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Role of Natural Polysaccharides Polymer, Biochar and Foliar Application of Melatonin in Suppression Water Deficit Impact on Maize Performance.

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ABSTRACT

Due to water scarcity In Egypt, two field trials were performed to assess the irrigation requirements using three water regimes as main plots [irrigation with 7920m^3 water ha^{-1} which represents the followed irrigation and irrigation with 6720 and 5856 m^3 water ha^{-1}which represents the water deficit], soil addition of absorbent substances as subplots [without, natural polymer (polysaccharides) and biochar] and foliar application of melatonin at rates of 0.0,1.0 and1.5 mmol L^{-1} as sub-subplots on the performance of maize plant. Also, water holding capacity (WHC) of soil was determined for each treatment at harvest stage. The obtained results indicated that maize plants irrigated with6720 and 5856 m^3 water ha^{-1} possess a low performance and cumulative yield compared to plants irrigated with 7920 m^3 water ha^{-1}.Soil addition of absorbent substances improved plant performance, but the natural polymer was more effective than biochar. The improvement of maize performance was increased as rate of melatonin increased. Soil addition of absorbent substances before sowing under water level of 6720 m^3 water ha^{-1} with foliar application of melatonin at the both studied rates realized better results than without any treatment under followed irrigation (with 7920 m^3 water ha^{-1}). Generally, water deficit stress (6720 and 5856 m^3 water ha^{-1}) led to raising antioxidants production in plant leaves, while absorbent substances and foliar application of melatonin led to a decline of the maize plant's self-production from these antioxidants.WHC values of soil after harvest elucidated that natural polymer was more effective than biochar in saving irrigation water.

Keywords: Natural polymer, melatonin, biochar and maize plant.

INTRODUCTION

Egypt hasn't sufficient water resources to face its actual agricultural requirements. Because of this crisis, saving irrigation water becomes essential for sustainable development. Thus, there is an urgent need to find solutions that raise plant resilience to water scarcity and balance water supply and demand. Water absorbent substances e.g., polymer hydro gels and biochar are promising approaches to address this need, as well as melatonin hormone, which has an appositive role in improving the resistance of plants against different abiotic stresses (El-Hadidi *et al.* 2020).

Polymer hydro gels play a major role in agricultural purposes and create a beneficial climate to plant growth moreover, they increase the efficiency of irrigation water, where polymer hydro gels are considered as water storage tank to prevent water loss. In general, they are hydrophilic networks that possess a high capacity for water absorption. These polymers can absorb water then swell and retain water up to hundreds of times their own dry weights (Dehkordi, 2017and Ahmed and Fahmy, 2019).

Biochar is a material that reduces rates of plant water consumption and enhances soil water availability, where it is charcoal made from pyrolyzed organic having a high surface area (Mosa *et al.* 2020).Bassouny and Abbas (2019) studied the role of biochar in saving irrigation water using maize as an indicator plant and found that biochar was so beneficial in this mission.

Melatonin (Ml) is a crucial biological hormone that has a vital role in regulating plant physiology, photosynthesis, immunological enhancement and antioxidant activity, thus scavenging produced Reactive Oxygen Species (ROS) in plants due to various abiotic stresses (Ali *et al.* 2020 and Kamiab, 2020).

Maize plant was used in this experiment due to its pronounced response to water alterations in the root zone. It is also one of the more important crops in terms of cultivated area in Egypt behind wheat and rice crops. Also, it has high nutritional value and its grain is used for producing healthy oil.

The current paper aims at evaluating the role of water-absorbent substances in combination with melatonin on improving maize performance under water deficit stress.

MATERIALS AND METHODS

1.Experimental Setup.

A field trial was performed at the Farm of Mansoura University, Egypt during two successive summer seasons (2019 and 2020) aiming at assessing the water deficit stress using three irrigation regimes as main plots [irrigation with 7920 m^3 water ha^{-1} which represented the full irrigation and irrigation with 6720 and 5856 m^3 water ha^{-1} which represented the water deficit],

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soil addition of absorbent substances as sub plots [without, natural polymer (polysaccharides) and biochar at rate of 1.0 Mg ha^{-1} for both] and foliar application of melatonin at rates of 0.0,1.0 and1.5 mmol L^{-1} as sub-sub plots (the volume of sprayed melatonin solution was 650 L ha^{-1}) on the performance of maize plant. Amount of water Irrigation was measured using a pump under a flooding system depend on the discharges rate of the irrigation water from this pump according to Vereiren and Gopling, (1984), where the source of irrigation was Nile River. The trial was laid out in a split split-plot design and the treatments were replicated three times. The experimental sub sub-plot area was 10.5 m^2 with a separator of 2.5 m between the main irrigation plots. Before seed sowing,water absorbent materials were thoroughly mixed with the surface soil layer (0-20 cm).Seeds of maize "*Zea mays* L. Cv single Hybride 10" were obtained from the Ministry of Agri. and Soil Rec (MASR) and were sown on May 28th, while harvesting was done on September20th during the two seasons. Chemical and organic fertilizers as well as all traditional agricultural practices were done according to the recommendation of MASR for the maize production. The spraying melatonin was repeated 3 times at biweekly intervals starting from the third irrigation. The melatonin was obtained from El-Gamhoria Company, Egypt.

