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IMPACT OF IRRIGATION INTERVALS AND SPRAYING WITH ASCORBIC ACID AND SALICYLIC ACID ON MORPHO-PHYSIOLOGICAL, QUALITY AND YIELD TRAITS OF MAIZE (*Zea mays* L.)

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ABSTRACT: Irrigation intervals play vital role in rationalizing irrigation water in arid and semi-arid areas. Afield experiment was conducted at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt during the 2022 and 2023 seasons to study the effects of irrigation scheduling; irrigated every 15, 20 and 25 days (three irrigation treatments) with (water spray as control (F1), spraying with 100 ppm salicylic acids (F2), spraying with 50 ppm ascorbic acids (F3) and spraying with 50ppm salicylic acid +50 ppm ascorbic acids (F4) on morpho-physiological and, yield traits and water relations of maize. The obtained results showed that water consumption and applied water every 20 and 25 days decreased by (7.0% and 17.3% and (6.2% and 16.6%), respectively, compared to 15 days as the average of the two seasons. The best growth, physiological, yield and yield components and grain equality values were achieved when maize plants were irrigated at 15 days, while the highest water productivity values were achieved when plants were irrigated after 20 days and 15 days' treatments. Plant height, leaf area, total chlorophyll, proline concentration, leaf transpiration, stomatal resistance, shelling percentage, 100-grain weight, biological and grain yields, water consumption and water productivity, carbohydrates, protein and oil percentages values for foliar spray treatments were taken in the descending order F4>F3>F2>F1 under the study conditions. Maximum grain yield was achieved when maize irrigated at 15 or 20 days with the F_4 treatment (spraying with salicylic acid 50 part per million +ascorbic acid spraying at concentration of 50 part per million F4), therefore it could be recommended to irrigation maize plants every 20 days with F_4 treatment for saving irrigation water and improving water productivity.

Key words: Irrigation, antioxidants, Zea mays, Salicylic acid, Ascorbic acid, Antioxidants.

INTRODUCTION

The maize crop (*Zea mays* L.) is widely cultivated worldwide. After wheat and rice, maize is the world's most significant cereal crop. The total cultivated area in Egypt is 2.26 million acres, and the total production is 7.2 million tons in 2023. Supplying nourishment for both people and animals, and it is also used in many industries to narrow the consumption/ production gap for maize. In Egypt, substantial emphasis should be placed on increasing maize productivity by improving yield per unit area or/ plant. Maize is widely recognized for its high nutritional and other production input needs. Thereby, foliar application with antioxidants and natural fertilizer is among the factors that reduce effects of water stress at the same time enhance maize productivity. One of the key reasons limiting agricultural productivity in Egypt and lowering the effectiveness of using dry lands is drought stress. Hence, it is feasible to employ

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semi-arid regions thanks to the identification of and usage of drought-tolerant crops and particular crop modification techniques. The maize crop needs enough water at all stages of physiological development in order to produce its maximum yield. **Irma Damayanti *et al*. (2021) and Syauqi and Amzeri (2023)** revealed that compared to other water treatment intervals, an irrigation interval treatment of providing water every 8 days offered superior growth and yields of maize (control, 14 days and 18 days).

Salicylic acid (SA) is regarded as a hormone-like compound that has a significant role in controlling a variety of physiological processes in plants, including, stomata closure, ions uptake and transport, biosynthesis inhibition of ethylene, membrane permeability, transpiration, photosynthesis, flowering and abiotic tolerance **(Ashraf *et al*., 2010; Seham *et al*., 2023 and Taj and Arshad 2025).** Application of SA increased plants' ability to withstand a variety of biotic and abiotic stressors, including salt, drought, and heat. Ascorbic acid is an important photocompose that plays a key role in response to biotic stress and pathogenesis. Apart from this role, recent studies have demonstrated that SA also participates in the signaling of abiotic stress responses, such as drought, high and low temperature, salinity, ozone, UV radiation, and heavy metals **(Darvishan *et al*., 2013 and Yaghoubian *et al*., 2014)**.

Ascorbic acid has been implicated in several types of biological activities in plants, such as an enzyme cofactor, as an antioxidant, as a donor/acceptor or in electron transport at the plasma membrane or in the chloroplast, all of which are related to oxidative stress resistance (**Darvishan *et al*., 2013)**. Therefore, the main purpose of this investigation aimed to study the effect of irrigation intervals and foliar application with antioxidants on yield and its attributes of maize plants.

MATERIALS AND METHODS

Experiment Location

During the two summer growing seasons of 2022 (Y1) and 2023(Y2), this study was carried out at Sakha Agricultural Research Station (31° 07' N Latitude, 30° 05' E Longitude), Kafr El-Sheikh, Egypt. Table (1) shows Agro-metrological data of the area of the experiment provided by Sakha Metrological Station. Before cultivation process, samples were collected from the soils of the experiment site for soil analysis. Pipette method was used to determine particle-size distribution, percent of soil total porosity in addition to bulk density consistent (**Klute 1986).** Soil field capacity, besides permanent wilting point, were determined using the pressure membrane method at 0.33 and 15 Atm, respectively, consistent with **James (1988).** pH and electrical conductivity of soil were analyzed according to **Page *et al*. (1982).** These measurements are presented in Table (2).

