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Impact of Exogenous Melatonin on Water Regime Stress to Stimulate Growth, Quality and Productivity of Okra Plants at Arid Regions

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Mona N. Shehata[1*] and Nahla. A. El-Magawry[2]

[1] Horticulture Department, Faculty of Agriculture and Natural Resources, Aswan University, Aswan, Egypt.
[2] Department of Vegetable, Medicinal and Aromatic Plants Breeding, Agricultural Research Center, Geza, Egypt.

ABSTRACT

The literature currently in circulation does not provide a clear picture of how melatonin affects okra plants under water regime stress. Thus, the objective of this study is to look into the impact of one of these biochemical substances on okra plants growing in stressful water regime environments. The obtained results showed that water regime stress (60, 80 and 100 % from ETo), foliar application of melatonin (100, 150 and 200 mg/L) significantly enhanced the height of plants, index of leaf area, number of branches per plant, root length, root weight, chlorophyll content, early yield, No. of fresh pods/plant, fresh pods weight/plant, fruit shape index, average pod length, average pod diameter, dry pod weight per plant, total fruits yield, TSS, Vitamin C and relative water content as comparison with the untreated plants. In contrast, the activity of the catalase enzyme was significantly lower than in the untreated plants. In conclusion, it can be said that applying melatonin topically is a good way to improve the productivity and growth performance of okra cultivated in water regime stress situations and the best treatment at all parameters was 100 % from ETo + 200 mg/L melatonin, but there were no significant differences between this treatment and 80 % from ETo + 200 mg/L melatonin.

Keywords: *Abelmoschus esculentus*, melatonin, catalase, water stress.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the more commonly summer vegetables and because of its exceptional nutritional value; it is widely consumed in Egypt Abdel-Fattah *et al.* (2020). The fruit of the okra plant is rich in calcium, protein, lipids, carbs, and vitamins A, B, and C (retinol, thiamin, riboflavin, niacin and ascorbic acid) Adiroubane and Letachoumanane (1992). Furthermore, dried okra seeds are consumed raw, frozen, pickled or dried in many Asian and African states in place of fruits and coffee (Matlob *et al*., 1989 and Hussein *et al*., 2011). Okra is planted on (4460.4 hec.) in Egypt, yielding (54051 tons) with an average production (13.15 tons/hec.) according to the FAO (2019), Egypt is the seventh-largest production country, behind Nigeria, India, Sudan, Mali, Iraq, and Cote d'Ivoire.

Melatonin is scientifically known as N-Acetyl-5-Methoxytryptamine (MEL) was first discovered in 1995 and has become increasingly important for its role and effects in the plant framework; it has been proven that MEL plays a major role in plant reactions to growth, generation, advancement and diverse stress factors Kul *et al.* (2019). Despite its administrative function, MEL is also a significant factor in the interaction of plants with natural pressure and its exterior application has shown a beneficial effect on decreasing influences of pressure on plants (Martínez *et al.*, 2018 and Kul *et al.*, 2019). The melatonin has been classified as a phytohormone because of its function in plants (Arnao and Hernández-Ruiz, 2020). Although, the precise origin of melatonin synthesis remains a mystery, chloroplasts are widely accepted to be essential to the process. Likewise, several inquiries into the interaction between the pressure-related flagging elements and melatonin have revealed a nuanced connection between reactive oxygen species (ROS) and melatonin. It has been demonstrated that the broad-spectrum cancer preventative drug melatonin has a high limit and proficiency for ROS rummaging (Tan *et al.*, 2000 and Allegra *et al.*, 2003). Further research has demonstrated that melatonin acts through redox-touchy administrative routes to establish a connection with the phone flagging systems Allegra *et al.* (2003) and Zhang *et al.* (2016). Even in low doses, melatonin is a very powerful hormone that protects living things from oxidative stress Galano *et al.* (2013).

Water lack can have a variety of negative effects, including reducing plant development and growth by slowing down division of cells and expansion Hashim *et al.* (2020), plant growth regulator imbalance Saied and Arenz (2014), photosynthesis Elkelish *et al.* (2021) and causing oxidative damages Ahmad *et al.* (2014) damaged the membrane of cells integrity, state of leaf water and eventually lower yield Elkelish *et al.* (2021). It reduces yield by modifies stomata activity and limiting nutrient uptake Kumawat and Sharma (2018). Reactive oxygen species (ROS) are produced when there is a water deficit, which deactivates cellular redox regulation Ibrahim *et al.* (2020$_a$). Furthermore, drought-tolerant techniques are developed by stressed plants, such as encouraging the production of suitable solutes and boosting the antioxidant device's components both enzymatic and non-enzymatic Ibrahim *et al.* (2020$_b$). There are various methods for making plants more resistant to drought, including foliar sprays of melatonin as an activator, in order to protect plant life in water deficits.

Therefore, the primary goal of this study is to determine how applied melatonin at varying concentrations

* **Corresponding author.**
E-mail address: mona.nemr73@gmail.com
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affects okra's ability to withstand drought in terms of its chemical composition, morphology, quality, and production. This information will help improve okra's resistance to drought so that it can be grown in arid regions.

MATERIALS AND METHODS

Location site

This research work was conducted during the autumn seasons of 2022 and 2023 at the Faculty of Agriculture and Natural Resources' experimental farm at Aswan University in Aswan, Egypt. The site is located approximately at 23°59′56″N latitude and 32°51′36″E longitude. Its average elevation above sea level is 85 meters.

Soil sampling: -

Table 1. presents the comprehensive findings from these analyses.

Random soil sampling with a range of 0 to 30 cm deep was collected from various locations throughout the planting field prior to seeding. Using the methods outlined by Page *et al.* (1982) and Jackson (1973), the essential physical and chemical features of the soil were examined. The comprehensive findings from these analyses displayed in Table (1).