2.Soil Sampling and Analysis.

Before cultivation, soil sample of the experimental soil at depth of (0-20 cm) was taken then was transferred to laboratory for analyzing, where it was clay texture containing 25% of silt, 20% of sand and 55% of clay, having O.M content of 1.25 g 100g^{-1}, available N of 64.6 mg kg^{-1}, available P of 8.05 mg kg^{-1} and available K of 335.6 mg kg^{-1}.also, its pH, soil EC and WHC values were 8.10,2.75 dSm^{-1} and38%, respectively. Also, water holding capacity (WHC) of soil was determined for each treatment at harvest stage, where all soil analysis were done according to **Buurman *et al*. (1996).**

3.Polymer and Biochar Preparation.

Natural polymer (cellulose) was prepared from rice straw and maize stalk using NaOH as described by Ahmed and Fahmy, (2019).

Biochar was prepared under the temperature of 450-500 °C for 30 minutes without O_2 as described by Lu *et al.*(2014)using plant residues (rice straw and maize stalk).

4.Measurement traits.

a- At a period of 75 days from sowing seed.

Chlorophyll content (SPAD value) in leaves was measured as well as phenols and proline in leaves were determined according to Eberhardt *et al.*(2000) and Bates *et al.* 1973), respectively.

b- At a period of 115 days from sowing seed (harvest stage).

- Maize plant height was measured as an average.
- **Yield and its component:** No. grain per cob, weight of 1000 grain, cob length, grain yield and biological yield were determined as well as harvest index was calculated according to the following equation;

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

- **Quality parameters:** Total carbohydrates in grain, crude grain protein and crude grain oil content were determined according to Hedge and Hofreiter (1962), AOAC, (2000), and AOAC, (1990), respectively. Crude protein % was done by multiplying Nitrogen% in grain (determined by Micro- Kjeldahl method) by 5.75.

5.Statistical Analysis.

Data was statistically analyzed according to Duncan, (1955).

RESULTS AND DISCUSSION

Results

1.Maize Performance.

Natural polymer, biochar and foliar application of melatonin significantly affected biochemical traits at 75 days after sowing *i.e.* chlorophyll (SPAD, reading), phenol and prolin (mg g^{-1} F.W) (Table1), plant height (cm), yield and its components at harvest stage *e.g.* grain and biological yield (Mg ha^{-1}) (Table 2) and grain quality parameters *i.e*. total carbohydrates, crude protein and crude oil (%) (Table 3) as well as soil WHC value (%) (Fig1).

***a.*Biochemical traits at 75 days after sowing.**

Regarding maize plant's self-production from antioxidants, drought stress (6720 and 5856 m^3 water ha^{-1}) led to raising phenol and proline contents in maize leaves at period of 75 days from sowing, where the decreases of water levels from 7920 to 6720 and 5856 m^3 water ha^{-1} caused an increase of maize self-production from phenol and proline as antioxidants to scavenge the ROS, thus alleviate water deficit stress. The obtained results are in accordance with those obtained by EI-Maghraby *et al.* (2011) and El-Sherpiny *et al*. (2020).

Generally, maize plants irrigated with water level of 5856 m^3 water ha^{-1} contained the highest phenol and proline contents followed by maize plants irrigated with water level of 6720 m^3 water ha^{-1}, while the lowest values were that of maize plants irrigated with water level of 7920 m^3 water ha^{-1}. On the other hand, the maize plant grown without water absorbent substances produced the phenol and proline more than that with these substances, where the lowest phenol and proline production were recorded with cellulose polymer followed by biochar and lately control treatment (without). The obtained results are in accordance with those obtained by Ahmed and Fahmy, (2019).

Also, the maize plants treated with melatonin at rates of 1.0 and1.5 mmol L^{-1}produced phenol and proline contents less than maize plants untreated. This is attributed to its positive role in scavenging ROS in the chloroplast in addition to vital role of melatonin in regulating plant physiology and photosynthesis and immunological enhancement. On the other hand, the phenol and proline contents decreased as application rate of melatonin increased (Kamiab, 2020).

Table 1. Effect of natural polymer, Biochar and Foliar application of melatonin on chlorophyll of maize plants and its content of phenol and prolin at 75 days from sowing.