Design and treatments of the experiment

The two factors were plotted in a strip plot design with three replications. The first factor was irrigation scheduling which allocated in vertical plots (Table 3), while the second factor was foliar spray with antioxidants (spraying with water as control , F1), spraying with 100 ppm salicylic acids (F2), spraying with 100 ppm ascorbic acids (F3), spraying with salicylic acid 50 part per million + ascorbic acid spraying at a concentration of 50 parts per million (F4), and the addition date was at the age of 25 and 35 days from planting at a rate of 200 cm3 and added to 200 liters of water placed in horizontal plots. These treatments were applied on one yellow maize. Single cross SC 168, where the experiment was planted on 1st and 6th June in 2022 and 2023 summer seasons, respectively. The site of field trial was well prepared after the end of previous wheat crop in both seasons, where it ploughed twice, harrowed, ridged 0.7 m apart and then divided into plots of 42 m2 (inclded10 ridges, 6 m length and 0.7m width for each). Plots were isolated by ditches 2.5 m width to avoid lateral seepage between irrigation treatments. On one side of the hills, maize seeds were planted in hills spaced 25 cm apart, thinned to one plant per hill. The number of plants per acre was 35,000 plants.

On one side of the ridge maize seeds were sown in hills 25 cm apart, thinned in single plant per hill before first irrigation (21days after planting). All treatments received 72 kg P_2O_5/ha superphosphate throughout land preparation before planting. The equivalent of 286 kg N/ha by Urea 46.5% was supplemented as a fertilizer dividing it into two equal dosages, before 1st and 2nd irrigations. Weeds, pest management and different agricultural practices for maize during both growth seasons were conducted as stated by the Agriculture Crop Research Center Recommendations.

Applied Water (AW)

Starting from the second irrigation after sowing, the timing of irrigation was determined based on the cumulative amount of pan evaporation. The irrigation water applied to each plot was measured using PVC spile tubes (1 m in length and 5 cm in internal diameter), which transfer water from the field canal into the plots. A fixed sliding gate was used to maintain constant water head at the center of the spile cross-section. The effective head was regularly measured during irrigation, and a stopwatch was used to record the irrigation duration. The volume of water delivered through each spile tube was calculated according to Majumdar (2002) using equation (1): $q = CA\sqrt{2gh}$ **(1)**

Wherever q represents water discharge (cm^3 s^{-1}), h represents average effective head (cm), g represents gravity acceleration (cm s^{-2}), A represents spile inner cross section area (cm^2) and C represents discharge coefficient = 0.62 (determined in the experiment).

Irrigation water quantity which delivered to each plot was determined according to the subsequent equation 2.

$$Q = q \times t \times n \quad (2)$$

Wherever Q represents water quantity m^3 per plot, q is discharge (m^3 min^{-1}), t is irrigation time (min) and n is spile tube number for each plot.

Water consumptive use (CU 85cm)

Water consumptive use was calculated using soil moisture depletion (SMD) method according to **Israelsen and Hansen (1962)** via equation 3.

$$Cu = \frac{\theta_2 - \theta_1}{100} * Db * d \quad (3)$$

Where, CU is water consumptive use (cm), d is soil layer depth (15 cm), Db is soil bulk density (g cm^{-3}) for this depth, θ_1 is gravimetric soil moisture (%) before irrigation, and θ_2 is gravimetric soil moisture (%) after 48 h from irrigation.

Soil moisture content was determined using gravimetric methods. Samples were obtained from 0-15, 15- 30, 30-45 and 45-60 cm depth from field plots before irrigation and after gravity water drainage. In the laboratory weighting method was used in order to determine soil moisture content as stated by **Klute (1986)**.

Productivity of irrigation water (PIW):

Productivity of irrigation water is defined as crop yield (kg) per cubic meter of applied irrigation water. It was calculated along with **Pereira *et al.* (2012)** as shown in Equation 4

$$\text{PIW (kg m}^{-3}\text{)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Amount of applied water m}^3\text{ ha}^{-1}} \quad (4)$$

Water productivity (WP)

Water productivity, in general, is defined as crop yield (kg) per cubic meter of consumed water. It was calculated along with **Pereira *et al.* (2012)**, as shown in Equation 5

$$\text{WP (kg m}^{-3}\text{)} = \frac{\text{Grain yield in kg ha}^{-1}}{\text{Water consumptive use (m}^3\text{ ha}^{-1}\text{)}} \quad (5)$$

Morpho-Physiological traits

Five randomly plants were collected from the center of every plot at silking stage (after 75days from planting) to measure corn ear leaf area through (blade length × maximum blade width × 0.75) according to **Saxena and Singh (1965)**. Plant height (cm) was determined as average of 10 plants. The height of the plant is measured with a graduated ruler from the soil surface to the top of the plant.

