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Improving Performance of Maize Plants Grown under Deficit Water Stress

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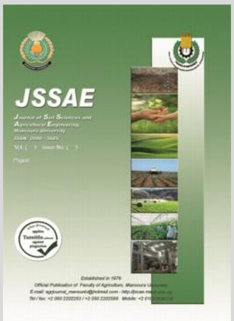

ABSTRACT

In Egypt, we are under the water poverty limit. Therefore, practical solutions must be undertaken to confront the water scarcity, which hinders agricultural development in Egypt. For this purpose, two field trials were performed to assess different irrigation intervals as main plots (irrigation every 8, 10 and 12 days), soil conditioners as subplots [without (control), biochar and compost] and foliar application of ascorbic acid at different rates (0.0, 5.0 and 10.0 mM) as sub-sub plots on maize plant performance and yield. Findings showed that deficit irrigation (irrigation every 10 and 12 days) caused a significant decline compared to irrigation every 8 days. Both soil conditioners improved plant performance and increased yield and quality of maize compared to plants grown without soil conditioners, but compost was more effective than biochar as a soil amendment in this regard. Also, the external application of ascorbic acid possessed a vital role in hindering the hazard effect of drought treatments, where plant performance and its yield increased as the rate of ascorbic acid increased. On the other hand, drought treatments led to raise antioxidants production in plant leaves at the period of 40 days from sowing to hinder the hazard effect of ROS, which were produced due to water deficit stress, while soil conditioners and foliar applications led to a decline of the maize plant's self-production from antioxidants.On the contrary, plants grown without studied substances cannot continue producing antioxidants under drought treatments in the advanced stage of growth (70 days from sowing).

***Keywords**:* Compost, biochar, irrigation systems and maize plant.

INTRODUCTION

Misuse of water resources and uneven water distribution, and inefficient irrigation techniques represent some of the main factors playing havoc with water security in Egypt, where the country has been suffering from severe water scarcity in recent years (Mosa, 2006 and El-Hadidi *et al.*, 2020).

Compost is considered as a wealthy source of organic matter, where their addition to the soil before cultivation leads to improve growth performance of higher plants and increase crop yield and quality and this due to its influences in enhancing both soil physical attributes *i.e.*, water holding capacity, structure, porosity, bulk density, hydraulic conductivity, compression strength and water permeability (El-Hadidi *et al.*, 2020). Also, compost possesses a vital role in improving soil chemical characteristics *e.g.*, soil content nutrients and organic matter (El-Ghamry *et al.*, 2019and Pérez *et al.*, 2021).

Biochar is a pure carbon product made from organic material. It's produced through a process called pyrolysis, where pyrolysis is the decomposition of organic matter in the absence of oxygen at very high temperatures (Mosa *et al.*, 2020). It changes the chemical structure of the organic matter undergoing the process. It leads to improve soil water availability and rates of plant water consumption as mentioned by Fischer *et al.*, (2019). In a study executed by Bassouny and Abbas (2019), biochar application to soil sown with maize plants at rate of 13, 26 and 39 ton biochar ha^{-1} under 60 or 80% of irrigation water requirements was beneficial in saving irrigation water. Besides, Ali, (2018) reported that both rice and soybean straw biochar possessed a positive role in improving the fertility properties of a new reclaimed sandy soil.

One of the protective methods from irrigation water deficit stress is the utilization of antioxidants which can improve plant tolerance to drought conditions and this positively reflect on improvement of growth, thus reducing the hazard effects of deficit water stress. In recent years, foliar application of antioxidants *e.g.*, ascorbic acid….. etc is effective for plants grown under biotic and abiotic stresses (Janda *et al.*, 2007 and Taha *et al.*, 2011). Ascorbic acid is a key antioxidant that has a positive role in plant stress physiology, plant growth and development, where it resists the harmful effect of reactive oxygen species in addition to its important role in cell division and expansion (Conklin, 2001). Mosa and Ramadan, (2011) stated that external application of ascorbic acid led to increasing cabbage yield.

Maize plants (*Zea mays* L.) are one of the more essential agronomy crops in the Egyptian market in terms in cultivated area and high nutritional value of its grain (Abo El-Ezz and Haffez, 2019 and El-Sherpiny, 2020) as well as its usage in producing healthy oil (Yaseen *et al.*, 2020).

This research work aimed at evaluating the role of both compost and biochar as soil conditioners in combination with different rates of ascorbic acid in saving irrigation water and improving the growth performance of one of the most crops sensitive to irrigation water deficit stress.

MATERIALS AND METHODS

1.Experimental Setup

Two field research trials were implemented at the Experimental Farm of Mansoura University, Egypt during seasons of 2020 and 2021 to assess both individual and interaction effects of different irrigation systems as main plots (irrigation every 8,10 and 12 days), soil conditioners

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as subplots [without (control), biochar and compost at rate of 10.0 ton fed^{-1} for both soil conditioners] and foliar application of ascorbic acid at different concentrations (0.0, 5.0 and 10.0 mM at volume of 450 L fed^{-1}) as sub-sub plots on growth performance, yield and its components of maize plant "Cv single Hybride 10" as well as some properties of soil fertility after harvest.

The trial execution was done in a split split-plot design with three replicates with area of 10.5 m^2 for each sub sub-plot with a separator of 3.0 m among the irrigation treatments. Before cultivation, both biochar and compost were mixed with the soil surface layer (0-30 cm depth).

Seeds of maize were obtained from the Ministry of Agri. and Soil Rec (MASR), where the cultivation was executed on May 26^{th}.

Before sowing, all plots received phosphatic fertilizer at rate of 0.476 Mg calcium superphosphate (6.6%P) ha^{-1}. The rates of N and K fertilizers were as follows: 0.285 Mg N ha^{-1}, which was divided into two equal doses of ammonium sulphate (20.6 % N), the first dose was applied before life watering (the 2^{nd} irrigation), and the 2^{nd} dose was applied before the next one (the 3^{rd} irrigation), while potassium fertilizer was applied at rate of 0.119 Mg potassium sulphate (39.8 % K) ha^{-1} in one dose before the fourth irrigation. Other traditional agricultural practices were executed according to the MASR recommendation.

Ascorbic acid was purchased from El-Gamhoria Company, Egypt, where its external application repeated four times with 10 days intervals starting from the third irrigation, while the harvest was done on September16^{th}.

2.Soil Sampling

Soil physical analyses of initial soil sample were done according to Dane and Topp (2020), while soil chemical analyses were done according to Sparks *et al.,* (2020). The analyses of the initial soil sample indicated that the experimental soil (at depth of 0-20 cm) possessed a clayey texture and contained 27% of silt, 22% of sand and 51% of clay with organic matter content of 1.25 %, pH value of 8.0, soil EC value of 2.9 dSm^{-1}, soil WHC value of 39%, available nitrogen value of 44.9 mg kg^{-1}, available phosphorus value of 6.90 mg kg^{-1} and available potassium value of 290.5 mg kg^{-1}. Values of soil properties were calculated as the average of the two studied seasons.

3.Biochar and compost characterization.

Biochar: Preparation process of biochar was executed according to Lu *et al.,* (2014). Plant residues (rice straw +wheat straw) were obtained from private farms and transferred to ARC, Giza, Egypt, where pyrolysis of of biochar was done without oxygen under the temperature of 400-500 °C for two hours. The produced biochar contained N of 1.33%,OC of 45.84%, pH value of 9.0, EC value of 5.0 dSm^{-1} and CEC value of 67.0 cmol kg^{-1}.

