retention, and increase water application efficiency "WAE" and sweet pepper productivity. Therefore, this study aims to investigate the effect of biochar and its combined effect on water application efficiency, water productivity, nitrogen concentration, and sweet pepper yield under sandy soil cultivation. Two field experiments were carried out during growing seasons 2017 and 2018 to study the effect of interaction of adding biochar and nitrogen fertilization stress (N) on water application efficiency, yield of sweet pepper (YSP), water productivity (WP) and vitamin C of sweet pepper. Three application rates of biochar (zero (control), 3.5, 7 and 10.5 ton ha^{-1}) were used under three levels from nitrogen fertilization stress (100%, 80% and 60% N) under drip irrigation methods. The results revealed that increasing the application of biochar materials with 100% N fertilization treatments had a positive impact on WAE, YSP, WP and vitamin C of sweet pepper. The most effective level in this regard when plant were treated and adding 10.5 ton ha^{-1} of biochar as well as when plant were irrigated with 100 % and adding 10.5 ton ha^{-1} of biochar in both seasons of 2017 and 2018 respectively. A similar direction was observed with vitamin C content of sweet pepper compared with control treatments and irrigation with 80 % of without adding biochar. In addition, water productivity parameter was significantly improved by application of adding biochar with N-fertilization. In conclusion the biochar application was recommended for a potential soil amendment as its significantly increased yield, water productivity and vitamin C.

***Keywords*:** Eco-friendly organic wastes, Water application efficiency, Water productivity, N-fertilization, pepper yield, Vitamin C.

Introduction

Applying chemical fertilizers is vital for crop and grain growth. Fertilization is the addition of fertilizers through irrigation water. Fertilizer management is especially important for irrigated cultivation of sandy soil where large amounts of fertilizer can be lost, if not properly managed, by deep filtration of groundwater. Soil moisture movement properties and nutrient dynamics The effect on crop growth and productivity significantly (Abdelraouf and Ragab, 2018). Many researchers found different ideal conditions for scheduling irrigation and fertilization using tensile measures under the drip irrigation system (Marwa, *et al*., 2017). Drip irrigation is highly efficient because the direct root area of each plant is only wet. This system also allows for the strict application of water-soluble fertilizers and other agricultural chemicals (El-Habbasha, *et al*., 2015). Some experimental results indicated a positive effect of increased fertilization rate N on yield using both wastewater in fish farms and irrigation water (Abdelraouf and Ragab, 2017). The total yield of onions along with nitrogen yielded about 80% of the recommended dose approximately the same yield as that of mineral enrichment N with a full dose (N100) in the first season but gave a higher yield in the second season (Abdelraouf *et al*., 2016)

The application of biochar to the soil has the possibility to increasing sandy soil fertility and nitrogen release (Pereira *et al.,* 2015) with the high content stable organic carbon in the biochar to change the soil properties. Recent studies have emphasized biochar as a possible technique to increase nutrient bioavailability and decrease nitrogen losses (Xu *et al.,* 2016) as well as decrease soil degradation (Cayuela *et al.,* 2014). Biochar amendment positively affect the chemical and physical properties of the soil on pH led to direct absorption of NH_4^+ –N and NO_3^- –N (Novak *et al.,* 2009), great cation exchange capacity (CEC) (Ding *et al*., 2010), improved water holding capacity (WHC) of the sandy soil.The application of boichar in sandy soil can inhancement of nutrients, first through plant roots and it is the main way and the second through soil application.Biochar was added at many and different rates to sandy soils. Use rates have been significantly effected on soil properties, and the highest application of doses had more effects. Thus, interest in the application of biochar as a technique to mitigate and reduce the effects of global warming is steadily increasing (Huang *et al.*, 2019; Shi, Liu and Zhang, 2019).

Commercially available mineral fertilizers possess advantages such as high solubility, facilitating the nutrient uptake by plants and better means of storage and handling

(Rashad *et al,* 2016). However, high inputs of these chemical fertilizers contribute to soil degradation, damage to the environment and loss of biodiversity. Most importantly, these chemicals have contaminated groundwater in many regions making it unfit for human consumption (Hafez, *et al.,* 2019). The long-term application of organic matter to soils raise significantly the organic carbon and hence organic matter content of the treated soil.

Many early studies stated that effective water management practices reduce nitrogen losses and reduce water use in plant production (Li *et al.,* 2006). Sanchis *et al.* (2012) reported a positive effect of biochar on reducing CH_4 emission, however, there was an offset by the increased in N_2O emissions. The highest yields are obtained through the combination of organic fertilizers and minerals Sediyama, *et al.,* (2009).According to (Yu *et al.*, 2019; Marcussi *et al.,* 2004), mineral nutrition is essential to increase productivity and improve the quality of the harvested bell peppers, and play important roles in plant metabolism. And is considered one of the most limiting nutrients for the bell pepper crop, because it influences the physiological processes that occur in plants and fruit production.

The presence of the addition biochar or organic wastes application in the sandy soil influences on physical properties of the same; increases the CEC by adsorbing metal ions nutrients from plants, such as calcium, iron, copper, or toxic to them; influence on soil pH; provides N, P, K to the soil and, consequently, influences nutrient uptake by plants (Nassar *et al.*, 2014; Laird *et al.,* 2010), among several functions. The nutrients should be provided through suitable sources on adequate amounts and forms in a right time to ensure that plants have adequate amounts of the nutrients required for high yields. There are two ways of application nutrients, first through plant roots and it is the main way and the second through foliar application (additional way). The interest in foliar fertilizers arose due to the multiple advantages of foliar application methods. It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase the crop yield and quality (Dobbelaere *et al.*, 2002; Kolota and Osinska, 2001).

Recent research has focused on a single effect of biochar and N fertilization. However, few studies on the combined effects of biochar with organic and inorganic amendments under the plant growth were found. It is interesting to conduct research to improve nutrients availability and to increase yield and water holding capacity by application of biochar integration under sweet pepper cultivation. The combined application biochar with N fertilizer is considered to be necessary to promote higher productivity. Therefore, the aim of this study was effect of biochar compared with N fertilization on soil nutrient status, levels of vitamin C in pepper fruits, sweet pepper yield and water productivity in sandy soil under two continue cultivation seasons.