Table 1. Soil analysis

Properties	**Season 2022**	**Season 2023**
	Values	
Sand percentage	97.2	97.6
Silt percentage	0.0	0.0
Clay percentage	3.48	3.59
Soil texture		Sandy
pH	8.65	8.78
Electric conductivity (dS/m^1)	3.11	3.15
Nitrogen (mg/kg^1)	19.03	15.19
Phosphorus (mg/kg^1)	3.38	3.46
Potassium (mg/kg^1)	152.46	151.51

Treatments:

The experiment consisted of two factors: the first factor of the trial comprised 3 drip irrigation regimes (60, 80, and 100% from ETo) and the second component included 4 applications of melatonin (100, 150, and 200 mg/L plus the control treatment "tap water"), administered both separately and in all combinations using a split plot design on three replicates. The following points were made using the treatments:

1. Irrigation systems treatments:

Every experimental plot was split up into three primary groups, each of which received three different irrigation water levels. (i.e., 60, 80, and 100 % from ETo). Using FAO Penman-Monteith Allen *et al.* (2006) technique (Equation 1), the crop reference evaporation (ETo) was computed as follows:

$$\mathbf{ET_o} = \frac{\mathbf{0.408\Delta\ (Rn - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}}{\mathbf{\Delta + \gamma\ (1 + 0.34\ U_2}}$$

Where:

ETo = "The daily reference evapotranspiration (mm/day)", es =" Saturation vapor pressure (kPa)", Ea = "Actual vapor pressure (kPa)", Δ = "The slope of vapor pressure curve (kPa °C^{-1})", γ = "The psychometric constant (kPa °C^{-1})", Rn = "Net radiation at the crop surface (MJ m^{-2}/day), G = "Soil heat flux density (MJ m^{-2} day^{-1}), T = "Mean daily air temperature at 2 m height (°C)"

The crop evapotranspiration (ETc) was estimated by using technique of dual crop coefficient for every crop phonological approach Allen *et al.*, (2006), Equation (2) looks like follows:

$$ET_c = (K_{cb} + K_e) \times ET_o$$

Where:

ET_c = crop evapotranspiration (mm), the reference crop evapotranspiration ETo (mm) is obtained by dividing the coefficient Kc into two distinct values: the soil water evaporation coefficient Ke and the basal crop coefficient K_{cb}. The network of drip irrigation was consists of lateral's GR with diameter (16 mm), and emitters with distance (25 cm). The outcomes of the water irrigation analysis are shown in Table (2).

Table 2. Characters of water irrigation analysis during two planting seasons (2022 and 2023)

	Water irrigation analysis		
pH	7.4	EC (dS cm^{-1})	0.66
	Ions mg/L		
Ca^{++}	80.12	HCO^-_3	590.2
K^+	26.01	$CO^=$	-
$Na^=$	345	Cl^-	255.8
Mg^{++}	144	SO_4	687.9

2.Treatments of melatonin:

Melatonin is a commercial compound obtained from Union for Agricultural Development Company. Plants were sprayed when 4-5 true leaves appeared about a month after planting. Okra plants were sprayed with melatonin in three stages, with an interval of 15 days between each stage. All foliar sprays were meticulously applied to cover the entire plant foliage, with runoff occurring early in the morning.

Experimental set up

The date of planting was (1st April). Seeds of the cultivar were acquired from the Ministry of Agriculture and Land Reclamation's vegetable Breeding Department at the Agricultural Research Center's Horticulture Research Institute. Morpho-agronomic characteristics as light green leaf and green fruit color and yellow flower color.

The experimental site for the cultivation of okra has been prepared in accordance with the recommendations of the Ministry of Agriculture in Egypt. While preparing the soil, A total of three doses of N as NH_4NO3 (33.5 % N), or 357.14 kg/ha, P was applied at a 357.14 kg/ha rate as Ca $(H_2PO_4)_2$ (15.5%, P_2O_5) and K as K_2SO_4 (48% K_2O), at a rate of 120 kg/ha. were given at various phases of the crop's development. The first dose was applied at the beginning of the vegetative growth phase, the second dosage at the initially begins of the flowering phase, and the third dosage was administered as soon as the crop entered the pod production stage. A distance of 0.30 meters separated each of the three rows of okra seeds, which were each 4 meters long and 3 meters wide. One seedling per hill was removed from the plants after 15 days of planting.

Harvesting

Fruit harvesting commenced for early yield 65 days after sowing, followed by subsequent harvesting cycles occurring every 3 days over a period of 80 days during both seasons.

Experimental data collection:

From each treatment within every duplicate, plants were random selected for gathering information on fruit quality, productivity, flowering, and growth.

1.Vegetative, root system and flowering parameters

The following vegetative root system and flowering characteristics were observed for okra plants during flowering and harvesting phases including No. of branches/plant, plant height (cm), leaf area index, root length (cm), root weight (gm) and evaluate the percentage of leaf greenness in okra leaves using the SPAD chlorophyll meter indicator Minolta, (1989); Yadava (1986) and days to flowering.

2. Yield and quality pod parameters

Fruit yield parameters include the number of fresh pods produced per plant, the weight of fresh pods per plant (g), the average pod length (cm), the pod diameter (mm), the fruit shape index, the weight of dry pods per plant (gm) and the total fruit production ton/fed.. Furthermore, the weight of all fruits harvested during the first four pickings was evaluated to determine the early yield ton per fed..

3.Chemical composition parameters

a- Chemical pod parameters

The fresh fruit juice's total soluble solids content (TSS) has been calculated using a hand refractrometer plus vitamin C. According to Ranganna (1986), the vitamin C content of fruits was determined by titrating them with potassium iodide, which was then computed as milligrams of vitamin C per 100 cm^3 of juice.

b- Catalase measures (unit mg^{-1} $protein^{-1}$):

Enzyme activity followed Chance and Maehly (1995) technique. The catalase activity was measured using a reaction solution that contained 0.1 mL of gum solution, pH 7, 5.9 mM hydrogen peroxide plus fifty mM buffered phosphate. The reaction was initiated by adding the sample then after 20 seconds the absorbance at 240 nm was measured. An absorbance variation of 0.01 units/ min was indicative of one unit of catalase enzyme activity.

4. Relative Water Content (RWC)

The estimation of RWC followed Abd Elbar *et al.* (2021) methodology. Fully formed leaf discs with a diameter of two centimeters were removed, weighed (FW) and submerged for two hours at 25 °C in filtered water before being weighed again for turgid weights (TW). After drying the samples for 24 hours at 110 °C in an oven, the dry weight (DW) was measured Perdones *et al.* (2016).

$$\mathbf{RWC}\,(\%) = \frac{(\mathbf{FW} - \mathbf{DW})}{\mathbf{TW} - \mathbf{DW}}\,\boldsymbol{x100}$$

Analytical statistics

All data were statistically analyzed in accordance with the protocol outlined by Snedecor and Cochran (1989), and as Duncan (1955) demonstrated, the treatment averages were contrasted applying multiple range tests by Duncan at the 0.05 level of probability.