Treatments			Chlorophyll (SPAD, reading)		Phenol (mg/g F.W)		Prolin (mg/g F.W)	
			1^{st}	2^{nd}	1^{st}	2^{nd}	1^{st}	2^{nd}
Irrigation regimes								
Water level of 7920m^3 ha^{-1}			39.27a	40.25a	12.63c	12.91c	3.28c	3.35c
Water level of 6720m^3 ha^{-1}			37.91b	38.72b	14.09b	14.42b	4.16b	4.24b
Water level of 5856m^3 ha^{-1}			33.24c	33.99c	17.08a	17.42a	5.97a	6.14a
Absorbent substances								
Without			35.12c	35.93c	15.97a	16.34a	5.30a	5.43a
Polymer			38.02a	38.88a	13.66c	13.95c	3.91c	4.00c
Biochar			37.28b	38.15b	14.18b	14.46b	4.20b	4.30b
Melatonin rates								
0.0 mmol L^{-1}			36.21c	36.98c	15.08a	15.39a	4.76a	4.87a
1.0 mmol L^{-1}			36.85b	37.75b	14.51b	14.79b	4.41b	4.52b
1.5 mmol L^{-1}			37.36a	38.23a	14.21c	14.56c	4.24c	4.34c
Interaction								
Water level of 7920m^3 ha^{-1}	Without	0.0 mmol L^{-1}	37.05klm	37.82k	14.87kl	15.33gh	4.65m	4.75j
		1.0 mmol L^{-1}	37.38jkl	38.53j	14.70lm	15.01hi	4.46n	4.55k
		1.5 mmol L^{-1}	37.71i-l	38.61ij	14.51mn	14.78i	4.27o	4.40l
	Polymer	0.0 mmol L^{-1}	39.97bcd	40.92c	12.11t	12.46mn	3.03w	3.09r
		1.0 mmol L^{-1}	40.80ab	41.37b	11.13v	11.24p	2.35z	2.40u
		1.5 mmol L^{-1}	41.12a	42.08a	10.47w	10.78q	2.11A	2.17v
	Biochar	0.0 mmol L^{-1}	39.66cde	40.88c	12.44s	12.68m	3.22v	3.25q
		1.0 mmol L^{-1}	39.22d-g	41.00c	11.88tu	12.21n	2.82y	2.93s
		1.5 mmol L^{-1}	40.55abc	41.06c	11.60u	11.74o	2.60y	2.65t
Water level of 6720m^3 ha^{-1}	Without	0.0 mmol L^{-1}	35.94no	36.74m	15.64i	15.97f	5.15j	5.20h
		1.0 mmol L^{-1}	36.35mno	37.08l	15.33ij	15.61fg	5.01k	5.10hi
		1.5 mmol L^{-1}	36.77lmn	37.66k	15.02jk	15.49g	4.88l	5.07i
	Polymer	0.0 mmol L^{-1}	38.26g-j	38.93gh	13.93o	14.22j	3.97q	4.09m
		1.0 mmol L^{-1}	39.12d-g	40.25e	13.01rq	13.27kl	3.49t	3.52p
		1.5 mmol L^{-1}	39.34def	40.55d	12.76rs	13.14l	3.37u	3.43p
	Biochar	0.0 mmol L^{-1}	37.94h0k	38.81hi	14.25n	14.41j	4.11p	4.18m
		1.0 mmol L^{-1}	38.55f-i	39.16fg	13.55p	14.10j	3.79r	3.83n
		1.5 mmol L^{-1}	38.90e-h	39.31f	13.28pq	13.55k	3.63s	3.70o
Water level of 5856m^3 ha^{-1}	Without	0.0 mmol L^{-1}	31.11w	31.68t	18.23a	18.38a	6.59a	6.85a
		1.0 mmol L^{-1}	31.63vw	32.44s	17.85b	18.23a	6.40b	6.59b
		1.5 mmol L^{-1}	32.16	32.79r	17.54bc	18.23a	6.25c	6.31c
	Polymer	0.0 mmol L^{-1}	33.25uv	33.65q	16.99de	17.49b	5.98e	6.23c
		1.0 mmol L^{-1}	34.85pq	35.73o	16.38gh	16.54de	5.54h	5.66f
		1.5 mmol L^{-1}	35.43op	36.47n	16.13h	16.46e	5.36i	5.40g
	Biochar	0.0 mmol L^{-1}	32.69tu	33.41q	17.26cd	17.59b	6.11d	6.23c
		1.0 mmol L^{-1}	33.72rs	34.16p	16.78ef	16.94c	5.82f	6.06d
		1.5 mmol L^{-1}	34.27qr	35.57o	16.58fg	16.91cd	5.71g	5.89e

1^{st}: First growing season 2019. 2^{nd}: Second growing season 2020.