Materials and Methods

Location and climate of experimental site

Field experiments were conducted during 2017 and 2018 seasons on sweet pepper and the farm was located in north Cairo–Egypt on sandy soil at Al-Nubariya Region, El Behira, Governorate,Egypt(latitude 30° 26' 28''N, longitude 30° 18' 0'' E, and mean altitude above sea level 21 m), Al Buhayra governorate, Egypt.. The sandy soil contains many problems, and this is due to the climate and parent material of this soil is silicateand quartz its, very poor in organic matter. The climate is arid and hot summers and semi- cool and wet winters. The average precipitation very low is 122 mm, and the average temperature is 23.15 (FAO, 2016). As shown in figure (1)

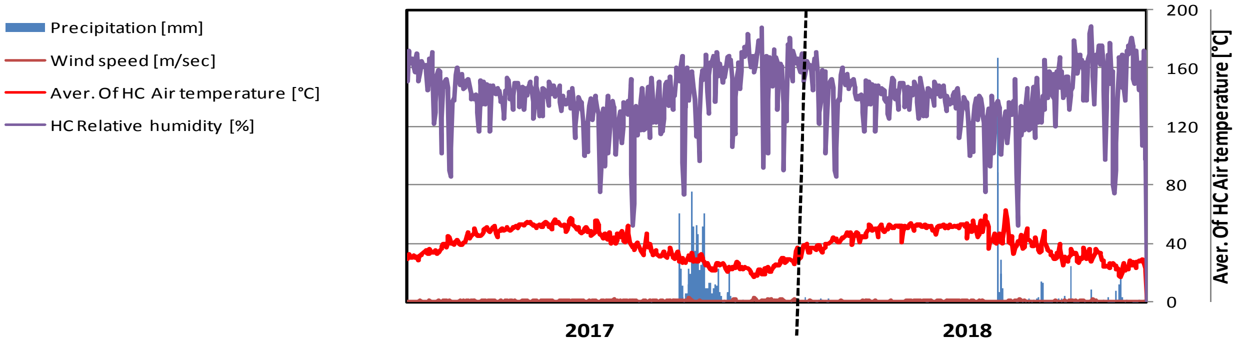


Fig. 1 : The data of average temperature, relative humidity and wind speed were obtained from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), weather station for El-Nubarya region, source: (Abdelraouf, 2019)

Physical and chemical properties of sandy soil and irrigation water:

Irrigation water source was an irrigation channel passing through the experimental area, with an average pH of 7.4 andelectrical conductivity (EC) 0.54 dS m^{-1}. The main physical and chemical properties of the soil illustrated in table (1), were determined in situ and in the laboratory at the beginning of the experiment. The main physical and chemical properties of irrigation water are reported in table 2.

Table 1 : Physical and chemical characteristics of the soil of the experimental area

Soil Characteristics	Soil depth (cm)		
	0–20	20-40	40-60
Physical parameters			
Texture	Sandy	Sandy	Sandy
Course sand (%)	47.00	57.22	40.72
Fine sand (%)	50.49	39.52	55.44
Silt + clay (%)	2.51	3.26	3.84
Bulk density (t m^{-3})	1.68	1.66	1.69
Organic matter (%)	0.65	0.40	0.25
Chemical parameters			
EC (dS m^{-1})	0.58	0.57	0.55
pH (1:2.5)	8.5	8.6	8.7
Total $CaCO_3$ (%)	7.06	2.43	4.62

Table 2 : Main characteristics of irrigation water of the experimental area

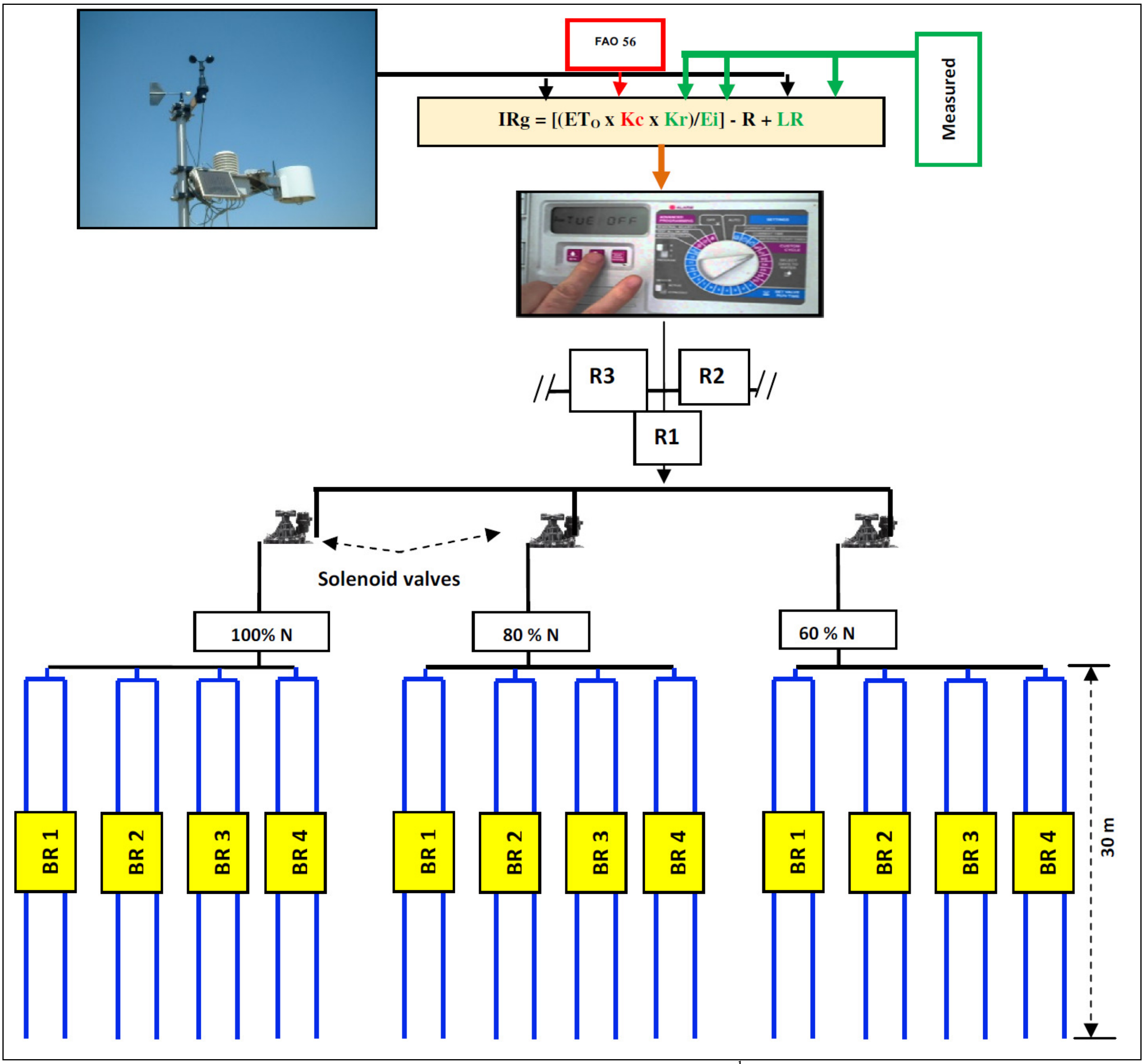
Parameter	Irrigation canal water, IW
Electric Conductivity, dS m^{-1}	0.54
pH	7.4
Chemical characteristics, concentrations in mg l^{-1}	
Calcium, Ca^{2+}	2.63
Magnesium, Mg^{2+}	1.42
Sodium, Na^{2+}	1.59
Potassium, K^{+}	0.13
Carbonate, CO_3^{2-}	< 0.01
Bicarbonate, HCO_3^{-}	1.60
Chloride, Cl^{-}	2.70
Sulphate, SO_4^{2-}	1.30

