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IMPACT OF IRRIGATION INTERVALS, POTASSIUM SILICATE, AND CHITOSAN ON THE PRODUCTIVITY AND WATER RELATIONS OF SOME BARLEY VARIETIES GROWN IN SANDY SOILS IN EGYPT

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ABSTRACT: Barley is one of the four top cereals produced worldwide. It was used as the first human food crop in the past. Nowadays, it is used for animal feeding and some industrial drinking. The objective of this study is to investigate the effect of two irrigation intervals based on accumulative pan evaporation (APE) coefficients and the effect of foliar application of anti-transpiration substances, potassium silicate, and chitosan, on two barley varieties, Giza 132 and Giza 134. Water relations, growth, yield, and yield components, as well as chemical composition, were studied. Two barley cultivation seasons were carried out at the Farm of El-Ismailia Agricultural Research Station, Egypt, during winter 2022/2023 and 2023/2024. The results demonstrated that the actual evapotranspiration (ET_a) for irrigation treatments varied between 1122.07 m^3/f and 1586.76 m^3/f in the first season and between 1152.27 m^3/f and 1614.81 m^3/f in the second season, respectively. Also, the split–split of combined analysis used for all parameters showed that increasing the irrigation from 1 APE to 2 APE significantly increased the morphological parameters, yield, yield characteristics, water use efficiency (WUE), and yield chemical composition (nitrogen, phosphorus, and potassium) uptake for the two studied barley cultivars. Moreover, the application of anti-transpiration significantly increased all the previous measurements compared to the control. Irrigation at 2 APE and chitosan for barley Giza 134 showed the highest significant values. Therefore, it is recommended to irrigate at 2 APE and to use chitosan with the barley Giza 134 cultivar in sandy soil under sprinkler irrigation in Northeast Egypt.

Keywords: Barley; actual evapotranspiration (ET_a); potassium silicate; chitosan

INTRODUCTION

Barley (Hordeum vulgare L.) is widely used in animal feeding, forming seventy percent of its global production. Additionally, it is a source of human food, providing high dietary fiber content. It is also used in other industrial and health products, providing some useful phytochemicals. Production is significantly impacted by decreasing irrigation water availability. Barley seasonal evapotranspiration (ET) varies between 100 and 500 mm. Barley is commonly cultivated in areas with less than 350 mm of rainfall around the Mediterranean Basin. Water consumptive use of barley ranges between 1 to 3 mm/ day at the starting stage, to 5 - 8 mm/day at mid-season. Barley water use efficiency is estimated to be about 1.2-1.4 kg/m^3 (Savin *et al.,* 2012). Barley varieties yielded the highest production on receiving the maximum amount of irrigation water (Bahadur *et al.,* 2013). The water stress has an adverse effect on barley varieties' grain yield. However, barley Giza 132 showed higher production than barley Giza 126 under these stress conditions (El-Seidy *et al.,* 2013). Ararssa *et al.* (2019) reported the highest barley water consumption, yield, and water use efficiency at the values of 577 mm, 1700 kg ha^{-1}, and 2.95,

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respectively. However, the lowest ones were recorded at 541 mm, 1480kg ha^{-1}, and 2.74, respectively.

Barley water consumption ranged between 156.78 to 566.79 mm depending on the number of irrigations per season. Increasing the number of irrigations resulted in an increasing water consumption of barley, reaching the value of 566.79 mm. It has also increased barley straw and grain yields as well as 1000-grain weight (g) (Bahadur & Chowdhury, 2019). Short irrigation periods, which result from increasing the accumulative pan coefficient treatments, have barely affected growth in clay soil, leading to increased barley plant height, spike length, number of spikes m^{-2}, number of grains $spike^{-1}$, 1000 grains weight, biological yield fed^{-1}, harvest index, grain and straw yields. The highest barley water consumptive use was measured at 1.1 APE, followed by 0.9 and 0.7. Moreover, the highest barley water use efficiency (WUE) was calculated at irrigation treatment 0.9 APE, followed by 1.1 APE, and finally at 0.7 APE (Abd El-Rahman *et al.,* 2012). The biological yield of barley varieties decreased to 0.410 m^3 kg ¹ at 100% Field Capacity (FC) irrigation and to 0.164 m^3 kg^{-1} at extremely severe water stress (25% FC) (Bijanzadeh *et al.*, 2021). Water consumption of barley varied between 1479.66 m^3 /f to 1557.78 m^3 /f and 1470 m^3 /f to 1544.76 m^3 /f in the first and second seasons, respectively. Barley water use efficiency was reported at values of 1.39 to 1.22 grain kg m-3 and 1.49 to 1.34 grain kg m^{-3} during the first and second seasons, respectively (Khalifa, 2025). Potassium silicate is a natural, highly soluble silicon fertilizer system and a lower-cost compound that increases crop production and enables crops to resist water stress (Artyszak, 2018; Giridhar *et al.,* 2020). The addition of potassium silicate had a significant effect on corn growth attributes, NPK levels, and vegetative production compared to the control treatment (Shedeed, 2018). The role of silicon has been helpful to decrease water loss through transpiration, osmotic adjustment, enhanced nutrient absorption, and activation of the plant defense system (Souri *et al.,* 2021). Also, potassium silicate increased NPK in the shoot and root of sugar beet (Ali *et al.,* 2023). Foliar potassium silicate increased corn WUE and kernels' production under water deficit (Gomaa *et al.,* 2021). Potassium silicate (KS) application significantly increased the faba bean height, the number of branches/plants, and the number of plants, pods per plant, the number of seed $pods^{-1}$, the weight of 100 seeds, and seed yield ha^{-1} and macronutrients (N, P, and K) content compared with control under watered and drought conditions. Chitosan is considered a family of linear binary copolymers of (1 → 4)-linked 2-acetamido-2-deoxyβ-D-glucopyranose (GlcNAc; A-unit) and 2-amino-2-deoxy-β-D-glucopyranose (GlcN; D-unit). The term chitosan refers to polysaccharides composed of different units of A and D, which are a white, hard, inelastic, and nitrogenous polysaccharide (Badawy & Rabea, 2011). Application of chitosan rendered the same effect under both normal watered and stress irrigation conditions of corn. Chitosan affected several mechanisms, including increased activity of antioxidant enzymes, decreased level of lipid peroxidation and hydrogen peroxide, and improved gas exchange and photosynthesis rate. (Almeida *et al.,* 2020; Hidangmayum *et al.,* 2019). Whereas foliar chitosan application and sufficient irrigation amount reversed the abovementioned effects. Water stress showed a detrimental effect on barley 1000-grain weight, grain yield ha^{-1}, and biological yield. However, the Chitosan application improved the barley plant height and yield characters under drought conditions (Hafez *et al.,* 2020). Growing Origanum plants under water stress has led to plant toxic damage. Chitosan application (500 mg/L) protected the marjoram plant against that harmful effect by activating defense mechanisms. It has enhanced the marjoram shoots' dry weight, increased total phenol, and essential oil contents (Mohammadi *et al.,* 2021). Chitosan application has enhanced cereal crop production under drought environments, where microelement corn yield uptake was increased (Kocięcka & Liberacki, 2021; Elshamly & Nassar, 2023).

