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Effect of Irrigation Scheduling and Potassium Foliar Spray on Growth, Yield and Water Productivity of Maize.

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ABSTRACT

Scheduling irrigation play avital role to rationalize irrigation water in arid and semi-arid regions. A field experiment was conducted at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt in 2019 and 2020 to study the effect of irrigation scheduling; Irrigation was applied at 1.2, 1.0 and 0.8 of accumulative pan evaporation (APE) and potassium foliar spray 0 (F_1), 1.0 (F_2), 2.0(F_3) and 3.0 (F_4) gL^{-1} K_2O on growth, physiology, yield and water productivity of maize. Results demonstrated that water consumptive use and applied water at 1.0 of APE and 0.8 of APE were decreased by 6.7% and 6.0%; 14.8% and 16.6%, respectively in comparison with to 1.2 of APE as an average of both seasons. The best growth, physiology, yield, and yield component were achieved when maize plants irrigated at 1.2 of APE, whereas the highest values of water productivity were achieved when plants irrigated at 1.2 of APE and 1.0 of APE treatments without any significant differences between them. Plant hight, leaf area, total chlorophyll, proline concentration, leaf transpiration, stomatal resistance, shelling percentage, 100 kernel weight, biological and grain yield, water consumptive use and water productivity took the descending arrange $F_4 > F_3 > F_2 > F_1$. Under study condition, it could be concluded that the application of irrigation at 1.0 of APE×F_4 interaction, achieved a reasonable grain yield, saved irrigation water, and enhanced water productivity in comparison with all studied treatments as well as, irrigation at 1.2 APE × F_4 interaction.

Keywords**:** Maize; potassium; irrigation; water productivity.

INTRODUCTION

Maize (*Zea mays* L.) is considered one of the main cereals crops in global food security due to its huge cultivation area and production, worldwide (Ghosh *et al.* 2020), it ranks number three after both wheat and rice and use in humans, poultry and livestock nutrition (Ali *et al.*2016). The harvested area in Egypt is about 1458881ha, that produces grains up to 7.5 million tons (FAOSTAT,2020). Maize production is exposed to many abiotic stresses, especially water shortage (Ul-Allah *et al.* 2020). Water shortage has emerged as one of the most serious problems, that could reduce maize yield up to 40% in semi-arid and arid regions (Daryanto *et al.* 2016 and Molla *et al.* 2019). Drought significantly decreased shoot, in addition to root lengths and weights, leaf transpiration, stomatal conductance, photosynthesis rates also total chlorophyll content in comparison with well-watered circumstances (Wasaya *et al.* 2021). Also, it has adverse impacts on crop physiology and morphology, hence decreasing crop yield (Maqsood *et al.* 2012). Irrigation scheduling is planning and decision being how much water to apply and when to apply it, that represent one of the most significant strategies in order to deal with shortage of water through achieving the optimum soil moisture status in the region of the root. Which promote plant growth, water productivity and also yield of the crop (Farrag *et al.* 2021). Optimum irrigation scheduling significantly enhanced water productivity, while saved irrigation water of corn (Shahrokhnia and Zare2022). One of the easy and applicable methods is scheduling the irrigation through the use of meteorological approach, which linked evapotranspiration from the crop with an open pan evaporation (Himanshu *et al.* 2012). Scheduling of irrigation at lower soil moisture depletion and increasing irrigation numbers until 6 irrigations per season were achieved the maximum leaf area index, the height of plant, grain yield and water productivity. But more irrigations number is not a standard to obtain maximum yield, increasing irrigation numbers from 6 to 10 irrigations per season didn't significantly affect maize grain yield (Mubeen *et al.* 2013). The yield of the grain did not change significantly when irrigation scheduling at 0.75 APE and 1.0 APE, but water productivity was higher when apply 0.75 APE (Tariq and Usman, 2009). Maize grain yield and applied water were increased when it irrigated at 1.0 APE compared to at 0.8 APE and 0.6 APE (Bibe *et al.* 2016). There weren't significant differences obtained between grain yield among 1.0 APE and 1.25 APE (Aulakh *et al.*2012). The highest growth rate, chlorophyll content, 1000 grain weight, plant height, yield of the grain and biological yield were gained of 1.25 APE which was statistically identical to 1.0 APE followed by 0.75 APE, then 0.50 APE, the amount of applied water was taken the descending order 1.25 >1.0> 0.75 >0.50 APE (Razzak *et al.* 2022).

