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Response of Maize Plants to Compost and Melatonin under Terraces and Alternate Furrow Irrigation Techniques

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THE CURRENT TREND is finding suitable irrigation techniques that conserve irrigation water and improve efficiency. So, a field experiment was conducted in the Experimental Farm of the Faculty of Agriculture, Mansoura Univ., El-Dakahlya Governorate, Egypt during the season of 2022, aimed to evaluate the growth performance and productivity of maize affected by different irrigation methods *i.e.,* terraces, traditional furrow and alternative furrow techniques as main plots under soil addition of compost as subplots (with application of compost at the rate of 7.0 ton fed^{-1} and the other without compost application), and foliar application of melatonin at different levels (1.0 and 2.0 mmol L^{-1}) as sub subplot. The trial was carried out in a split split-plot design with three replicates. The results showed that plants grown under alternative furrow irrigation technique without compost and melatonin had the highest values of enzymatic antioxidants *i.e.,* superoxide dismutase SOD (80.26, unit mg^{-1} $protein^{-1}$), peroxidase enzyme POD (246.54, unit mg^{-1} $protein^{-1}$), and catalase enzyme CAT (89.07, unit mg^{-1} $protein^{-1}$), at the period of 70 days from sowing, while the maize plants grown under terraces irrigation technique with compost and simultaneously sprayed with melatonin at the rate of 2.0 mmol L^{-1} possessed the lowest values of these enzymatic antioxidants (69.25, 178.28 and70.57 unit mg^{-1} $protein^{-1}$ for SOD,POD and CAT, respectively). On the contrary, the maximum values of growth parameters and chemical constitute at 70 days from sowing (fresh and dry weight, leaf area chlorophyll content, N, P, K) as well as yield and its components and bio chemical traits of grains at harvest stage *e.g.,* the weight of 1000 grain , cob length, No. of rows cob^{-1}, grain and biological yield, total carbohydrates, protein and oil content in grain were recorded with terraces irrigation technique plus compost and melatonin at rate of 2.0 mmol L^{-1}. Generally, it can be concluded that maize plant irrigation should be with the terrace technique and simultaneously addition of compost as water absorbent substance and foliar application of melatonin as a biological hormone regulates plant physiology.

Keywords: Terraces, furrow, alternate, compost, melatonin and maize.

1. Introduction

Due to the continuously increasing population in Egypt, the gap between both demands and supplies of irrigation water is extending day after day and will reach alarming levels posing a threat to Food security (Sary *et al.,* 2021). In Egypt, people are under the water poverty limit (less than 1000 m^3 of water per person per year) (Abdelhaleem *et al.,* 2021). Irrigation scheduling is considered a strategy to delivery of irrigation water for a crop timely and accurately. (Ashour *et al.*, 2021).

Researchers are working on finding new techniques to conserve irrigation water. One of the pioneers who penetrate this field was Milligan (1973) when introduced a very interesting title " Should I irrigate only every other row?", where he stated that

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this technique achieved huge water savings (nearly 50%), while the grain yield of maize was normal or only slightly reduced. According to the annual report of the ICARDA organization (2000), the alternate furrow irrigation strategy was presented as an able method to enhance soil and water resources thus raising economic outputs in the region, which used this technique (Golzardi *et al.,* 2017). Abd El-Halim, (2013) reported that alternate furrow irrigation is one of the most effective tools to reduce irrigation water quantity and costs, produce a higher crop yield, enhance irrigation efficiency, and increase maize yield. Kannan *et al.,* (2009) reported that the terrace technique is one of the necessary measures to raise water conservation as well as assessment the depletion of essential elements for obtaining maximum crop yield.

Compost is a wealthy source of organic matter (Hussein *et al.,* 2022). It improves the plant growth performance and increase crop yield and quality due to it enhances soil physical attributes *i.e.,* structure, porosity, bulk density, water holding capacity, hydraulic conductivity, compression strength and water permeability (Ghazi *et al.,* 2022) and soil chemical characteristics such as soil content of nutrients and organic matter (Awwad *et al.,* 2022).

Melatonin is a crucial biological hormone that possesses so important role in regulating higher plant physiology (Saleh *et al.,* 2019) photosynthesis (Abd El-Ghany and Attia, 2020), immunological enhancement and antioxidant activity (Tripathi *et al.,* 2021) and scavenging produced Reactive Oxygen Species (ROS) responsible for destroying plant cells in plants due to various abiotic stresses (Arnao and Hernández- Ruiz, 2021).

Maize plant (*Zea mays* L.) was used in this research trial due to its pronounced response to water alterations in its root zone (El-Sherpiny *et al.,* 2020). Moreover, it is one of the more important crops in Egypt, where its cultivated area in Egypt is approximately 2.7 million feddan behind wheat and rice crops (Yaseen *et al.,* 2020). Also, maize has a high nutritional value represented in its minerals *i.e.,* nitrogen, phosphorus, potassium and magnesium as well as its grain is used for producing healthy oil (Ghazi and El-Sherpiny, 2021).

So, the specific objectives of the current investigation were to evaluate the response of maize plants grown under different irrigation techniques (terraces, traditional furrow and alternative) to compost soil addition with foliar application of melatonin.

2. Material and Methods

2.1 Experimental Site

The current research work was conducted in the Experimental Farm of Faculty of Agriculture, Mansoura Univ., El-Dakahlya Governorate, Egypt during season of 2022.