Compost: Compost was purchased from El-Shaffei Company, Egypt, where it contained total nitrogen value of 1.32 %, total phosphorus value of 0.50 %, total potassium value of 0.80 %, organic carbon value of 19.08 %, C/N ratio of 14.45, pH value of 6.57 and EC value of 4.00 dSm^{-1}.

4.Measurement traits.

Plant's self-production from enzymatic antioxidants in maize tissues at periods of 40 and 70 days from cultivation.

Enzymatic antioxidants [Superoxide Dismutase (SOD), peroxidase enzyme (POD) and catalase enzyme (CAT)] were determined using spectrophotometric method as described by Alici and Arabaci, (2016).

Plant's growth parameters and chemical content in maize tissues at period of 70 days from sowing.

Chlorophyll content in leaves was determined as SPAD value/ F.W as well as chemical constituents in maize (stover + leaves, D.W) *i.e.,* N, P, K were estimated according to Walinga *et al*., (2013).

Measurements at harvest.

- **Yield and its components: At harvesting stage,** number of grain cob^{-1}, weight of 1000 grain, cob length, number of rows cob^{-1}, grain yield and biological yield values were determined. In addition, harvest index was calculated according to the following equation;

$$\text{Harvest index} = \frac{\text{Economical yield (grain yield)}}{\text{Biological yield (grain + straw yields)}} \times 100$$

- **Bio chemical traits:** Total carbohydrates, crude protein and crude oil contents in grain were determined according to AOAC, (2000), where crude protein % in grain was calculated by multiplying N% in grain by 5.75.
- **Soil attributes at harvest.**

Available soil nutrients *i.e.,* N, P and K and water holding capacity of soil (WHC) were determined as formerly mentioned with sample of initial soil.

5.Statistical Analysis.

Data was statistically analyzed according to Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

Results

1.Plant's self-production from enzymatic antioxidants in maize tissues at periods of 40 and 70 days from cultivation.

Data of Tables 1 and 2 show the individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on maize plant's self-production from enzymatic antioxidants at different stages from plant's life period during seasons of 2020 and 2021.

Results indicated that plants irrigated every 12 days had the highest values of Superoxide Dismutase (SOD, unit mg^{-1} $protein^{-1}$) Peroxidase Enzyme (POD, unit mg^{-1} $protein^{-1}$) and Catalase Enzyme (CAT, unit mg^{-1} $protein^{-1}$) at period of 40 days from sowing followed by that irrigated every 10 days, while the lowest values of these antioxidants were realized when plants irrigated every 8 days at the same period. On the contrary, at period of 70 days from sowing, plants irrigated every 12 days had the lowest values of these antioxidants followed by that irrigated every 10 days, while the highest values of these antioxidants were realized when plants irrigated every 8 days at the same period. It can be said that water drought treatments (irrigation every 10 and 12) led to raise antioxidants content in maize leaves at period of 40 days from sowing compared to plants irrigated every 8 days, where the increase of irrigation intervals from 8 to 10 and 12 days caused raising self-production from these enzymatic antioxidants in maize tissues to tolerate water deficit stress, where maize plants upregulated various scavenging mechanisms to alleviate water deficit stress-induced damage. Meanwhile, at the period of 70 days from sowing, the plant's self-production from these enzymatic antioxidants in maize tissues declined with continuing the water-deficit stress for a long time. It can be explained the negative effect of drought treatments as follows; any variation in the stomata opening influences the photosynthesis process and stomatal conductance. In the early stages of water stress, reduced stomatal conductance inhibits transpiration rate more than it decreases the intercellular CO_2 concentration that is the main and driving factor for photosynthesis.

Table 1. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on maize plant's self-production from enzymatic antioxidants at different stages from plant's life period during season of 2020.

Treatments			Enzymatic antioxidants (at 40 days)			Enzymatic antioxidants (at 70 days)		
			SOD	POD	CAT	SOD	POD	CAT
			(unit mg^{-1} protein^{-1})					
Irrigation intervals								
Irrigation every 8 days			76.79c	203.54c	76.14c	74.35a	218.03a	75.90a
Irrigation every 10 days			79.49b	222.39b	81.46b	71.43b	202.25b	71.47b
Irrigation every 12 days			86.90a	263.85a	92.76a	65.14c	163.92c	62.24c
LSD at 5%			0.70	0.42	0.88	0.52	3.23	0.21
Soil conditioners additions								
Without (control)			84.25a	248.34a	88.36a	67.52c	178.77c	65.61c
Biochar			80.23b	226.00b	82.56b	70.89b	197.88b	70.74b
Compost			78.69c	215.44c	79.44c	72.51a	207.55a	73.25a
LSD at 5%			0.69	0.31	0.60	0.50	1.03	0.06
Ascorbic acid external application								
Without (control)			81.59a	233.49a	84.60a	69.74b	191.36c	69.01c
At rate of 5.0 mM			80.93b	230.04b	83.59b	70.30ab	194.86b	69.86b
At rate of 10.0 mM			80.66b	226.25c	82.17c	70.88a	197.98a	70.74a
LSD at 5%			0.61	0.58	0.70	0.59	1.58	0.18
Interaction								
Irrigation every 8 days	Without (control)	Without (control)	81.60jkl	233.13m	84.50kl	69.72jk	193.13no	68.95o
		At rate of 5.0 mM	80.87klm	230.25n	83.42lm	70.31jk	195.99mn	69.75n
		At rate of 10.0 mM	80.27lmn	226.63o	79.17op	70.98ij	198.61lm	70.64m
	Biochar	Without (control)	75.49stu	199.49v	75.41rst	74.95cde	221.74ef	76.59f
		At rate of 5.0 mM	74.99s-v	195.75w	74.46stu	75.46bcd	225.13de	77.53e
		At rate of 10.0 mM	74.38tuv	191.57x	73.64tuv	76.08a-d	227.67cd	78.53d
	Compost	Without (control)	73.88uv	188.01y	72.56uvw	76.63abc	230.32bc	79.41c
		At rate of 5.0 mM	73.44v	184.56z	71.58vw	77.19ab	233.48ab	80.35b
		At rate of 10.0 mM	76.16rst	182.47z	70.49w	77.79a	236.22a	81.31a
Irrigation every 10 days	Without (control)	Without (control)	83.49hi	245.55j	87.58hij	67.86lmn	179.77q	66.40r
		At rate of 5.0 mM	82.87ij	241.19k	86.64ij	68.56klm	186.41p	67.26q
		At rate of 10.0 mM	82.39ijk	237.24l	85.55jk	69.16kl	189.63op	68.08p
	Biochar	Without (control)	79.55mno	222.27p	81.40mn	71.47hij	202.00kl	71.61l
		At rate of 5.0 mM	78.82nop	218.65q	80.48no	72.11ghi	205.14jk	72.39k
		At rate of 10.0 mM	78.06opq	214.22r	79.39nop	72.62f-i	209.34ij	73.28j
	Compost	Without (control)	77.45pqr	210.90s	78.43opq	73.08fgh	212.49hi	73.93i
		At rate of 5.0 mM	76.70qrs	207.74t	77.32pqr	73.69efg	216.00gh	74.69h
		At rate of 10.0 mM	76.07rst	203.74u	76.35qrs	74.36def	219.44fg	75.57g
Irrigation every 12 days	Without (control)	Without (control)	89.63a	276.97a	97.29a	63.21t	153.01x	58.91z
		At rate of 5.0 mM	88.86ab	273.67b	96.10ab	63.75st	155.10x	59.79z
		At rate of 10.0 mM	88.27abc	270.40c	94.95bc	64.14rst	157.31wx	60.68y
	Biochar	Without (control)	87.71bcd	267.17d	93.85cd	64.69q-t	159.99vw	61.46x
		At rate of 5.0 mM	86.91cde	264.57e	92.82de	65.04p-s	163.04uv	62.26w
		At rate of 10.0 mM	86.17def	260.33f	91.58ef	65.63o-r	166.89tu	63.04v
	Compost	Without (control)	85.53efg	257.89g	90.37fg	66.03opq	169.80st	63.79u
		At rate of 5.0 mM	84.88fgh	253.98h	89.48gh	66.61nop	173.46rs	64.69t
		At rate of 10.0 mM	84.13ghi	249.65i	88.42ghi	67.18mno	176.71qr	65.54s
LSD at 5%			1.82	1.75	2.09	1.75	4.77	0.53