Generally, it can be said that water absorbent substances *e.g.,* cellulose polymer and biochar as well as melatonin have a beneficial role in reducing maize plant's requirements from phenol and proline self-production.

Concerning chlorophyll content (SPAD, reading), the maize plants irrigated with 6720 and 5856 m^3 water ha^{-1} possess a low chlorophyll content compared to plants irrigated with 7920 m^3 water ha^{-1}.Also, soil addition of absorbent substances increased chlorophyll content, but the natural polymer was more effective than biochar. Regarding melatonin, the values of chlorophyll content in leaves increased as rate of melatonin increased (Ali *et al.* 2020).

Water helps in cell enlargement due to turgor pressure and cell division, which ultimately increases the growth of the plant. It is essential for the germination of seeds, growth of plant roots, and nutrition and multiplication of soil organisms and also water is essential in the hydraulic process in the plant. So, all biochemical traits were impacted by partial root-zone drying (Ahmed and Fahmy, 2019).

b. Yield and measurement of qualitative traits at 115 days after sowing. .

It is clear that yield and measurement of qualitative traits as well as plant height at harvest stage (Tables 2 and 3) were significantly affected due to studied water levels, where the values significantly increased as water levels reduced. Therefore, the highest values of all yield and measurement of qualitative traits as well as plant height were realized when maize plants were irrigated with 7920 m^3 water ha^{-1} followed by plants irrigated with 6720 and 5856 m^3 water ha^{-1}, respectively. These results illustrated those maize plants grown under both water levels of 6720 and 5856 m^3 water ha^{-1} possess a low performance and cumulative yield compared to plants irrigated with 7920 m^3 water ha^{-1} (traditional irrigation water level). Generally, increasing all yield and measurement qualitative traits as well as plant height of maize plants irrigated with 7920 m^3 water ha^{-1} may be attributed to provides water requirements of maize in the root zone necessary for all biological and physiological processes compared to maize plants irrigated with water levels of 6720 and 5856 m^3 water ha^{-1} (water deficit stress). The results are in harmony with the findings of El-Hadidi *et al.* (2020)

Table 2. Effect of natural polymer cellulose, Biochar and Foliar application of melatonin on height of maize plants, maize yield and its components at 115 days from sowing .