Additionally, the percentages of nitrogen, phosphorus, and potassium in barley shoots and grains were increased as a result of chitosan (250 and 500 mg/L) and sodium silicate (Farouk & AL-Sanoussi, 2019).

Several studies have shown the effect of chitosan and potassium silicate on different crops; however, very few studies have investigated that effect under different irrigation intervals on Barley cultivars, especially in our region. The objective of this study is to investigate the effect of two irrigation intervals based on cumulative pan evaporation (APE) coefficients: 2 APE and 1 APE, as well as the effect of foliar application of anti-transpiration substances, including potassium silicate and chitosan, on two barley varieties: Giza 132 and Giza 134. Water relations, growth, yield, and yield components, as well as chemical composition, were studied.

MATERIALS AND METHODS

Site of performing the experiment

The field trial was conducted during the winter seasons of 2022/2023 and 2023/2024 at the farm of the Ismailia Agricultural Research Station, Ismailia Governorate, in northeastern Egypt, situated at 30°35'41.9" N latitude, 32°16'45.8" E, and an elevation of 14m. Some soil physical and chemical properties have been measured according to Klute (1982) and Pansu and Gautheyrou (2006). These determinations are shown in Tables 1-2. The chemical properties of the soil sample were all tested before sowing in the experimental soil (0-30cm depth).

Table 1. Soil particle fraction and moisture constants of the investigated soil.

Soil depth, cm	Soil particle fraction				texture	Bulk density, g/cm^3	Field capacity, θ_v %	Wilting point, θ_v %	Available water mm/20 cm
	Coarse sand, %	Fine Sand, %	Silt, %	Clay, %					
0-20	69.00	24.31	4.56	2.13	sandy	1.65	14.4	3.24	22.32
20-40	72.41	22.20	4.35	1.04	sandy	1.68	10.56	2.11	16.9
40-60	78.15	19.10	1.81	0.94	sandy	1.71	8.57	1.60	13.94

Table 2: Chemical properties of a representative soil sample before sowing in the experimental soil (0-30cm depth).

Characters / Sowing seasons	Available N, mg kg^{-1}	Available P, mg kg^{-1}	Available K, mg kg^{-1}	EC, (dS m^{-1})	pH	$CaCO_3$ (%)	Organic Matter (O.M.) (%)
Winter seasons 2022/2023 (1st Season)	16.30	4.20	45.12	0.48	7.54	0.39	0.15
Winter seasons 2023/2024 (2nd Season)	17.92	5.01	45.34	0.53	7.61	0.33	0.18

PH (1:2.5 soil: water suspension) **EC** (1:5 soil: water extract)

Climatological Data

The climatic records from December to April, during the planting seasons, are presented in Table 3. These data included maximum and minimum temperatures (T_{max} and T_{min}), $T_{dew\ point}$ (C^o), relative humidity (%), and wind speed (ms^{-1}) during the growing season.

The monthly mean meteorological data of Ismailia Station for the winter seasons of 2022/2023 and 2023/2024.

Trial Factors

To achieve the objectives of this study, irrigation intervals were determined based on cumulative pan evaporation coefficients. Two intervals were selected: 2 APE and 1 APE, which correspond to the main plots. Two barley varieties, Giza 132 (V1) and Giza 134 (V2), were assigned to the subplots. The anti-transpiration applications, including a control group (control), potassium silicate (KS), and chitosan (Chito), were allocated in a split-split plot design. Each plot measured 3 × 3.5 m. The anti-transpiration treatments were applied by spraying at 35, 50, and 75 days after sowing. A sprinkler irrigation system was utilized to irrigate the experiment

Table 3: Average monthly weather data during the growing seasons of 2022/2023 and 2023/2024.

Months	Temperature, C°			$T_{dew\ p.}$ C	Relative humidity (%)			wind speed, ms^{-1}
	Max.	Min.	Ave.		Max.	Min.	Ave.	
During the winter season 2022/2023								
Dec.	22.24	11.22	18.08	10.20	79.48	37.94	61.94	2.49
Jan	20.29	10.59	16.28	7.55	78.39	34.74	58.81	2.64
Feb	18.53	10.77	14.59	5.94	76.00	38.50	58.16	3.21
Mar	24.77	14.32	19.80	6.94	73.68	25.58	48.32	3.56
Apr	28.24	16.78	22.33	7.50	71.70	21.67	43.75	3.93
During the winter season 2023/2024								
Dec.	22.38	15.14	18.55	11.07	81.52	43.84	64.35	2.89
Jan	20.14	12.90	16.57	6.72	72.58	36.10	54.54	2.76
Feb	20.84	12.62	16.57	7.43	80.03	33.86	58.23	3.23
Mar	33.91	14.93	19.54	7.75	73.71	28.58	50.71	3.42
Apr	29.67	18.54	23.68	10.66	76.07	23.53	49.89	4.07

Preparation of the solution spray application

The rate of 300 mg Si L^{-1} was used to apply K_2SiO_3 , which contained 487.1 g K L^{-1} and 113.9 g Si L^{-1}. 3 ml L^{-1} of the K-Silicate standard solution (4 L per plot) was employed. The chitosan stock solution (4 L per plot) was applied at a rate of 5 mL L^{-1}. Techno Gene Company, China, supplied chitosan and K-silicate.