2.2 Analysis of Soil and Compost

Before maize sowing, at a depth of 0.0-30 cm, a composite initial soil sample was taken then analyzed depending on Dane and Topp (2020) and Sparks *et al.,* (2020). Table 1 illustrates the characteristics of the initial soil. Plant residues (stover plus leaves of maize) were obtained then the composting process was done 7 months before the execution of the research field experiment in the site of the experiment as described by El-Hammady *et al.,* (2003). Table 2 shows the characteristics of the compost studied.

Table 1. Properties of the initial soil.

Characteristics	Values
Available N, mg kg^{-1}	49.5
Available P, mg kg^{-1}	7.20
Available K, mg kg^{-1}	205
Organic matter,%	1.35
EC_w, dS m^{-1}	2.85
pH (1:2.5 soil suspension)	8.00
Sand,%	15.00
Silt ,%	37.20
Clay,%	47.80
Texture class is clayey	

Table 2. The characteristics of the compost studied.

Properties	Values
C:N ratio	**11.5**
Total C, %	**18.4**
Total N, %	**1.60**
pH	**6.14**
EC, dSm^{-1}	**3.45**
P , mg kg^{-1}	**0.92**
K, mg kg^{-1}	**0.85**
Mn, mg kg^{-1}	**28.0**
Zn , mg kg^{-1}	**25.0**

1. Experimental Setup.

A field experiment was conducted aiming to evaluate the growth performance and productivity of maize "***Zea mays* L. Cv single Hybride 10**" affected by different irrigation regimes *i.e.*, terraces, traditional furrow and alternative furrow techniques the main plots under soil addition of compost the sub plot (the first with application of compost at rate of 16.8 ton ha^{-1} and other without compost) with foliar application of melatonin at different levels (1.0 and 2.0 mmol L^{-1}) as sub subplot.

The schematic diagram illustrating the distribution of titanium treatments as related to the layout of the trial

Treatments	Terraces	Control	Without (control)	R_1	R_2	R_3
			Melatonin at rate of 1.0 mmol L^{-1}	R_2	R_3	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_3	R_2	R_1
		Compost	Without (control)	R_1	R_2	R_3
			Melatonin at rate of 1.0 mmol L^{-1}	R_2	R_3	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_3	R_2	R_1
	Furrow	Control	Without (control)	R_1	R_2	R_3
			Melatonin at rate of 1.0 mmol L^{-1}	R_2	R_3	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_3	R_2	R_1
		Compost	Without (control)	R_1	R_2	R_3
			Melatonin at rate of 1.0 mmol L^{-1}	R_3	R_2	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_1	R_2	R_3
	Alternative	Control	Without (control)	R_2	R_3	R_1
			Melatonin at rate of 1.0 mmol L^{-1}	R_3	R_2	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_1	R_2	R_3
		Compost	Without (control)	R_2	R_3	R_1
			Melatonin at rate of 1.0 mmol L^{-1}	R_3	R_2	R_1
			Melatonin at rate of 2.0 mmol L^{-1}	R_1	R_2	R_3

The source of irrigation was Nile River**.** The volume of sprayed melatonin solution was 600 L ha^{-1}. The trial was carried out in a split split-plot design with sub sub-plot area of 10.5 m^2 and the treatments were replicated three times. At one month before sowing, compost was mixed with the soil surface layer. Seeds were obtained from the Ministry of Agri. and Soil Rec (MASR). The sowing was executed on May 6th. Before sowing, the experimental site received calcium superphosphate (6.6%P) at rate of 600 kg per hectare. Also, 600 kg urea (46 % N) per hectare was applied after divided into two equal doses, the first dose was applied before life watering (the 2nd irrigation), and the 2nd dose was applied before the next one (the 3rd irrigation). Potassium sulphate (39.8 % K) was applied at rate of 120.0 kg per hectare in one dose before the fourth irrigation. The external application of melatonin was repeated three times with 15 days intervals starting from the third irrigation. On Augustus 30th, the harvest process was done. Other traditional agricultural practices were executed according to the MASR recommendation.

2.3 Measurement traits

Measurements at 70 days from cultivation

Enzymatic antioxidants: Superoxide Dismutase SOD, peroxidase enzyme POD and catalase enzyme CAT were estimated according to **Alici and Arabaci, (2016).**
Growth criteria: Fresh and dry weight and leaf area.

Photosynthetic pigments: Chlorophyll content in maize tissues (SPAD value, F.W).

Chemical constituents: N, P, K were estimated in maize (stover + leaves, D.W) *i.e.,* according to **Walinga *et al*., (2013).** The oven-dried samples were wet digested by a mixture of perchloric and sulfuric acids (1:1) according to the method of **Peterburgski, (1968).**

Measurements at harvest

Plant height and Maize yield: grain yield and biological yield were estimated as well as harvest index was calculated according to the following equation;

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

Yield components: No. of seeds cob^{-1}, weight of 1000 seed, cob length, No. of rows cob^{-1} were calculated.

Bio chemical traits of grains: According to **AOAC, (2000)**, total carbohydrates; crude protein and crude oil content were determined**.** Crude protein in maize grain was calculated by multiplying N% in grain by 5.75.