Treatments			Plant height (cm) 1st	Plant height (cm) 2nd	Grain yield (Mg ha-1) 1st	Grain yield (Mg ha-1) 2nd	Biological yield (Mg ha-1) 1st	Biological yield (Mg ha-1) 2nd	Harvest index (%) 1st	Harvest index (%) 2nd
Irrigation regimes										
Water level of 7920m3 ha-1			198.35a	205.87a	6.46a	6.60a	12.63a	12.87a	51.04a	51.20a
Water level of 6720m3 ha-1			193.17b	200.32b	5.92b	6.04b	12.13b	12.40b	48.75b	48.64b
Water level of 5856m3 ha-1			181.03c	188.20c	4.50c	4.60c	10.58c	10.80c	42.39c	42.48c
Absorbent substances										
Without			185.40c	192.78b	5.04c	5.14c	11.16c	11.39c	44.87c	44.89c
Polymer			194.50a	201.60a	6.03a	6.16a	12.20a	12.45a	49.14a	49.24a
Biochar			192.65b	200.01a	5.81b	5.93b	11.99b	12.23b	48.18b	48.20b
Melatonin rates										
0.0 mmol L-1			188.97c	196.03b	5.40c	5.52c	11.57c	11.80b	46.32c	46.40c
1.0 mmol L-1			191.24b	198.51a	5.67b	5.80b	11.82b	12.09a	47.64b	47.64b
1.5 mmol L-1			192.33a	199.85a	5.80a	5.92a	11.95a	12.18a	48.22a	48.27a
Interaction										
Water level of 7920m3 ha-1	Without	0.0 mmol L-1	189.82no	195.64ghi	5.63o	5.73jk	11.79lm	12.02j	47.73i-l	47.70fgh
		1.0 mmol L-1	190.80mn	196.65fgh	5.71n	5.83ij	11.92kl	12.16ij	47.91h-k	47.94fgh
		1.5 mmol L-1	191.93lm	200.19efg	5.82m	5.94hi	12.01jkl	12.30hi	48.49g-j	48.31fg
	Polymer	0.0 mmol L-1	200.46de	208.92abc	6.64e	6.80d	12.85b-e	13.12bc	51.64bc	51.86bcd
		1.0 mmol L-1	203.82ab	211.39a	7.02b	7.16ab	13.14ab	13.42a	53.39a	53.33ab
		1.5 mmol L-1	205.13a	212.61a	7.11a	7.28a	13.24a	13.44a	53.72a	54.17a
	Biochar	0.0 mmol L-1	199.16ef	206.15bcd	6.51f	6.67d	12.77cde	12.98bcd	51.00cd	51.41cd
		1.0 mmol L-1	201.35cd	209.48ab	6.79d	6.96c	12.93bcd	13.18ab	52.48ab	52.85bcd
		1.5 mmol L-1	202.65bc	211.82a	6.91c	7.03bc	13.03abc	13.20ab	53.03a	53.25ab
Water level of 6720m3 ha-1	Without	0.0 mmol L-1	187.19qr	194.78hij	5.35r	5.45m	11.48no	11.70kl	46.59lm	46.59hij
		1.0 mmol L-1	187.91pq	194.92hij	5.43q	5.55lm	11.61mno	11.89jk	46.79klm	46.67hij
		1.5 mmol L-1	188.71op	195.82ghi	5.54p	5.67kl	11.72lmn	11.99j	47.25jkl	47.30ghi
	Polymer	0.0 mmol L-1	194.42jk	201.28ef	6.01k	6.15fg	12.24hij	12.51fgh	49.11e-h	49.21ef
		1.0 mmol L-1	197.26gh	203.76de	6.32h	6.49e	12.56efg	12.87cde	50.32de	50.43de
		1.5 mmol L-1	198.19fg	204.53cde	6.41g	6.52e	12.64def	12.88cde	50.75cd	50.61de
	Biochar	0.0 mmol L-1	193.30kl	200.60ef	5.91l	6.02gh	12.13ijk	12.39ghi	48.72f-i	48.59fg
		1.0 mmol L-1	195.12ij	203.27de	6.09j	6.20f	12.34ghi	12.63efg	49.40efg	49.09ef
		1.5 mmol L-1	196.38hi	203.90de	6.20i	6.29f	12.45fgh	12.77def	49.79def	49.23ef
Water level of 5856m3 ha-1	Without	0.0 mmol L-1	175.80ij	183.28o	3.74A	3.81u	9.80w	9.97s	38.13u	38.20o
		1.0 mmol L-1	177.64x	187.07l-o	3.98z	4.06t	9.94vw	10.13rs	40.04t	40.11n
		1.5 mmol L-1	178.77wx	186.64mno	4.16y	4.26s	10.17uv	10.34r	40.88st	41.15mn
	Polymer	0.0 mmol L-1	180.74v	187.78k-o	4.49w	4.60q	10.64st	10.84pq	42.23qr	42.45lm
		1.0 mmol L-1	184.68st	191.71i-l	5.04t	5.17n	11.16pq	11.41mn	45.15no	45.30jk
		1.5 mmol L-1	185.79rs	192.44h-k	5.20s	5.30n	11.32op	11.57lm	45.91mn	45.78ijk
	Biochar	0.0 mmol L-1	179.84vw	185.88no	4.36x	4.45r	10.44tu	10.71q	41.75rs	41.59lmn
		1.0 mmol L-1	182.57u	188.33k-n	4.68v	4.79p	10.81rs	11.11op	43.31pq	43.08l
		1.5 mmol L-1	183.44tu	190.68j-m	4.85u	4.98o	10.98qr	11.14no	44.13op	44.67k

Cont. Table 2.