Construction of an irrigation system

A fixed-sprinkler system with buried laterals placed underground (50 cm) deep, with only the riser pipe and sprinkler head above the surface. A valve is present on each sprinkler riser that turns the sprinkler on or off during the irrigation time. An impact sprinkler (RC 160-S, Spain-made) with a 4 mm nozzle is operating at 3.45 bar. It discharges at the rate of 1.14 m^3/h (9.5 mm/h) and is placed on a 10 by 12 spacing (10 m between sprinklers along the lateral, and 12 m between parallel lateral positions).

Irrigation practice

The daily evaporation was recorded using an evaporimeter, following the Class A open pan evaporation standard (Table 4). Irrigation time was calculated when the accumulative daily evaporation, mm (APE), is equal to the available soil water, mm. Irrigation treatments were 2 APE and 1APE. Also, the total available soil moisture was managed according to the gradual increment of effective root depth (Table 1). Hence, the water regime started 20 days after the barley sowing date. Then, total available soil moisture was 22.32, 39.22, and 53.16 mm in December, January, and February till the end of the season, respectively.

Agricultural practices

Barley (Hordeum vulgare, varieties Giza 132 and 134) was grown for grain production at a rate of 60 kg fed^{-1} at high density. The experimental soil was plowed twice using disc tillage. Mono super phosphate (P_2O_5, 15%) was applied as top dressing at a rate of 200 kg ha^{-1}. Potassium sulfate (100 kg ha^{-1}, 48% K_2O) was applied in two equal doses: the first during soil preparation and the second 30 days after sowing. The barley crop received a total of 60 kg N fed^{-1} from ammonium nitrate (33% N), divided into four doses: 10 kg N fed^{-1} at 20 and 35 days, followed by 20 kg N fed^{-1} at 50 and 65 days after planting.

Barley seeds were sown on December 8th in 2022 and 2023, at a depth of 3 cm and with a row spacing of 20 cm. The barley was harvested on April 19th in both 2023 and 2024.

Table 4: Average daily pan evaporation and irrigation dates during barley growing seasons

In winter 22/2023				In winter 23/2024			
date	Average Ep, mm/7-day	Irrigation time for every treat		date	Average Ep, mm/7-day	Irrigation time for every treat	
		2 APE	1 APE			2 APE	1 APE
8/12 -14/12	2.71	8-10-12-14	8-10-12-14	8/12 -14/12	2.54	8-11-13-15	8-11-13-15
15/12 - 21/12	2.90	20	20	15/12 - 21/12	2.67	20	20
22/12 - 28/12	2.35	25	25	22/12 - 28/12	3.01	25	25
29/12 - 4/1	3.00	2/1		29/12 - 4/1	2.14	29/12	3/1
5/1 - 11/1	1.69	9/1	5/1	5/1 - 11/1	3.14	8/1	11/1
12/1 - 18/1	2.39	16/1		12/1 - 18/1	3.31	12/1	16/1
19/1 - 25/1	3.09	22/1	19/1	19/1 - 25/1	2.40	16/1-22/1	23/1
26/1 - 1/2	4.11	27/1-31/1	28/1	26/1 - 1/2	2.06	28/1	
2/2 -8/2	3.57	5/2	2/2	2/2 -8/2	2.86	2/2-8/2	2/2
9/2 - 15/2	2.50	11/2	14/2	9/2 - 15/2	3.97	14/2	15/2
16/2 - 22/2	3.47	19/2		16/2 - 22/2	3.27	20/2	
23/2 - 1/3	4.00	27/2	25/2	23/2 - 1/3	4.20	26/2-1/3	27/2
2/3 - 8/3	5.66	3/3-8/3	3/3	2/3 - 8/3	4.89	6/3	6/3
9/3 - 15/3	4.67	14/3	12/3	9/3 - 15/3	4.60	12/3	
16/3 - 22/3	4.67	19/3		16/3 - 22/3	5.50	16/3-21/3	16/3
23/3 - 29/3	5.50	24/3-28/3	23/3	23/3 - 29/3	3.76	28/3	28/3
30/3 - 5/4	6.00	2/4	2/4	30/3 - 5/4	7.20	1/4-4/4	4/4
6/4 - 12/4	5.23	6/4-11/4	11/4	6/4 - 12/4	7.00	8/4-11/4	11/4
13/4 - 19/4	5.30			13/4 - 19/4	6.50		

Irrigation measurements

Actual evapotranspiration for barley (ET_a)

Soil moisture sensor (S-345, China) was used to determine the volumetric soil moisture before and after irrigation, as actual evapotranspiration for barley (ET_a). It can immediately record the reading on the numerical display, in addition to at the harvesting time. The equation of Israelsen and Hansen (1962) was used to compute the ET_a between two successive irrigations. It's described below

$$ET_a = \{(\theta_2 - \theta_1) / 100\} \times D \times 10$$

Where:

ET_a actual evapotranspiration, mm.

θ_2 = soil moisture percentage after irrigation.

θ_1 = soil moisture percentage just before irrigation.

D = soil layer depth, cm.