2.4 Statistical Analysis

Data was statistically analyzed according to Gomez and Gomez, (1984). Treatment means were compared by using the least significant difference (LSD) at 0.05 level of probability, all statistical analysis was performed using the analysis of variance technique by means of the CoStat computer software package (Version 6.303, CoHort, USA, 1998–2004).

3. Results and Discussion

3.1 Enzymatic antioxidants in plant tissues after 70 days from sowing

Currently, it is known that environmental stress increases plant production of Reactive Oxygen Species (ROS) responsible for plant cell damage. Data in Table 3 show the effect of the different irrigation regimes, compost soil addition and melatonin levels on maize plant's self-production of enzymatic antioxidants such as superoxide dismutase (**SOD,** unit mg^{-1} $protein^{-1}$), peroxidase enzyme (**POD,** unit mg^{-1} $protein^{-1}$) and catalase enzyme (**CAT,** unit mg^{-1} $protein^{-1}$) after 70 days from plant's life period.

Individual effect of the studied irrigation regimes: It is noticed from **Fig 1** that plants grown under alternative furrow irrigation technique without compost and melatonin had the highest values of enzymatic antioxidants *i.e.*, superoxide dismutase SOD (80.26, unit mg^{-1} $protein^{-1}$), peroxidase enzyme POD (246.54, unit mg^{-1} $protein^{-1}$), and catalase enzyme CAT (89.07, unit mg^{-1} $protein^{-1}$), at the period of 70 days from sowing, while the maize plants grown under terraces irrigation technique with compost and simultaneously sprayed with melatonin at the rate of 2.0 mmol L^{-1} possessed the lowest values of these enzymatic antioxidants (69.25, 178.28 and70.57 unit mg^{-1} $protein^{-1}$ for SOD,POD and CAT, respectively).. It can be said that irrigation techniques *i.e.*, alternative and traditional furrow led to raise maize plant's self-production of enzymatic antioxidants in tissues compared to the corresponding maize plants grown under terraces irrigation technique to tolerate water deficit stress and water flood stress. Generally, it can be said that terraces irrigation technique was the best irrigation technique. Similar results were found by **Tarolli, (2018) and Eid *et al.,* (2022).**

Individual effect of the compost soil addition: Also, as shown in Fig 2, the plants treated with compost had the lowest values of all aforementioned studied enzymatic antioxidants compared to the maize plants grown on the corresponding soil without compost. The plants grown without compost soil addition produced superoxide dismutase (**SOD**, unit mg^{-1} $protein^{-1}$), peroxidase enzyme (**POD**, unit mg^{-1} $protein^{-1}$) and catalase enzyme (**CAT,** unit mg^{-1} $protein^{-1}$) more than that grown on the corresponding soil treated with compost to scavenge ROS, where the production of ROS was higher under control treatment (without compost) in comparison to compost treatment.

Individual effect of foliar application of melatonin: Fig 3 illustrated that the plants treated with melatonin at both studied rates (1.0 and 2.0 mmol L^{-1}) produced antioxidants less than the plants grown without external application of melatonin. On the other hand, the 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} $protein^{-1}$) decreased as the melatonin rate increased. The maize plants sprayed with melatonin at rates of 1.0 and 2.0 mmol L^{-1} contained the SOD, POD and CAT less than the corresponding maize plants grown without melatonin.

Interaction effect: It is noticed , as shown in Table 3 , that plants grown under alternative irrigation technique without compost and melatonin had the highest values of all aforementioned studied enzymatic antioxidants at the period of 70 days from sowing while the maize plants grown under terraces irrigation technique with compost and simultaneously sprayed with melatonin at rate of 2.0 mmol L^{-1} possessed the lowest 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} $protein^{-1}$). Generally, it can be noticed that alternative and traditional furrow strategies led to raising enzymatic antioxidants production in tissues of plants to hinder the hazardous impact of ROS, while soil addition of compost and external application of melatonin led to a decline of the maize plant's self-production from enzymatic antioxidants.