Total chlorophyll content was determined according to **Lichtenthaler and Buschmann (2001),** and proline content was determined according to **Bates *et al.* (1973).**

Table 1. The meteorological data of the studied site in 2022 and 2023 seasons.

	Months	Air temperature (c°)			Relative humidity (%)			Wind speed km d^{-1}	Pan Evaporation (mmd^{-1})
		Max.	Min.	Mean	Max.	Min.	Mean		
2022	May	31.9	28.3	30.1	78.9	50.9	64.9	91.3	7.54
	June	33.9	29.9	31.9	82.6	59.6	71.1	108.6	8.36
	July	35.2	30.7	33.0	84.6	64.2	74.4	105.3	8.97
	August	38.2	32.8	35.5	87.3	66.9	77.1	97.6	9.45
	September	37.6	31.9	34.8	89.9	69.3	79.6	94.2	8.09
	October	34.6	29.8	32.2	80.6	65.5	73.1	73.5	7.29
2023	May	36.0	27.5	31.7	88.4	48.9	68.6	84.0	6.56
	June	38.3	29.0	33.7	92.5	57.2	74.9	99.9	7.27
	July	39.8	29.8	34.8	94.8	61.6	78.2	96.9	7.80
	August	43.2	31.8	37.5	97.8	64.2	81.0	89.8	8.22
	September	42.5	30.9	36.7	91.7	66.5	79.1	86.7	7.04
	October	39.1	28.9	34.0	90.3	62.9	76.6	67.6	6.34

Table 2. Chemical and physical properties of the soil at experiment site as a mean value of both 1st and 2nd seasons.

Soil depth (cm)	F.C[1] (%)	P.W.P[2] (%)	A. W[3] (%)	Mm	Bulk density (g cm-^{3})	Total porosity (%)	Particle size distribution Sand (%)	Silt (%)	Clay (%)	Texture class	ECe (ds m^{-1})	pH 1:2.5
0-15	42.93	23.33	19.60	32.67	1.14	56.98	24.40	21.31	54.29	Clayey	1.93	7.78
15-30	38.97	21.18	17.79	29.65	1.20	54.72	23.16	21.48	55.36	Clayey	2.25	8.04
30-45	37.30	28.27	17.03	28.38	1.25	52.83	22.28	21.70	56.02	Clayey	2.63	8.21
45-60	35.78	19.45	16.33	27.22	1.34	49.43	20.74	21.07	56.19	Clayey	2.81	8.54
Mean	38.75	21.06	17.69	29.48	1.23	53.49	22.64	21.89	55.47	Clayey	2.40	8.14

F.C[1] = Field capacity, P.W.P[2]= Permanent wilting point, A. W[3]= Available water

Table 3. Date and number of irrigations in each irrigation interval treatment.

Irrigation interval	Date of irrigation								
	Zero	1st	2nd	3rd	4th	5th	6th	7th	total
15 days	Planting	**21**	**36**	**51**	**66**	**81**	**96**	x	**6**
20 days	Planting	**21**	**41**	**61**	**81**	**101**	x	×	**5**
25 days	Planting	**21**	**46**	**71**	**96**	x	×	×	**4**

Stomatal resistance (S cm^{-1}) and transpiration rate (µg H_2O m^{-2} s^{-1}) determined using

Portable Steady's State Porometer (LI – COR Model LI 1600) on fully expanded ear leave on five randomly selected plants.

Yield and yield components traits:

Five ears from every plot were taken for number of kernels per year in addition to shelling percentage. Also, samples from the two central 8.4 m^2 ridges were harvested to determine 100-kernel weight (g), biological yield (kg /ha) and grain yield (kg/ ha) at moisture content of 15.5%.

Quality of grains as carbohydrates % **(Shumaila and Safdar 2009).** Protein (%): nitrogen % and protein was calculated by multiplying the N by factor 5.75. and oil% according to **(A.O.A.C 2000).**

Statistical analysis

Statistical analysis of variance (ANOVA) was done in each year to obtain data by using computer application of Statistical Analysis System **(SAS 2008)**. The mean differences between treatments were investigated by Duncan's Multiple Range Test at 5% level of probability as outlined by **Snedecor and Cochran (1989).**

RESULTS AND DISCUSSION

Water Relations

Water consumptive use and applied water

The values of water consumptive use (CU) and applied water (AW) in (Table 4), showed that the values of water consumptive use and applied water after 20 and 25days irrigation intervals decreased by (7% and 17.3%), (6.2% and 16.6%), respectively in comparison with 15 days as an average of both seasons. These results agree with **Aulakh *et al*. (2012), Bibe *et al*. (2016) and Razzak *et al.* (2022).** Water consumptive use and applied water values for foliar spray treatments were taken in the descending order F4 >F3>F2>F1, in the 1st and the 2nd seasons. The maximum values of water consumptive use and applied water use were obtained at irrigation interval (F4) 5561and 8426 m3/ha, respectively, as an average of 2022 and 2023 seasons. Noticeable differences were documented between the interaction among scheduling irrigation and antioxidants foliar spray treatment the lowermost values were recorded after 25 days with F1 interaction to be 4620 and 7000 m3/ha as mean of both seasons, while the highest values were recorded at irrigation interval 15 days × F4 interaction, 5971 m^3/ha and 9048 m^3/ seasons. Water consumptive use and applied water values were reduced after 25 days×F1 interaction by 22.6% in comparison with 15 days × F4 interaction as the mean of both studied seasons (Table 4).