Water use efficiency (WUE)

Represents the ratio of the final (commercial) yield to the amount of water used for actual evapotranspiration (Stricevic *et al.,* 2018). It is estimated as:

$$WP = Y/ET_a$$

Where:

WP is water productivity (kg/m^3), Y is yield (kg/ha), and ET_a is actual evapotranspiration (m^3/ha).

Barley crop parameters

One square meter sample of mature barley was harvested from each plot on April 19, during the first and second seasons. These samples were used to evaluate various barley characteristics, including the heading date (HD), number of spikes/ m^2 (NS), number of grains/ spike (NG), plant height in cm (PH), spike length in cm (SL), and yield components. The yield components measured included straw (ST) in ton/ ha, grain (GK) in kg/ f and ha, and water use efficiency (WUE) in kg/ m^3.

Barley yield composition (kg fed^{-1})

Barley grain and straw samples were taken from each previous sample to determine the chemical composition. Samples were oven-dried for 48 hours at 70°C, ground in a stainless-steel mill, and then digested using a sulfuric acid and hydrogen peroxide combination as described in the procedure by Pag *et al.* (1982). Finally, the digestion liquids were taken out for spectrophotometric analysis for P%, as well as N%, using the Kjeldahl method (Pag *et al.*, 1982). The percentage of K was measured using a flame photometer, as described by Jackson (1973).

NPK uptake = (NPK %) × yield, kg/100

Soil macro nutrients availability (g kg^{-1})

Air-dried soil samples from treatment plots were taken, sieved through a 2.0 mm sieve, and kept for analysis. These soil samples were extracted in KCl (1:10 w/v) to determine soil available N they were also extracted using 0.5 N in $NaHCO_3$ to determine soil available P and extracted by 1N NH_4OAc at pH 7.0 to determine soil available K. An average of three replicate soil samples was analyzed

Statistical Analysis

A split-split plot design was analyzed using R software (R Core Team, 2022), employing the 'agricolae' package for analysis of variance (ANOVA) with three replications and mean separation via the Least Significant Difference (LSD) test. A combined analysis of data from the two seasons was conducted after applying Bartlett's test to check the homogeneity of variance across the two seasons.

RESULTS AND DISCUSSION

Actual evapotranspiration of barley ET_a, mm

The results for the winter seasons of 2022/2023 and 2023/2024 are shown in Tables 5 and 6. The total barley ET_a ranged from 267.17 mm (1,122 m³/f) to 377.8 mm (1,586.8 m³/f), and from 274.35 mm (1,152.27 m³/f) to 384.53 mm (1,217.16 m³/f) when irrigated at 2AEP and 1AEP during the first and second seasons, respectively. These results align with Abd El-Rahman *et al.* (2012). Additionally, monthly and daily ET_a started low at the beginning of the season, then gradually increased until reaching a peak in March of both cultivation seasons. Afterward, these values declined in April at the end of the growing season. Proper and adequate irrigation is an essential factor for crop production, especially in semi-arid and arid regions. Barley production generally requires more frequent irrigation on sandy soil. Water consumption by barley increases as the frequency of irrigation increases. Reducing irrigation intervals results in higher barley yields (Savia *et al.*, 2012; Bahadur *et al.*, 2013; Bahadur & Chowdhury, 2019). Meskelu *et al.* (2017) and Prajapat *et al.* (2020) demonstrated that irrigation at higher ET_c results in more frequent irrigation. Therefore, this leads to increased water consumption by wheat. A shorter irrigation period raises soil water content at the depth of wheat roots, making water uptake (ET_a) easier. Conversely, longer irrigation periods increase the soil's water-holding capacity over time. As a result, the plant adopts a strategy of decreasing water uptake (ET_a) under these conditions (Gameh *et al.*, 2017; Al-Farouk *et al.*, 2024).

Tables 5 and 6 also showed that the total barley Giza 134 ET_a decreased by 4.64 % and 5.15% compared with Giza 132 ET_a at first and second seasons, respectively. The drought adaptation mechanisms for barley varieties were previously attributed to decreasing assimilation level, controlling opening and closing of stomata, disrupting photosynthetic pigments, improving creation of reactive oxygen species, and reducing crop growth and yield formation (Chmielewska *et al.*, 2016, and Sabagh *et al.*, 2019).

Whereas the total ET_a saved (4.25% and 3.95%) and (6.07% and 6.89%) when (KS) and (Chito) were applied compared with control (cont.) at first and second barley growth seasons. But that saved 1.75%and 2.83% with foliar spray of (Chito) compared with (KS) at first and second barley growth. These results agreed with Souri *et al.* (2021), Almeida *et al.* (2020), and Hidangmayum *et al.* (2019). The lowest total ET_a values obtained were 361.2, 366.9, and 259.9, 262.7 for an interaction 2AEP, chitosan, and barley Giza134 and 1AEP, chitosan, and barley Giza134 at first and second season, respectively.

Table 5: Monthly, daily, and total actual evapotranspiration (ET_a) affected by irrigation intervals and the foliar application of the anti-transpiration, potassium silicate, for two barley varieties during the first season of 2022/2023.