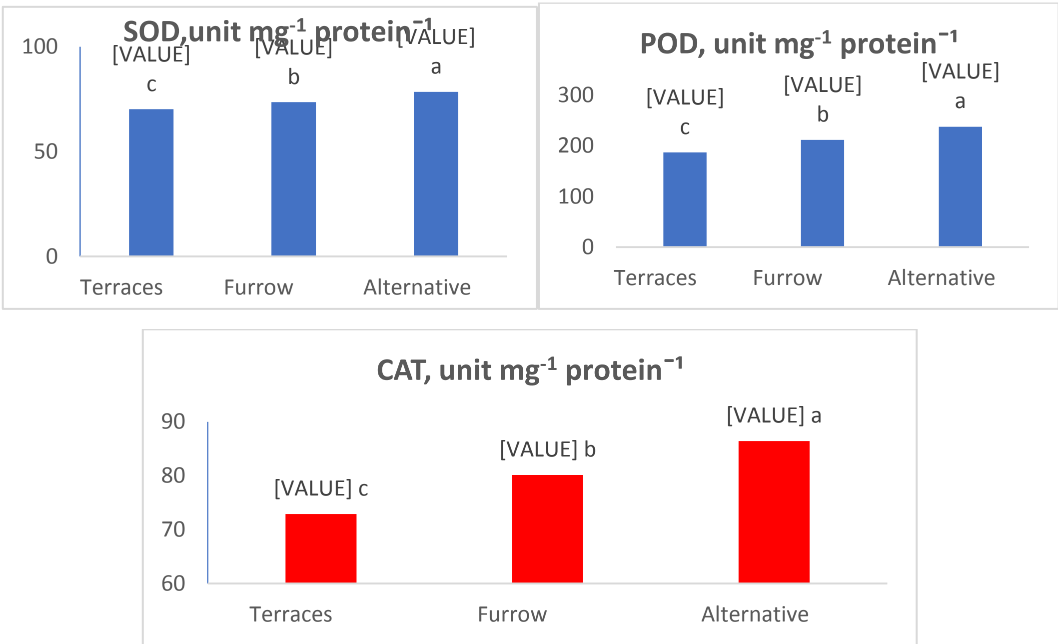

Fig 1. Effect of irrigation regimes (as individual effect) on maize plant's self-production from enzymatic antioxidants at 70 days from sowing.

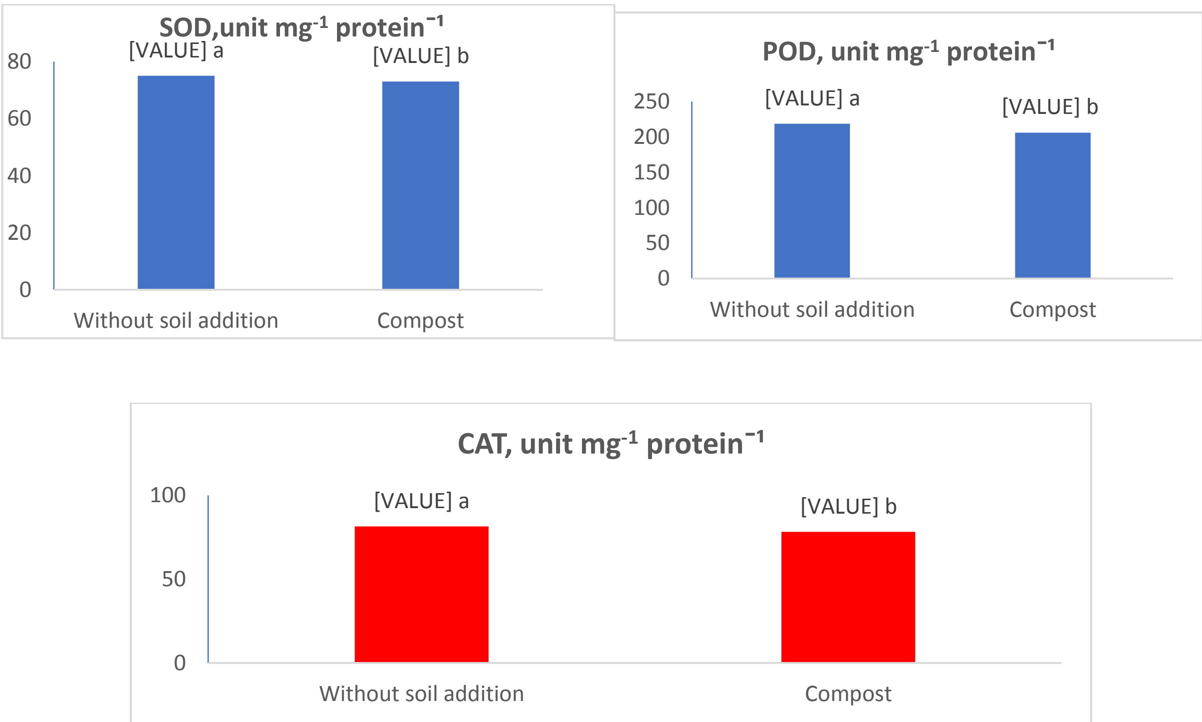

Fig 2. Effect of compost addition (as individual effect) on maize plant's self-production from enzymatic antioxidants at 70 days from sowing.