Water productivity and productivity of irrigation water

Effect of irrigation intervals 15, 20 and 25, foliar spray with antioxidants (F1, F2, F3 and F4) and their interactions on water productivity and productivity of irrigation water are shown in Table (5). The differences were recorded among irrigation scheduling treatments and antioxidants foliar spray treatments, for water productivity and productivity of irrigation water. Maximum values were found when maize irrigated at 20 days and 15 days' treatments in both seasons. However, the minimum value was recorded after 25 days for both traits in both studied seasons. Water productivity after 25 days decreased by 7.34 % compared to 20 days as an average of both seasons, indicated that long irrigation intervals significantly raised water use efficiency. **Shahrokhi and Zare (2022)** stated that water productivity was increased by applying the best irrigation scheduling, which keeps optimum soil moisture in the root zone. The maximum values of water productivity and productivity of irrigation water were obtained from F_3 and F_4 in both seasons, while the lowest values were found from F_1 in both seasons. Water productivity and productivity of irrigation water were reduced by 10.4% and 10.9% of F_1 compared to F_4 as an average of both seasons. The differences were obtained through the interaction between irrigation scheduling and foliar spray, the maximum water productivity value was obtained of 20 days with F_4 followed by 20 days with F_3 to be 1.747 and 1.676 kgm^{-3}respectively as average two seasons, while the lowest value was obtained of 25 days with F_1 to be 1.420 kgm^{-3} as an average of the two seasons. **Tefera (2021)** reported that the maximum maize water productivity was obtained when the optimum irrigation scheduling was done as an irrigation interval of 15 days in addition to increasing the amount of recommended applied fertilizer by 25%.

Morpho-Physiological traits

Maize growth and development attributes

The results in Table (6) showed that in two seasons the differences between foliar spray treatments, irrigation intervals and their interaction were significant for plant height, leaf area. Foliar spray was taken the descending order F_4> F_3> F_2> F_1, on all traits in two seasons. Plant height, leaf area and total chlorophyll increase with foliar antioxidants application which might be a result of the enzymatic activity which assisted plants to increase their heights and photosynthetic activity. **Amanullah *et al.* (2016), Khan *et al*. (2010) and Abo-Marzoka *et al*. (2016)** indicated that salicylic acid and ascorbic acid significantly affected growth trait of maize. Irrigation interval after 15 days followed 20 days showed the highest values for growth traits in both seasons, while the irrigation interval after 25 days showed the lowest values for previous traits in two seasons. The highest values obtained at 15 days with F_4 followed 20 days with F_4, meanwhile the lowest values obtained from 25 days with F_1 for all morpho-physiological traits in the 1st and 2nd seasons. These results are in agreement with **Reddy *et al.* (2004)** stated that the drought stress reduced the uptake of essential elements and affected photosynthetic capacity and vegetative growth.

Results displayed in Table (7) revealed significant differences were obtained for proline content, stomatal resistance and leaf transpiration between irrigation intervals, foliar spray with antioxidants and their interaction. The concentration of proline and stomata resistances were increased when irrigation intervals were increased, from 15 to 25 days in two seasons. These results agree with **Reddy *et al.* (2004),** who found that drought stress reduced the uptake of essential elements and affected photosynthetic capacity. **Kumar *et al.* (2014)** observed that higher proline content was found in maize leaf under severe water-stressed treatments, while the lowest proline content in mild water deficit, which received 100% of crop evapotranspiration. Also, the results in Table 7 showed that the leaf transpiration was decreased when irrigation intervals increased, from 15 days to 25 days in two seasons. This might be a result of the decrease in available moisture content of soil, hence decrease in transpiration rate as well as grain yield. **Wasaya *et al*. (2021)** demonstrated that stomatal conductance, transpiration and photosynthesis rates significantly reduced under deficit irrigation treatments in comparison with well-watered conditions. In this concern, a significant reduction of transpiration rate was obtained under deficit irrigation in comparison with full irrigation of maize. As Regrad in Table 7, proline concentration, leaf transpiration and stomatal resistance were increased with antioxidants foliar spray as followed F4> F3> F2> F1 in both studied seasons. This may be due to the dominant role of antioxidants in the closing and opening of stomata. **Damon and Rengel *et al*. (2008)** found that the stomatal activity decreases and transpiration loss increases, if antioxidants inadequate in plant tissues. The maximum values of proline and stomatal resistance were obtained for plants received 25 days with F_4 while leaf transpiration at 15 days with F_1 in both seasons, but the lowest values were found for plants treated with 15 days with F_1 interaction for proline and stomata resistances and 25 days with F_4 for transpiration rate in both seasons. **Wasaya *et al.* (2021)** stated that the antioxidants foliar spray can potentially reduce the negative impacts of drought in maize and improved growth attributes and proline under severe drought conditions.