RESULTS AND DISCUSSION

1. Vegetative, root system and day to flowering parameters

The information presented in Table (3) demonstrated how levels of irrigation and melatonin concentration affected the foliage growth characters of okra in the seasons of 2022 and 2023, including plant height (cm), index of leaf area, No. of branches/plant, index of chlorophyll level (SPAD), root length (cm), and root weight (gm).

The outcomes displayed in Table (3) shown that enhancement of irrigation levels from 60 % up to 100 % from ETo led to a large and steady increase in the vegetative growth parameters.

The data showed that the plants that received 100% of their water from ETo had the greatest mean values of height of the plants (116.27 and 117.07 cm), No. of branches/plant (5.59 and 5.81), leaf area index (2.82 and 2.94), SPAD chlorophyll content (34.42 and 32.05), root length (34.20 and 32.00 cm) and root weight (162.54 and 159.69 gm) of okra plants throughout two seasons. These outcomes concur with those attained by Sharma *et al.* (2016) and Tiwari *et al.* (1998) on plant of okra. We agree with Al-Bayati *et al.* (2020) on the vegetative development boundaries No. of branches per plant and plant height were further developed day by day using the drip water system. According to Ibrahim *et al.* (2020) trickling water system frameworks can save between 70 and 80 percent of the water used in traditional water system frameworks. In the study by Kotb *et al.* (2018) the most notable critical mean upsides of roots, stems and leaves were achieved by rehashing the development of the water system using the lower measure (30% exhaustion percentage). Agreed with Müller *et al.* (2016), who said that a proper booking of the trickle water system assists lessening water by pushing through vegetation by improving the accessibility of soil water within the root area, our outcomes addressed expanding okra markers through the water system. Furthermore, a lack of water results in a reduction of vegetative boundaries, based on the kind of harvest growth stage and favorable circumstances Kirda (2002). As reported by Diego *et al.* (2019), okra plants alter their metabolism to better withstand stress when they receive very little irrigation (25% of ETc).

The data shown in Table (3) demonstrate abundantly evident that, when compared to the untreated plants (tap water), all growth indices including root system and chlorophyll SPAD, significantly increased in response to melatonin spraying at varied concentrations (100, 150, and 200 mg/L). The okra treated with varying concentrations of melatonin showed the lowest vigor of plant growth, whereas the treatment of 200 mgl^{-1} melatonin produced the highest results. Conversely, control plants (those that were given water) showed less vigorous development. Throughout the course of both experiment seasons these increases were real and statistical.

These results are consistent with research that raised chlorophyll content in tomatoes by (Karaca and Cekic, 2019), boosted root growth in cucumbers by (Farag, 2020) and increased chlorophyll content in peppers by (Kaya and Doganlar, 2019). Melatonin may be the cause of this outcome because it speeds up growth, slows down senescence, and affects cell division, root and coleoptile formation, tropism responses, and circadian rhythm modulation (Zhang *et al.*, 2016).

The effects of the interaction between irrigation levels and various melatonin treatment concentrations on okra growth indicators during both experimental seasons are displayed in Table (3). These findings showed that melatonin treatment of okra plants was superior at all watering levels. When there were no significant variations between 100% ETo + 200 mg/L melatonin and 80% ETo + 200 mg/L melatonin on these parameters, It was showed that the plants receiving 100% ETo irrigation and 200 mg/L melatonin treatment had the highest average values. Melatonin, a unique, powerful and natural antioxidants that efficiently reduces the oxidative effects of water scarcity in plants, may be responsible for these discoveries (Arnao and Hernández-Ruiz, 2015; Arnaoand Hernández-Ruiz, 2019). In addition, melatonin can be used topically (Li *et al.*, 2019) also mixed with irrigation (Xia *et al.*, 2020) in order to lessen the impacts of drought stress.

Table 3. Impact of irrigation amounts and exogenous melatonin on vegetative stages, chlorophyll and root system parameters of okra during 2022 and 2023 seasons.

Treatments		Plant heights (cm)		No. branches /plant		Index of Leaf area		Chlorophyll content index		Root length (cm)		Root weight gm/plant	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Impact of irrigation levels (from ETo)													
60 %		79.87c	81.00c	2.44c	2.80c	1.38c	1.42c	25.15b	23.84c	22.21c	22.79c	118.68c	121.12c
80 %		115.32b	115.63b	5.46b	5.32b	2.76b	2.78b	34.20a	31.70b	33.07b	31.26b	161.10b	158.08b
100 %		116.27a	117.01a	5.59a	5.81a	2.82a	2.94a	34.42a	32.05a	34.20a	32.00a	162.54a	159.69a
Impact of melatonin (mg/L)													
Control		76.26d	76.58d	2.93d	2.81d	1.45d	1.34d	23.67d	21.46d	22.52d	21.23d	112.98d	113.68d
100 mg/L		103.00c	106.58c	4.56c	4.68c	2.18c	2.26c	28.80c	26.12c	29.00c	27.88c	144.24c	141.03c
150 mg/L		114.02b	114.65b	5.21b	4.98b	2.58b	2.65b	33.69b	32.66b	32.84b	31.43b	160.42b	161.24b
200 mg/L		122.37a	120.89a	5.35a	6.09a	3.06a	3.17a	38.87a	36.55a	35.84a	34.91a	173.73a	170.26a
Impact of irrigation levels (from ETo) X melatonin (mg/L)													
60 %	Control	71.73h	69.05g	1.20j	1.26h	1.04h	0.93h	20.07h	18.59h	19.87h	20.27j	104.69g	110.38j
	100 mg/L	76.20g	79.61f	2.27i	2.51g	1.28g	1.39f	24.96g	22.89f	21.82g	22.14h	114.00f	116.08h
	150 mg/L	82.57e	84.40e	3.07h	3.27f	1.49f	1.51e	27.18f	26.09d	23.03f	23.44g	123.94e	122.89g
	200 mg/L	89.00d	90.92d	3.20g	4.14e	1.70e	1.83d	28.41e	27.78c	24.12e	25.29f	132.07d	135.14f
80 %	control	77.76fg	79.60f	3.70f	3.23f	1.40fg	1.28g	23.97g	22.11g	23.80ef	20.93i	113.72f	112.94i
	100 mg/L	115.86c	120.12c	5.68d	5.73c	2.68c	2.71c	31.33c	27.74c	32.47d	30.30e	160.45c	154.53e
	150 mg/L	129.70b	129.48b	6.27c	5.30d	3.16b	3.25b	37.04b	36.00b	37.29c	34.90c	180.45b	182.03c
	200 mg/L	138.25a	135.84a	6.39ab	7.00a	3.80a	3.86a	44.45a	40.95a	41.30a	39.50a	195.54a	189.25a
100 %	control	79.28f	81.09f	3.89e	3.93e	1.92d	1.81d	26.97f	23.67e	23.88ef	22.48h	120.54e	117.71h
	100 mg/L	116.93c	120.02c	5.74d	5.80c	2.59c	2.67c	30.12d	27.72c	32.70d	31.20d	158.26c	152.48e
	150 mg/L	129.80b	130.07b	6.29bc	6.38b	3.09b	3.18b	36.84b	35.89b	38.21b	35.94b	176.87b	178.80d
	200 mg/L	139.05a	135.91a	6.45a	7.13a	3.67a	3.82a	43.76a	40.92a	42.10a	39.93a	193.57a	186.40b