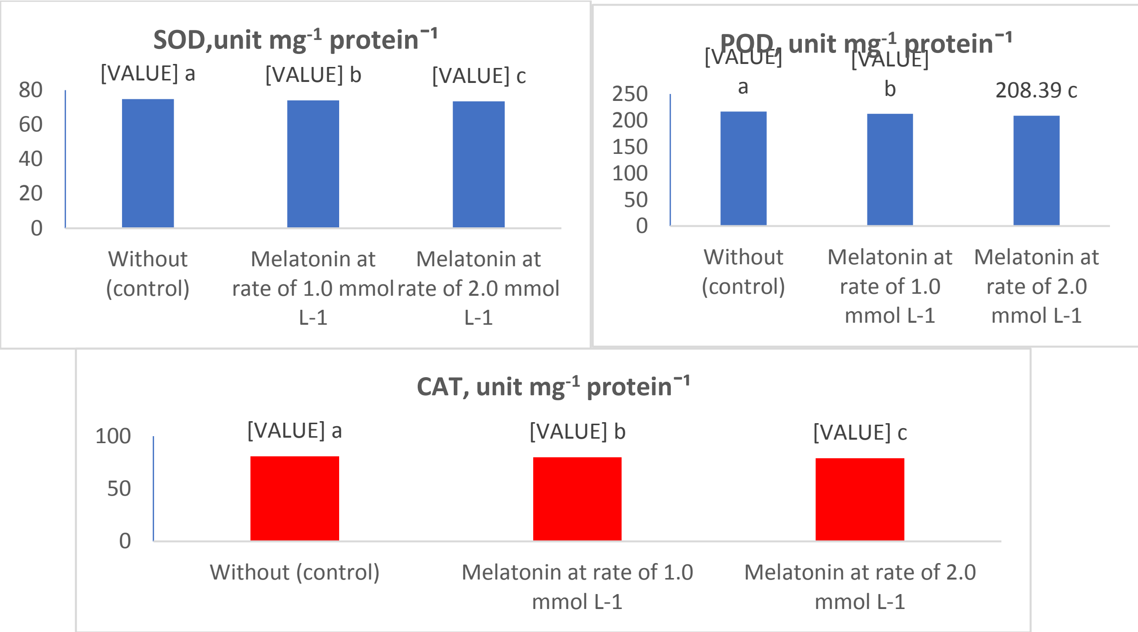

Fig 3. Effect of melatonin foliar application (as individual effect) on maize plant's self-production from enzymatic antioxidants at 70 days from sowing.

Table 3. Interaction effect of irrigation regimes, compost and melatonin on maize plant's self-production from enzymatic antioxidants at 70 days from sowing.

Treatments			SOD	POD	CAT
			(unit mg^{-1} $protein^{-1}$)		
Terraces	**Control**	**Without (control)**	71.35	196.50	75.19
		Melatonin at rate of 1.0 mmol L^{-1}	70.87	192.96	74.34
		Melatonin at rate of 2.0 mmol L^{-1}	70.39	189.22	73.31
	Compost	**Without (control)**	70.00	185.26	72.43
		Melatonin at rate of 1.0 mmol L^{-1}	69.33	181.35	71.43
		Melatonin at rate of 2.0 mmol L^{-1}	69.25	178.28	70.57
Furrow	**Control**	**Without (control)**	75.76	224.60	83.06
		Melatonin at rate of 1.0 mmol L^{-1}	74.49	217.71	82.20
		Melatonin at rate of 2.0 mmol L^{-1}	73.76	214.63	81.10
	Compost	**Without (control)**	73.08	210.40	79.10
		Melatonin at rate of 1.0 mmol L^{-1}	72.55	202.84	78.26
		Melatonin at rate of 2.0 mmol L^{-1}	71.93	199.74	77.20
Alternative	**Control**	**Without (control)**	80.26	246.54	89.07
		Melatonin at rate of 1.0 mmol L^{-1}	79.55	244.48	87.96
		Melatonin at rate of 2.0 mmol L^{-1}	79.04	240.25	86.89
	Compost	**Without (control)**	78.30	236.69	85.59
		Melatonin at rate of 1.0 mmol L^{-1}	77.06	232.60	84.69
		Melatonin at rate of 2.0 mmol L^{-1}	76.45	228.20	84.17
LSD at 5%			**0.88**	**4.69**	**0.99**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

Growth performance and chemical content in maize tissues after 70 days from sowing as well as maize yield and other measurements at harvest stage.

It is clear that growth criteria *i.e.,* fresh and dry weight (g $plant^{-1}$) and leaf area (cm^2 $plant^{-1}$) as well as chlorophyll content in leaves (SPAD value, F.W) and chemical constituents in maize (stover + leaves, D.W) *i.e.,* N, P, K % **(Table 4)** after 70 days from sowing were significantly affected due to the studied treatments. Also, plant height after harvest as well as yield [grain and biological yield (metric ton fed^{-1}) and harvest index (%)] and its components [No. of seeds cob^{-1}, weight of 1000 seed (g), cob length, No. of rows cob^{-1}] **(Table 5)** and biochemical characteristics *i.e.*, total carbohydrates, crude protein and crude oil content in grain (%) **(Table 6)** were significantly affected by the investigated irrigation regimes, compost and melatonin.

Individual effect of the studied irrigation regimes:
Tables 4, 5 and 6 show that the maximum values of growth parameters and chemical constitutes as well as yield and its components and biochemical traits of grains were recorded when the maize plants were grown under terraces irrigation technique followed by traditional furrow and lately alternative furrow techniques. For example, the values of fresh and dry weight (g $plant^{-1}$), leaf area (cm^2 $plant^{-1}$) and chlorophyll content in leaves (SPAD value, F.W) were 912.22, 284.22, 601.11 and 38.75, respectively under terraces irrigation technique. While, the lowest values were 792.78, 244.39, 548.39 and 35.20 for fresh and dry weight (g $plant^{-1}$), leaf area (cm^2 $plant^{-1}$) and chlorophyll content in leaves (SPAD value, F.W), respectively under alternative furrow techniques.

Table 4. Effect of irrigation regimes, compost and melatonin on growth performance and chemical constituents in leaves of maize plants at 70 days from sowing.