Yield and yield components

The kernels number per ear, shelling%, 100 kernel weight, biological yield and grain yield were affected by different irrigation scheduling, foliar spray and the interaction among them (Table 8). The maximum values of kernel number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield were obtained after 15 days and, foliar spray treatment F_4, respectively in the two seasons. The values of kernels number per ear, shelling percentage, 100 kernels weight, biological yield in addition to grain yield were reduced by 6.5%, 2.6%, 5.3%, 7.1% and 3.7% respectively for maize plants irrigated at 20 days, whereas they reduced by 19.6%, 15.4%, 11.7%, 21.7% and 20.5%, respectively for plants exposed 25 days compared to 15 days as an average of the two seasons. That results are harmony with **Aulakh *et al.* (2012), Maqsood *et al.* (2012), Mubeen *et al.* (2013), Ul-Allah *et al.* (2020) and Razzak *et al.* (2022)** they stated that the decrease in yield and yield component owing to increase in irrigation intervals may occur because of the exposure of the plants to stress of water, which reduces shoot in addition to root growth, stomatal conductance, transpiration and photosynthesis rates and total chlorophyll contents in comparison with well-watered circumstances. Grain weight of ear per plant significantly decreased with increasing water deficit, while foliar application of salicylic acid or ascorbic acid, especially at 200 ppm tended to reverse this negative effect and increased the yield. **Bahrani *et al.* (2012)** reported higher 1000-grain weight with recurrent irrigation supplies at optimum intervals.

On the other hand, the results in Table (8) showed that the number of kernels per ear was increased by 15.2%, 10.3% and 5.7%, shelling percentage by 11.1%, 8.7 and 5.2%, 100 kernels weight by 17.1%, 11.8% and 6.0 %, biological yield was augmented by 2.1%, 4.7% and 8.2% and grain yield values was improved by 16.6%, 11.9% and 4.5% for F_4, F_3 and F_2, respectively compared to F_1 as mean of both seasons. The obtained results showed an increase in 100-grain weight and grains per ear with raising fertilization by foliar spray with antioxidants from F_1, F_2, F_3 and F_4. The increment of previous yield traits may be due to the importance of foliar spray with antioxidants. The highest values of kernel number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield were recorded after 15 days with F_4 followed 20 days with F_4 interactions, whereas the lowest values were obtained after 25 days with F1 interaction. Maize grain yield for plants treated with 15 days with F4 interaction increased by 13.6% in comparison with 25 days with F_1 interaction as a mean of both seasons. Also. the results showed that irrigation interval after 15 days with F_4 treatment was not significant differences than after 20 days with F_4 treatment for all yield and yield components traits. This study recommended using the two treatments particular irrigation interval after 20 days with F_4 (spray with 50 ppm salicylic +50ppm ascorbic acids) to provide irrigation water. These results are in agreement with the results found by **Aslam *et al.* (2014) and Amanullah *et al.* (2016), Gomaa *et al.* (2021), Wasaya *et al.* (2021), Maqsood *et al.* (2012) and Bahrani *et al.* (2012).**

Grain quality traits

The crude protein content, total carbohydrates and oil percentages were significantly affected by different irrigation scheduling, foliar spray and the interaction among them (Table 9). The maximum values of crude protein, total carbohydrates and oil percentages were obtained at after 15 days and foliar spray treatment F_4 in the two studied seasons, while the lowest values were obtained at 25 days and foliar spray treatment F_1 in two Seasons. The highest values of carbohydrate %, protein % and oil% were obtained at after 15 days with F_4, while the lowest values were recorded at 25 days with F_4. Similar results were obtained by **Lihiang and Lumingkewas (2017)**.

Table 4. Effects of irrigation intervals and antioxidants spray on water consumptive use (CU) and applied water (AW) at 2022 and 2023 seasons for maize crop.

Irrigation intervals (I)	Foliar spray (F)	(CU)(m^3ha^{-1})			AW (m^3ha^{-1})		
		2022	2023	Mean	2022	2023	Mean
15 days	F1	5580 d	5920 c	5750 d	8329 d	8837d	8583 d
	F2	5620 c	5962 a	5791 c	8436 c	8899c	8668 c
	F3	5794 b	5913 d	5854 b	8649 b	8959b	8804 b
	F4	6000 a	5942 b	5971 a	9092 a	9003a	9048 a
Mean		**5749**	**5934**	**5842**	**8626**	**8924**	**8776**
20 days	F1	5580 d	5340 d	5238 d	7782 d	8091 d	7936 d
	F2	5620 c	5543 c	5351 c	7815 c	8398 c	8107 c
	F3	5794 b	5691 b	5528 b	8128 b	8623 b	8376 b
	F4	6000 a	5782 a	5616 a	8256 a	8761 a	8509 a
Mean		**5277**	**5589**	**5433**	**7995**	**8468**	**8232**
25 days	F1	5580 d	4753 d	4620 d	6799 d	7201 d	7000 d
	F2	5620 c	4805 c	4706 c	6981 c	7281 c	7132 c
	F3	5794 b	5021 b	4893 b	7219 b	7607 b	7413 b
	F4	6000 a	5234 a	5096 a	7510 a	7930 a	7720 a
Mean		**3954**	**4953**	**4829**	**7128**	**7505**	**7316**
Overall mean of F	F1	5067 d	5338 d	5189 d	7637 d	8043 d	7840 d
	F2	5128 c	5437 c	5274 c	7744 c	8193 c	7969 c
	F3	5307 b	5541 b	5410 b	7999 b	8396 b	8198 b
	F4	5469 a	5653 a	5561 a	8286 a	8565 a	8426 a