Potassium (K) is one of the vital macronutrients, that improves the growing, yield besides water productivity of plants as well as maize under both water stress and normal conditions, it alleviated drought susceptibility under water stress conditions (Ul-Allah *et al.* 2020). The application of foliar K is an important strategy to overcome the unsuitable soil characteristics which reduces the availability of K, as supplemental source of K. Supplemental potassium as a foliar application (1% K_2O) at reproductive stage significantly

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enhanced physiology, quantity, and quality of maize grain yield under both water stress and normal conditions, so, it could be used to overcome potassium deficiency in the conditions of water stress (Farooq *et al.* 2012). During drought conditions potassium can reduce evapotranspiration because of its main mission in closing and opening of stomata that affect leaves transpiration plus CO_2 enters leaves. Transpiration rate will increase, but stomatal activity will decrease, if K is inadequate in plant tissues (Damon and Rengel, 2008). Maize grain yield and its components were significantly increased when Potassium foliar spray was applied compared to soil application, the grain yield values under foliar treatment were taken the descending order with 3% > 2% > 1% K_2O foliar spray (Ali *et al.* 2016). Potassium deficiency significantly decreased both leaves size and number because of the decrease in plant photosynthetic activity (William, 2008). The adverse impacts of drought in maize could be ameliorated, when applied the optimum doses of potassium as foliar spray, due to its role of maintaining optimum cell turgidity and osmotic potential. Foliar application of K_2SO_4 at 2% improved growth attributes, total chlorophyll (9%) and relative water content (10%) under severe drought (Wasaya *et al.* 2021). Potassium foliar spray as K-silicate three times significantly increased maize grain yield under both deficit and normal irrigation conditions and enhanced water productivity(Gomaa *et al.* 2021).The best of our knowledge, there is a lack of the studies that addressed the impact of scheduling of irrigation in addition to K foliar application upon maize crop, Thus the chief object of this study is demonstrating impacts of scheduling of irrigation and potassium foliar spray upon maize crop yield, its yield components besides its water productivity.

MATERIALS AND METHODS

Location of the experiment:

During the summer growing seasons of 2019 and 2020, we performed a field experiment at Sakha Agricultural Research Station (31° 07' N Latitude, 30° 05' E Longitude), Kafr El-Sheikh, Egypt aiming at studying influence of irrigation scheduling and K foliar spray concentrations upon maize growth, yield, and water relations. As demonstrated in table (1): Sakha agro-metrological station provided us with the agro-metrological data of the area of the experiment.

Table 1. The meteorological data of the studied site in 2019 and 2020 season.

Months		Air temperature (c°)			Relative humidity (%)			Wind speed	Pan Evaporation
		Max.	Min.	Mean	Max.	Min.	Mean	km d^{-1}	(mmd^{-1})
2019	June	33.00	28.00	30.50	81.50	50.00	65.75	103.00	8.46
	July	33.50	28.40	30.95	85.20	54.40	69.8	83.80	8.08
	August	34.20	28.90	31.55	85.70	55.60	70.65	68.70	6.82
	September	36.70	32.50	33.90	87.60	58.40	72.50	79.90	4.81
	October	30.30	26.70	28.50	87.30	54.30	70.80	56.60	3.84
2020	June	31.10	25.20	28.15	78.00	42.60	60.30	111.80	8.44
	July	33.7	27.30	30.50	84.20	51.10	67.65	101.70	8.79
	August	34.60	28.20	31.40	85.30	49.60	67.45	92.4	8.03
	September	34.60	27.10	30.85	86.70	47.70	67.20	93.30	6.24
	October	31.50	24.60	28.05	84.80	47.10	65.95	72.70	4.12

Before cultivation process, we collected samples 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 with Klute, (1986). Soil field capacity besides permanent wilting point were determined through using pressure membrane method at 0.33 and 15 Atm, respectively consistent with James, (1988). pH and electrical conductivity of soil were analyzed consistent with Page *et al.*, (1982) as presented in Table (2).

Table 2. chemical and physical properties of the soil at experiment site as a mean value of both1st and 2nd seasons.

Soil depth	F.C[1]	P.W.P[2]	A.W[3]		Bulk density	Total porosity	Particle size distribution			Texture	EC_e	pH
(cm)	(%)	(%)	(%)	mm	(g cm^{-3})	(%)	Sand (%)	Silt (%)	Clay (%)	class	(dS m^{-1})	1:2.5
0-15	42.09	21.86	20.23	33.98	1.12	57.74	23.92	22.85	53.23	Clayey	1.89	7.63
15-30	38.21	21.03	17.18	30.41	1.18	55.47	22.71	23.02	54.27	Clayey	2.21	7.88
30-45	36.57	20.31	16.26	30.00	1.23	53.58	21.84	23.24	54.92	Clayey	2.58	8.05
45-60	35.08	19.96	15.12	29.71	1.31	50.57	20.33	24.58	55.09	Clayey	2.75	8.37
Mean	37.99	20.79	17.19	31.03	1.21	54.34	22.20	23.42	54.38	Clay	2.36	

1 = Field capacity, 2 = Permanent wilting point, A.W= Available water

Design and treatments of the experiment:

The experiment was plotted in a strip design containing three replications. Irrigation scheduling treatments were allocated in vertical plots whereas, potassium foliar spray concentrations were distributed in the horizontal plots. Irrigation scheduling treatments were *i.e.*,1.2 accumulative pan evaporation (APE),1.0 APE, and 0.8 APE, the available water content in soil profile was transformed to water depth (124.1 mm), every irrigation time was defined once accumulative pan evaporation was amounted 155.1±5, 124.1± 5 and 103.4±5 mm for 0.8, 1.0 and 1.2 APE respectively. Potassium foliar spray treatments were control (foliar spray with water) 0 ppm (F_1), 1.0 gL^{-1} (F_2), 2.0 gL^{-1} (F_3) and 3.0 g$L^{-1}$of K_2O were applied twice after30 and 45 days respectively from sowing date.