2. Days to flowering, yield and quality pod parameters

It is possible to think of yield and its various components as a reflection of every growth characteristic. The responses of okra's physical pod parameters, i.e., fruit shape index, pod diameter (mm), pod length (cm), early yield (ton/fed.), number of fresh pods per plant, fresh pod weight/plant (gm), dry pod weight/plant (gm), and total pod yield (ton/fed.), to irrigation levels and melatonin concentrations during both seasons were displayed in Tables 4 and 5.

Regarding the impact of the irrigation amounts in the two seasons, there were notable increases in yield and physical pod parameters along with a reduce in the number of days to flowering (62.99 and 63.34) (Tables 4 and 5). With only one exception of the fruit shape index, which decreased as irrigation amounts increased from 60% to 80% from ETo, the highest values were obtained from 100% of the ETo treatment during both seasons, followed by 80%, then 60%. In contrast, there was no discernible difference between 80% and 100% from ETo during either of the experimental seasons. The outcomes for physical pod characteristics and yield are in accordance with comparable outcomes to those described by (Tiwari *et al.,* 1998), (Panigrahi *et al.,* 2014) and (Sharma *et al.,* 2016). Frequent and consistent application of drip irrigation keeps the crop root zone wet, which increases the plant's availability of water and nourishment (Kaushal *et al.,* 2011).

Table 4. Impact of irrigation amounts and exogenous melatonin on flowering, quality pod parameters of okra during 2022 and 2023 seasons.

Treatments		Days to flowering		Fresh pod length (cm)		Fresh pod diameter (mm)		Fruit shape index	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Impact of irrigation levels (from ETo)									
60 %		70.72a	71.91a	3.26c	3.31c	12.33c	12.14c	0.26a	0.27a
80 %		63.80b	63.79b	3.81b	3.85b	14.91b	15.35b	0.26ab	0.25b
100 %		62.99c	63.34c	3.98a	3.89a	16.19a	15.53a	0.25b	0.25b
Impact of melatonin (mg/L)									
Control		70.94a	71.15a	3.16d	3.15d	11.60d	11.18d	0.27a	0.28a
100 mg/L		67.00b	66.80b	3.47c	3.49c	13.72c	14.43c	0.25b	0.24b
150 mg/L		64.74c	64.77c	3.92b	3.96b	15.43b	15.35b	0.25b	0.26c
200 mg/L		61.42d	62.73d	4.19a	4.15a	17.17a	16.40a	0.25b	0.25d
Impact of irrigation levels (from ETo) X melatonin (mg/L)									
60 %	Control	75.12a	75.51a	2.79j	2.88h	10.70k	10.37l	0.26bc	0.28b
	100 mg/L	72.51b	73.27b	3.13i	3.25f	12.44i	12.31i	0.25cd	0.27c
	150 mg/L	70.65c	70.80c	3.47f	3.51f	12.65h	12.56h	0.27ab	0.28b
	200 mg/L	64.61e	68.06e	3.65de	3.62e	13.54f	13.34g	0.27b	0.27c
80 %	Control	69.84c	69.65d	3.29h	3.25g	11.48j	11.43k	0.29a	0.29a
	100 mg/L	64.15e	63.58f	3.60e	3.58ef	13.03g	15.43f	0.27ab	0.24e
	150 mg/L	61.17g	61.81g	3.93c	4.17c	16.47d	16.70d	0.24de	0.25d
	200 mg/L	60.05h	60.12h	4.47a	4.40a	18.67b	17.84b	0.24de	0.25de
100 %	Control	67.87d	68.29e	3.38g	3.31f	12.62h	11.73j	0.27b	0.28b
	100 mg/L	64.34e	63.55f	3.68d	3.63d	15.70e	15.56e	0.24de	0.24e
	150 mg/L	62.39f	61.69g	4.35b	4.19b	17.16c	16.80c	0.25c	0.25d
	200 mg/L	59.61h	60.02h	4.52a	4.43a	19.29a	18.02a	0.23e	0.24e

Notably, information in Tables (4 and 5) demonstrated how melatonin affected metrics related to quality, yield and number of days to flowering. It was found increased significantly with spraying of melatonin. All concentration increased the yield and physical parameters over the control except fruit shape index when the number of days to flowering fell as spraying increased at high concentrations of melatonin. On the contrary, the greatest yield parameter values were recorded with 200 mg/ L comparing to the untreated plants (tap water).

Days to flowering, yield and physical pod parameters of okra are significantly impacted by the interaction between the two elements under study, namely irrigation levels and melatonin concentrations in the two seasons. Tables (4 and 5) with data indicated that the lowest values for the number of days till flowers appears and the highest values of No. fresh pods per plant, fresh pods weight/plant (g), diameter of fresh pod (mm), the average pod length (cm), dry pods weight/plant (gm), early yield ton per fed. and average total pod yield ton/fed. were resulted from irrigation okra with 100% when interaction with 200 mg/L, However, there was no discernible difference between the treatment groups receiving 100% + 200 mg/L or 80% + 200 mg/L treatment on all yield and quality pod parameters. Improved quality and quantity of the yield on okra are agreement with those obtained by (Khalid *et al.,* 2022) in crops under abiotic stresses. This result may be due to melatonin is efficient in reducing oxidative damage, leaf senescence brought on by drought, and photosystem inhibition, all of which increase crop production (Sharma, *et al.,* 2020) on carya plants.

Table 5. Impact of irrigation amounts and exogenous melatonin on early yield and yield parameters of okra during 2022 and 2023 seasons.