Table 5. Effect of irrigation intervals and antioxidants foliar spray on water productivity and productivity of irrigation water (kg m^{-3}) in the2022 and 2023 growing seasons.

Season	Irrigation intervals (I) treatments	Foliar spray (F) treatments			
		F1	F2	F3	F4
		Water productivity (kg m^{-3})			
2022	**15 days**	**1.013 a**	1.036 a	1.084 b	1.061 b
	20 days	0.993 b	1.068 b	1.123 a	1.147 a
	25 days	0.955 c	0.983 c	1.050 c	1.054 c
Mean		**0.987**	**1.029**	**1.086**	**1.087**
2023	**15 days**	0.999 a	1.020 b	1.058 b	1.117 b
	20 days	0.996b a	1.031 a	1.089 a	1.160 a
	25 days	0.920 b	0.971 c	1.037 c	1.039 c
Mean		**0.972**	**1.007**	**1.061**	**1.105**
		Productivity of irrigation water (kg m^{-3})			
		F1	F2	F3	F4
2022	**15 days**	1.512 a	1.556 ab	1.618 b	1.608 b
	20 days	1.504 ab	1.617 a	1.701 a	1.737 a
	25 days	1.446 b	1.489 b	1.591 c	1.596 c
Mean		**1.487**	**1.554**	**1.637**	**1.647**
2023	**15 days**	1.492 b	1.522 b	1.603 ab	1.692 ab
	20 days	1.510 a	1.563 a	1.651 a	1.757 a
	25 days	1.393 c	1.472 c	1.571 b	1.574 b
Mean		**1.465**	**1.519**	**1.608**	**1.674**

Table 6. Impact of irrigation intervals, treatments and the interaction among them on morpho-physiological traits of maize plants during 2022and 2023 growth seasons

Treatments	2022					2023				
Irrigation intervals(I)	Foliar spray (F) treatments									
	F1	F2	F3	F4	Mean	F1	F2	F3	F4	Mean
	Plant height (cm)									
15 days	279 ef	290 cd	302 b	313 a	296 a	284 c	294 c	314 b	327 a	305 a
20 days	270 gh	275 fg	291 c	301 b	285 b	273 g	277 f	295 c	317 b	291 b
25 days	250 i	266 h	275 fg	285 de	269 c	252 h	271 g	280ef	288 d	273 c
Mean	266 d	277 c	289 b	300 b	-	270 d	281c	296 b	310 a	-
	Leaf area (cm^2)									
15 days	736.5d	782.9c	798.7b	831.0a	787.3a	755.2b	795.2b	827.2b	849.7a	806.8 a
20 days	695.1f	732.1d	779.7c	828.7a	758.9b	708.6e	747.9d	794.7c	846.4a	774.4 b
25 days	639.5h	658.4g	704.9ef	714.5e	679.3c	657.8g	676.3f	711.2e	752.5d	699.5 c
Mean	690.4d	724.5c	761.1b	791.4a	-	707.2d	740 c	778 b	816 a	-
	Total chlorophyll (mg/dm^2 LA)									
15 days	5.62d	5.73bc	5.97a	5.95a	5.82a	5.63c	5.78b	5.99a	6.00a	5.85 a
20 days	5.16g	5.39e	5.71c	5.80b	5.51b	5.32c	5.51d	5.72b	5.95a	5.63 b
25 days	4.64i	4.96h	5.26f	5.40c	5.06c	4.76g	5.12f	5.32c	5.54d	5.19 c
Mean	5.14 d	5.36 c	5.65 b	5.72 a	-	5.24 d	5.47 c	5.68 b	5.83 a	-

Table 7. Maize physiological characteristics as affected by irrigation intervals, antioxidants foliar spray treatments and the interaction between them during 2022 and 2023growing seasons.