Treatments			Chlorophyll, SPAD	Fresh weight (g $plant^{-1}$)	Dry weight (g $plant^{-1}$)	Leaf area, cm^2 $plant^{-1}$	N, %	P, %	K, %
Irrigation regimes									
Terraces			38.75a	912.22a	284.22a	601.11a	3.18a	0.350a	2.96a
Furrow			38.00b	880.11b	273.33b	588.44b	3.04b	0.335b	2.85b
Alternative			35.20c	792.78c	244.39c	548.39c	2.75c	0.302c	2.59c
LSD at 5%			**0.16**	**2.07**	**2.95**	**10.98**	**0.04**	**0.002**	**0.03**
Soil addition									
Without soil addition			36.51b	834.78b	255.59b	568.30b	2.87b	0.319b	2.72b
Compost			38.12a	888.63a	279.04a	590.33a	3.10a	0.339a	2.88a
LSD at 5%			**0.31**	**3.15**	**1.98**	**10.77**	**0.02**	**0.001**	**0.02**
Foliar application									
Without (control)			36.90c	850.89c	262.78b	574.50b	2.94b	0.324c	2.78b
Melatonin at rate of 1.0 mmol L^{-1}			37.36b	861.67b	267.56ab	579.78ab	3.00a	0.329b	2.79b
Melatonin at rate of 2.0 mmol L^{-1}			37.68a	872.56a	271.61a	583.67a	3.02a	0.334a	2.83a
LSD at 5%			**0.29**	**2.81**	**5.25**	**9.14**	**0.03**	**0.001**	**0.02**
Interaction									
Terraces	**Control**	**Without (control)**	37.60	872.00	264.00	583.33	3.00	0.336	2.85
		Melatonin at rate of 1.0 mmol L^{-1}	38.00	879.33	269.33	588.00	3.05	0.338	2.86
		Melatonin at rate of 2.0 mmol L^{-1}	38.21	887.33	277.67	595.00	3.06	0.342	2.88
	Compost	**Without (control)**	39.30	935.00	294.67	609.67	3.26	0.358	3.04
		Melatonin at rate of 1.0 mmol L^{-1}	39.35	945.33	298.00	613.67	3.30	0.361	3.06
		Melatonin at rate of 2.0 mmol L^{-1}	40.05	954.33	301.67	617.00	3.33	0.368	3.09
Furrow	**Control**	**Without (control)**	36.68	838.67	255.00	570.00	2.91	0.312	2.74
		Melatonin at rate of 1.0 mmol L^{-1}	37.28	849.33	259.00	576.33	2.93	0.325	2.74
		Melatonin at rate of 2.0 mmol L^{-1}	37.26	859.00	261.67	579.00	2.95	0.332	2.77
	Compost	**Without (control)**	38.66	897.67	281.67	598.00	3.10	0.343	2.90
		Melatonin at rate of 1.0 mmol L^{-1}	38.88	911.33	289.67	601.00	3.13	0.348	2.92
		Melatonin at rate of 2.0 mmol L^{-1}	39.23	924.67	293.00	606.33	3.23	0.354	3.01
Alternative	**Control**	**Without (control)**	33.92	762.67	233.33	536.00	2.64	0.293	2.53
		Melatonin at rate of 1.0 mmol L^{-1}	34.64	774.33	238.67	543.00	2.68	0.297	2.56
		Melatonin at rate of 2.0 mmol L^{-1}	34.98	790.33	241.67	544.00	2.67	0.298	2.59
	Compost	**Without (control)**	35.26	799.33	248.00	550.00	2.73	0.304	2.61
		Melatonin at rate of 1.0 mmol L^{-1}	36.04	810.33	250.67	556.67	2.88	0.308	2.61
		Melatonin at rate of 2.0 mmol L^{-1}	36.35	819.67	254.00	560.67	2.91	0.310	2.65
LSD at 5%			**0.71**	**6.87**	**12.85**	**22.39**	**0.07**	**0.003**	**0.06**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

Table 5. Effect of irrigation regimes, compost and melatonin on yield of maize plants and its components.