On the other hand, maize plants grown without biochar and compost (control) produced higher values of antioxidants than that with other plants grown on soil treated with soil conditioners at period of 40 days from sowing. While at the other studied period (70 days), self-production from these enzymatic antioxidants in maize tissues took reverse direction, where the maize plants grown without biochar and compost (control) produced the studied antioxidants less than that grown with soil conditioners taking into consideration that compost was superior to biochar. This performance might be attributed to that both biochar and compost can hold a high quantity of irrigation water in their pores, thus they can retain more irrigation water in the root zone to be up taken by maize plants as needed, thus both biochar and compost help in tolerance of the water deficit stress (irrigation every 10 and 12 days). The superiority of compost compared to biochar may be due to its high content of organic matter and nutrients. In other worlds, compost was more effective than biochar, where the nutrients content in compost is higher than biochar and this is the advantage of compost.

Data of the same Tables illustrated that at period of 40 days from sowing, the maize plants treated with ascorbic acid at both studied rates produced antioxidants less than maize plants grown without external application of ascorbic acid. While at period of 70 days from sowing, the highest values of these antioxidants were recorded when plants sprayed with ascorbic acid at rate of 10.0 mM. This is attributed to the vital role of ascorbic acid (vitamin C) in cell division, cell wall expansion and scavenging ROS in the chloroplast as well as its vital role in the ascorbate-glutathione pathway.

Table 2. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on maize plant's self-production from enzymatic antioxidants at different stages from plant's life period during season of 2021.

Treatments			Enzymatic antioxidants (at 40 days)			Enzymatic antioxidants (at 70 days)		
			SOD	POD	CAT	SOD	POD	CAT
			(unit mg^{-1} $protein^{-1}$)					
Irrigation intervals								
Irrigation every 8 days			76.06c	202.20c	75.93c	72.75a	212.45a	72.95a
Irrigation every 10 days			79.10b	220.90b	80.88b	69.84b	197.15b	69.30b
Irrigation every 12 days			86.49a	261.99a	92.09a	63.76c	159.89c	59.76c
LSD at 5%			0.93	4.17	0.22	0.20	3.18	0.70
Soil conditioners additions								
Without (control)			83.83a	246.76a	88.07a	66.00c	174.51c	63.16c
Biochar			79.87b	224.45b	81.99b	69.36b	192.77b	68.11b
Compost			77.96c	213.88c	78.84c	71.00a	202.21a	70.74a
LSD at 5%			0.80	1.36	0.13	0.06	0.94	0.64
Ascorbic acid external application								
Without (control)			81.18a	231.95a	84.04a	68.24c	186.77c	66.13c
At rate of 5.0 mM			80.55b	228.39b	82.95b	68.81b	189.68b	67.07b
At rate of 10.0 mM			79.93c	224.75c	81.92c	69.30a	193.04a	68.80a
LSD at 5%			0.52	1.80	0.20	0.17	1.60	0.48
Interaction								
Irrigation every 8 days	Without (control)	Without (control)	81.16klm	231.94lm	83.90m	68.39j	188.83l	66.10k
		At rate of 5.0 mM	80.53lmn	228.54mn	82.82n	68.61ij	190.33kl	67.98j
		At rate of 10.0 mM	79.97mno	224.89no	81.83o	68.98i	194.28jk	68.77ij
	Biochar	Without (control)	75.07tuv	198.21uv	74.88v	73.50d	215.55de	72.77ef
		At rate of 5.0 mM	74.60uv	194.38vw	73.88w	74.07c	218.62cd	73.64de
		At rate of 10.0 mM	74.16uvw	190.23wx	73.06x	74.26c	222.74bc	74.61cd
	Compost	Without (control)	73.54vwx	186.81xy	72.08y	75.30b	224.11b	75.46c
		At rate of 5.0 mM	72.99wx	183.55yz	70.99z	75.34b	226.50ab	77.06c
		At rate of 10.0 mM	72.55x	181.27z	69.95z	76.31a	231.10a	80.13b
Irrigation every 10 days	Without (control)	Without (control)	83.03hij	244.03ij	87.01j	66.14l	175.88n	64.38a
		At rate of 5.0 mM	82.48ijk	239.76jk	85.97k	67.23k	181.24m	64.61l
		At rate of 10.0 mM	81.84klm	235.94kl	84.93l	67.42k	185.57lm	66.06l
	Biochar	Without (control)	79.14nop	220.79op	80.92p	70.17h	196.45j	69.67k
		At rate of 5.0 mM	78.54opq	216.89pq	79.84q	70.66gh	201.30i	70.44hi
		At rate of 10.0 mM	77.72qrs	212.97qr	78.84r	70.78fg	203.31hi	72.11h
	Compost	Without (control)	77.13rst	209.36rs	77.86s	71.22f	207.76gh	70.26h
		At rate of 5.0 mM	76.35stu	206.20st	76.75t	72.39e	209.97fg	71.01gh
		At rate of 10.0 mM	75.68a	202.17tu	75.80u	72.56e	212.88ef	75.19fg
Irrigation every 12 days	Without (control)	Without (control)	89.14ab	275.33a	96.55a	61.58q	149.72t	56.07q
		At rate of 5.0 mM	88.52abc	271.68ab	95.39b	62.57p	150.87t	56.79pq
		At rate of 10.0 mM	87.79b	268.70bc	94.26c	63.05op	153.82st	57.64p
	Biochar	Without (control)	87.28cd	265.20cd	93.48d	63.02op	156.51s	59.20o
		At rate of 5.0 mM	86.46cde	262.58de	92.13e	63.39o	158.56rs	59.85no
		At rate of 10.0 mM	85.85def	258.78ef	90.90f	64.37n	161.92qr	60.71n
	Compost	Without (control)	85.14efg	255.91fg	89.66g	64.86mn	166.12pq	61.27mn
		At rate of 5.0 mM	84.48fgh	251.90gh	88.75h	65.01m	169.72op	62.28n
		At rate of 10.0 mM	83.77ghi	247.79hi	87.74i	66.00l	171.77no	63.99l
LSD at 5%			1.57	5.40	0.59	0.52	4.79	1.43

It can be noticed that drought treatments led to raise antioxidants production in plant leaves at the period of 40 days from sowing to hinder the hazard effect of Reactive Oxygen Species (ROS), which were produced due to water deficit stress, while soil conditioners and external application of ascorbic acid led to a decline of the maize plant's self-production from these antioxidants at the same period. On the contrary, plants grown without studied substances cannot continue producing antioxidants under drought treatments in the advanced stage of growth (70 days from sowing). Our findings are in accordance with those of Mosa and Ramadan, (2011); El-Hadidi *et al.*, (2020) and El-Sherpiny, (2020).

2.Chemical content in maize tissues at period of 70 days from sowing as well as yield, its components and quality of maize grain.