Irr. Treat.	**Varieties.**	**Substance.**	**December***		**January**		**February**		**March**		**April****		Total, mm	Total, m^3/f
			Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm		
2APE	V1	Cont.	33.80	1.47	74.30	2.40	97.50	3.48	139.50	4.50	60.20	3.17	405.30	1702.26
		KS	33.80	1.47	74.30	2.40	96.20	3.44	129.00	4.16	54.10	2.85	387.40	1627.08
		Chito.	33.80	1.47	70.80	2.28	91.10	3.25	125.20	4.04	50.50	2.66	371.40	1559.88
	V2	Cont.	33.80	1.47	74.30	2.40	90.50	3.23	125.00	4.03	56.40	2.97	380.00	1596.0
		KS	33.80	1.47	70.80	2.28	85.00	3.04	118.80	3.83	53.10	2.79	361.50	1518.3
		Chito.	33.80	1.47	70.80	2.28	84.60	3.02	118.50	3.82	53.50	2.82	361.20	1517.04
Mean														1586.76
1APE	V1	Cont.	33.80	1.47	57.30	1.85	61.80	2.21	83.20	2.68	44.40	2.34	280.50	1178.1
		KS	33.80	1.47	57.30	1.85	56.10	2.00	80.50	2.60	40.00	2.11	267.70	1124.34
		Chito.	33.80	1.47	55.50	1.79	57.40	2.05	78.40	2.53	40.00	2.11	265.10	1113.42
	V2	Cont.	33.80	1.47	57.30	1.85	56.40	2.01	77.00	2.48	43.00	2.26	267.50	1123.5
		KS	33.80	1.47	55.50	1.79	56.00	2.00	77.00	2.48	40.00	2.11	262.30	1101.66
		Chito.	33.80	1.47	55.50	1.79	55.60	1.99	75.00	2.42	40.00	2.11	259.90	1091.58
Mean														1122.07
Mean over all	V1		33.80	1.47	64.92	2.09	76.68	2.74	105.97	3.42	48.20	2.54	330.03	1386.11
	V2		33.80	1.47	64.04	2.07	71.35	2.55	98.55	3.18	47.67	2.51	315.40	1324.68
	Cont.		33.80	1.47	65.80	2.12	76.55	2.73	106.18	3.43	51.00	2.68	333.33	1399.97
	KS		33.80	1.47	64.48	2.08	73.33	2.62	101.33	3.27	46.80	2.46	319.73	1342.85
	Chito.		33.80	1.47	63.15	2.04	72.18	2.58	99.23	3.20	45.90	2.42	314.25	1319.85

*Sowing date: 8/12/2022 **harvest date19/4/2023

Table 6: Monthly, daily, and total actual evapotranspiration (ET_a) affected by irrigation intervals and the foliar application of the anti-transpiration, potassium silicate, for two barley varieties during the first season of 2023/2024.

Irr. Treat.	Varieties.	Substance.	December*		January		February		March		April**		Total, mm	Total, m^3/f
			Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm	Monthly, mm	Daily, mm		
2APE	V1	Cont.	35.70	1.55	76.00	2.45	102.70	3.54	134.50	4.34	65.50	3.45	414.40	1740.48
		KS	35.70	1.55	76.00	2.45	102.30	3.53	123.30	3.98	56.90	2.99	394.20	1655.64
		Chito.	35.70	1.55	71.20	2.30	95.90	3.31	120.60	3.89	52.10	2.74	375.50	1577.10
	V2	Cont.	35.70	1.55	76.00	2.45	94.10	3.24	120.40	3.88	60.80	3.20	387.00	1624.00
		KS	35.70	1.55	71.20	2.30	92.50	3.19	119.40	3.85	50.40	2.65	369.20	1550.64
		Chito.	35.70	1.55	71.20	2.30	91.80	3.17	118.00	3.81	50.20	2.64	366.90	1540.98
Mean														1614.81
1APE	V1	Cont.	35.70	1.55	60.10	1.94	64.10	2.21	83.20	2.68	46.70	2.46	289.80	1217.16
		KS	35.70	1.55	60.10	1.94	60.70	2.09	80.50	2.60	43.70	2.30	278.70	1170.54
		Chito.	35.70	1.55	56.20	1.81	61.10	2.11	77.40	2.50	42.30	2.23	272.70	1145.34
	V2	Cont.	35.70	1.55	60.10	1.94	60.00	2.07	74.00	2.39	43.70	2.30	273.50	1148.70
		KS	35.70	1.55	56.20	1.81	58.80	2.03	77.00	2.48	41.00	2.16	268.70	1128.54
		Chito.	35.70	1.55	56.20	1.81	58.10	2.00	72.70	2.35	40.00	2.11	262.70	1103.34
Mean														1152.27
Mean overall	V1		35.70	1.55	66.60	2.15	81.14	2.80	103.25	3.33	51.20	2.69	337.89	1419.12
	V2		35.70	1.55	65.15	2.10	75.89	2.62	96.92	3.13	47.69	2.51	321.34	1349.63
	Cont.		35.70	1.55	68.05	2.20	80.23	2.77	103.03	3.32	54.18	2.85	341.18	1432.96
	KS		35.70	1.55	65.88	2.13	78.58	2.71	100.05	3.23	48.00	2.53	328.21	1378.48
	Chito.		35.70	1.55	63.70	2.05	76.45	2.64	97.18	3.13	46.15	2.43	319.18	1340.56

*Sowing date: 8/12/2023 **harvest date: 19/4/2024

Barley crop parameters

Table 7 and Figures 1-2 illustrate the results obtained for barley characters. The short irrigation interval (IR1) revealed a substantial increase in all barley character data. Conversely, the extended irrigation period (IR2) led to a substantial reduction in all of the investigated characteristics. The percentage increments from IR1 to IR2 for the barley characters were as follows: 2.16 (HD), 5.9 (NS), 5.15 (NG), 3.71 (PH), 15.04 (SL), 45.32 (ST), 92.03 (GT), and 36.72% (WUE). The same results have been stated by Abd El-Rahman *et al.* (2012). El-Sayed *et al.* (2022) indicated that the disturbance of water movement from the xylem to the lengthening cells and the modifications in the physicochemical properties of the cell walls led to stopping plant growth. The soil water scarcity significantly decreased the leaf dry matter accumulation, chlorophyll a and b substances, and the plants' development.

The recorded data for V1 was significantly lower than that for V2. The values decreased by 3.18(HD), 2.2 (NS), 9.49 (NG), 2.49 (PH), 21.92 (SL), 4.93 (ST), 6.62 (GT), and 11.6% (WUE). These results are consistent with those obtained by Abd El-Rahman *et al.* (2012), Bijanzadeh *et al.* (2021), and Khalifa *et al.* (2025).