Maize (c.v. single cross hybrid yellow 168) was implanted on 1st and 6th June in 2019 and 2020 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 m^2(inclded10 rows, 6m length and 0.7m width for each). Plots were isolated by ditches 1.5m width to avoid lateral seepage between treatments. On one side of the ridge maize grains were sown in hills 25 cm apart, thinned in single plant per hill before first irrigation (21days after planting). All treatments were received 40 kgP_2O_5 per ha calcium superphosphate (15.5%P_2O_5) throughout land preparation before planting. The equivalent of 286 kg N per ha (from ammonium nitrate (33.5% N)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 crop during both growth seasons were conducted as stated by the Agriculture Research Center recommendations.

Applied Water (AW):

Irrigation scheduling treatments for maize were applied after the plant establishment, with the second irrigation from planting, when to irrigate was defined through accumulate the amount of pan evaporation. The applied irrigation for every plot was measured through using UPVC (1m length and 5 cm inner diameter) spile tubes, that allow water discharge from the field canal into each plot. A fixed sliding gate was used to keep appropriate constant head over the center of spile cross-section, effective head was regularly measured during irrigation processing and a stopwatch was used to record the time of irrigation. Quantity of water delivered by the spile tube was calculated as stated by (Majumdar 2002) using the subsequent equation 1:

$$q = CA\sqrt{2gh} \quad (1)$$

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)

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

$$CU = \sum_{i=1}^{n=4} Di \times Bdi \times (\theta_{2i} - \theta_{1i}) / 100 \quad (3)$$

Where, CU is water consumptive use (cm), Di is soil layer depth (15 cm), Bdi is soil bulk density ($g\ cm^{-3}$) for this depth, $\theta_{1i}$is gravimetric soil moisture (%) before irrigation, θ_{2i} is gravimetric soil moisture (%) after 48 h from irrigation, n is number of soil layers.

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)

Water Productivity (WP):

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

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

Growth characteristics:

Five randomly plants were collected from the center of every plot at silking stage (after 75days from planting) to measure corn leaf area through (blade length × maximum blade width × 0.75) according to Saxena and singh(1965). Plant height (cm) was determined from 10 plants.

Physiological traits:

Chemical content of leaves as total chlorophyll content and proline accumulation was determined according to Lichtenthaler and Buschmann (2001) and Bates et al., (1973).

Stomatal resistance (S cm^{-1}) and transpiration rate (µg $H_2O\ m^{-2}\ s^{-1}$):

Portable Steady state Porometer (LI – COR Model LI 1600) was used aiming at determining both of them on fully expanded ear leave on five randomly selected plants.

Yield and yield components:

Five plants were gathered haphazardly at the harvest starting by the fourth ridge in every plot aiming at measuring number of kernels per ear in addition to shelling percentage. Thereafter, the two central ridge plants were collected to determine 100-kernel weight (g), biological yield (kg ha^{-1}) and grain yield (kg ha^{-1}) at moisture content of 15.5%

Statistical analysis:

Statistical analysis of variance (ANOVA) was done to obtain data by COSTAT software. The mean differences between treatments were investigated by Duncan's Multiple Range Test at 5% level of significance (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

1. Water relations

Water consumptive use and applied water

The maximum values of water consumptive use and applied water (Table 3) were founded after 1.2 of APE compared to 1.0 of APE and 0.8 of APE, the values of water consumptive use and applied water after 1.0 of APE and 0.8 of APE were decreased by 6.5% and 14.8%, 6.2% and 16.6%, respectively in comparison with1.2 of APE as an average of both seasons. So these results agree with the results found by Aulakh *et al.*, (2012) Bibe *et al.*, (2016)and Razzak *et al.*,(2022), they reported that applied water amounts were augmented with increase the factor of APE, whereas water consumptive use was increased by increasing applied water amount(Salim *et al.* 2019 and Farrag *et al.*2021). water consumptive use and applied water values for potassium foliar spray treatments were taken the descending order $F_4 > F_3 > F_2 > F_1$ in the 1st and also the 2nd seasons. Noticeable differences were documented between the interactions among scheduling irrigation and potassium foliar spray treatments. The maximum values of water consumptive use and applied water were gotten from 1.2 of APE×F_4 to be 66.24 cm and 8301 m^3ha^{-1}respectively as an average of 2019 and 2020 seasons, While lowermost values were recorded after 0.8 of APE×F_1 interaction to be 51.98 cm and 6422 m^3ha^{-1} as mean of both seasons. water consumptive use and applied water values were reduced after 1.0 of APE×F_4 interaction by 6.69% and 5.96% in comparison with 1.2 of APE× F_4 interaction as the mean of both studied seasons (Table 3). This might be owing to the importance of potassium role for decreasing crops water requirement during drought conditions due to its dominant role to control closing and opening of stomata, which affect leaves transpiration that will be reflected into water loss. The stomatal activity reduces and transpiration increases, if K is inadequate in plant tissues (Damon and Rengel, 2008).