It is clear that chlorophyll content in leaves (SPAD value, F.W) as well as chemical constituents in maize (stover + leaves, D.W) *i.e.,* N, P, K % (Tables 3 and 4) at period of 70 days from sowing as well as yield *i.e.,* grain and biological yield (Mg h^{-1}) and harvest index (%) (Table 5 and 6), physical traits *i.e.,* No. of grain cob^{-1}, weight of 1000 grain (g), cob length (cm), No. of rows cob^{-1} (Table 7 and 8) and bio chemical traits *i.e.,* total carbohydrates, crude protein and crude oil content in grain (%) (Table 9 and 10) during seasons of 2020 and 2021 were significantly affected due to the studied irrigation intervals, where the values of all above mentioned parameters significantly increased as irrigation intervals reduced. In other words, the highest values of aforementioned traits were realized when maize plants were irrigated every 8 days followed by that irrigated every 10 then 12 days.

These obtained results confirm that maize plants grown under drought treatments (irrigation every 10 and 14 days) had a low performance, yield and its components compared to that irrigated every 8 days as traditional flooding irrigation. The improvement of plant performance at 70 days from sowing expressed in chlorophyll, N, P and K content as well as increases of yield and its components and quality traits (at harvest stage) for maize irrigated every 8 days could be due to sufficient both nutrients and irrigation water at the root zone of plants essential for all biological and physiological processes e.g., cell division and cell elongation (Zhang *et al*., 2019 and El-Sherpiny *et al*., 2020) comparing with plants irrigated every 10 and 12 days (water deficit stress).

Table 3. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on plant's growth parameters and chemical content in maize tissues at period of 70 days from sowing during season of 2020.

Treatments			Chlorophyll, SPAD reading	N, %	P, %	K, %
Irrigation intervals						
Irrigation every 8 days			40.26a	3.12a	0.357a	2.95a
Irrigation every 10 days			38.75b	2.94b	0.337b	2.78b
Irrigation every 12 days			34.00c	2.50c	0.291c	2.41c
LSD at 5%			0.05	0.01	0.002	0.01
Soil conditioners additions						
Without (control)			35.90c	2.67c	0.308c	2.54c
Biochar			38.42b	2.89b	0.332b	2.75b
Compost			38.68a	3.01a	0.345a	2.85a
LSD at 5%			0.05	0.03	0.002	0.02
Ascorbic acid external application						
Without (control)			37.09c	2.81c	0.324c	2.68c
At rate of 5.0 mM			37.68b	2.86b	0.328b	2.71b
At rate of 10.0 mM			38.24a	2.89a	0.332a	2.75a
LSD at 5%			0.09	0.03	0.003	0.02
Interaction						
Irrigation every 8 days	Without (control)	Without (control)	37.93i	2.83kl	0.323klm	2.69kl
		At rate of 5.0 mM	38.38h	2.86jkl	0.328jkl	2.71kl
		At rate of 10.0mM	38.43h	2.90jk	0.331jk	2.74jk
	Biochar	Without (control)	40.73d	3.16def	0.362de	2.99de
		At rate of 5.0 mM	40.78d	3.19cde	0.366cd	3.03cd
		At rate of 10.0mM	41.07c	3.23cd	0.371bc	3.06bc
	Compost	Without (control)	41.24c	3.26bc	0.374abc	3.10ab
		At rate of 5.0 mM	41.53b	3.31ab	0.378ab	3.12ab
		At rate of 10.0mM	42.24a	3.35a	0.381a	3.15a
Irrigation every 10 days	Without (control)	Without (control)	36.63k	2.72no	0.315no	2.60mn
		At rate of 5.0 mM	37.21j	2.76mn	0.317mn	2.62mn
		At rate of 10.0mM	37.78i	2.79lm	0.321lmn	2.66lm
	Biochar	Without (control)	38.97g	2.93ij	0.336ij	2.78ij
		At rate of 5.0 mM	39.02g	2.98hi	0.340hi	2.81hi
		At rate of 10.0mM	39.31f	3.01h	0.344gh	2.83hi
	Compost	Without (control)	39.38f	3.05gh	0.349fg	2.87gh
		At rate of 5.0 mM	40.11e	3.10fg	0.352ef	2.90fg
		At rate of 10.0mM	40.36e	3.12efg	0.356de	2.94ef
Irrigation every 12 days	Without (control)	Without (control)	31.58q	2.36s	0.273v	2.24v
		At rate of 5.0 mM	32.29p	2.40s	0.279uv	2.30uv
		At rate of 10.0mM	32.90o	2.43s	0.283tu	2.33tu
	Biochar	Without (control)	33.81n	2.41s	0.286tu	2.37st
		At rate of 5.0 mM	35.54l	2.53s	0.291st	2.40rs
		At rate of 10.0mM	36.59k	2.55qr	0.294rs	2.46qr
	Compost	Without (control)	33.57n	2.59pqr	0.300qr	2.49pq
		At rate of 5.0 mM	34.28m	2.62pq	0.304pq	2.53op
		At rate of 10.0mM	35.43l	2.66op	0.309op	2.56no
LSD at 5%			0.26	0.08	0.007	0.06

Regarding soil addition of biochar and compost conditioners, the data of the same Tables indicated pronouncedly differences between both soil conditioners, where compost was the superior treatment followed by biochar, while untreated maize plants possessed the lowest values of all aforementioned parameters. The promoting effect of both compost and biochar conditioners is due to their vital role in preventing soil moisture losses, while outperformed compost compared with biochar is may be attributed to its high content of nutrients and organic matter (Kim *et al*., 2016; Rehman *et al*., 2016 and Ch'ng *et al*., 2019).

Concerning the external application of ascorbic acid, the data in the same Tables elucidated that spraying ascorbic acid at rates of 5.0 and10.0 mM gave values of chemical content (Chl, N, P and K) in maize tissues at the period of 70 days from sowing as well as yield, its components and quality of maize grain better than plants without spraying, where the values of all aforementioned traits increased as the rate of ascorbic acid increased and this trend may be due to the ability of ascorbic acid to regulate plant physiology as well as its role in the absorption and transmission of ions and raising tolerance of maize plant to drought stress via scavenging ROS, which were produced due to water deficit stress (Conklin, 2001 and Mosa and Ramadan, 2011).

Generally, the combined treatment of irrigation every 8 days, compost and external application of ascorbic acid realized the highest values of chemical content in maize tissues at period of 70 days from sowing as well as yield, its components and quality of maize grain, while the lowest values were noted when maize plants irrigated every 12 days without soil conditioners and ascorbic acid spraying. Taking into consideration that addition of both biochar and compost conditioners before sowing with irrigation every 10 days recorded better results of chemical content in maize tissues at period of 70 days from sowing as well as yield, its components and quality of maize grain than non-addition of soil conditioners with irrigation every 8 days (traditional irrigation) at all ascorbic acid treatments.

Table 4. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on plant's growth parameters and chemical content in maize tissues at period of 70 days from sowing during season of 2021.