Treatments	2022					2023				
Irrigation intervals (I)	Foliar spray (F) treatments									
	F1	F2	F3	F4	Mean	F1	F2	F3	F4	Mean
	Proline ($mg\ g^{-1}$f.w)									
15 days	0.64k	0.79j	0.95i	1.05b	0.86c	0.68h	0.84g	1.01f	1.11f	0.91c
20 days	1.06h	1.29g	1.37f	1.51e	1.31b	1.11f	1.35e	1.42e	1.54d	1.36b
25 days	1.80d	1.88c	2.04b	2.25a	1.99a	1.93c	1.95c	2.11b	2.34a	2.08a
Mean	1.17d	1.32c	1.45b	1.60a	-	1.24d	1.38c	1.51b	1.66a	-
	Stomatal resistance ($S\ cm^{-1}$)									
15 days	0.43d	0.44be	0.48ab	0.51a	0.48c	0.45d	0.45d	0.50cd	0.53bc	0.48c
20 days	0.47e	0.51d	0.53cd	0.57a	0.58b	0.49cd	0.54bc	0.57b	0.73a	0.58b
25 days	0.51f	0.55f	0.57e	0.58d	0.62a	0.52bc	0.57b	0.68a	0.74a	0.63a
Mean	0.47d	0.50c	0.53b	0.55a	-	0.49d	0.52c	0.58b	0.67a	-
	Leaf transpiration rate ($\mu g\ H_2O\ m^{-2}\ s^{-1}$)									
15 days	12.25a	11.32b	10.86bcd	10.40cde	11.21a	12.08a	12.60ab	12.91bc	13.22c	12.70a
20 days	11.58ab	11.12bc	10.51cde	10.10de	10.82a	10.26bc	10.76d	11.27def	12.48fg	11.20b
25 days	10.51cde	10.27de	9.98ef	9.31f	10.02b	9.63de	10.07efg	10.40gh	10.97h	10.27c
Mean	11.44a	10.90b	10.45c	9.94d	-	10.66a	11.14b	11.53c	12.22d	-

Table 8. Effect of irrigation intervals and foliar spray treatments on yield and its components of maize during 2022 and 2023 seasons.

Treatments	2022					2023				
Irrigation intervals (I)	Foliar spray (F) treatments									
	F1	F2	F3	F4	Mean	F1	F2	F3	F4	Mean
	No. of kernels per ear									
15 days	505.73d	523.24c	555.17b	576.80a	540.24a	521.70d	534.98c	563.72b	589.98a	552.60a
20 days	437.75g	474.83e	529.42c	571.65a	503.41b	456.29g	505.52e	525.92cd	583.08a	517.70b
25 days	409.94h	429.51g	437.75g	452.17f	432.34c	419.93i	441.46h	449.39gh	471.33f	445.53c
Mean	451.14d	475.86c	507.45b	533.54b	-	465.97d	493.99c	513.01b	548.13a	-
	Shelling (%)									
15 days	73.54de	74.78cde	77.97bc	81.47a	76.94a	73.34e	77.25c	79.83b	85.39a	78.95a
20 days	71.89e	72.51de	75.71cd	81.27ab	75.34b	72.10ef	74.37de	76.53cd	83.12a	76.53b
25 days	62.01h	64.27gh	66.85fg	67.88f	65.25c	63.86h	65.10h	67.77fg	69.73fg	66.62c
Mean	69.15c	70.52c	73.51b	76.87a	-	69.77d	72.24c	74.71b	79.41a	-
	100 kernel weight (g)									
15 days	37.63de	40.61cde	42.23nc	44.99a	41.36a	38.16e	41.21c	42.85b	45.80a	42.00a
20 days	34.55e	36.48de	40.11cd	43.90ab	38.76b	36.01ef	38.21de	41.67cd	44.70a	40.15b
25 days	32.97h	35.44gh	37.27fg	39.06f	36.18c	34.89h	36.14h	38.75g	40.06fg	37.46c
Mean	35.05c	37.51c	39.87b	42.65a	-	36.35d	38.52e	41.09b	43.52a	-
	Grain yield (kg ha^{-1})									
15 days	8439e	8742d	9373bc	9648a	9050a	8830cd	9077c	9476b	10053a	9360a
20 days	7725f	8343e	9126e	9467ab	8665b	8062ef	8662d	9394b	10159a	9069b
25 days	6490h	6860g	7581f	7763f	7173c	6623h	7073g	7890f	8240e	7456c
Mean	7551d	7981c	8693b	8959a	-	7838d	8271c	8920b	9484a	-
	Biological yield (t ha^{-1})									
15 days	16.20bc	16.80ab	17.19a	17.31a	16.87a	17.05bc	17.42ab	17.77ab	18.03a	17.56a
20 days	14.96e	15.26de	15.73cd	16.66ab	15.66b	15.64d	15.88d	16.40cd	17.49ab	16.35b
25 days	12.90g	13.12g	13.36fg	13.86f	13.31c	13.31e	13.42e	13.7e	14.02e	13.64c
Mean	14.68c	15.06bc	15.43b	15.94a	-	15.33c	15.57bc	15.98ab	16.51a	-

Table 9. Effect of irrigation intervals and foliar spray treatments on carbohydrates, protein and oil percentages of maize during 2022 and 2023 seasons.