Experimental design:

The experimental design was three levels of irrigation water deficit [100%, 80% and 60% from nitrogen requirements for sweet pepper] plotted in main plot and three application rates of biochar [0 (control) , 3.5, 7 and 10.5 ton/ha.] plotted in sub-main plot as shown in fig. (2)**.**

Biochar production method:

Pyrolysis experiments were carried out by simple reactors for producing biochar from corn straw using metal scrap drums MSD. The feedstock (corn straw) was placed in the reactor to pyrolysis at low-temperatures. After pyrolysis, the reactor was left inside the furnace to cool to room temperature. The biochars and ash obtained were weighed. Figure (3) include full description for biochar production stages from corn straw.



BR 1,2,3,4 : Application Rates of biochar, ton $ha.^{-1}$ N: Nitrogen

Fig. 2 : Layout of experimental design

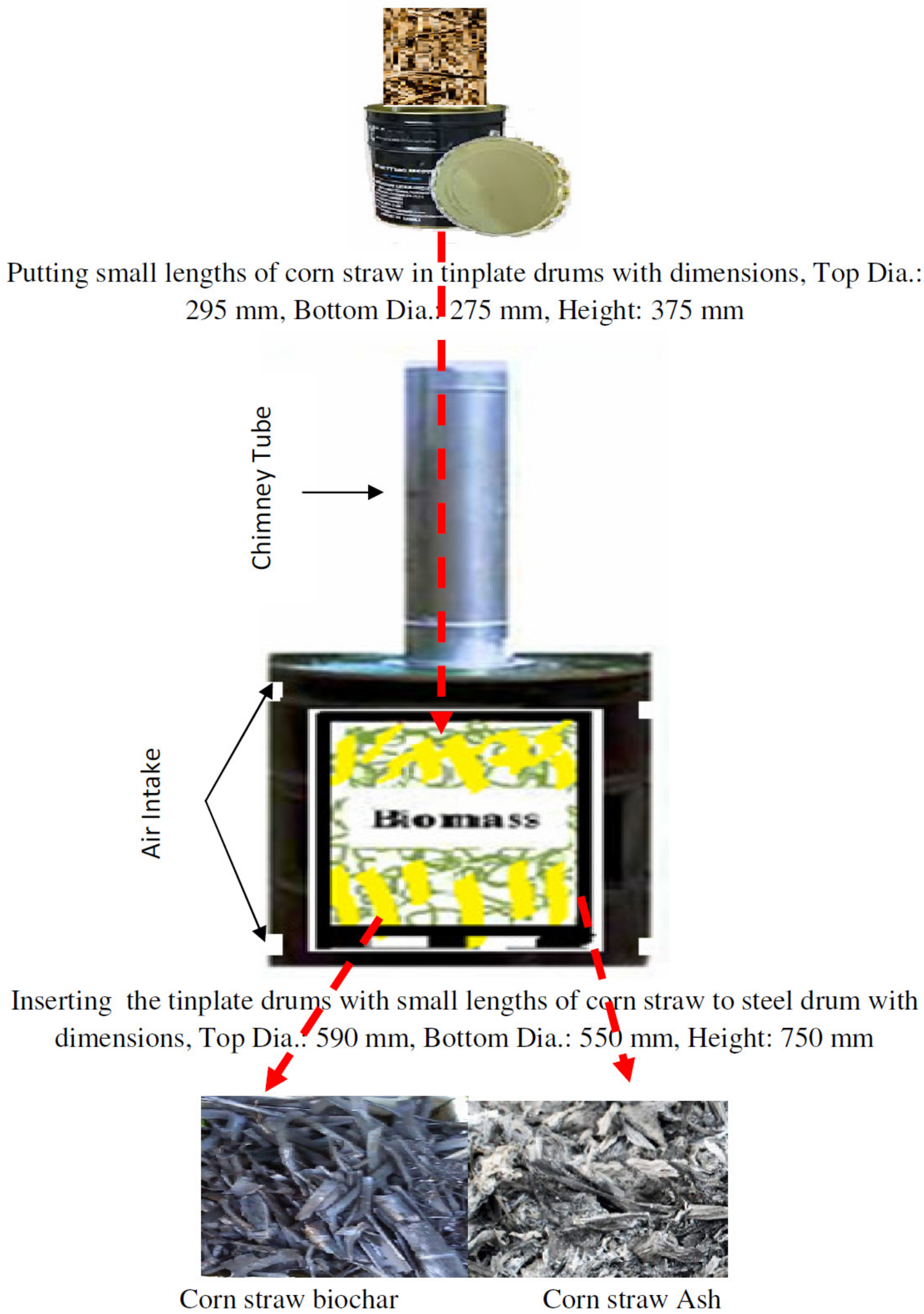


Fig. 3 : Using metal scrap drums "MSD" for producing the biochar

Irrigation requirements for sweet pepper: Daily irrigation water was calculated by following equation (1) and seasonal irrigation water was 5760 m^3/ha./season for 100% full irrigation "FI" for 2017 and 6000 m^3/ha./season for 2018 under drip irrigation system:

$$IRg = [(ET_O \times Kc \times Kr) / Ei] - R + LR \qquad ...(1)$$

Where: IRg = Gross irrigation requirements, mm/day; ET_O= Reference evapotranspiration, mm/day ,Kc = Crop factor (FAO-56); Kr = Ground cover reduction factor and the values of Kr measured by Keller equation: Kr = GC% + 0, 15. (1 – GC %), Where GC%: ground cover = (shaded area per plant/area per plant); Ei = Irrigation efficiency, %, R = Water received by plant from sources other than irrigation, mm (for example rainfall), LR = Amount of water required for the leaching of salts, mm. Total water volumes for each treatment and application rate of biochar were reported in table (3)

Table 3 : Total water volumes and biochar rates during 2017 and 2018 seasons for each treatment

Deficit Irrigation, kg	**Symbol**	**N Fertigation Stress, kg ha^{-1}**		**Biochar rates, ton ha.$^{-1}$**	**Symbol**
		2017	**2018**		
100% N	F1	144	144	0	BR0
80%N	F2	115.2	115.2	3.5	BR1
60% N	F3	86.4	86.4	7.0	BR2
				10.5	BR3

Evaluation Parameters

Water application efficiency: Water application efficiency (AE_{IW}) is the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. The AE_{IW} was calculated using equation 2:

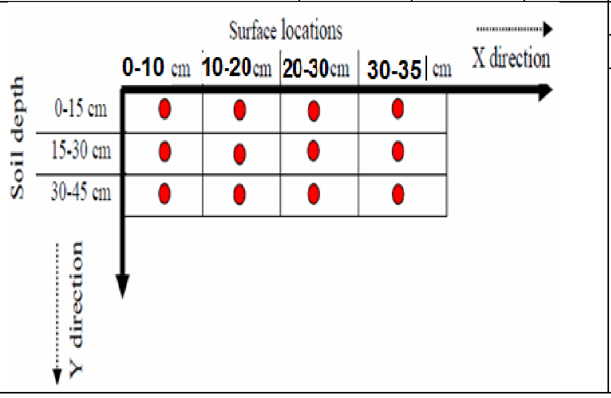
$$AE_{IW} = Ds/ Da \qquad ...(2)$$

Where AE_{IW} is the application efficiency of irrigation water,%, Ds is the depth of stored water in the root zone, cm by equation 3

$$Ds = (\theta 1 - \theta 2) * d * \rho \qquad ...(3)$$

Where: Da is the depth of applied water (mm), d is the soil layer depth (mm), θ1 is the average of soil moisture content after irrigation (g/g) in the root zone , θ2 is the average of soil moisture content before irrigation (g/g) in the root zone, ρ = bulk density of soil (g/cm^3) as shown as in table 2.

Table 4 : Application efficiency of irrigation water at peak of irrigation requirement for sweet pepper

Soil depth, cm	**θ_1 %**	**θ_2 %**	**d, mm**	**ρ, g.mm^{-3}**	**$D_s = (\theta_1 - \theta_2)*d*\rho$ mm**		**$D_s = \sum D_{s1+} D_{s2+} D_{s3}$ mm**	**D_a, mm**	**$AE_{IW} = [D_s/ D_a]*100$**
					D_{s1}				
					D_{s2}				
					D_{s3}				

AE_{IW} = Application efficiency of irrigation water, D_s =Depth of stored water in root zone, D_a =Depth of applied water, d =Soil layer depth, θ_1 =Average of soil moisture content after irrigation, θ_2 = Average of soil moisture content before irrigation, ρ = Relative bulk density of soil (dimensionless).D_{s1}= Depth of stored water in root zone from 0 – 15 cm ,D_{s2}= Depth of stored water in root zone from 15 – 30 cm, D_{s3}= Depth of stored water in root zone from 30 – 45cm

Yield of sweet pepper: At harvest, yield as kg per m^2 and ton per hectare were calculated.

Water productivity of sweet pepper: The "$WP_{sweet\ pepper}$" was calculated according to James, (1988) by equation (3) as follows:

$$WP_{sweet\ pepper} = Ey/Ir \qquad ...(3)$$

Where: $WP_{sweet\ pepper}$ is water productivity of sweet pepper ($kg_{sweet\ pepper}$ / m^3_{water}), Ey is the economical yield (kg /ha.); Ir is the applied amount of irrigation water (m^3_{water} /ha./season).

Nitrogen fertigation productivity of sweet pepper "$NFP_{sweet\ pepper}$" was calculated by equation (4) as follows:

$$NFP_{sweet\ pepper} = Ey/NFA \qquad ...(4)$$

Where: $NFP_{sweet\ pepper}$ is Nitrogen fertigation productivity of sweet pepper ($kg_{sweet\ pepper}$ / $kg_{N\ fertilizer}$), Ey is the economical yield (kg /ha); NFA is the Nitrogen Fertigation Amount ($kg_{N\ fertilizer}$ /ha./season).

Vitamin C of sweet pepper: At harvesting time, samples of green pepper fruits were randomly harvested from each sub-plot to measure vitamin C. Vitamin C (mg/100 ml juice) was determined as the method described in A.O.A.C. (1990).