Treatments			Chlorophyll, SPAD reading	N, %	P, %	K, %
Irrigation intervals						
Irrigation every 8 days			39.72a	3.19a	0.365a	3.04a
Irrigation every 10 days			38.24b	3.01b	0.345b	2.87b
Irrigation every 12 days			33.55c	2.58c	0.298c	2.48c
LSD at 5%			0.05	0.01	0.002	0.03
Soil conditioners additions						
Without (control)			35.43c	2.73c	0.315c	2.62c
Biochar			37.92b	2.97b	0.340b	2.83b
Compost			38.17a	3.08a	0.353a	2.94a
LSD at 5%			0.05	0.02	0.002	0.02
Ascorbic acid external application						
Without (control)			36.60c	2.89c	0.332c	2.76c
At rate of 5.0 mM			37.18b	2.93b	0.336b	2.80b
At rate of 10.0 mM			37.73a	2.96a	0.340a	2.83a
LSD at 5%			0.09	0.02	0.003	0.02
Interaction						
Irrigation every 8 days	Without (control)	Without (control)	37.42i	2.89lm	0.331lm	2.76klm
		At rate of 5.0 mM	37.84h	2.93kl	0.335kl	2.79jkl
		At rate of 10.0 mM	37.93h	2.96jk	0.340jk	2.82jk
	Biochar	Without (control)	40.20d	3.24de	0.370de	3.09de
		At rate of 5.0 mM	40.25d	3.27cd	0.375cd	3.12cd
		At rate of 10.0 mM	40.56c	3.31c	0.380bc	3.15bcd
	Compost	Without (control)	40.65c	3.33bc	0.382abc	3.19abc
		At rate of 5.0 mM	40.97b	3.38ab	0.387ab	3.21ab
		At rate of 10.0 mM	41.68a	3.42a	0.390a	3.24a
Irrigation every 10 days	Without (control)	Without (control)	36.14k	2.79no	0.322no	2.67no
		At rate of 5.0 mM	36.72j	2.82n	0.324mn	2.70mno
		At rate of 10.0 mM	37.28i	2.85mn	0.328lmn	2.73klm
	Biochar	Without (control)	38.41g	2.99ij	0.344ij	2.86ij
		At rate of 5.0 mM	38.52g	3.05hi	0.349hi	2.91hi
		At rate of 10.0 mM	38.80f	3.07gh	0.353gh	2.92hi
	Compost	Without (control)	38.90f	3.11fg	0.357fgh	2.96fg
		At rate of 5.0 mM	39.57e	3.18ef	0.360fg	3.01df
		At rate of 10.0 mM	39.80e	3.20e	0.365ef	3.04ef
Irrigation every 12 days	Without (control)	Without (control)	31.17q	2.41v	0.280v	2.30v
		At rate of 5.0 mM	31.86p	2.46uv	0.286uv	2.38u
		At rate of 10.0 mM	32.47o	2.49tu	0.290tu	2.40tu
	Biochar	Without (control)	33.37n	2.55st	0.293tu	2.45st
		At rate of 5.0 mM	35.07l	2.59rs	0.298st	2.48rs
		At rate of 10.0 mM	36.10k	2.61rs	0.301rs	2.54qr
	Compost	Without (control)	33.13n	2.65qr	0.307qr	2.57pq
		At rate of 5.0 mM	33.83m	2.69pq	0.311pq	2.60pq
		At rate of 10.0 mM	34.96l	2.73op	0.316op	2.63op
LSD at 5%			4.23	0.27	0.07	0.008

Table 5. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on yield of maize plants during season of 2020.

Treatments			Grain yield (Mg h-1)	Biological yield (Mg h-1)	Harvest index (%)
Irrigation intervals					
Irrigation every 8 days			6.56a	12.78a	51.27a
Irrigation every 10 days			6.01b	12.35b	48.59b
Irrigation every 12 days			4.57c	10.70c	42.67c
LSD at 5%			0.01	0.03	0.12
Soil conditioners additions					
Without (control)			5.10c	11.33c	44.76c
Biochar			5.85b	12.07b	48.17b
Compost			6.20a	12.43a	49.60a
LSD at 5%			0.01	0.03	0.16
Ascorbic acid external application					
Without (control)			5.60c	11.83c	46.94c
At rate of 5.0 mM			5.72b	11.93b	47.63b
At rate of 10.0 mM			5.82a	12.07a	47.95a
LSD at 5%			0.01	0.03	0.15
Interaction					
Irrigation every 8 days	Without (control)	Without (control)	5.75m	11.98j	47.96hi
		At rate of 5.0 mM	5.81l	12.03j	48.27h
		At rate of 10.0 mM	5.86k	12.15i	48.24g
	Biochar	Without (control)	6.76e	12.92d	52.28cd
		At rate of 5.0 mM	6.90d	12.95d	53.24a
		At rate of 10.0 mM	6.86cd	12.98d	52.88ab
	Compost	Without (control)	6.92c	13.16c	52.56bc
		At rate of 5.0 mM	7.05b	13.24b	53.27a
		At rate of 10.0 mM	7.18a	13.62a	52.73bc
Irrigation every 10 days	Without (control)	Without (control)	5.38p	11.80k	45.55l
		At rate of 5.0 mM	5.47o	11.83k	46.21k
		At rate of 10.0 mM	5.60n	11.85k	47.29j
	Biochar	Without (control)	5.93j	12.46k	47.62ij
		At rate of 5.0 mM	6.12i	12.56h	48.71fg
		At rate of 10.0 mM	6.18h	12.59g	49.05f
	Compost	Without (control)	6.37g	12.65fg	50.33e
		At rate of 5.0 mM	6.41g	12.67e	50.55e
		At rate of 10.0 mM	6.60f	12.70e	52.01d
Irrigation every 12 days	Without (control)	Without (control)	3.86y	9.99t	38.65s
		At rate of 5.0 mM	4.00x	10.09s	39.61r
		At rate of 10.0 mM	4.20w	10.22r	41.05q
	Biochar	Without (control)	4.52v	10.56q	42.79p
		At rate of 5.0 mM	4.66u	10.69p	43.56o
		At rate of 10.0 mM	4.72s	10.87o	43.41o
	Compost	Without (control)	4.91r	10.98n	44.76n
		At rate of 5.0 mM	5.10q	11.26m	45.26lm
		At rate of 10.0 mM	5.22p	11.61l	44.93mn
LSD at 5%			0.04	0.08	0.46

3. Soil properties at harvest.

Data in Table 11 illustrate the impact of the studied treatments on soil available nutrients *i.e.*, N, P and K and soil water holding capacity (WHC) after harvest during seasons of 2020 and 2021.

Soil N, P and K.

The soil under irrigation every 8 days, which represented the followed irrigation for maize plants had the lowest values of soil available N, P, K as a result of improving the performance of maize plants under this irrigation treatment compared to drought treatments (irrigation every 10 and 12 days). Thus maize plants irrigated every 8 days absorbed more N, P and K from soil and this made the residues of these nutrients in the soil after harvest less compared to soils of drought treatments.

Also, usage both biochar and compost clearly increased available soil N,P and K compared to the corresponding soil without soil additions, but the content of these nutrients in soil treated with compost was more than that treated with biochar and this attributed to the high content of compost frm nutrients and organic matter.

The same Table indicates that external application of ascorbic acid led to a decline in the values of available soil N, P and K compared to the soil containing plants grown without ascorbic acid and this may be due to the role of ascorbic acid in improving maize plant status, where this improvement was a result of raising plants absorption from N, P and K of soil more than unsprayed plants taking into consideration that plant absorption from these nutrients increased as the ascorbic acid rate increased, thus the values of available soil N, P and K decreased as the ascorbic acid rate increased.

Table 6. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on yield of maize plants during season of 2021.