Treatments			Plant height, cm	No. of seeds cob^{-1}	Weight of 1000 seed, g	Cob length, cm	No. of rows cob^{-1}	Grain yield (metric ton ha^{-1})	Biological yield (metric ton ha^{-1})	Harvest index, %
Irrigation regimes										
Terraces			205.95a	365.94a	34.68a	19.71a	14.50a	5.80a	11.71a	49.52a
Furrow			202.76b	348.89b	33.78b	18.00b	13.56a	5.41b	11.43b	47.28b
Alternative			191.26c	299.44c	31.41c	14.14c	10.67b	4.32c	10.07c	42.86c
LSD at 5%			**0.38**	**8.50**	**0.25**	**0.30c**	**1.10**	**0.07**	**0.19**	**0.24**
Soil addition										
Without soil addition			196.94b	324.11b	32.55b	15.84b	12.11b	4.83b	10.72b	44.86b
Compost			203.04a	352.07a	34.02a	18.73a	13.70a	5.53a	11.41a	48.25a
LSD at 5%			**1.49**	**4.90**	**0.16**	**0.32**	**0.71**	**0.03**	**0.06**	**0.27**
Foliar application										
Without (control)			198.30b	333.50b	32.99c	16.76c	12.56a	5.03c	10.90c	45.88c
Melatonin at rate of 1.0			200.42a	338.67a	33.30b	17.29b	12.89a	5.16b	11.08b	46.38b
Melatonin at rate of 2.0			201.25a	342.11a	33.57a	17.80a	13.28a	5.34a	11.22a	47.40a
LSD at 5%			**1.78**	**4.44**	**0.14**	**0.29**	**N.S**	**0.05**	**0.11**	**0.47**
Interaction										
Terraces	**Control**	**Without (control)**	199.25	342.33	33.41	17.07	13.33	5.25	11.27	46.61
		Melatonin at rate of 1.0 mmol L^{-1}	204.05	350.00	33.96	17.65	13.67	5.38	11.30	47.63
		Melatonin at rate of 2.0 mmol L^{-1}	206.57	361.33	34.21	18.35	14.00	5.57	11.47	48.53
	Compost	**Without (control)**	208.32	376.33	35.35	21.18	15.00	6.12	12.04	50.89
		Melatonin at rate of 1.0 mmol L^{-1}	208.67	380.67	35.54	21.87	15.33	6.16	12.06	51.12
		Melatonin at rate of 2.0 mmol L^{-1}	208.84	385.00	35.59	22.15	15.67	6.33	12.10	52.34
Furrow	**Control**	**Without (control)**	196.02	328.67	32.34	15.59	12.33	4.88	10.72	45.51
		Melatonin at rate of 1.0 mmol L^{-1}	198.87	330.33	32.69	16.17	12.67	5.01	11.07	45.24
		Melatonin at rate of 2.0 mmol L^{-1}	199.05	338.00	33.18	16.56	13.00	5.16	11.24	45.94
	Compost	**Without (control)**	206.80	366.67	34.53	19.24	14.33	5.61	11.58	48.47
		Melatonin at rate of 1.0 mmol L^{-1}	207.66	371.00	34.87	19.68	14.33	5.87	11.96	49.09
		Melatonin at rate of 2.0 mmol L^{-1}	208.16	358.67	35.08	20.79	14.67	5.93	12.00	49.43
Alternative	**Control**	**Without (control)**	188.05	283.00	30.86	13.59	9.33	3.83	9.61	39.89
		Melatonin at rate of 1.0 mmol L^{-1}	190.30	290.33	31.03	13.81	10.00	4.03	9.74	41.39
		Melatonin at rate of 2.0 mmol L^{-1}	190.30	293.00	31.30	13.78	10.67	4.33	10.07	43.00
	Compost	**Without (control)**	191.37	304.00	31.47	13.89	11.00	4.48	10.19	43.93
		Melatonin at rate of 1.0 mmol L^{-1}	192.99	309.67	31.71	14.57	11.33	4.53	10.34	43.80
		Melatonin at rate of 2.0 mmol L^{-1}	194.56	316.67	32.06	15.19	11.67	4.72	10.46	45.14
LSD at 5%			**4.38**	**10.86**	**0.34**	**0.70**	**0.70**	**0.13**	**0.26**	**1.14**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

Table 6. Effect of irrigation regimes, compost and melatonin on quality traits of maize grains.

Treatments			Carbohydrates, %	Protein, %	Oil, %
Irrigation regimes					
Terraces			68.93a	13.80a	5.83a
Furrow			67.90a	13.20b	5.29b
Alternative			65.41b	11.22c	4.05c
LSD at 5%			**1.03**	**0.21**	**0.06**
Soil addition					
Without soil addition			66.44b	12.12b	4.69b
Compost			68.39a	13.35a	5.43a
LSD at 5%			**0.68**	**0.10**	**0.03**
Foliar application					
Without (control)			66.85b	12.47c	4.91c
Melatonin at rate of 1.0 mmol L^{-1}			67.48a	12.75b	5.05b
Melatonin at rate of 2.0 mmol L^{-1}			67.92a	12.99a	5.21a
LSD at 5%			**0.62**	**0.11**	**0.10**
Interaction					
Terraces	**Control**	**Without (control)**	67.28	12.70	5.24
		Melatonin at rate of 1.0 mmol L^{-1}	67.68	12.99	5.34
		Melatonin at rate of 2.0 mmol L^{-1}	67.89	13.47	5.64
	Compost	**Without (control)**	69.61	14.38	6.15
		Melatonin at rate of 1.0 mmol L^{-1}	70.15	14.51	6.29
		Melatonin at rate of 2.0 mmol L^{-1}	70.97	14.72	6.29
Furrow	**Control**	**Without (control)**	66.57	12.13	4.61
		Melatonin at rate of 1.0 mmol L^{-1}	67.18	12.46	4.76
		Melatonin at rate of 2.0 mmol L^{-1}	67.35	12.58	5.05
	Compost	**Without (control)**	68.31	13.86	5.68
		Melatonin at rate of 1.0 mmol L^{-1}	68.40	14.05	5.75
		Melatonin at rate of 2.0 mmol L^{-1}	69.60	14.11	5.88
Alternative	**Control**	**Without (control)**	63.43	10.47	3.68
		Melatonin at rate of 1.0 mmol L^{-1}	65.23	11.11	3.91
		Melatonin at rate of 2.0 mmol L^{-1}	65.37	11.18	3.94
	Compost	**Without (control)**	65.89	11.27	4.11
		Melatonin at rate of 1.0 mmol L^{-1}	66.23	11.39	4.24
		Melatonin at rate of 2.0 mmol L^{-1}	66.33	11.89	4.44
LSD at 5%			**1.52**	**0.27**	**0.24**

Means within a row followed by a different letter (s) are statistically different at a 0.05% level.