The obtained data also elucidated that the values HD, NS, NG, PH, SL, ST, GT, and WUE were enhanced significantly with potassium silicate (KS) addition compared to the control treatment (cont.). The improvements were achieved at the values of 3.70, 5.14, 4.66, 3.15, 8.23, 11.86, 17.87, and 23.56%, respectively. Also, applied chitosan (chito.) compared to (cont..) significantly enhanced the above-mentioned traits at the values of 6.93, 7.15, 7.44, 6.97, 15.72, 16.57, 36.25, and 45.4%, respectively. Applied (chito.) compared to (KS) had a significant effect on the same parameters. The increments were achieved at the values of 3.11%, 5.78%, 2.66%, 3.7%, 15.72%, 4.21%, 15.6%, and 17.68%, respectively. Maghsoudi *et al.* (2015) demonstrated that potassium silicate enhanced light utilization efficiency in four wheat varieties' chlorophyll under water stress conditions. Water stress led to a decrease in wheat water consumption. The same trend by applying chitosan was observed by Hafez et al. (2020). Seham *et al.* (2021) demonstrated that drought conditions significantly reduced plant characters, yield, chlorophyll content, and NPK %. On the other hand, potassium silicate treatment improved the borage morphological characters, production, and water use efficiency under water stress. Karvar *et al.* (2023) indicated that foliar potassium silicate application reduced the effects of water deficit, including low concentration of chlorophyll, cell water turgor, increased oxidant enzymes, proline acid, and corn sweet yield. So, potassium silicate addition enhanced the biological attributes and crop production. Potassium silicate also produced equal performance under stress conditions compared to conditions of non-water restriction. Similar effects were observed with sprayed chitosan (140 mg L^{-1}) when applied to a maize crop under both standard irrigation conditions and water-restricted conditions. Drought was found to increase antioxidant enzymes, gas replacement, and decrease peroxidation and hydrogen peroxide, which support the application of chitosan to overcome water deficit (Rabêlo *et al*., 2019; Almeida *et al.*, 2020; Faqir *et al.,* 2021).

The interaction effect of irrigation intervals and barley varieties was significant for ST, GT, and WUE (Table 7). The highest values were obtained at the irrigation parameter of 2APE (IR1) and barley Giza 134 for the above-mentioned traits. Meanwhile, the lowest results were recorded at the irrigation parameter of APE (IR2) and barley Giza 132 for the above-statement attributes.

The interaction effect of irrigation scheduling and anti-transpiration substance application was also significant for ST, GT, and WUE (Table 7). The highest measurement parameters were produced at the irrigation of IR1 (2APE) with applied (chito.), followed by IR1 with (KS) interaction treatment. While the lowest values were obtained by irrigation 1APE (IR2) without any treatment of anti-transpiration substances, the control.

The interaction effect of barley varieties and anti-transpiration substances is shown in Table 7. The results demonstrated that the studied characters for the two barley varieties increased significantly with the application of foliar potassium silicate (KS) and chitosan. The addition of KS led to an increase in the characteristics of the two barley varieties, including HD, NS, NG, PH, SL, ST, GT, and WUE parameters. Also, the same effect was found with spray chito. The effect of chitosan application was more than the effect of adding KS for the above two barley varieties' characteristics. However, the best treatment was obtained from barley Giza 134 when treated with chitosan substance. Whereas the worst effect was found without foliar substance applied (control) for barley Giza 132 parameters.

Regarding the interaction effect of irrigation intervals, barley varieties, and anti-transpiration substances, the results in Table 7, Figure 1, and Figure 2 show a significant triple interaction effect of irrigation intervals, barley varieties, and anti-transpiration substances. The short irrigation period (IR1), barley Giza 134 (V2), and chitosan interaction yielded the highest HD, NS, NG, PH, SL, ST, GT, and WUE values. But, the lowest HD, NS, NG, PH, SL, ST, GT, and WUE values were recorded under IR2, V1, and T1 interaction treatment.

Table 7: Effect of irrigation intervals and anti-transpiration substances on some characters, straw yield, grain yield, and Water use efficiency of barley varieties under study