Table 3. Seasonal water consumptive use and applied water as affected by irrigation scheduling, potassium foliar spray in addition to the interaction between them during 2019 and 2020 growing seasons.

Treatments		CU (cm)			AW (m^3ha^{-1})		
Treatments	Foliar spray	2019	2020	Mean	2019	2020	mean
1.2 of APE	F_1	60.38	63.14	61.76	7641	8107	7874
	F_2	61.87	64.98	63.42	7739	8164	7952
	F_3	63.37	65.90	64.63	7935	8219	8077
	F_4	65.21	67.28	66.24	8341	8260	8301
Mean		62.68	65.32	64.00	7914	8188	8051
1.0 of APE	F_1	57.16	58.31	57.73	7139	7423	7281
	F_2	58.65	59.69	59.17	7170	7705	7438
	F_3	60.03	61.53	60.78	7457	7911	7684
	F_4	60.26	63.37	61.81	7574	8038	7806
Mean		59.00	60.72	59.86	7335	7769	7552
0.8 of APE	F_1	52.33	51.64	51.98	6238	6606	6422
	F_2	53.25	53.71	53.48	6405	6680	6543
	F_3	54.74	56.24	55.49	6623	6979	6801
	F_4	56.12	57.73	56.93	6890	7275	7083
Mean		54.17	54.86	54.51	6539	6885	6712
Overall mean of F	F_1	56.58	57.73	57.16	7006	7379	7193
	F_2	57.96	59.46	58.71	7105	7516	7311
	F_3	59.34	61.18	60.26	7338	7703	7521
	F_4	60.49	62.79	61.64	7602	7858	7730

Water productivity

Irrigation scheduling, potassium foliar spray and the interaction between them affected water productivity (Fig 1). Significant differences were recorded among irrigation scheduling treatments and potassium foliar spray treatments, water productivity maximum values were found when maize irrigated at 1.2 of APE and 1.0 of APE treatments with no any significant differences among them, however the lowermost values were recorded after 0.8 of APE in both studied seasons. Water productivity after 0.8 of APE was decreased by 7% compared to 1.0 of APE as an average of the two seasons. These consequences were in harmony with those found by Gomaa *et al.*, (2021), they indicated long irrigation intervals significantly raised water use efficiency. Water productivity was increased by applying the best irrigation scheduling, that keep optimum soil moisture in the root zone (Shahrokhnia and Zare2022). As well as the maximum values of water productivity was obtained from F_3 and F_4 with no any significant differences among them, while the lowermost values were found from F_1. Water productivity significantly reduced by 11.5% of F_1 compared to F_4 as an average of the 1st and 2nd seasons. Significant differences were obtained through the interaction between irrigation scheduling and potassium foliar spray, the maximum water productivity values were obtained of 1.0 of APE × F_4 followed by 1.2 of APE×F_4 without any significant differences between them to be 1.22 and 1.15 kgm^{-3}respectively, while the lowest value was obtained of 0.8 of APE×F_1 to be 1.0 kgm^{-3} as an average of the two seasons. These consequences were in accordance with the consequences found by Gomaa *et al.*, (2021). In this concern Tefera (2021)reported that the maximum maize water productivity was obtained when the optimum irrigation scheduling was done as an irrigation interval of 14 days in addition to increasing the amount of recommended applied fertilizer by 25%.

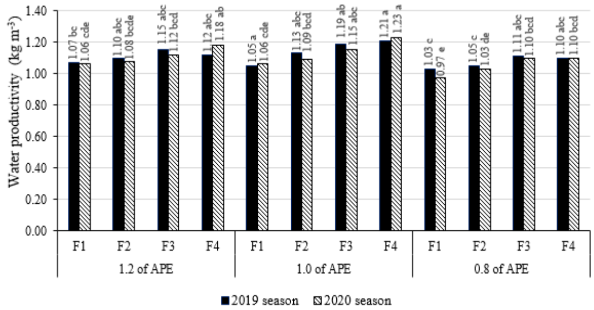

Fig. 1. Water productivity (kg m^{-3}) as influenced by the interaction between irrigation scheduling and potassium foliar spray in the 1st and 2nd growing seasons.