Treatments			Grain yield (Mg h-1)	Biological yield (Mg h-1)	Harvest index (%)
Irrigation intervals					
Irrigation every 8 days			6.75a	13.16a	51.25a
Irrigation every 10 days			6.18b	12.71b	48.58b
Irrigation every 12 days			4.71c	11.01c	42.69c
LSD at 5%			0.06	0.12	0.76
Soil conditioners additions					
Without (control)			5.25c	11.66c	44.76c
Biochar			6.02b	12.42b	48.15b
Compost			6.38a	12.80a	49.60a
LSD at 5%			0.04	0.11	0.65
Ascorbic acid external application					
Without (control)			5.76c	12.80c	46.98b
At rate of 5.0 mM			5.89b	12.28b	47.63a
At rate of 10.0 mM			5.99a	12.42a	47.91a
LSD at 5%			0.05	0.08	0.55
Interaction					
Irrigation every 8 days	Without (control)	Without (control)	5.7491i	12.32fg	47.98ee
		At rate of 5.0 mM	5.97hi	12.38fg	48.23ef
		At rate of 10.0 mM	6.03hi	12.52f	48.15ef
	Biochar	Without (control)	6.96d	13.29cd	52.38a
		At rate of 5.0 mM	7.09cd	13.33c	53.23a
		At rate of 10.0 mM	7.06cd	13.38bc	52.74a
	Compost	Without (control)	7.12bc	13.55bc	52.60a
		At rate of 5.0 mM	7.26ab	13.62b	53.30a
		At rate of 10.0 mM	7.39a	14.03a	52.68a
Irrigation every 10 days	Without (control)	Without (control)	5.53k	12.14gh	45.58hu
		At rate of 5.0 mM	5.63jk	12.18gh	46.22ghi
		At rate of 10.0 mM	5.76j	12.20gh	47.17fgh
	Biochar	Without (control)	6.11h	12.82e	47.63efg
		At rate of 5.0 mM	6.30g	12.94e	48.71def
		At rate of 10.0 mM	6.36g	12.97e	49.02cde
	Compost	Without (control)	6.55f	13.03e	50.32cd
		At rate of 5.0 mM	6.59f	13.05de	50.51bc
		At rate of 10.0 mM	6.79e	13.06de	52.01ab
Irrigation every 12 days	Without (control)	Without (control)	4.00q	10.27m	38.91n
		At rate of 5.0 mM	4.12q	10.40m	39.58mn
		At rate of 10.0 mM	4.32p	10.52m	41.06lm
	Biochar	Without (control)	4.65o	10.89l	42.70kl
		At rate of 5.0 mM	4.80n	11.00kl	43.59jk
		At rate of 10.0 mM	4.85n	11.19jk	43.37jk
	Compost	Without (control)	5.05m	11.29j	44.73ij
		At rate of 5.0 mM	5.25l	11.59i	45.31i
		At rate of 10.0 mM	5.37l	11.96h	44.9ij
LSD at 5%			0.14	0.25	1.66

Table 7. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on grain physical traits of maize plants after harvesting during season of 2020.

Treatments			No. grains per cob	Weight of 1000 grains	Cob length (cm)	No. of rows per cob
Irrigation intervals						
Irrigation every 8 days			380.37a	36.95a	24.67a	17.15a
Irrigation every 10 days			355.67b	35.57b	22.57b	15.44b
Irrigation every 12 days			291.30c	32.44c	16.87c	12.67c
LSD at 5%			1.50	0.09	0.06	1.03
Soil conditioners additions						
Without (control)			318.59c	33.58c	19.05c	13.30c
Biochar			346.07b	35.28b	21.89b	15.37b
Compost			362.67a	36.09a	23.18a	16.59a
LSD at 5%			4.59	0.09	0.13	0.59
Ascorbic acid external application						
Without (control)			336.48c	34.71c	20.88c	14.81b
At rate of 5.0 mM			342.56b	34.99b	21.39b	15.07ab
At rate of 10.0 mM			348.30a	35.26a	21.85a	15.37a
LSD at 5%			2.30	0.08	0.15	0.53
Interaction						
Irrigation every 8 days	Without (control)	Without (control)	337.67k	34.74n	21.30j	15.00h-l
		At rate of 5.0 mM	346.67j	35.00m	21.80i	15.33g-k
		At rate of 10.0 mM	351.00j	35.28l	22.20i	15.33g-k
	Biochar	Without (control)	387.00ef	37.26e	25.17d	17.67a-d
		At rate of 5.0 mM	390.00de	37.50d	25.57cd	17.67a-d
		At rate of 10.0 mM	396.67cd	37.82c	25.90c	18.00abc
	Compost	Without (control)	401.00bc	38.04c	26.37b	18.33ab
		At rate of 5.0 mM	405.00ab	38.34b	26.70ab	18.33ab
		At rate of 10.0 mM	408.33a	38.59a	27.07a	18.67a
Irrigation every 10 days	Without (control)	Without (control)	319.67l	33.81q	19.60m	13.00n-r
		At rate of 5.0 mM	325.33l	34.14p	20.13l	13.33m-q
		At rate of 10.0 mM	348.33j	34.44o	20.70k	13.67l-p
	Biochar	Without (control)	352.00ij	35.57k	22.90h	15.67f-j
		At rate of 5.0 mM	358.33hi	35.83j	23.20gh	16.00e-i
		At rate of 10.0 mM	361.33h	36.08i	23.60fg	16.33d-h
	Compost	Without (control)	368.67g	36.45h	23.90f	16.67c-g
		At rate of 5.0 mM	380.67f	36.74g	24.37e	17.00b-f
		At rate of 10.0 mM	386.67ef	37.01f	24.70e	17.33a-e
Irrigation every 12 days	Without (control)	Without (control)	276.67q	31.26x	14.50s	11.00t
		At rate of 5.0 mM	280.33pq	31.60w	15.30r	11.33st
		At rate of 10.0 mM	281.67pq	31.93v	15.90q	11.67rst
	Biochar	Without (control)	286.67op	32.24u	16.30q	12.00q-t
		At rate of 5.0 mM	291.00o	32.53t	16.97p	12.33p-t
		At rate of 10.0 mM	291.67o	32.72t	17.40p	12.67o-s
	Compost	Without (control)	299.00n	32.99s	17.87o	14.00k-o
		At rate of 5.0 mM	305.67mn	33.20s	18.47n	14.33j-n
		At rate of 10.0 mM	309.00m	33.46r	19.17m	14.67j-m
LSD at 5%			6.91	0.23	0.46	n.s

Table 8. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on grain physical traits of maize plants after harvesting during season of 2021.