Irr. Treat.	Variety.	Subst.	HD	NS	NG	PH	SL	ST	GT	WUE
2APE	V1	Cont.	87.67 f	332 g	54.17 d	76.33 g	6.333 g	2.728 e	1.5323 f	0.8903 g
		KS	90.33 e	353 de	57.33 cd	79.50cde	7.000 defg	3.027 c	1.7167d	1.0462d
		Chito.	93.67 bc	374 b	58.50 bc	82.50 ab	7.417 cde	3.204 b	2.0037b	1.2777b
	V2	Cont.	90.00 e	344 ef	60.67abc	79 def	8.050 bc	2.798 d	1.5955e	0.9968 e
		KS	93.67 bc	364 bc	61.17 ab	80.83bcd	8.333 b	3.160 b	1.8485 c	1.2050 c
		Chito.	95.67 a	386.7 a	62.50 a	84.50 a	9.167 a	3.262 a	2.1467 a	1.4042 a
		L.S. D	1.58	10.99	3.523	2.06	0.759	0.04345	0.03981	0.02553
Main of irrigation values at 2APE			91.83a	358.9 a	59.06 a	80.44 a	7.717 a	3.030 a	1.8072 a	1.1367a
1APE	V1	Cont.	85.33 g	319.5 h	48.67 e	73.83 h	5.417 h	1.812 k	0.7552 k	0.6308 j
		KS	87.67 f	337.5 fg	54 d	77.33 fg	6.25 g	2.077 i	0.9275 j	0.8095h
		Chito.	92.00 d	354.5cde	57.33 cd	78.67 ef	6.583 fg	2.127 h	1.0452 h	0.9258 f
	V2	Cont.	88.00 f	328 gh	58.00 bc	76.50 g	6.917 efg	2.005 j	0.7745 k	0.6823 i
		KS	92.33 cd	337 fg	59.33 bc	77.67efg	7.333 cdef	2.189 g	0.9967 i	0.8938 g
		Chito.	94.00 b	356.7cd	59.67abc	81.33 bc	7.750 bcd	2.300 f	1.1478 g	1.0460d
		L.S. D	1.58	10.99	3.523	2.06	0.759	0.04345	0.03981	0.02553
Main irrigation values at 1APE			89.89 b	338.9 b	56.17 b	77.56 b	6.708 b	2.085 b	0.9411b	0.8314 b
Irrigation treatments LSD			0.6324	11.38	1.878	1.761	0.4666	0.02232	0.02723	0.02105
Mean overall		V1	89.44 b	345.1 b	55.00 b	78.03 b	6.500 b	2.496 b	1.330 b	0.9301 b
		V2	92.28 a	352.7 a	60.22 a	79.97 a	7.925 a	2.619 a	1.418 a	1.0380 a
Barely varieties of LSD			0.9125	7.271	2.252	1.096	0.4904	0.0234	0.02173	0.01276
Mean overall		Cont.	87.75 c	330.9 c	55.38 b	76.42 c	6.679 c	2.336 c	1.164 c	0.8001 c
		KS	91.00 b	347.9 b	57.96 a	78.83 b	7.229 b	2.613 b	1.372 b	0.9886 b
		Chito.	93.83 a	368.0 a	59.50 a	81.75 a	7.729 a	2.723 a	1.586 a	1.1634 a
Ant-transpiration substance L.S.D.			0.79	5.497	1.761	1.03	0.3795	0.02172	0.01991	0.01277
Interaction of IR X V		F Test	ns	ns	ns	ns	ns	*	*	**
Interact. of IR X Ant. trans.		F Test	ns	ns	ns	ns	ns	***	***	***
Interact. of V2 X Anti-trans.		F Test	*	ns	*	ns	ns	ns	**	**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1'

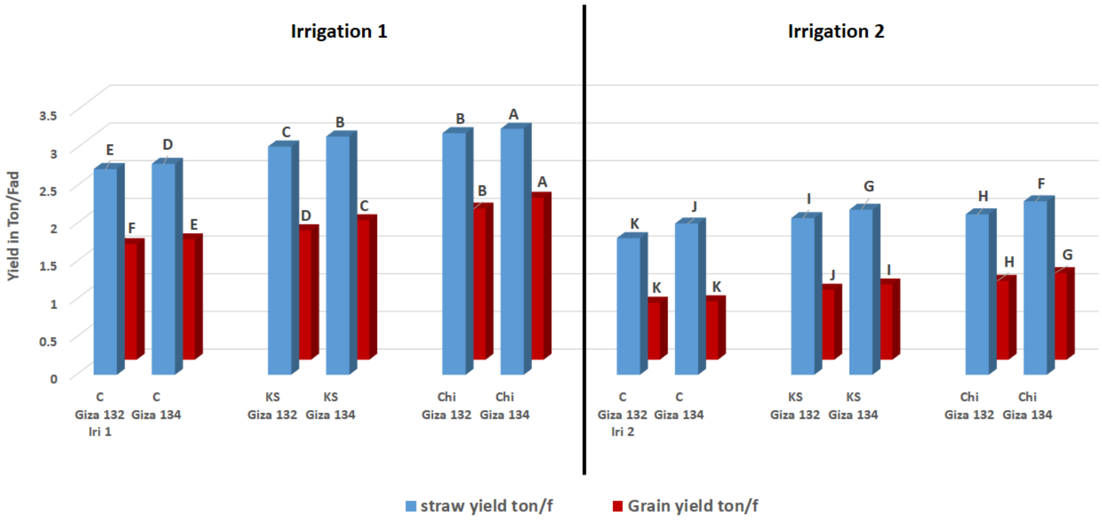

Figure 1. Effect of irrigation intervals, barley varieties, and anti-transpiration substances on barley straw and grain yield (Ton/Fad)

C: Control Treatment, KS: Potassium silicate Treatment, Chi: Chitosan

Different letters represent a significant difference at P<0.05 according to the least significant difference (LSD).

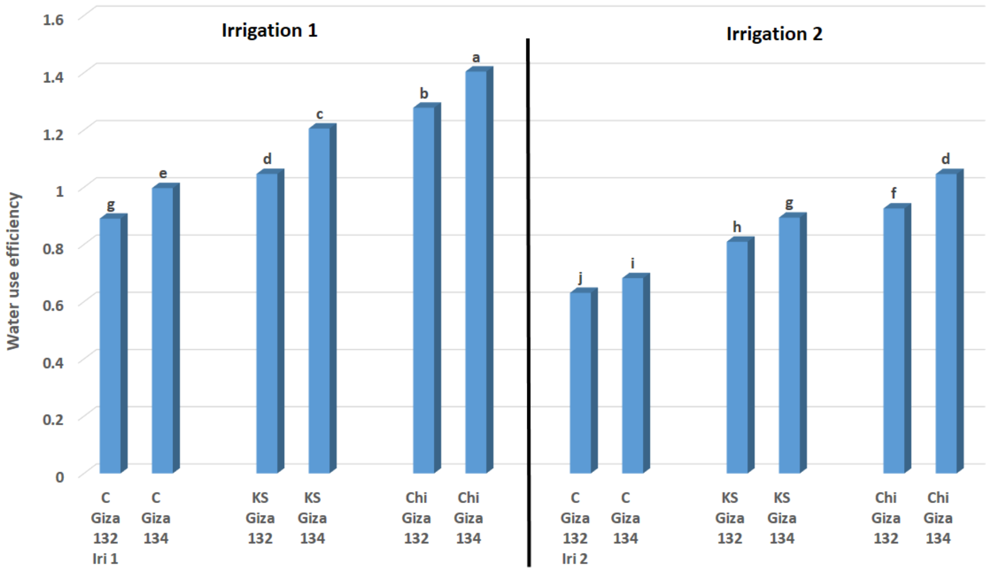

Figure 2. Effect of irrigation intervals, barley varieties, and anti-transpiration substances on barley water use efficiency

C: Control Treatment, KS: Potassium silicate Treatment, Chi: Chitosan

Different letters represent a significant difference at P<0.05 according to the LSD.