2. maize growth and yield

Vegetative growth

The impact of irrigation scheduling and potassium foliar spray of some vegetative growth characteristics displayed that, there are significant differences of plant height, leaf area and total chlorophyll among different irrigation scheduling, potassium foliar spray and finally the interaction among them (Table 4). The maximum values of abovementioned maize vegetative characteristics were obtained after 1.2 of APE, instead the lowermost values of them were founded in plants irrigated with 0.8 of APE in both studied seasons. The vegetation growth parameters as well as grain yield were increased at 1.25APE followed by 1.0 APE irrigation scheduling (Pritee *et al.* 2015). The values of plant height, leaf area and chlorophyll under different potassium foliar spray treatments were taken the descending order F_4> F_3> F_2> F_1 in the 1st and 2nd seasons. plant height and leaf area increase with increasing the applied foliar K application might be a result of the enzymatic activity which assisted plants to increase their heights and photosynthetic activity (Amanullah *et al.* 2016).The highest values of plant height and total chlorophyll were found after 1.2 of APE×F_4 followed by 1.2 of APE×F_3 and 1.0 of APE×F_4, whereas the elevated values of leaf area were obtained after 1.2 of APE×F_4 and 1.0 of APE×F_4 with no essential difference among them, but the lowermost values of plant height, leaf area and total chlorophyll were found after 0.8 of APE×F_1 in the 2019 and 2020 season (Table 4). This may be due to the importance of potassium foliar spray in ameliorating drought negative impacts on maize by preserving cell turgidity and osmotic potential, improved growth attributes, total chlorophyll, as well as the application of optimum irrigation scheduling which enhance photosynthetic rate, total chlorophyll contents and maize yield (Wasaya *et al.* 2021)

2. Physiological parameters

Data displayed in Table (5) revealed significant differences were obtained for proline content, stomatal resistance and leaf transpiration between scheduling irrigation, potassium foliar spray treatments and the interaction between them. The concentration of proline was reduced when irrigation intervals were increased, the proline concentration was taken the descending order 0.8 of APE>1.0 of APE>1.2 of APE, these results cope with those reported by Sampath kumar *et al.*, (2013) observed higher proline content in maize leaf under severe water-stressed treatments, while the lowest proline content in mild water deficit that received 100% of crop evapotranspiration. Leaf transpiration and stomatal resistance were decreased when irrigation intervals were increased, they were taken the descending order 1.2 of APE>1.0 of APE>0.8 of APE. This might be a result of the decrease in available moisture content of soil, hence decrease in transpiration rate as well as grain yield (Klimešová *et al.*2021). These finding cope with those presented by Wasaya *et al.,* (2021), they 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(Martínez-Cob *et al.*2009 and Xuan *et al.* 2021). Proline concentration, leaf transpiration and stomatal resistance were increased when the potassium foliar spray concentration increased, they were taken the descending order F_4> F_3> F_2> F_1 in both studied seasons. This may be due to the dominant role of K in the closing and opening of stomata, which affect transpiration. The stomatal activity decreases and transpiration loss increases, if K is inadequate in plant tissues (Damon and Rengel, 2008). The maximum values of leaf transpiration and stomatal resistance were obtained for plants received 1.2 of APE×$F_4$and 1.0 of APE× F_4 interactions without any essential differences among them, whoever the lowest values were found for plants treated with 0.8 of APE×F_1 interaction in the two studied seasons (Table 5). The highest values of proline concentration were obtained for the treatment of 0.8 of APE×F_4 interaction, while the lowermost values were found of 1.2 of APE×F_1 interaction in both seasons. Potassium foliar spray can potentially reduce the negative impacts of drought in maize and improved growth attributes and proline under severe drought conditions (Wasaya *et al.*2021).

Table 4. Impact of irrigation scheduling, potassium foliar spray treatments and the interaction among them on vegetative growth traits of maize plants during 2019 and 2020 growth seasons.

Treatments	1st season					2nd season				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
Plant height (cm)										
1.2 of APE	266 ef	276 cd	288 b	298 a	282 a	270 c	280 c	299 b	311 a	290 a
1.0 of APE	257 gh	262 fg	277 c	287 b	271 b	260 g	264 f	281 c	302 b	277 b
0.8 of APE	238 i	253 h	262 fg	271 de	256 c	240 h	258 g	267 ef	274 d	260 c
Mean	254	263	276	285 a		257 d	267 c	282 b	295 a	
Leaf area (cm^2)										
1.2 of APE	708.2 d	752.8 c	768.0 b	799.0 a	757.0 a	726.2 d	764.6 c	795.4 b	817.0 a	775.8 a
1.0 of APE	668.4 f	703.9 d	749.7 c	796.8 a	729.7 b	681.3 e	719.1 d	764.1 c	813.8 a	744.6 b
0.8 of APE	614.9 h	633.1 g	677.8 ef	687 e	653.2 c	632.5 g	650.3 f	683.8 e	723.6 d	672.6 c
Mean	663.8 d	696.6 c	731.8 b	760.9 a		680.0 d	711.3 c	747.8 b	784.8 a	
Total chlorophyll (mg/dm^2 LA)										
1.2 of APE	5.35 d	5.46 bc	5.69 a	5.67 a	5.54 a	5.36 c	5.50 b	5.70 a	5.71 a	5.57 a
1.0 of APE	4.91 g	5.13 e	5.44 c	5.52 b	5.25 b	5.07 e	5.25 d	5.45 b	5.67 a	5.36 b
0.8 of APE	4.42 i	4.72 h	5.01 f	5.14 e	4.82 c	4.53 g	4.88 f	5.07 e	5.28 d	4.94 c
Mean	4.89 d	5.10 c	5.38 b	5.44 a		4.99 d	5.21 c	5.41 b	5.55 a	