Treatments			No. grains per cob	Weight of 1000 grains	Cob length (cm)	No. of rows per cob
Irrigation intervals						
Irrigation every 8 days			377.37a	36.67a	24.72a	15.11a
Irrigation every 10 days			352.26b	35.30b	22.61b	14.07a
Irrigation every 12 days			289.04c	32.20c	16.90c	10.96b
LSD at 5%			0.80	0.10	0.06	2.18
Soil conditioners additions						
Without (control)			314.52c	33.33c	19.08c	12.19b
Biochar			344.04b	35.02b	21.92b	13.59a
Compost			360.11a	35.82a	23.22a	14.37a
LSD at 5%			0.74	0.08	0.13	1.14
Ascorbic acid external application						
Without (control)			334.00c	34.45c	20.92c	13.07a
At rate of 5.0 mM			340.00b	34.73b	21.42b	13.41a
At rate of 10.0 mM			344.67a	34.99a	21.88a	13.67a
LSD at 5%			0.92	0.08	0.15	n.s
Interaction						
Irrigation every 8 days	Without (control)	Without (control)	334.67m	34.48n	21.30j	13.33b-j
		At rate of 5.0 mM	344.00l	34.73m	21.80i	13.67a-i
		At rate of 10.0 mM	348.00k	35.02l	22.20i	14.00a-h
	Biochar	Without (control)	384.00ef	36.98e	25.27d	15.33a-d
		At rate of 5.0 mM	386.67e	37.27d	25.67cd	15.67abc
		At rate of 10.0 mM	393.67d	37.50c	26.00c	15.67abc
	Compost	Without (control)	398.00c	37.72c	26.47b	16.00ab
		At rate of 5.0 mM	401.67b	38.04b	26.70ab	16.00ab
		At rate of 10.0 mM	405.67a	38.31a	27.07a	16.33a
Irrigation every 10 days	Without (control)	Without (control)	317.67p	33.56q	19.70m	12.67d-l
		At rate of 5.0 mM	323.67o	33.87p	20.23l	13.00c-k
		At rate of 10.0 mM	331.00m	34.18o	20.70k	13.33b-j
	Biochar	Without (control)	349.67k	35.32k	22.90h	14.00a-h
		At rate of 5.0 mM	356.67j	35.57j	23.20gh	14.33a-g
		At rate of 10.0 mM	363.33i	35.82i	23.60fg	14.33a-g
	Compost	Without (control)	366.67h	36.18h	23.90f	14.67a-f
		At rate of 5.0 mM	378.00g	36.47g	24.47e	15.00a-e
		At rate of 10.0 mM	383.67f	36.73f	24.80e	15.33a-d
Irrigation every 12 days	Without (control)	Without (control)	274.67w	31.03x	14.60s	9.33m
		At rate of 5.0 mM	277.00w	31.37w	15.30r	10.00lm
		At rate of 10.0 mM	280.00v	31.69v	15.90q	10.33klm
	Biochar	Without (control)	283.67u	32.00t	16.30q	10.67j-m
		At rate of 5.0 mM	288.67t	32.29t	16.97p	11.00i-m
		At rate of 10.0 mM	290.00t	32.47s	17.40p	11.33h-m
	Compost	Without (control)	297.00s	32.75s	17.87o	11.67g-m
		At rate of 5.0 mM	303.67r	32.95r	18.47n	12.00f-m
		At rate of 10.0 mM	306.67q	33.21q	19.27m	12.33e-l
LSD at 5%			2.76q	0.23	0.46	2.86

Table 9. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on grain quality traits of maize plants after harvesting during season of 2020..

Treatments			Carbohydrates, %	Protein, %	Oil, %
Irrigation intervals					
Irrigation every 8 days			73.52a	15.15a	5.91a
Irrigation every 10 days			71.57b	13.94b	5.21b
Irrigation every 12 days			67.56c	11.32c	3.65c
LSD at 5%			0.07	0.01	0.02
Soil conditioners additions					
Without (control)			68.90c	12.38c	4.21c
Biochar			71.17b	13.73b	5.06b
Compost			72.58a	14.30a	5.51a
LSD at 5%			0.09	0.02	0.04
Ascorbic acid external application					
Without (control)			70.44c	13.31c	4.79c
At rate of 5.0 mM			70.95b	13.46b	4.93b
At rate of 10.0 mM			71.26a	13.65a	5.07a
LSD at 5%			0.17	0.03	0.04
Interaction					
Irrigation every 8 days	Without (control)	Without (control)	70.44i	13.57m	4.75ij
		At rate of 5.0 mM	70.77hi	13.64lm	4.85i
		At rate of 10.0 mM	70.97gh	13.72l	5.00h
	Biochar	Without (control)	74.18d	15.61e	6.05d
		At rate of 5.0 mM	74.32d	15.68e	6.17c
		At rate of 10.0 mM	74.60cd	15.81d	6.46b
	Compost	Without (control)	74.93bc	15.95c	6.61a
		At rate of 5.0 mM	75.14bc	16.13b	6.61a
		At rate of 10.0 mM	76.33a	16.26a	6.70a
Irrigation every 10 days	Without (control)	Without (control)	69.70j	12.92o	4.32l
		At rate of 5.0 mM	70.35i	12.81p	4.46k
		At rate of 10.0 mM	70.46i	13.10n	4.66j
	Biochar	Without (control)	71.36fg	13.84k	5.15g
		At rate of 5.0 mM	71.54f	14.05j	5.31f
		At rate of 10.0 mM	71.59f	14.24i	5.50e
	Compost	Without (control)	72.88e	14.48h	5.62e
		At rate of 5.0 mM	72.88e	14.81g	5.93d
		At rate of 10.0 mM	73.36e	15.19f	5.97d
Irrigation every 12 days	Without (control)	Without (control)	65.15n	10.43w	3.19r
		At rate of 5.0 mM	66.05m	10.53w	3.29qr
		At rate of 10.0 mM	66.26m	10.73v	3.40q
	Biochar	Without (control)	66.40m	11.24u	3.53p
		At rate of 5.0 mM	68.16l	11.49t	3.60p
		At rate of 10.0 mM	68.37l	11.57t	3.74o
	Compost	Without (control)	68.92k	11.71s	3.86n
		At rate of 5.0 mM	69.31jk	11.96r	4.11m
		At rate of 10.0 mM	69.42jk	12.21q	4.15m
LSD at 5%			0.50	0.10	0.12

Soil water holding capacity (WHC, %).

Irrigation intervals as well as external application of ascorbic acid had an unclear impact on value of WHC (%) of soil, where the most effective factor was soil conditioners. So, results presentation will be confined to biochar and compost impacts.

WHC value of soil at harvest stage increased with both soil conditioners compared to corresponding soil of subplot without biochar and compost. This could be attributed to that both biochar and compost holds a high quantity of irrigation water, where both substances can retain more irrigation water in the root zone. On other hand, soil WHC (%) value with biochar was more than that with compost substance and this may be attributed to the ability of biochar to hold soil water in its pores, thus it helps in decreasing the infiltration rate of the soil. The results are in harmony with the findings of Conklin, (2001); Mosa and Ramadan, (2011); Kim *et al*., (2016); Rehman *et al*., (2016);Ch'ng *et al*., (2019); Zhang *et al*., (2019) and El-Sherpiny *et al*., (2020).

Table 10. Individual effect of soil conditioners and external application of ascorbic acid as well as their interaction influence on grain quality traits of maize plants after harvesting during season of 2021.