Treatments			No. grains per cob 1st	No. grains per cob 2nd	Weight of 1000grains 1st	Weight of 1000grains 2nd	Cob length (cm) 1st	Cob length (cm) 2nd
Irrigation regimes								
Water level of 7920m3 ha-1			371.70a	385.41a	36.55a	37.33a	24.41a	24.94a
Water level of 6720m3 ha-1			345.30b	358.30b	35.21b	35.91b	22.29b	22.80b
Water level of 5856m3 ha-1			285.00c	295.81c	32.09c	32.76c	16.69c	17.01c
Absorbent substances								
Without			308.30c	320.67c	33.22c	33.90c	18.84c	19.27c
Polymer			351.15a	363.78a	35.55a	36.37a	22.64a	23.18a
Biochar			342.56b	355.07b	35.08b	35.72b	21.89b	22.31b
Melatonin rates								
0.0 mmol L-1			325.74c	338.26c	34.19c	34.78c	20.37c	20.81c
1.0 mmol L-1			335.70b	347.93b	34.69b	35.48b	21.27b	21.68b
1.5 mmol L-1			340.56a	353.33a	34.97a	35.74a	21.74a	22.27a
Interaction								
Water level of 7920m3 ha-1	Without	0.0 mmol L-1	329.67lm	342.67jk	34.36k	35.12h	21.10m	21.70k
		1.0 mmol L-1	334.00kl	346.33j	34.62k	35.31h	21.57lm	22.00jk
		1.5 mmol L-1	338.67k	352.00i	34.91j	35.74g	22.00l	22.40ij
	Polymer	0.0 mmol L-1	383.00de	396.33d	37.11d	37.74d	25.27de	26.10c
		1.0 mmol L-1	397.67ab	411.33ab	37.88b	38.94b	26.37ab	26.67b
		1.5 mmol L-1	403.33a	415.33a	38.20a	39.34a	26.77a	27.60a
	Biochar	0.0 mmol L-1	377.00ef	392.00d	36.85de	37.70d	24.90ef	25.43d
		1.0 mmol L-1	388.00cd	403.33c	37.42c	38.02c	25.62cd	26.23bc
		1.5 mmol L-1	394.00bc	409.33b	37.62bc	38.03c	26.07bc	26.37bc
Water level of 6720m3 ha-1	Without	0.0 mmol L-1	311.67o	324.67m	33.44n	34.09j	19.37p	19.83mn
		1.0 mmol L-1	318.33n	330.00l	33.77m	34.62i	19.93o	20.30m
		1.5 mmol L-1	324.00mn	338.67k	34.07l	34.68i	20.50n	21.10l
	Polymer	0.0 mmol L-1	350.33ij	364.00g	35.74h	35.91fg	22.90jk	23.37h
		1.0 mmol L-1	367.67g	381.67e	36.33f	37.20e	24.07gh	24.63ef
		1.5 mmol L-1	372.67fg	386.00e	36.60ef	37.66d	24.37fg	25.07de
	Biochar	0.0 mmol L-1	346.00j	357.33h	35.20i	35.90g	22.63k	22.80i
		1.0 mmol L-1	356.33hi	367.67g	35.70h	36.13f	23.27ij	23.97g
		1.5 mmol L-1	360.67h	374.67f	36.03g	36.97e	23.57hi	24.13fg
Water level of 5856m3 ha-1	Without	0.0 mmol L-1	269.67v	281.33e	30.92v	31.38o	14.30v	14.37s
		1.0 mmol L-1	273.00v	283.67st	31.26u	32.07n	15.10u	15.40r
		1.5 mmol L-1	275.67uv	286.67rs	31.59t	32.12n	15.70t	16.30q
	Polymer	0.0 mmol L-1	284.00st	295.00pq	32.16rs	32.93m	16.77s	17.30p
		1.0 mmol L-1	298.67pq	310.67n	32.87op	33.79k	18.33q	18.47o
		1.5 mmol L-1	303.00p	313.67n	33.11o	33.81k	18.97p	19.40n
	Biochar	0.0 mmol L-1	280.33tu	291.00qr	31.89s	32.28n	16.10t	16.37q
		1.0 mmol L-1	287.67rs	296.67p	32.36qr	33.19l	17.17s	17.43p
		1.5 mmol L-1	293.00qr	303.67o	32.63pq	33.27l	17.73r	18.07o

See footnote of table1.

Table 3. Effect of natural polymer cellulose, Biochar and Foliar application of melatonin on maize plants content of carbohydrates, protein and oil at 115 days from sowing.