Treatments	2022					2023				
Irrigation intervals(I)	Foliar spray (F) treatments									
	F1	F2	F3	F4	Mean	F1	F2	F3	F4	Mean
	Carbohydrates %									
15 days	63.76d	67.97d	69.09a	71.24a	68.02a	61.32c	63.31b	65.90a	67.21a	61.32a
20 days	60.90g	63.37e	64.50c	66.18a	63.74b	59.25d	61.65c	62.58ab	63.14ab	59.25b
25 days	58.96h	59.44g	60.32g	61.05d	59.94c	56.49f	58.09d	61.56c	62.19b	56.49c
Mean	61.21d	63.59c	64.64b	66.16a	-	59.02d	61.02c	63.35b	64.18ab	-
	Protein %									
15 days	10.05a	10.44a	10.89a	11.02a	10.60a	10.39b	11.03a	11.35a	11.85a	11.16a
20 days	9.82b	9.59b	9.04b	10.56a	9.75b	9.74bc	9.91bc	10.33b	10.67b	10.16b
25 days	8.19bc	8.68bc	8.91bc	9.62b	8.85c	8.05c	8.57c	9.05b	9.83bc	8.88c
Mean	9.35b	9.57b	9.61b	10.40a	-	9.39b	9.84b	10.24b	10.78b	-
	Oil %									
15 days	5.13b	5.57ab	6.51a	6.69a	5.98a	5.48ab	5.97ab	6.24a	6.98a	6.17a
20 days	4.93b	5.15b	5.65ab	6.28a	5.50b	4.14c	4.92bc	5.57b	5.83ab	5.12b
25 days	4.02c	4.45bc	5.23b	5.95ab	4.91c	3.84d	4.41c	4.89bc	5.37b	4.63c
Mean	4.69bc	5.06b	5.80b	6.31a	-	4.49c	5.10bc	5.57b	6.06ab	-

CONCLUSION

The results showed that water consumption and applied water every 20 and 25 days decreased by (7.0% and 17.3%) and (6.2% and 16.6%), respectively, compared to 15 days as the average of the two seasons. The best growth, morpho-physiological, yield and yield components values were achieved when maize plants were irrigated at 15 days, while the highest water productivity values were achieved when plants were irrigated after 20 days and 15 days treatment. Plant height, leaf area, total chlorophyll, proline concentration, leaf transpiration, stomatal resistance, shelling percentage, 100-grain weight, biological and grain yields, water consumption and water productivity, carbohydrates, protein and oil percentages values for foliar spray treatments were taken the descending order $F_4>F_3>F_2>F_1$. Under the study conditions, the results showed that the interaction of irrigation every 15 days with F_4 treatment achieved high grain yield and grain quality with saving irrigation water and improving water productivity compared to all studied treatments.

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تأثير فترات الري والرش بحمضي الأسكوربيك والسالسيلك على الصفات المورفسيولوجية وجودة ومحصول حبوب الذرة الشامية

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تلعب فترات الري دوراً حيوياً في ترشيد مياه الري في المناطق القاحلة وشبه القاحلة. أجريت تجربة حقلية بمحطة بحوث سخا الزراعية بكفر الشيخ – مصر خلال موسمي 2022 و2023 لدراسة تأثير الري حيث تم ري نباتات الذرة كل 15 يومً و20 يومً و25 يومً كذلك تأثير الرش الورقي بمضادات الأكسدة (رش بالماء (F1)، رش بـ 100 جزء في المليون من حمض الساليسيليك (F2)، رش بـ 100 جزء في المليون من حمض الأسكوربيك (F3) ورش بـ 50 جزء في المليون من حمض الساليسيلليك+ 50 جزء في المليون من حمض الأسكوربيك (F4). على الصفات المورفسيولوجية والجودة والمحصول والعلاقات المائية.

أظهرت النتائج أن استهلاك المياه والمياه المضافة كل 20 يومً و25 يومً انخفض بنسبة 7.0% و17.34%؛ 6.2% و16.6% على التوالي مقارنة بـ 15 يوم كمتوسط للموسمين. تم تحقيق أفضل قيم الصفات المور فسيولوجية والمحصول ومكوناته والجودة عند ري نباتات الذرة كل15 يوم، في حين تم تحقيق أعلى قيم لإنتاجية المياه عند ري النباتات كل 20 يوم ومعاملة 15 يوم ،بينما الزيادة في ارتفاع النبات، المساحة الورقية، الكلوروفيل الكلي، تركيز البرولين، معدل النتح بالأوراق، مقاومة الثغور، عدد الحبوب بالصف نسبة التصافى، وزن 100حبة، محصول الحبوب والمحصول البيولوجي، استهلاك الماء وإنتاجية الماء ومحتوي حبوب الذرة من الكربوهيدرات والبروتين والزيت، اتخذت الترتيب التنازلي F4> F3> F2> F1، تحت ظروف الدراسة في كلا الموسمين.

أظهرت النتائج أن الري كل 15 يوم مع المعاملة F4 حقق إنتاجية حبوب عالية مع توفير مياه الري وتحسين إنتاجية المياه مقارنة بجميع المعاملات المدروسة.

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