Treatments			Carbohydrates ,%	Protein, %	Oil, %
Irrigation intervals					
Irrigation every 8 days			73.79a	15.19a	6.08a
Irrigation every 10 days			71.82b	13.97b	5.36b
Irrigation every 12 days			67.76c	11.35c	3.75c
LSD at 5%			1.23	0.14	0.05
Soil conditioners additions					
Without (control)			69.16c	12.41c	4.33c
Biochar			71.40b	13.76b	5.19b
Compost			72.80a	14.33a	5.66a
LSD at 5%			0.39	0.13	0.03
Ascorbic acid external application					
Without (control)			70.67b	13.33c	4.92c
At rate of 5.0 mM			71.18ab	13.48b	5.06b
At rate of 10.0 mM			71.51a	13.69a	5.21a
LSD at 5%			0.57	0.10	0.04
Interaction					
Irrigation every 8 days	Without (control)	Without (control)	70.77hi	13.60j	4.87jk
		At rate of 5.0 mM	71.03hi	13.68j	4.99j
		At rate of 10.0 mM	71.16hi	13.77j	5.14i
	Biochar	Without (control)	74.41b-e	15.62d	6.22cd
		At rate of 5.0 mM	74.53b-e	15.72cd	6.33c
		At rate of 10.0 mM	74.82bcd	15.87bcd	6.64b
	Compost	Without (control)	75.25abc	15.96bc	6.79a
		At rate of 5.0 mM	75.50ab	16.14ab	6.79a
		At rate of 10.0 mM	76.64a	16.31a	6.90a
Irrigation every 10 days	Without (control)	Without (control)	69.94ijk	12.93kl	4.43m
		At rate of 5.0 mM	70.68hij	12.82l	4.59l
		At rate of 10.0 mM	70.73hij	13.14k	4.78k
	Biochar	Without (control)	71.70gh	13.86ij	5.28h
		At rate of 5.0 mM	71.71gh	14.10hi	5.46g
		At rate of 10.0 mM	71.88fgh	14.27gh	5.66f
	Compost	Without (control)	73.01efg	14.53fg	5.77f
		At rate of 5.0 mM	73.12d-g	14.82f	6.10e
		At rate of 10.0 mM	73.57c-f	15.22e	6.15de
Irrigation every 12 days	Without (control)	Without (control)	65.38l	10.45r	3.27s
		At rate of 5.0 mM	66.21l	10.54qr	3.38s
		At rate of 10.0 mM	66.53l	10.76q	3.50r
	Biochar	Without (control)	66.51l	11.28p	3.63q
		At rate of 5.0 mM	68.38k	11.50op	3.69q
		At rate of 10.0 mM	68.68k	11.62o	3.83p
	Compost	Without (control)	69.04jk	11.74no	3.97o
		At rate of 5.0 mM	69.49ijk	11.98mn	4.22n
		At rate of 10.0 mM	69.60ijk	12.24m	4.26n
LSD at 5%			1.71	0.29	0.12

Table 11. Impact of the studied treatments on soil available nutrients and soil water holding capacity (WHC) after harvest during seasons of 2020 and 2021.

Treatments			N		P		K		WHC	
			(mg kg^{-1})						(%)	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation every 8 days	Without (control)	Without (control)	42.17	43.81	8.19	8.38	212.77	217.45	36.55	37.28
		At rate of 5.0 mM	42.04	43.55	8.12	8.30	212.08	216.11	36.76	37.61
		At rate of 10.0 mM	41.79	43.23	8.05	8.22	211.51	216.37	36.97	37.86
	Biochar	Without (control)	44.53	45.95	8.96	9.14	223.91	228.16	40.04	40.80
		At rate of 5.0 mM	44.23	45.95	8.87	9.12	222.34	226.12	40.33	41.18
		At rate of 10.0 mM	43.94	45.35	8.79	8.97	220.84	225.04	40.68	41.62
	Compost	Without (control)	47.92	49.93	9.79	10.02	240.35	245.40	38.46	39.42
		At rate of 5.0 mM	47.28	48.93	9.70	9.93	238.93	242.28	38.11	38.87
		At rate of 10.0 mM	46.92	48.56	9.59	9.85	237.03	242.48	38.77	39.62
Irrigation every 10 days	Without (control)	Without (control)	42.80	44.17	8.41	8.56	215.16	217.74	36.39	37.26
		At rate of 5.0 mM	42.61	44.19	8.29	8.46	214.40	217.83	36.35	37.08
		At rate of 10.0 mM	42.37	43.85	8.23	8.46	213.51	217.78	36.67	37.29
	Biochar	Without (control)	45.59	47.23	9.22	9.44	227.92	231.34	40.93	41.71
		At rate of 5.0 mM	45.22	46.94	9.13	9.36	226.65	230.50	40.81	41.67
		At rate of 10.0 mM	44.90	46.25	9.03	9.24	225.36	228.52	40.20	41.12
	Compost	Without (control)	48.95	50.91	10.10	10.32	245.67	250.34	38.18	39.13
		At rate of 5.0 mM	48.64	50.32	10.01	10.22	243.74	248.61	38.39	39.35
		At rate of 10.0 mM	48.31	49.86	9.89	10.08	241.95	247.03	38.30	38.87
Irrigation every 12 days	Without (control)	Without (control)	43.58	45.28	8.68	8.83	219.17	222.46	37.05	37.72
		At rate of 5.0 mM	43.29	44.98	8.60	8.82	217.35	221.04	36.82	37.41
		At rate of 10.0 mM	43.03	44.58	8.51	8.69	216.01	220.76	36.92	37.44
	Biochar	Without (control)	46.52	48.12	9.51	9.70	235.18	238.71	40.49	41.30
		At rate of 5.0 mM	46.18	47.66	9.42	9.68	231.77	235.71	40.77	41.63
		At rate of 10.0 mM	45.92	47.71	9.35	9.57	229.89	233.11	40.55	41.48
	Compost	Without (control)	49.85	51.45	10.39	10.65	250.16	254.91	38.70	39.67
		At rate of 5.0 mM	49.52	51.45	10.29	10.53	248.82	253.80	38.59	39.36
		At rate of 10.0 mM	49.22	51.14	10.21	10.43	247.30	252.49	38.87	39.73

CONCLUSION

Obtained findings of the current research work increase our knowledge as for the efficacy of a combination among soil conditioners *e.g.*, biochar and compost and external application of antioxidants *e.g.*, ascorbic acid on improving growth performance and crop yield of maize plants under water deficit stress.It can be concluded that soil addition of both biochar and compost with external application of ascorbic acid represents an attractive option for programs of sustainable crop management under found water scarcity in Egypt.

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تحسين أداء نباتات الأذرة النامية في ظل إجهاد نقص المياه

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في مصر، يعيش الناس تحت حد الفقر المائي. وبالتالي، لابد من إيجاد حلول عملية لمواجهة ندرة المياه التي تعيق التنمية الزراعية في مصر، لذلك تم إجراء تجربتين حقليتين لتقييم أنظمة ري مختلفة كمعاملات رئيسية (الري كل 8،10 و12 يومًا)، ومحسنات التربة كمعاملات منشقة اولي [بدون (كنترول)، بيوشار، سماد المكمورة] والرش الورقي لحمض الأسكوربيك بمعدلات مختلفة (0.0، 5.0، 10.0 ملي مولر) كمعاملات منشقة ثانية على كل من أداء ومحصول نبات الأذرة. أظهرت النتائج أن معاملات الجفاف (الري كل 10 و12 يومًا) تسببت في انخفاض معنوي في أداء نبات الأذرة وإنتاجيتها مقارنة بنباتات الأذرة المروية كل 8 أيام كري تقليدي. قام كلا محسني التربة المدروسين [بيوشار، سماد المكمورة] بتحسين أداء النبات وزيادة محصول وجودة الأذرة مقارنة بالنباتات النامية بدون محسنات التربة، ولكن سماد المكمورة كان أكثر فعالية من البيوشار. أيضًا، كان للتطبيق الورقي لحمض الأسكوربيك دور حيوي في كبح التأثير الضار لمعاملات الجفاف، حيث زاد أداء النبات وإنتاجيته مع زيادة المعدل المستخدم من حمض الأسكوربيك. من ناحية أخرى، أدت معاملات الجفاف إلى زيادة الإنتاج الذاتي للنباتات من مضادات الأكسدة في فترة 40 يومًا بعد الزراعة وذلك لإعاقة التأثير الضار للجزيئات الشاردة (ROS)، والتي يتم انتاجها نتيجة إجهاد العجز المائي، بينما تسببت محسنات التربة المدروسة والرش الورقي لحمض الأسكوربيك إلى انخفاض الإنتاج الذاتي للنبات من مضادات الأكسدة. على العكس من ذلك، لا يمكن للنباتات النامية بدون المواد المدروسة الاستمرار في إنتاج مضادات الأكسدة تحت ظروف الجفاف في مرحلة النمو المتقدمة (70 يومًا من الزراعة) .