Treatments		Number of fresh pods per plant		Fresh pod weight (gm per plant)		Early yield (ton per fed.)		Total pod yield (ton per fed.)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Impact of irrigation levels (from ETo)									
60 %		25.30c	25.22c	233.82c	224.24b	0.26b	0.28b	4.26c	4.08c
80 %		32.17b	31.90b	315.49b	316.30a	0.47a	0.47a	5.74b	5.76b
100 %		33.05a	32.26a	323.79a	320.46a	0.48a	0.48a	5.89a	5.83a
Impact of melatonin (mg/L)									
Control		22.39d	22.69d	189.23d	202.42d	0.22d	0.24d	3.44d	3.69d
100 mg/L		27.34c	27.33c	291.35c	282.23c	0.39c	0.40c	5.30c	5.14c
150 mg/L		33.27b	32.24b	306.25b	304.16b	0.46b	0.44b	5.57b	5.54b
200 mg/L		37.70a	36.91a	377.30a	359.18a	0.55a	0.55a	6.87a	6.54a
Impact irrigation levels (from ETo) X melatonin (mg/L)									
60 %	Control	19.35h	20.14h	169.56j	187.25h	0.20j	0.21h	3.09e	3.41h
	100 mg/L	23.60g	24.17f	225.42g	216.14f	0.25g	0.26f	4.10de	3.93f
	150 mg/L	27.30e	26.82e	237.44f	227.47e	0.28f	0.29e	4.32de	4.14e
	200 mg/L	30.96c	29.74c	302.86e	266.08d	0.31e	0.37d	5.51cd	4.84d
80 %	Control	22.81g	23.53g	185.30i	204.39g	0.22i	0.24g	3.37e	3.72g
	100 mg/L	28.75d	28.75d	329.93c	314.05c	0.46d	0.46c	6.01bc	5.72c
	150 mg/L	36.09b	34.93b	334.17c	341.75b	0.55c	0.52b	6.08b	6.22b
	200 mg/L	41.05a	40.37a	412.55a	404.99a	0.67b	0.65a	7.51a	7.37a
100 %	Control	25.01f	24.39f	212.82h	215.63f	0.23h	0.26f	3.88de	3.93f
	100 mg/L	29.68d	29.07d	318.71d	316.49c	0.46d	0.47c	5.80bc	5.76c
	150 mg/L	36.41b	34.97b	347.15b	343.25b	0.56c	0.52b	6.32b	6.25b
	200 mg/L	41.09a	40.62a	416.49a	406.45a	0.68a	0.65a	7.58a	7.40a

3. The structure of chemicals parameters and Relative Water Content (RWC)

The structure of chemicals parameters plus "Relative Water Content" for growth seasons of 2022 and 2023 are shown in Table (6). These parameters are impacted by irrigation levels, melatonin concentrations and their interactions.

Table 6. Impact of irrigation amounts and exogenous melatonin on chemical composition parameters and relative water content of okra during 2022 and 2023 seasons.

Treatments		TSS % (Brix)		Vitamin C (mg/100 g)		Catalase ($mg^{-1}protein^{-1}$)		Relative Water Content % (RWC)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Impact of irrigation levels (from ETo)									
60 %		3.70c	3.66b	12.24c	12.41c	66.97a	65.58a	65.31c	66.26c
80 %		4.70b	4.40a	13.76b	13.99b	44.26b	45.09b	78.69b	81.10b
100 %		4.89a	4.44a	13.88a	14.12a	42.72c	43.72c	80.30a	81.80a
Impact of melatonin (mg/L)									
control		3.53d	3.48d	11.94d	11.95d	62.92a	64.05a	63.68d	63.56d
100 mg/L		4.10c	3.97c	12.56c	12.67c	53.67b	53.38b	73.63c	75.20c
150 mg/L		4.61b	4.29b	13.77b	14.33b	49.31c	48.33c	77.18b	78.78b
200 mg/L		5.50a	4.93a	14.89a	15.05a	39.38d	40.10d	84.58a	88.02a
Impact of irrigation levels (from ETo) X melatonin (mg/L)									
60 %	control	3.37i	3.33j	11.65j	11.71g	83.36a	78.86a	59.86j	61.38h
	100 mg/L	3.47h	3.44i	12.16h	11.95f	69.25b	67.89b	62.24i	64.34f
	150 mg/L	3.67g	3.69f	12.47g	12.93d	62.51c	63.62c	65.56g	64.19f
	200 mg/L	4.30f	4.17e	12.66f	13.03cd	52.77e	51.96f	73.58e	75.14d
80 %	control	3.49h	3.51h	12.00i	11.95f	54.99d	59.40d	64.07h	63.45g
	100 mg/L	4.37f	4.22d	12.72f	13.00cd	46.27g	46.14g	78.72d	80.60c
	150 mg/L	4.93d	4.56c	14.37d	15.00b	43.04h	40.63h	82.28c	86.03b
	200 mg/L	6.11a	5.29a	16.03a	16.00a	32.74i	34.19i	89.67a	94.34a
100 %	control	3.73g	3.60g	12.17h	12.20e	50.40f	53.90e	67.10f	65.86e
	100 mg/L	4.45e	4.24d	12.81e	13.08c	45.49g	46.11g	79.92d	80.65c
	150 mg/L	5.22c	4.61b	14.48c	15.07cd	42.36h	40.73h	83.70b	86.12b
	200 mg/L	6.18a	5.31a	16.08a	16.12a	32.62i	34.14i	90.49a	94.58a

The findings shown in Table 6 show that irrigation amounts have a significantly led to the highest okra total soluble solids content TSS (%), Vitamin C and "RWC" during both seasons compared to control plants but decrease catalase enzyme (unit mg^{-1} $protein^{-1}$). Specifically, the highest level of water irrigation 100% from ETo resulted in the highest mean values for TSS (4.89 and 4.44%), Vitamin C (13.88 and14.12 mg/100 g**)** and (RWC) (80.30 and 81.80 %), and lowest value of catalase enzyme (42.72 and 43.72unit mg^{-1} $protein^{-1}$).

The findings in Table (6) reveal that foliage spray of melatonin concentrations at the highest concentration (200 mg/L) produced the mean values that were highest for okra fruits chemical composition, including vitamin C, TSS % and RWC %, when concentration of the catalase (unit mg-1 protein-1) decreased with successive increases of melatonin concentrations. In comparison, control plants exhibited the lowest significant mean values during both seasons.