Statistical Analysis: All the obtained data in the two seasons of study were statistically analyzed using the analysis of variance method according to Snedecor and Cochran (1980). However, means were distinguished by the Duncan's multiple range test(Duncan, 1955).

Results and Discussion

The effect of N-fertilization stress and biochar rate application, including water application efficiency, yield, water productivity, N-fertigation productivity, Vitamin C of the sweet pepper in sandy soil has been determined. The data of analysis of the tested organic wastes (biochar) and N-fertilization are presented in figs. (4,5,6,7, 8 and tables (5 and 6).

Water application efficiency

As it presented in figure (4) the obtained results signify that, there was a constructive impact of application rate of biochar on AE_{IW}. However, the AE_{IW} in both seasons were increased as a result of increasing the application rate of biochar and not affected by increasing of N-fertigation rate. The increasing of AE_{IW} might be attributed to application rate of biochar only. Enhancing the water holding capacity within the root zone by increasing the application rate of biochar. Although the efficiency of adding irrigation water was not affected by increasing the added rate of nitrogen fertilization with irrigation water, it would logically increase the nitrogen concentration in the effective root zone of the sweet pepper plant, with the addition of nitrogen mineral fertilizers added with the amount of irrigation water fixed under all treatments, which would have a positive effect on increasing and improving the productivity and quality of the cultivated crop.

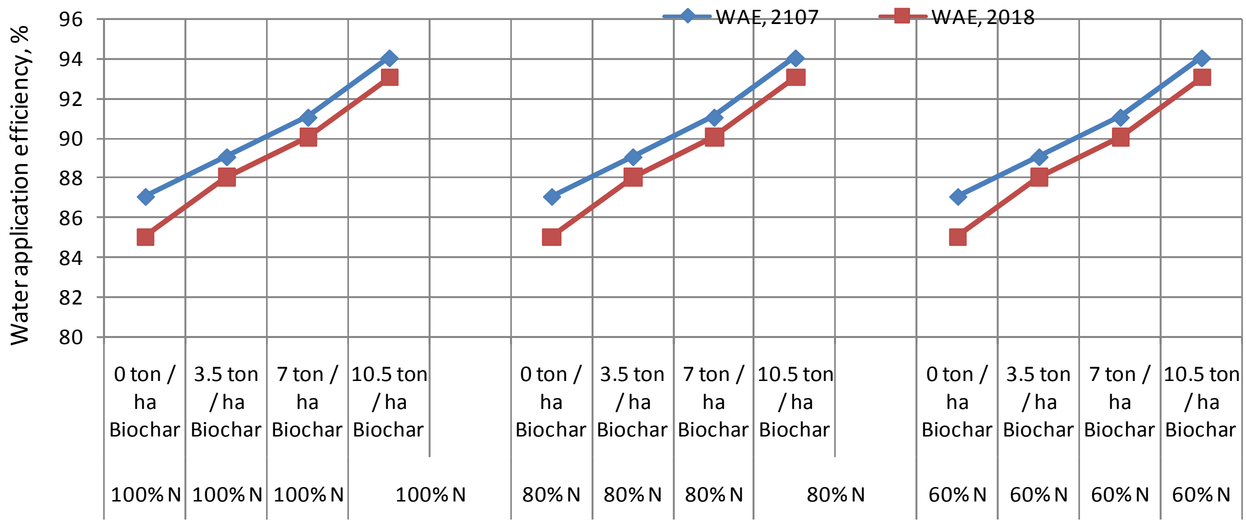


Fig. 4 : Effect of N-fertigation stress and biochar rate on the water application efficiency during seasons 2017 and 2018

Yield of sweet pepper " YSP"

Effect of interaction between N-fertigation stress and application rate of biochar on YSP is exhibited in table. (5, 6) and figure (5) .Significant differences among treatments due to interaction were attained in YSP in both experimental seasons 2017 and 2018. It is worthy to mention that in most cases the highest values of the significantly affected character in the two seasons were exhibited by added 10.5 ton ha^{-1} of biochar with 100%, 80% and 60% of N fertigation stress. Meanwhile, the lowest significant interaction values of YSP were 21.13 ton. ha^{-1} and 19.9 ton. ha^{-1}, 20.90 ton. ha^{-1} and 19.7 ton. ha^{-1} and 12.67 ton. ha^{-1} and 11.9 ton. ha^{-1} in the first and second season, respectively with 100% and without adding biochar. The main reasons for the improvement of YSP under 100% and the addition 10.5 tons. ha^{-1} of biochar may be due to; 1)- The addition of 80% reduces the total volume of water which stored in the root zone and thus reduces the loss by deep percolation thereby increasing the concentration of mineral fertilizer within the root zone and allowing the opportunity to increase nutrient absorption, 2)- Increased rate of biochar that improved water holding capacity inside root zone resulting in enhanced AE_{IW}. The decomposition of biochar resulted to increase the availability nutrients. This results agreement with (Pereira *et al.,* 2015 ; Xu *et al.,* 2016).