Table 5. Maize physiological characteristics as affected by irrigation scheduling, potassium foliar spray treatments and the interaction between them during 2019 and 2020growing seasons.

Treatments	1st season					2nd season				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
Proline (mg g^{-1}f.w)										
1.2 of APE	0.63 k	0.77 j	0.93 i	1.03 h	0.84 c	0.67 h	0.82 g	0.99 f	1.09 f	0.89 c
1.0 of APE	1.04 h	1.26 g	1.34 f	1.48 e	1.28 b	1.09 f	1.32 e	1.39 e	1.51 d	1.33 b
0.8 of APE	1.76 d	1.84 c	2.0 b	2.21 a	1.95 a	1.89 c	1.91 c	2.07 b	2.29 a	2.04 a
Mean	1.14 d	1.29 c	1.42 b	1.57 a		1.22 d	1.35 c	1.48 b	1.63 a	
Stomatal resistance(S cm^{-1})										
1.2 of APE	0.50 d	0.54 bc	0.56 ab	0.57 a	0.61 a	0.51 bc	0.56 b	0.67 a	0.73 a	0.62 a
1.0 of APE	0.46 e	0.50 d	0.52 cd	0.56 a	0.57 b	0.48 cd	0.53 bc	0.56 b	0.72 a	0.57 b
0.8 of APE	0.42 f	0.43 f	0.47 e	0.5 d	0.47 c	0.44 d	0.44 d	0.49 cd	0.52 bc	0.47 c
Mean	0.46 d	0.49 c	0.51 b	0.54 a		0.48 d	0.51 c	0.57 b	0.66 a	
Leaf transpiration rate(µg H_2O m^{-2} s^{-1})										
1.2 of APE	10.20 cde	10.65bcd	11.10 b	12.01 a	10.99 a	11.84 c	12.35 bc	12.66 ab	12.96 a	12.45 a
1.0 of APE	9.90 de	10.30 cde	10.90 bc	11.35 ab	10.61 a	10.06 fg	10.55 def	11.05 d	12.24 bc	10.98 b
0.8 of APE	9.13 f	9.78 ef	10.07 de	10.30 cde	9.82 b	9.44 h	9.87 gh	10.20 efg	10.75 de	10.07 b
Mean	9.74 d	10.24 c	10.69 b	11.22 a		10.45 d	11.92 c	11.30 b	11.98 a	

2. Yield and yield components

There are significant differences of kernels number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield as affected by different irrigation scheduling, potassium foliar spray and the interaction among them (Table 6). The maximum values of kernels number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield were obtained after 1.2 of APE and F_4 compared to the other irrigation scheduling and potassium foliar spray treatments, respectively in the two studied 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 1.0 of APE, whereas they reduced by 19.6%, 15.4%, 11.7%, 21.7% and 20.5% respectively for plants exposed to 0.8 of APE compared to 1.2 of APE as an average of the two studied seasons. That consequences agree with that reported by Aulakh *et al.* (2012)

Maqsood *et al.* (2012), Mubeen *et al.* (2013) and Ul-Allah *et al.* (2020)and Razzak *et al.* (2022).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 (Wasaya *et al.* 2021). The yield reduction could reach40% Daryanto *et al.* ,(2016)and Molla *et al.*,(2019),the cause of grains reduction per ear and 100-grain weight irrigated at 0.8 APE or deficit irrigated plots compared to plots that irrigated at 1.0 and 1.2 APE may occur as a result of shortage in water at different growth stages which impacted formation of the grains and adapts translocation from source to grains. Higher grains per ear were founded with raising irrigation water in comparison with non irrigated plots, whereas higher values of grains per ear and 1000 grains weight under high irrigation frequencies (Kuşçu and Demir 2012). Also, Bahrani *et al.,* (2012) reported higher 1000-grain weight with recurrent irrigation supplies at optimum intervals.On the other hand, number of kernels per ear were increased by 15.2%, 10.3% and 5.7%, shelling percentage was increase by 11.1%, 8.7 and 5.2%, 100 kernels weight was increased 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 studied seasons. These results were good agreement with the results founded by Amanullah *et al.,* (2016), this may be due to the importance role of potassium as one of the main macronutrients, which enhance the growth, maize yield beneath both normal and water stressful conditions (Ali *et al.*2016; Ul-Allah *et al.* 2020 and Basha *et al.* 2021). Additionally, potassium is very important element which increases the rate of carbon dioxide integration, translocation of photosynthetic outputs from leaves to grain, the rate of grain fills and the period of fills, and increase the maize grain yield, the optimal availability of K under deficit irrigation could enhance development of roots and activate it sufficiently to absorb water from soil (Farooq *et al.* 2012). Maqsood *et al.,* (2013) found an essential increase in weight of the grains in addition to higher numbers of grains per ear with higher potassium application. Confirmatory results were founded by Hussain *et al.,* (2007) and Aslam *et al.*,(2014) obtained an increasing in 1000-grain weight and grains per ear with raising fertilization by potassium.