Moreover, the combination of the highest irrigation rate (100% from ETo) with the highest melatonin concentrations (200 mg/L) contributed to a significant enhanced in TSS (%), Vitamin C and (RWC %) in comparison with plants within control, which exhibited the lowest significant mean values during both seasons and while decreasing catalase (unit mg^{-1} $protein^{-1}$). Regarding the chemical composition parameters and the RWC (Relative Water Content)., the application of (100% from ETo) combined with the highest applied level of melatonin concentrations (200 mg/L) resulted in the best significant mean values during the two seasons, while, there were not any significant variations between the treatment with (100% from ETo + 200 mg/L melatonin) and the treatment with the (80% from ETo + 200 mg/L melatonin) on chemical composition parameters and RWC. These results correspond with those that (EL-Bauome *et al.,* 2022) in cauliflower. These results may be due to one or more of these reasons melatonin controls stomatal motility, which helps plants in drought maintain their water status. (Wei *et al.,* 2018), maintaining cell membrane integrity (Wu *et al.,* 2016), lowering cytotoxic biochemical biological indicators like MDA and H_2O_2 and increasing the activity of antioxidant enzymes (Khan *et al.,* 2020). Melatonin inhibits the reversible effects of drought stress by regulating the synthesis and activity of essential organic substances, particularly proteins, nitrogen-related molecules, and chlorophyll Zhao *et al.* (2015).

CONCLUSION

The results demonstrated significant positive effects when used irrigation at 100 % from ETo, showing improvements in all assessed characteristics. Similarly, melatonin, when individually applied as a foliar spray at the highest concentration (200 mg/L), exhibited significant positive impacts across all studied traits. Moreover, combining irrigation at 100 % from ETo with 200 mg/L melatonin resulted in substantial increases in the evaluated parameters, but there was not a significant variation between the two doses (100% + 200 mg/L or 80 % + 200 mg/L) in the many characteristics.

Based on the positive outcomes observed, it is recommended to consider foliar spraying with melatonin at a concentration of 200 mg/L for maximizing the growth, flowering, and yield of okra in arid regions. The synergistic effects observed with the combined application of 80% of ETo + 200 mg/L and melatonin suggest the potential for an integrated approach. Future studies could explore and fine-tune the optimal ratios for achieving the best results. It is recommended that more research be done to better understand the physiological and molecular elements that underlie the favorable responses to melatonin during water stress. This would contribute to a more comprehensive understanding of their interactions and potential synergies. Considering the practical implications, farmers and agricultural practitioners in arid regions may benefit from adopting foliar spraying with melatonin to decrease the water pressure in plants and enhance okra productivity.

In summary, the results emphasize not only the promising potential of melatonin, but also the importance of using it to increase plant capacity to water stress regime and also for sustainable agricultural practices in difficult environments.

REFERENCES

Abd Elbar, O. H., Elkelish, A., Niedbała, G., Farag, R., Wojciechowski, T., Mukherjee, S., Abou-Hadid, A. F., El-Hennawy, H. M., Abou El-Yazied, A., Abd El-Gawad, H. G. (2021). Protective effect of -aminobutyric acid against chilling stress during reproductive stage in tomato plants through modulation of sugar metabolism, chloroplast integrity, and antioxidative defense systems. Front. Plant Sci., 12, 663750. [CrossRef]

Abdel-Fattah, B. E. S., Haridy, A. G., and Abbas, H. S. (2020). Response to planting date, stress tolerance and genetic diversity analysis among okra (*Abelmoschus esculentus* L.) Moench.) varieties. Genet Resour Crop Evol, 67, 831–851.

Adiroubane, D., and Letachoumanane, S. (1992). Growth and yield performance of okra (*Abelmoschus esculentus* L.) cultivars. Ind J Agric Sci, 68, 168–170.

Ahmad, P., Jamsheed, S., Hameed, A., Rasool, S., Sharma, I., Azooz, M., Hasanuzzaman, M. (2014). Drought stress induced oxidative damage and antioxidants in plants. In Oxidative Damage to Plants; Elsevier: Amsterdam, The Netherlands; pp. 345–367. [CrossRef]

Allegra, M., Reiter, R. J., Tan, D. X.; Gentile, C., Tesoriere, L. and Livrea, M. A. (2003). The chemistry of melatonin's interaction with reactive species. J. Pineal Res. 2003, 34, 1-10.

Arnao, M. B. and Hernandez-Ruiz, J. (2020). Is phytomelatonin a new plant hormone? Agronomy, 10:95.

Arnao, M. B., Hernández-Ruiz, J. (2019). Melatonin: A New Plant Hormone and/or a Plant Master Regulator? Trends Plant Sci., 24, 38–48. [CrossRef] [PubMed]

Arnao, M. B., Hernandez-Ruiz, J. (2015). Functions of melatonin in plants: A review. J. Pineal Res., 59, 133–150. [CrossRef]

Chance, B. and Maehly, A. C. (1995). Assay of catalase and peroxidase. Methods in Enzymology, vol. 2: 764-775. http:// dx.doi.org/10.1016/S0076-6879(55)02300-8.

Diego, B., Farias, S., Paulo, S. O. S., Ariovaldo, A. T., Maria, I. F., Tiago, J. S., Pryanka, T. Nascimento F., Luiz, F. G. O. J. (2019). Physiological and productive parameters of the okra under irrigation levels. Scientia Horticulturae Volume 252, 27 June, Pages 1-6.

Duncan, D. B. (1955). "Multiple Range and Multiple F Tests". Biometrics, 11: 1–42. doi :10. 2307/3001478

EL-Bauome, H. A., Emad, A. A., Mahmoud A. M. A., Doaa, B. E. D., Moodi, S. A., Mohamed, M. E., Mohammed, A. B., Salem, M. A., Nadi, A. A., Fahad, M. A., Abdulrahman, A., Ismail, A. I., Eldessoky, S. D. and Samar, M. A. D. (2022). Exogenous Proline, Methionine, and Melatonin Stimulate Growth, Quality, and Drought Tolerance in Cauliflower Plants. Agriculture, 12, 1301. https://doi.org/ 10.3390/ agriculture12091301. https://www. mdpi. com/journal/agriculture.

Elkelish, A., El-Mogy, M. M., Niedbała, G., Piekutowska, M., Atia, M. A. M., Hamada, M. M. A., Shahin, M., Mukherjee, S., El-Yazied, A. A., Shebl, M., *et al.* (2021). Roles of exogenous-lipoic acid and cysteine in mitigation of drought stress and restoration of grain quality in wheat. Plants, 10, 2318. [CrossRef].