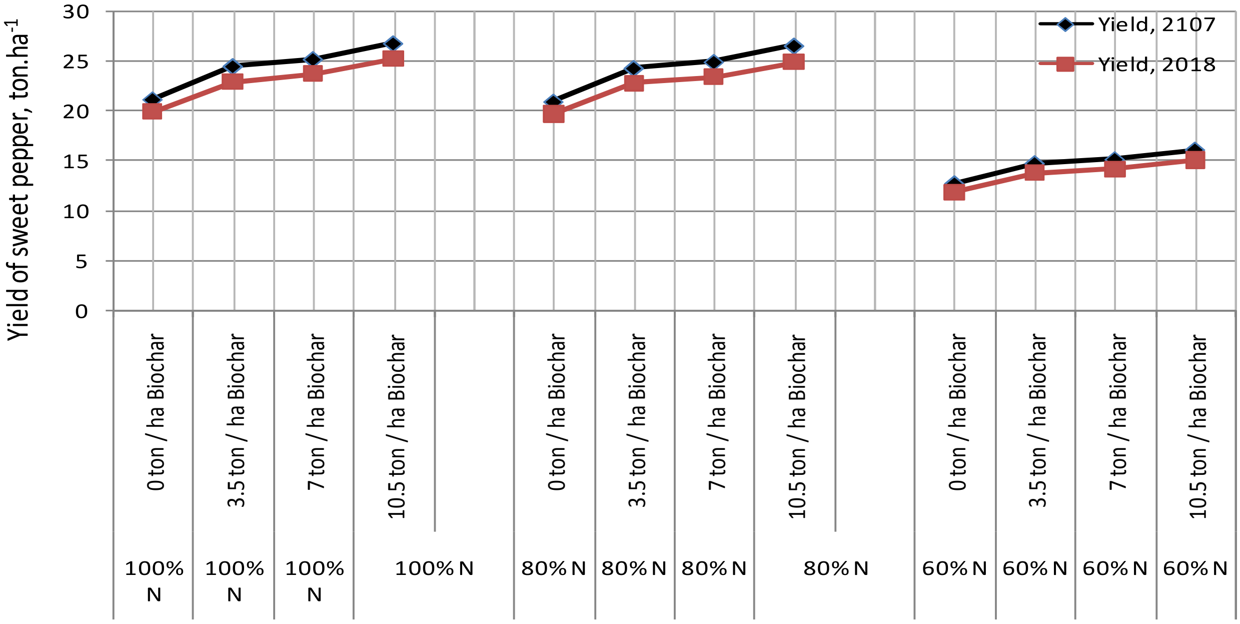


Fig 5 : Effect of N-fertigation stress and biochar rate on the yield of sweet pepper during seasons 2017 and 2018

Water productivity of sweet pepper "WP $_{\text{sweet pepper}}$"

The Effect of N-Fertigation stress on water productivity of sweet pepper "WP sweet pepper" is illustrated in table (5) and figure (6). Data are shown that WP sweet pepper was affected by N-fertigation stress N% application rate. Decreasing fertigation stress N% amount to 100% of resulted the highest values for WP sweet pepper (4.7 and 4.19 kg $^{\text{sweet pepper}}$ / $m^3{}_{\text{water}}$) followed by 80 % of resulted values for WP sweet pepper (4.6 and 4.15 kg sweet pepper / m^3 water) followed by 60 % of resulted values for WP sweet pepper (2.8 and 2.52 kg $_{\text{sweet pepper}}$ / $m^3{}_{\text{water}}$) in both seasons 2017 and 2018 respectively. While the lowest values of WP sweet pepper were obtained with 60%N-fertigation stress.

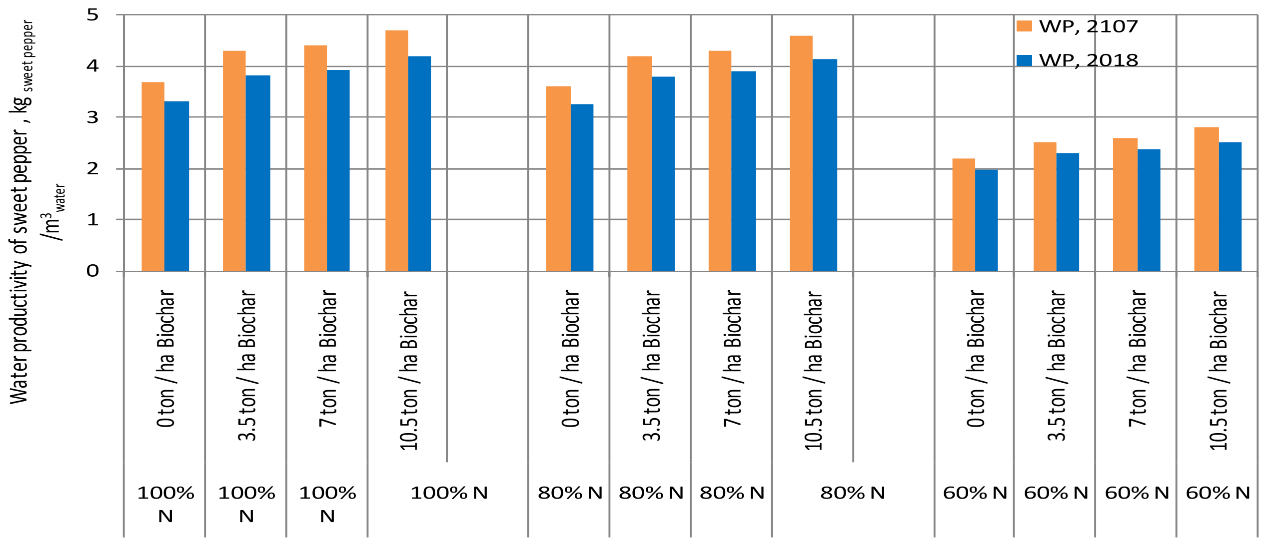


Fig. 6 : Effect of N-fertigation stress and biochar rate on the water productivity of sweet pepper during seasons 2017 and 2018

N-Fertigation productivity of sweet pepper "NFP$_{sweet\ pepper}$"

The effect of N-fertigation stress and biochar rate on the N-fertigation productivity of sweet pepper " NFP $_{sweet\ pepper}$" is illustrated in tables (5 and 6) and figure (7). Data are shown that NFP $_{sweet\ pepper}$ was affected by N-fertigation stress application rate. Decreasing fertigation stress N% amount to 100% of resulted the highest values for NFP $_{sweet\ pepper}$ (186.1and 174.7 kg $_{sweet\ pepper}$ / kg $_{N\ fertilizer}$) followed by 80 % of resulted values for NFP $_{sweet\ pepper}$ (230.2and 216.3 kg $_{sweet\ pepper}$ / kg $_{N\ fertilizer}$) followed by 60 % of resulted values for NFP $_{sweet\ pepper}$ (186.1and174.7 kg $_{sweet\ pepper}$ / kg $_{N\ fertilizer}$) in both seasons 2017 and 2018 respectively. Increased values N-fertigation productivity of sweet pepper with increased productivity of the crop and a decrease in the values of mineral nitrogen fertilizers added with rice water, although the lowest amount of nitrogen mineral fertilizers added with irrigation water was at 60% nitrogen, but the productivity values at this treatment were much lower than the productivity values under 80% Nitrogen and 100% nitrogen Abdelraouf, (2019).