Individual effect of the compost soil addition: Also, as shown in Tables 4, 5 and 6, the plants treated with compost had the highest values of growth parameters and chemical constitutes as well as yield and its components and biochemical traits of grains compared to the maize plants grown on the corresponding soil without compost. For example, the values of plant height (cm), grain yield (metric ton h^{-1}) and Oil (%) were 203.04, 5.53 and 5.43, respectively under compost treatment. While, the lowest values were 196.94, 4.83 and 4.69, for plant height (cm), grain yield (metric ton h^{-1}) and Oil (%), respectively under control treatment (without compost).

Individual effect of foliar application of melatonin: The data in the same Tables elucidated that spraying melatonin at rates of 1.0 and 2.0 mmol L^{-1} achieved values of growth parameters and chemical constitutes as well as yield and its components and bio chemical traits of grains better than the corresponding plants without spraying melatonin, where the values of all aforementioned characteristics increased as the rate of melatonin increased. For example, the values of carbohydrates,(%) and protein (%) were 67.92 and 12.99, respectively with melatonin rate of 2.0 mmol L^{-1}. While, the lowest values were 66.85 and 12.47, for carbohydrates, (%) and protein (%), respectively under control treatment (without melatonin).

Interaction effect: Also, as shown in Tables 4, 5 and 6, the maximum values of growth criteria, as well as chlorophyll content in leaves (SPAD value, F.W) and chemical constituents in maize (stover + leaves, D.W) after 70 days from sowing as well as plant height after harvest and yield and its components and bio chemical characteristics were recorded when the maize plants were grown under terraces irrigation technique with compost and simultaneously sprayed with melatonin at rate of 2.0 mmol L^{-1}.

4. Discussion

The superiority of terraces may be due to the improvement of soil aeration conditions and sequential aeration, which enhanced the gas exchange system. Alternative furrow irrigation may create drought conditions, which might cause a negative effect on the stomata opening and influence the photosynthesis process and stomatal conductance. While traditional furrow irrigation may be made the aeration not good, which affected the values of growth parameters and chemical constitutes as well as yield and its components and biochemical traits of grains. It is also worth noting the area covered by irrigation water under terraces irrigation technique was less than an area in ordinary cultivation. These findings are in harmony with those of Husain et al., (2013), Rashid et al., (2016),Tarolli, (2018) and Eid *et al.,* (2022). Irrigation techniques *i.e.,* alternative and traditional furrow led to raise maize plant's self-production of enzymatic antioxidants in tissues compared to the corresponding maize plants grown under terraces irrigation technique to tolerate water deficit stress and water flood stress. The plants might upregulate various scavenging mechanisms of ROS to alleviate water deficit and flood stress induced damage due to both alternative and traditional furrow strategies.

The superiority of compost might be attributed to that compost is a wealthy source of organic matter, thus improved the maize plant growth performance and increased maize yield and quality. Also, compost may be enhanced soil physical attributes *i.e.,* structure, porosity, bulk density, water holding capacity, hydraulic conductivity, compression strength and water permeability and soil chemical characteristics such as soil content of nutrients and organic matter. Also, compost amendment can hold a high quantity of irrigation water, thus help in the water deficit stress tolerance. The obtained results are in accordance with those of Tartoura, (2010), Nguyen *et al.,* (2012), Hussein *et al.,* (2022), Ghazi *et al.,* (2022) and Awwad *et al.,* (2022).

The plants grown without compost produced **SOD**, **POD** and **CAT** more than that grown on the corresponding soil treated with compost to scavenge ROS, where the production of ROS was higher under control treatment (without compost) in comparison to compost treatment. This performance might be attributed to that compost amendment can hold a high quantity of irrigation water and supply nutrients to maize plants, thus compost help in the water deficit stress tolerance. Production and removal of ROS which is produced in peroxisomes, chloroplasts, and mitochondria are strictly controlled. The equilibrium between ROS production and scavenging is broken under environmental stress, resulting in oxidative damage to DNA, proteins and lipids. It is clear that soil addition of compost markedly alleviated oxidative stress damage in maize induced by decreasing activated oxygen species, thus reducing lipid peroxidation. In other words, soil addition of compost might reduce ROS accumulation in compost-treated maize plants. The obtained results are in accordance with those of Tartoura, (2010) and Nguyen *et al.,* (2012). The superiority of melatonin may be due to the ability of melatonin to enhance photosynthesis, regulate plant physiology and immunological (Fleta‐ Soriano *et al.*, 2017, Ye *et al.,* 2016 and Alharby and Fahad 2020). The maize plants sprayed with melatonin at rates of 1.0 and 2.0 mmol L^{-1} contained the SOD, POD and CAT less than the corresponding maize plants grown without melatonin and this could be due to the vital role of melatonin substance in raising plant immunity, thus more scavenging ROS in the chloroplast of maize plants without the need to produce more enzymatic antioxidants. Generally, this role alleviated the maize plant's self-production from the SOD, POD and CAT. These findings are compatible with those of Fleta‐ Soriano *et al.,* (2017), Ye *et al.,* (2016) and Alharby and Fahad (2020).

5. Conclusion

The obtained results confirmed that the best interaction treatment was terraces irrigation technique plus compost plus melatonin at rate of 2.0 mmol L^{-1} as a biological hormone regulates plant physiology. Generally, this study provides evidence for that the terraces irrigation is a vital irrigation technique for maize as well as it shows the beneficial impact of compost addition and melatonin foliar application in enhancing the drought tolerance of maize under alternative furrow technique .

Conflicts of interest

Authors have declared that no competing interests exist.

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