Treatments			Carbohydrates		Protein		Oil	
			(%)					
			1st	2nd	1st	2nd	1st	2nd
Irrigation regimes								
Water level of 7920m³ ha⁻¹			74.01a	75.42a	14.92a	15.19a	5.85a	5.95a
Water level of 6720m³ ha⁻¹			72.70b	73.99b	13.81b	14.06b	5.14b	5.21b
Water level of 5856m³ ha⁻¹			68.42c	69.66c	11.17c	11.37c	3.62c	3.69c
Absorbent substances								
Without			69.99c	71.30c	12.17c	12.41c	4.19c	4.27c
Polymer			72.86a	74.27a	14.06a	14.32a	5.33a	5.39a
Biochar			72.28b	73.48b	13.67b	13.90b	5.10b	5.20b
Melatonin rates								
0.0 mmol L⁻¹			71.09c	72.38b	12.92c	13.15c	4.65c	4.74c
1.0 mmol L⁻¹			71.85b	73.15a	13.38b	13.63b	4.91b	4.97b
1.5 mmol L⁻¹			72.19a	73.53a	13.60a	13.85a	5.05a	5.15a
Interaction								
Water level of 7920m³ ha⁻¹	Without	0.0 mmol L⁻¹	71.84klm	73.19fgh	13.15no	13.40m	4.72o	4.81lm
		1.0 mmol L⁻¹	72.13jkl	73.34fg	13.36mn	13.56lm	4.84n	4.93kl
		1.5 mmol L⁻¹	72.37jk	73.73efg	13.55lm	13.85kl	4.97m	5.07jk
	Polymer	0.0 mmol L⁻¹	74.59cd	75.86a-d	15.40de	15.71cd	6.15e	6.26de
		1.0 mmol L⁻¹	75.35ab	77.10ab	16.01ab	16.34ab	6.56b	6.69ab
		1.5 mmol L⁻¹	75.59a	77.16a	16.19a	16.51a	6.71a	6.80a
	Biochar	0.0 mmol L⁻¹	74.37de	75.76a-d	15.19ef	15.39de	6.01f	6.12ef
		1.0 mmol L⁻¹	74.83bcd	76.15abc	15.62cd	15.90c	6.28d	6.38cd
		1.5 mmol L⁻¹	75.04ef	76.44abc	15.81bc	16.03bc	6.44c	6.52bc
Water level of 6720m³ ha⁻¹	Without	0.0 mmol L⁻¹	71.07no	72.28ghi	12.52qr	12.76o	4.29r	4.38op
		1.0 mmol L⁻¹	71.39mn	72.38ghi	12.76pq	13.00no	4.42q	4.52no
		1.5 mmol L⁻¹	71.61lmn	73.25fg	13.00op	13.27mn	4.58p	4.69mn
	Polymer	0.0 mmol L⁻¹	73.02hi	74.45def	13.98jk	14.26ij	5.28k	5.39ih
		1.0 mmol L⁻¹	73.71fg	75.30cde	14.70gh	14.99fg	5.71h	5.51gh
		1.5 mmol L⁻¹	74.05ef	75.48bcd	14.93fg	15.14ef	5.85g	5.97f
	Biochar	0.0 mmol L⁻¹	72.62ij	73.79efg	13.78kl	14.02jk	5.12l	5.23ij
		1.0 mmol L⁻¹	73.29gh	74.46def	14.22ij	14.43hi	5.42j	5.54gh
		1.5 mmol L⁻¹	73.51gh	74.51def	14.43hi	14.70gh	5.55i	5.69g
Water level of 5856m³ ha⁻¹	Without	0.0 mmol L⁻¹	65.81w	67.12n	10.10z	10.28w	3.20A	3.24v
		1.0 mmol L⁻¹	66.56v	67.79mn	10.44yz	10.66v	3.28z	3.34v
		1.5 mmol L⁻¹	67.17u	68.64lmn	10.68xy	10.89uv	3.40y	3.45uv
	Polymer	0.0 mmol L⁻¹	68.55s	69.89kl	11.19vw	11.40st	3.59w	3.66tu
		1.0 mmol L⁻¹	70.24pq	71.60hij	11.92st	12.12pq	3.98t	4.05qr
		1.5 mmol L⁻¹	70.60op	71.61hij	12.19rs	12.39p	4.11s	4.20pq
	Biochar	0.0 mmol L⁻¹	67.91t	69.07lm	10.94wx	11.09tu	3.50x	3.58tu
		1.0 mmol L⁻¹	69.20r	70.19jkl	11.41uv	11.63rs	3.70v	3.80st
		1.5 mmol L⁻¹	69.74q	70.98ijk	11.65tu	11.88qr	3.85u	3.92rs

See footnote of table1.

Regarding water absorbent substances, results elucidated pronouncedly differences among all soil addition treatments, where polymer was more effective than biochar, while the lowest values of all yield and measurement qualitative traits as well as plant height realized with untreated maize plants. The promotional influence of polymer cellulose and biochar is due to their great role in preventing soil moisture losses, while superior of polymer cellulose compared to biochar is could be attributed to the ability of the polymer cellulose to retain water up to hundreds of times their own dry weight of the sample.

Concerning spraying melatonin, the data in the same Tables elucidated that spraying melatonin at rates of 1.0 and1.5 mmol L^{-1}gave results better than non-foliar, but the improvement of maize performance increased as rate of melatonin increased.

Generally, foliar application of melatonin caused improvement of yield and measurement qualitative traits as well as plant height. This may be due to its ability to regulate plant physiology, enhance photosynthesis and immunological and make maize plant tolerance to drought stress via scavenging produced ROS in plants due to water deficit stress (Mosa *et al.* 2020).

Regarding for interaction effect, the combination of irrigation with 7920 m^3 water ha^{-1}, treating with cellulose polymer and foliar application of melatonin at rate of 1.5 mmol L^{-1} noted the highest values of all aforementioned traits, while the lowest values were realized when maize plant irrigated with 5856 m^3 water ha^{-1} without water absorbent substances and melatonin. Taking into account that soil addition of both absorbent substances before sowing under water level of 6720 m^3 water ha^{-1} with foliar application of melatonin at the both studied rates realized better results than without any treatment under traditional irrigation (with 7920 m^3 water ha^{-1}).