Elkelish, A., Ibrahim, M. F. M., Ashour, H., Bondok, A., Mukherjee, S., Aftab, T., Hikal, M., El-Yazied, A.A., Azab, E., Gobouri, A.A., *et al.* (2021). Exogenous application of nitric oxide mitigates water stress and reduces natural viral disease incidence of tomato plants subjected to deficit irrigation. Agronomy, 11, 87. [CrossRef].

FAO. (2019). http://faostat.fao.org.

Farag, M. M., Mahmoud, A., Arnao, M. B., Sheteiwy, M. S., Dafea, M., Soltan, M., Elkelish, A., Hasanuzzaman, M., Ai, S. (2020). Melatonin-induced water stress tolerance in plants: Recent Advances. Antioxidants, 9, 809. [CrossRef] [PubMed]

Galano, A., Tan, D. X. and Reiter, R. J. (2013). On the free radical scavenging activities of melatonin's metabolites, AFMK and AMK. J. PinealRes., 54: 254- 257.

Hashim, A., Alharbi, B., Abdulmajeed, A., Elkelish, A., Hozzein, W., Hassan, H. (2020). Oxidative stress responses of some endemic plants to high altitudes by intensifying antioxidants and secondary metabolites content. Plants, 9, 869. [CrossRef] [PubMed].

Hussein, H. A., Metwally, A. K., Farghaly, K. A., and Bahawirth, M. A. (2011). Effect of irrigation interval (water stress) on vegetative growth and yield in two genotypes of Okra. Aust J Basic Appl Sci, 5(12), 3024-3032.

Li, D., Zhang, D., Wang, H., Li, H., Song, S., Li, H., Li, R. (2019**)**. Effects of melatonin on germination and amino acid content in different wheat varieties seeds under polyethylene glycol stress. BioRxiv, 2019, 710954.

Ibrahim, M. F. M., Abd Elbar, O. H., Farag, R., Hikal, M., El-Kelish, A., El-Yazied, A. A., Alkahtani, J., Abd El-Gawad, H.G. (2020_a). Melatonin counteracts drought induced oxidative damage and stimulates growth, productivity and fruit quality properties of tomato plants. Plants, 9, 1276. [CrossRef].

Ibrahim, M. F. M., El-Samad, G. A., Ashour, H., El-Sawy, A. M., Hikal, M., Elkelish, A., El-Gawad, H. A., El-Yazied, A. A., Hozzein, W. N., Farag, R. (2020_b). Regulation of agronomic traits, nutrient uptake, osmolytes and antioxidants of maize as influenced by exogenous potassium silicate under deficit irrigation and semiarid conditions. Agronomy, 10, 1212. [CrossRef].

Ibrahim, Y. M., Abdalla, M. M., Ali, O. O. and Abdalhi, M. A. (2020). Effect of irrigation systems and water amount on yield of eggplant (*Solanum melongena*) under arid conditions. Agric. Biol. Sci. J., 6(3): 143-147.

Jackson, A., (1973). Soil Chemical Analysis. Prentice- Hall. India Private Limited, New Delhi.

Karaca, P., Cekic, F. Ö. (2019). Exogenous melatonin-stimulated defense responses in tomato plants treated with polyethylene glycol. Int. J. Veg. Sci., 25, 601–609. [CrossRef]

Kaushal, A. A., Lodhi, A. S. and Singh, K. G. (2011). Economics of growing sweet pepper under low tunnels. Progressive Agriculture, 11(2), 426–430.

Kaya, A., Doganlar, Z. B. (2019). Melatonin improves the multiple stress tolerance in pepper (*Capsicum annuum*). Sci. Hortic., 256, 108509. [CrossRef]

Khalid, M., Hafiz, M. R., Nisar, A., Sehar, N., Fozia, S., Shakeel, A., Muhammad, U. Iqrar, A., Rana, M. A., Qamar, U. Z. and Hon-Ming, L. (2022). Using exogenous melatonin, glutathione, proline, and glycine betaine treatments to combat abiotic stresses in crops. Int. J. Mol. Sci., 23, 12913. https://doi.org/10.3390/ijms232112913. https:// www. mdpi.com/journal/ijms.

Khan, A., Numan, M., Khan, A., Lee, L., Imran, M., Asaf, S., Al-Harrasi, A. (2020). Melatonin: awakening the defense mechanisms during Plant Oxidative Stress. Plants, 9, 407. [CrossRef].

Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit irrigation practices, FAO Water Report, Rome 22.

Kotb, H. M., Hegazi, H. H., Ghoneim, I. M. and Feleafel, M. N. (2018). Effect of water regime system and potassium silicate on dry mass production of sweet pepper plants grown in calcareous soil under greenhouse. Alex. J. Agric. Sci. 63(2):105-118.

Kul, R., Esringu, A., Dadasoglu, E., Sahin, U., Turan, M., Turan, M., Ors, S., Ekinci, M., Agar, G. and Yildirim, E. (2019). Melatonin: role in increasing plant tolerance in abiotic stress conditions. Abiotic and biotic stress in Plants, 1-19.

Kumawat, K. R., Sharma, N. (2018). Effect of drought stress on plants growth. Pop. Kheti, 6, 239–241.

Li, J., Yang, Y., Sun, K., Chen, Y., Chen, X., Li, X. (2019). Exogenous melatonin enhances cold, salt and drought stress tolerance by improving antioxidant defense in tea Plant (*Camellia sinensis* L.) O. Kuntze). Molecules, 24, 1826. [CrossRef]

Martinez, V., Nieves-Cordones, M., Lopez-Delacalle, M., Rodenas, R., Mestre, T. C., Garcia-Sanchez, F., Rubio, F., Nortes, P. A., Mittler, R., Rivero, R. M. (2018). Tolerance to stress combination in tomato plants: New Insights in the Protective Role of Melatonin. Molecules, 23, 535. [CrossRef] [PubMed].

Matlob, A. N., Sultan, A. M., and BdulBdul, K. S. (1989). Production of vegetables (revised version), the Directorate of Library for printing and publishing, the University of Mosul, Mosul, Iraq, pp: 674.

Minolta (1989). SPAD-502 Owner's manual. Industrial meter division. Minolta Corp., Ramsey,N.J.

Müller, T., Bouleau, C. R. and Perona, P. (2016). Optimizing drip irrigation for eggplant crops in semi-arid zones using evolving thresholds. Agricultural Water Management, 177: 54-65.