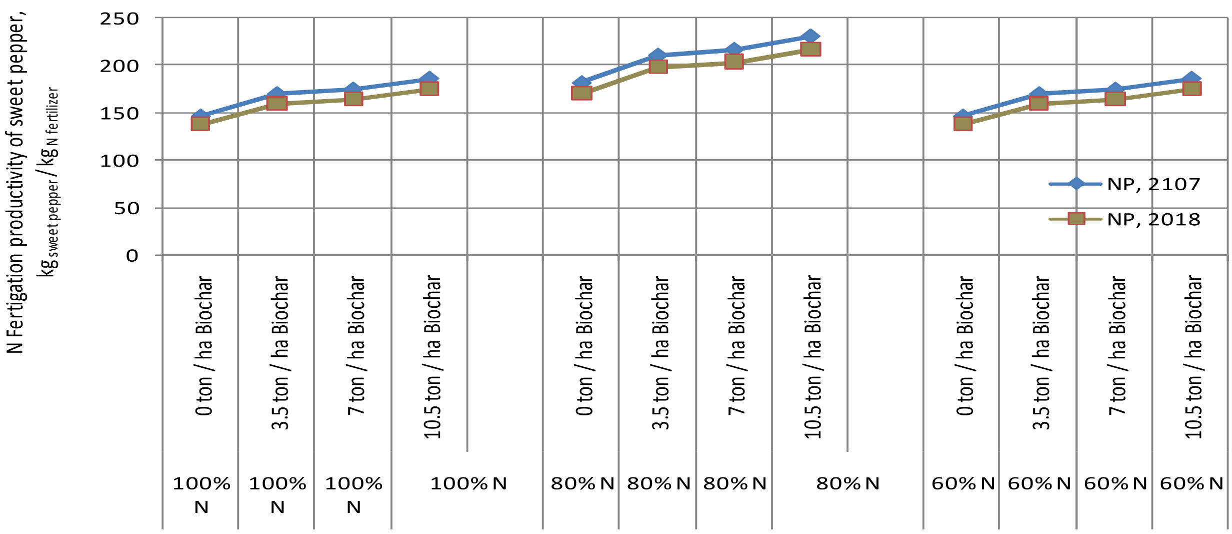


Fig. 7 : Effect of N -fertigation stress and biochar rate on the N- fertigation productivity of sweet pepper during seasons 2017 and 2018

Vitamin C of sweet pepper "V.C"

Effect of interaction between N-fertigation stress and application rate of biochar on vitamin C of sweet pepper is exhibited in table (5and 6) and figure (8). Significant differences due to interaction were attained in vitamin C parameter in both experimental seasons. The highest significant interaction values of vitamin C decreasing N-fertigation stress amount to 100% of resulted the highest values for VC $_{sweet\ pepper}$ (131.2and 122.7) followed by 80 % of resulted values for VC sweet pepper (124.6and 116.6) followed by 60 % of resulted values for VC $_{sweet\ pepper}$ (98.4 and 92.0) in both seasons 2017 and 2018 respectively, under the rate of adding 10.5 ton ha^{-1} of biochar. The main causes for increase vitamin C of sweet pepper under 100%, 80% and 60 % and using 10.5 $tons.ha^{-1}$ of biochar, this may be due to: 1) Increasing of application rate of biochar, which increase the water holding capacity inside root zone leading to enhanced and mitigate water stress on plants; 2)-Degradation of biochar increased the availability of nutrients. This results agreement with Marcussi *et al.,* 2004; Laird, *et al.,*2010; Pereira *et al.,* 2015 , and Xu *et al.,* 2016).