Table 6. Yield and yield components of maize plants as affected by irrigation scheduling, foliar spray treatments in addition to the interaction between them during 2019 and 2020 growing seasons.

Treatments	1st season					2nd season				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
					No. of kernels per ear					
1.2 of APE	491 d	508 c	539 b	560 a	524 a	506.5 d	519.4 c	547.3 b	572.8 a	537 a
1.0 of APE	425 g	461 e	514 c	555 a	489 b	443.0 g	490.8 e	510.6 cd	566.1 a	503 b
0.8 of APE	398 h	417 g	425 g	439 f	420 c	407.7 i	428.6 h	436.3 gh	457.6 f	433 c
Mean	438 d	462 c	492 b	518 a		452 d	480 c	498 b	532 a	
					Shelling (%)					
1.2 of APE	71.40 de	72.60cde	75.70bc	79.10 a	74.70 a	71.20 e	75.00 c	77.50 b	82.90 a	76.65 a
1.0 of APE	69.80 e	70.40 de	73.50 cd	78.90ab	73.15 b	70.00ef	72.20 de	74.30 cd	80.70 a	74.30 b
0.8 of APE	60.20 h	62.40gh	64.90fg	65.90 f	63.35 c	62.00 h	63.20 h	65.80 g	67.70fg	64.68 c
Mean	67.13 c	68.47 c	71.37 b	74.63 a		67.73 d	70.13 c	72.53 b	77.10 a	
					100 kernel weight (g)					
1.2 of APE	36.53 ef	39.43 cd	41.00 bc	43.68 a	40.16 a	37.05 f	40.01 cd	41.6 bc	44.47 a	40.78 a
1.0 of APE	33.54 gh	35.42 fg	38.94 cd	42.62 ab	37.63 b	34.96 g	37.10 ef	40.46 cd	43.40 ab	38.98 b
0.8 of APE	32.01 h	34.41 fg	36.18 ef	37.92 de	35.13 c	33.87 g	35.09 g	37.62 ef	38.89 de	36.37 c
Mean	34.03 d	36.42 c	38.71 b	41.41 a		35.29 d	37.40 c	39.89 b	42.25 a	
					Biological yield (t ha^{-1})					
1.2 of APE	15.73 bc	16.31 ab	16.69 a	16.81 a	16.38 a	16.55 bc	16.91 ab	17.25 ab	17.50 a	17.05 a
1.0 of APE	14.52 e	14.82 de	15.27 cd	16.17 ab	15.20 b	15.18 d	15.42 d	15.92 cd	16.98 ab	15.87 b
0.8 of APE	12.52 g	12.74 g	12.97 fg	13.46 f	12.92 c	12.92 e	13.03 e	13.38 e	13.61 e	13.24 c
Mean	14.25 c	14.62 bc	14.98 b	15.48 a		14.88 c	15.12 bc	15.51 ab	16.03 a	
					Grain yield (kg ha^{-1})					
1.2 of APE	8193 e	8487 d	9100 bc	9367 a	8786 a	8573 cd	8813 c	9200 b	9760 a	9087 a
1.0 of APE	7500 f	8100 e	8860 c	9191 ab	8413 b	7827 ef	8410 d	9120 b	9863 a	8805 b
0.8 of APE	6301 h	6660 g	7360 f	7537 f	6964 c	6430 h	6867 g	7660 f	8000 e	7239 c
Mean	7331 d	7749 c	8440 b	8698 a		7610 d	8030 c	8660 b	9208 a	