Page, A. L., R. H. Miller and D. R. Keeney (1982). Methods of Soil Analysis. Part 2. Chemical and microbiological properties. Amer. Soc. Agron. Madison Wisconsom, USA.

Panigrahi, P., Sahu N. N. and Pradhan, S. (2014). Evaluating partial root-zone irrigation and mulching in okra (*Abelmoschus esculentus* L.) under a sub-humid tropical climate. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 112(2), 169–175.

Perdones, Á., Escriche, I., Chiralt, A., Vargas, M. (2016). Effect of chitosan–Lemon essential oil coatings on volatile profile of strawberries during storage. Food Chem., 197, 979–986. [CrossRef]

Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable Products, New Delhi: Tata McGraw-Hill Book Co, pp. 106

Saied, E. M., Arenz, C. (2014). Small molecule inhibitors of ceramidases. Cell. Physiol. Biochem., 34, 197–212. [CrossRef]

Sharma, A., Wang, J., Xu, D., Tao, S., Chong, S., Yan, D., Li, Z., Yuan, H., Zheng, B. (2020). Melatonin regulates the functional components of photosynthesis, antioxidant system, gene expression, and metabolic pathways to induce drought resistance in grafted carya cathayensis plants. Sci. Total Environ., 713, 136675. [CrossRef] [PubMed]

Sharma, P., Kaushal, A., Singh, A. and Garg, S. (2016). Growth and yield attributes of okra under influence of drip irrigation. Sharma, P. *et al.* Int. Journal of Engineering Research and Applications www.ijera.com. ISSN: 2248-9622, Vol. 6, Issue 2, (Part - 5) February, pp.85-91.

Snedecor, G. W. and Cochran, W. G. (1989). Statistical methods, eighth edition. Iowa State University Press. pp. 491

Tan, D. X., Manchester, L. C., R. J., Plummer, B. F., Limson, j., Weintraub, S. T., Qi, W. (2000). Melatonin directly scavenges hydrogen peroxide: A potentially new metabolic pathway of melatonin biotransformation. Free Radic. Biol. Med., 29: 1177-1185.

Tiwari, K. N., Mal, P. K., Singh, R. M. and Chattopadhyay, A. (1998). Response of okra (*Abelmoschus esculentus* M.) to drip irrigation under mulch and non-mulch conditions, Agricultural Water Management, 38, 91-102.

Wei, J., Li, D.-X., Zhang, J.-R., Shan, C., Rengel, Z., Song, Z. B., Chen, Q. (2018). Phytomelatonin receptor PMTR1-mediated signaling regulates stomatal closure in Arabidopsis thaliana. J. Pineal Res., 65, e12500. [CrossRef] [PubMed].

Wu, Y., Lian, H., Mou, X. (2016). Effect of foliar spraying exogenous melatonin on physiological and biochemical characteristics of Dendranthema morifolium 'Chuju' seedlings under drought stress. Acta Bot. Boreali Occident. Sin., 36, 2241–2246.

Xia, H., Ni, Z., Hu, R., Lin, L., Deng, H., Wang, J., Tang, Y., Sun, G., Wang, X., Li, H. (2020). Melatonin alleviates drought stress by a non-enzymatic and enzymatic antioxidative system in kiwifruit seedlings. Int. J. Mol. Sci., 21, 852. [CrossRef]

Yadava, U. L. (1986). A rapid and nondestructive method to determine chlorophyll in intact leaves. Horticulture Science 21: 1449 –1450.

Zhang, N., Sun, Q., Li, H., Li, X., Cao, Y., Zhang, H., Li, S., Zhang, L., Qi, Y., Ren, S., Zhao, B. and Guo, Y-D. (2016). Melatonin improved anthocyanin accumulation by regulating gene expressions and resulted in high reactive oxygen species scavenging capacity in cabbage. Front. Plant Sci., 7:197.

Zhao, H., Su, T., Huo, L., Wei, H., Jiang, Y., Xu, L., Ma, F. (2015). Unveiling the mechanism of melatonin impacts on maize seedling growth: Sugar metabolism as a case. J. Pineal Res., 59, 255–266. [CrossRef].

تأثير الميلاتونين الخارجي على إجهاد نظام المياه لتحفيز النمو والجودة والإنتاجية لنباتات البامية في المناطق القاحلة

منى نمر شحاته[1] و نهلة احمد المغارى[2]

[1] قسم بساتين - خضر - كلية الزراعة والموارد الطبيعية – جامعة اسوان - مصر
[2] قسم تربية نباتات الخضر والنباتات الطبية والعطرية – مركز البحوث الزراعية – جيزة- مصر

الملخص

الأبحاث المتداولة حاليًا لا تقدم صورة واضحة عن كيفية تأثير الميلاتونين على نباتات البامية تحت ضغط النظام المائي. وبالتالي فإن الغرض من هذه الدراسة هو دراسة تأثير إحدى هذه المواد البيوكيميائية على نباتات الباميا التي تنمو في البيئات المائية المجهدة. أظهرت النتائج التي تم الحصول عليها أن الإجهاد المائي (60 و 80 و 100٪ من (ETo والرش الورقي بالميلاتونين (100 و 150 و 200 ملجم/لتر) أدى إلى تحسين ملحوظ ($P \leq 0.05$) في ارتفاع النبات وعدد الفروع والاوراق/النبات، دليل المساحة الورقة، طول الجذر، وزن الجذر، محتوى الكلوروفيل ، المحصول المبكر، عدد القرون الطازجة/نبات، وزن القرون الطازجة/نبات ومتوسط طول القرن، قطر القرن، مؤشر شكل الثمرة، وزن القرون الجافة/النبات والمحصول الكلى بالطن/الفدان، TSS، فيتامين C والمحتوى المائي النسبي مقارنة بالنباتات غير المعامة. وعلى العكس من ذلك، انخفض نشاط إنزيم الكتاليز بشكل ملحوظ مقارنة بالنباتات غير المعاملة. واخيرا يمكن أن نستنتج أن التطبيق الورقي للميلاتونين يمكن اعتباره استراتيجية مناسبة لتعزيز أداء النمو وإنتاجية البامية المزروعة تحت ظروف إجهاد النظام المائي ، وكانت أفضل معاملة هي 100٪ من ETo + 200 ملجم/لتر ميلاتونين، بينما لم تكن هناك فروق معنوية بين هذه المعاملة والمعاملة 80٪ من ETo + 200 ملجم/لتر ميلاتونين .