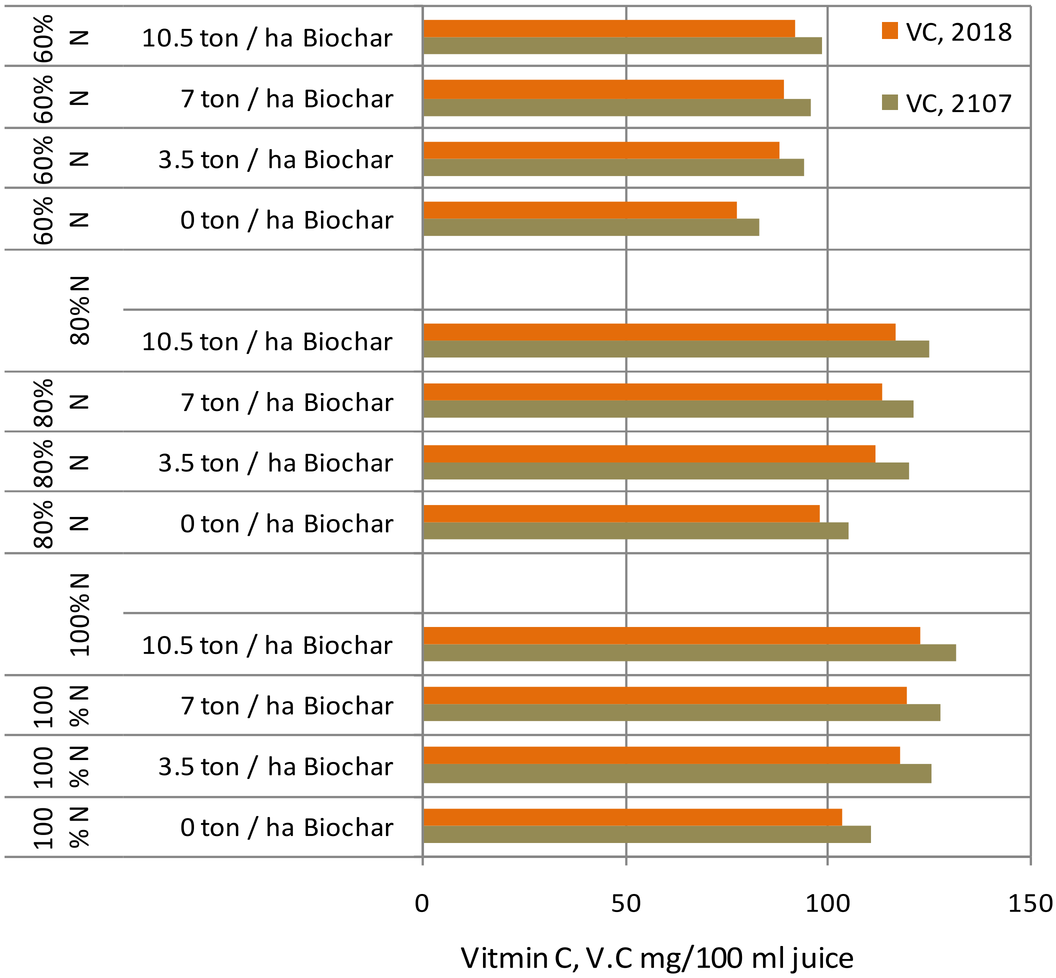


Fig. 8 : Effect of N-fertigation stress and biochar rate on the Vitamin C of sweet pepper during seasons 2017 and 2018

Table 5 : Effect of N-fertigation stress and biochar rate on the yield, water productivity, N-Fertigation productivity and Vitamin C of sweet pepper during season 2017.

Treatments		**Yield, ton.ha^{-1}**	**Water productivity, kg $_{sweet\ pepper}$ / m^3 $_{water}$**	**N Fertigation Productivity, kg $_{sweet\ pepper}$ / kg $_{N\ fertilizer}$**	**Vitamin C, V.C mg/100 ml juice**
Fertigation stress, N%	**Biochar rate ton.ha^{-1}**				
100	0.0	21.13	3.7	146.7	110.2
100	3.5	24.47	4.3	170.0	125.5
100	7	25.17	4.4	174.8	127.2
100	10.5	26.77	4.7	186.1	131.2
80	0.0	20.90	3.6	181.5	104.7
80	3.5	24.27	4.2	210.3	119.7
80	7	24.90	4.3	216.3	120.9
80	10.5	26.53	4.6	230.2	124.6
60	0.0	12.67	2.2	146.7	82.7
60	3.5	14.70	2.5	170.0	94.1
60	7	15.10	2.6	174.8	95.4
60	10.5	16.07	2.8	186.1	98.4
L S D $_{0.05}$		10.98	0.178	8.23	1.41

Table 6 : Effect of N-fertigation stress and biochar rate on the yield, water productivity, N-Fertigation productivity and vitamin C of sweet pepper during season 2018.

Treatments		Yield, $ton.ha^{-1}$	Water productivity $kg_{sweet\ pepper} / m^3_{water}$	N Fertigation Productivity $kg_{sweet\ pepper} / kg_{N\ fertilizer}$	Vitamin C, VC mg/100 ml juice
Fertigation stress, N%	Biochar rate $ton.ha^{-1}$				
100	0.0	19.9	3.31	137.8	103.1
100	3.5	22.9	3.83	159.7	117.4
100	7	23.7	3.94	164.2	119.0
100	10.5	25.2	4.19	174.7	122.7
80	0.0	19.7	3.27	170.5	97.9
80	3.5	22.8	3.79	197.6	111.6
80	7	23.4	3.90	203.2	113.1
80	10.5	24.9	4.15	216.3	116.6
60	0.0	11.9	1.99	137.8	77.3
60	3.5	13.8	2.29	159.7	88.1
60	7	14.2	2.37	164.2	89.2
60	10.5	15.1	2.52	174.7	92.0
L S D 0.05 %		**0.916**	**0.151**	**7.73**	**1.32**

Conclusions

Water application efficiency in both seasons were increased as a result of increasing the application rate of biochar and not affected by increasing of N-fertigation rate. The increasing of AE_{IW} might be attributed to application rate of biochar only. Enhancing the water holding capacity within the root zone by increasing the application rate of biochar. Although the efficiency of adding irrigation water was not affected by increasing the added rate of nitrogen fertilization with irrigation water, it would logically increase the nitrogen concentration in the effective root zone of the sweet pepper plant, with the addition of nitrogen mineral fertilizers added with the amount of irrigation water fixed under all treatments, which would have a positive effect on increasing and improving the productivity and quality of the cultivated crop.

There were a significant differences in the values of yield of sweet pepper among treatments due to interaction were attained in YSP in both experimental seasons 2017 and 2018. It is worthy to mention that in most cases the highest values of the significantly affected character in the two seasons were exhibited by added 10.5 ton ha^{-1} of biochar with 100%, 80% and 60% of N fertigation stress. The main reasons for the improvement of YSP under 100% and the addition 10.5 tons. ha^{-1} of biochar may be due to; 1)- The addition of 80% reduces the total volume of water which stored in the root zone and thus reduces the loss by deep percolation thereby increasing the concentration of mineral fertilizer within the root zone and allowing the opportunity to increase nutrient absorption, 2) -Increased rate of biochar that improved water holding capacity inside root zone resulting in enhanced AE_{IW} .The decomposition of biochar resulted to increase the availability nutrients.

Water productivity of sweet pepper was affected by N-fertigation stress N% application rate. Decreasing fertigation stress N% amount to 100% of resulted the highest values for WP sweet pepper followed by 80 % of resulted values for WP sweet pepper followed by 60 % of resulted values for WP sweet pepper in both seasons 2017 and 2018 respectively. While the lowest values of WP sweet pepper were obtained with 60%N-fertigation stress.

There were significant differences in the values of Vitamin C of sweet pepper. The highest significant interaction values of vitamin C decreasing N-fertigation stress amount to 100% of resulted the highest values for $V.C_{sweet\ pepper}$ followed by 80 % of resulted values for VC sweet pepper followed by 60 % of resulted values for $VC_{sweet\ pepper}$ in both seasons 2017 and 2018 respectively. The main causes for increase vitamin C of sweet pepper under 100%, 80% and 60 % and using 10.5 $tons.ha^{-1}$ of biochar, this may be due to: 1) Increasing of application rate of biochar, which increase the water holding capacity inside root zone leading to enhanced and mitigate water stress on plants; 2)-Degradation of biochar increased the availability of nutrients.

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