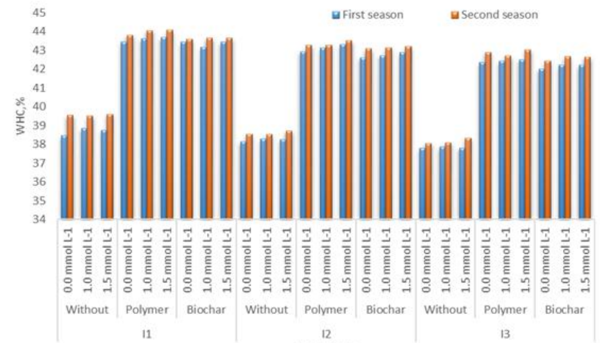

Fig .1. Impact of the studied treatments on water holding capacity (WHC) after harvest of maize plants.

I1: Water level of 7920 m^3 ha^{-1}, I2: Water level of 6720 m^3 ha^{-1} and **I3: Water level of 5856 m^3 ha^{-1}**

2.WHC of Soil.

Irrigation regimes and foliar application of melatonin possess an unclear influence on value of water holding capacity (WHC, %) of soil, where the most effective factor was water absorbent substances. So, results presentation will be confined to polymer and biochar impacts.

WHC value of soil after harvesting maize plants increased with water absorbent substances addition compared to corresponding soil without these materials. This could be attributed to that the studied absorbent substances holds a high quantity of irrigation water in its pores, where both polymer and biochar can retain more irrigation water in the root zone to be uptaked by maize plants as need, thus these absorbent substances help in tolerance the water deficit stress (6720 and 5856 m^3 water ha^{-1}).WHC with polymer was more effective than that with biochar substance and this may be attributed to the ability of the polymer to retain water up to hundreds of times their own dry weight, thus it helps in decreasing infiltration rate of soil.

Our findings are in accordance with those obtained by Dehkordi, (2017); Ahmed and Fahmy, (2019); Mosa *et al.*(2020); Ali *et al.*(2020) and Kamiab, (2020).

CONCLUSION

In the present study, alleviation of drought stress by soil addition of absorbent substances and exogenous application of melatonin on maize plant was investigated. The deficit stress severely inhibited the growth of maize. The results suggested that water absorbent substances (*e.g.,* polymer and Biochar) and melatonin have a great potential in improving water-deficit stress tolerance in maize

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دور بوليمر البولي سكاريد الطبيعي والفحم الحيويوالرش الورقي للميلاتونين في التغلب على تأثير العجز المائي على أداء نبات الأذرة

كريم فكري فودة

قسم الأراضي –كلية الزراعة –جامعة المنصورة

بسبب ندرة المياه في مصر تم إجراء تجربتين حقليتين لتقييم الري باستخدام ثلاثة أنظمة كمعاملات رئيسية [الري بـ 7920 م^3 من المياه / الفدان والذي يمثل الري المتبع والري بـ 6720 و5856 م^3 من المياه / الهكتار ويمثلا الاجهاد المائي]، الإضافة الأرضية لمواد ماصة للمياه كمعاملات منشقة اولي [بدون اضافة، بوليمر طبيعي (عديد التسكر) وفحم الحيوي]، الرش الورقي للميلاتونين بمعدلات 0.0، 1.0و1.5 ملمول/لتركمعاملات منشقه ثانية على أداء نبات الأذرة. كما تم تحديد سعة الاحتفاظ بالماء (WHC) للتربة لكل معاملة في مرحلة الحصاد. أشارت النتائج المتحصل عليها إلى أن نباتات الأذرة المروية بـ 6720 و5856 م^3 من المياه / الفدان امتلكت أداء ومحصول منخفض مقارنة بالنباتات المروية بـ 7920 م^3 من المياه / الهكتار. أدت إضافة المواد الماصة للمياه اليالتربة لتحسين أداء النبات، لكن البوليمر الطبيعي كان أكثر فعالية من الفحم الحيوي. كما ازداد تحسن أداء الأذرة بزيادة معدل الميلاتونين.أدت الجمع بين إضافة المواد الماصة للمياه الي التربة قبل الزراعة مع الري ب 6720 م^3 من المياه / الهكتاروالإضافة الورقية للميلاتونين بكلا المعدلين المدروسين إلى نتائج أفضل من عدم الإضافة الأرضية والرش الورقي تحت الري بمعدل (7920 م^3 من المياه / الهكتار). عموما أدى الإجهاد المائي (6720 و5856 م^3 من المياه / الهكتار) إلى زيادة إنتاج مضادات الأكسدة في أوراق النبات، بينما تسببتالمواد الماصة للمياه والرش الورقي للميلاتونين في انخفاض الإنتاج الذاتي لنبات الذرة من مضادات الأكسدة. كما أشارت قيم WHC للتربة بعد الحصاد إلى أن البوليمر الطبيعي كان أكثر فعالية من الفحم الحيوي في احتفاظ التربة بالمياه وتوفير مياه الري.