The highest values of kernels number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield (Table 6) were recorded after 1.2 of APE×F_4 and 1.0 of APE×F_4 interactions with on important differences among them, whereas the lowermost values were gotten after 0.8 of APE×F_1interaction for the 1st and 2nd studied seasons. Maize grain yield for plants treated with 1.0 of APE×F_4 interaction was increased by 13.6% in comparison with 1.2 of APE×F_1 interaction as a mean of both seasons. The increment of number of kernels, shelling percentage, 100 kernel weight and grain yield may be due to the importance of foliar spray of potassium to overcome the deficiency of K, that improve the growth and maize yield (Gomaa *et al.* 2021 and Wasaya *et al.* 2021). Increasing numbers of irrigation in addition to levels of K, that essentially raised grain and biological yield. Higher grain and biological yield were obtained in plots which irrigated at 1.2 and1.0 APE, however lower biological yield was founded in plots which irrigated at 0.8 APE. likely, increased levels of potassium also raised biological and grain yield of maize. The probable cause may be due to the optimum moisture supply at critical phases of crop growth ended by the best crop growth and photosynthesis formation that eventually increased grain and maize biological yield. The results in this study confirmed the consequences found by Maqsood *et al.,* (2013) and Bahrani *et al.,* (2012) exposed higher grain in addition to biological yield with full irrigation in comparison with high irrigation frequencies. The possible cause for increasing grain and biological yield with the application of foliar potassium may be owing to the improvement in roots growth which ended by better uptake of moisture and hence crop survival under severe drought circumstances (Pettigrew, 2008). Confirmatory findings were obtained by Aslam *et al.,* (2014) recorded higher grain in addition to biological yield with proper dose of K fertilizers. Our results cope with those obtained by Tariq *et al.*,(2011) and Maqsood *et al.*,(2013).

CONCLUSION

This study was done in order to define the optimum irrigation scheduling by using a simple and applicable method for farmers, which depending on accumulate from pan evaporation (class A pan) and potassium foliar spray to overcome unfavorable soil conditions that reduce its availability, especially in arid regions. Under study circumstances, we can concluded that, Applying 1.0 of APE×F_4 interaction, irrigation scheduling when accumulate 1.0 of pan evaporation with potassium foliar spray 3.0 gL^{-1} K_2O twice, 30 and 45 days after planting. as it achieved the maximum values of stomatal resistance, kernels number per ear, shelling percentage, 100 kernel weight, biological yield and grain yield without any significant differences with irrigation at 1.2 of APE×F_4 interaction. But irrigation at 1.0 of APE×F_4 increased applied water and water productivity by 6% compared to irrigation at 1.2 APE × F4 interaction.

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تأثير جدولة الري والرش الورقي بالبوتاسيوم على النمو والمحصول وانتاجية المياه للذرة الشامية

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الملخص

الملخص العربيان لجدولة الري دور أساسي في ترشيد استخدام مياه الري في المناطق الجافة وشبة الجافة. أجريت تجربة حقلية بمحطة البحوث الزراعية بسخا- محافظة كفر الشيخ– مصر في عامي ٢٠١٩ و ٢٠٢٠ لدراسة تأثير جدولة الري (الري عند تجميع ١,٢ و ١,٠ و ٠,٨ من بخر الوعاء التراكمي والرش الورقي بالبوتاسيوم بتركيزات صفر (F_1) و ١ (F_2) و ٢ (F_3) و ٣ (F_4) جرام/لتر K_2Oعلى النمو وبعض الصفات الفسيولوجية والمحصول وانتاجية المياه للذرة الشامية. أوضحت النتائج أن قيم الاستهلاك المائي والماء المضاف لمعاملات الري عند تجميع ١,٠ و٠,٨ من بخر الوعاء التراكمي قد انخفضت بمقدار ٦,٧% و٦,٠%، ١٤,٨% و١٦,٦% على الترتيب مقارنة بمعاملة الري عند تجميع ١,٢ من بخر الوعاء التراكمي كمتوسط للموسمين. لقد كانت أفضل قيم للنمو والصفات الفسيولوجية والمحصول ومكوناته لمعاملة الري عند تجميع ١,٢ من بخر الوعاء التراكمي، وحيث ان اعلى القيم لإنتاجية المياه تم الحصول عليها لمعاملة الري عند تجميع ١,٢ و ١,٠ من بخر الوعاء التراكمي دون وجود فرق معنوي بينهما. لقد أخذت قيم طول النبات والمساحة الورقية وتركيز الكلوروفيل الكلى والبرولين والنتح ومقاومة الثغور بالأوراق ومعدل التفريط ووزن ١٠٠ حبة والمحصول البيولوجي ومحصول الحبوب والاستهلاك المائي وانتاجية المياه الترتيب التنازلي التالي: $F_4 > F_3 > F_2 > F_1$. تحت ظروف اجراء التجربة يمكن التوصية بتطبيق التفاعل (1.0 of APE × F_4) بين معاملة الري عند تجميع ١,٠ من بخر الوعاء التراكمي والرش الورقي بالبوتاسيوم بتركيز ٣جرام/لتر لتحقيها انتاج جيد من محصول الحبوب وتوفير مياه الري وتحسين إنتاجية المياه مقارنة بباقي المعاملات المدروسة وبالمثل بمعاملة التفاعل (1.0 of APE × F_4) بالري عند تجميع ١,٢ من بخر الوعاء التراكمي والرش الورقي بالبوتاسيوم ٣ جرام/لتر.