Barley yield composition (kg fed^{-1})

The data presented in Table 8 and Figures 3-4 show that both NPK uptake in barley straw and grain were significantly influenced by irrigation intervals based on APE, different barley varieties, and anti-transpiration measures. Overall, all the parameters studied had a significant effect on the NPK content (kg/ f) absorbed by barley in both the straw and grain.

The present results illustrate that the effect of short irrigation periods (IR1) led to a significant increase in straw and grain NPK content, more than the effect of long irrigation periods. These increment percentages were 26.72, 15, 45.87, 38.19, 63.57, and 72.78 for NPK straw and grain, respectively. Bechtaoui *et al.* (2021) concluded that decreased grain index and NP uptake occurred under low and medium soil water content. Phosphorus has mainly a role in the construction of plant roots. Therefore, decreasing uptake led to an increase in lateral root growth compared to primary root growth. Consequently, root penetration will be decreased.

When the difference in NPK uptake between the two barley varieties was studied, the data in Table 9 indicated that barley Giza134 (V2) had a significant ability to absorb NPK more than barley Giza132 (V1). The different NPK percentages between V2 and V1were 10, 12.59, 8.01, 11.82, 7.3, and 11.73 for NPK straw and grain, respectively. Elshamly (2023) revealed that maize yield and water use efficiency were significantly affected by chitosan, followed by potassium silicate addition. These applications produced the same values for corn production and water use efficiency, with 100% and 70% of maize water requirement in the Toshka area, which also applies to other arid regions. El-Bassiouny *et al.* (2023) elucidate that chitosan at different concentrations caused increases in the percentage of wheat grain nitrogen, phosphorus, potassium, and calcium compared to untreated ones. The highest levels of minerals were recorded with a 100 mg L^{-1} chitosan application, which caused increases of 47%, 11%, and 11% in N, K, and Ca, respectively. It's worth mentioning that 150 mg L^{-1} chitosan induced a maximum increase of P by 54%.

Regarding the effect of anti-transpiration treatments on straw and grain NPK uptake, the application of anti-transpiration treatments had a significant effect on NPK straw and grain uptake (Table 8). Spray potassium silicate (KS) has enhanced NPK straw and grain uptake compared with the untreated treatment (control). The different effects between chitosan and potassium application significantly increased NPK straw and grain uptake by 18.47, 18.16, 2.04, 21.89, 5.9, and 16.29%. The greatest differences of NPK straw and grain contents were identified with chitosan application compared to untreated, which produced an improvement of 42.13, 44.81, 21.38, 63.69, 30.82, and 43.19 %, respectively. Elevated soil water content resulted in a higher total NPK percentage in the sorghum crop. However, reduced water content led to a decline in both phosphorus and potassium levels in the sorghum plant. Furthermore, the nitrogen content in plants was moderately influenced by soil water availability. Potassium silicate significantly increased sorghum NPK uptake and WUE (Abdeen & Mancy, 2018).

Short irrigation intervals and foliar application of chitosan produced high yield, N, P, and K%, and water benefit. Also, a wide irrigation period and chitosan application improved crop yield under decreased irrigation. (Doklega *et al.*, 2022; Massoud *et al.*, 2022).

Regarding the interaction effect of irrigation intervals (IR) and barley varieties (V) on NPK straw and grain uptake, the results in Table 8 demonstrate that IR1 and V2 showed the highest NPK straw and grain uptake. The lowest NPK straw and grain contents were recorded under IR2 and V1 treatment. Barley Giza134 showed a large amount of NPK absorption under low irrigation intervals. The difference between the two barley varieties was not significant in straw NPK uptake when irrigated at 2 APE (IR1). However, it achieved significance in barley grain NPK content at the IR1 treatment.

The data in Table 8 indicated that barley straw and grain NPK content were highest with irrigation at 2APE (IR1) and chitosan spraying (chito) compared to other interaction IR and anti-transpiration treatments. Generally, it can be observed that the lowest straw and grain NPK amounts were obtained under the IR2 and control treatments.

Regarding the effect of interaction between barley varieties (v) and anti-transpiration substances on NPK uptake, the results in Table 8 revealed that the effect of potassium silicate and chitosan application led to a significant increase in grain NPK for barley Giza 132 and 134. The maximum values of straw and grain NPK uptake were obtained with spray chitosan (chito.) and barley Giza 134(V2), followed by barley Giza 132(V1). These were followed by straw and grain NPK uptake values produced by potassium silicate (KS) application with V2, followed by V1. Whereas the lowest straw and grain NPK values were found when the control treatment and V1 were used.

Table 8: Effect of irrigation intervals and anti-transpiration on barley varieties' straw and grain NPK uptake:

Irr. treat.	varieties	substance	SNU	SPU	SKU	GNU	GPU	GKU
2APE	V1	Cont.	16.45de	7.190 g	22.36 c	22.41 h	16.021 d	11.728 e
		KS	20.22 b	9.098 d	25.93 b	28.48 e	18.820 c	16.043 c
		Chito.	24.62 a	10.937 ab	27.00 ab	34.28 b	19.691 b	18.064 b
	V2	Cont.	18.25 c	8.144 ef	22.76 c	24.55 fg	16.118 d	14.540 d
		KS	21.24 b	9.908 c	26.84 ab	31.28 c	19.878 ab	16.456 c
		Chito.	25.28 a	11.532 a	27.58 a	38.11 a	20.485 a	19.865 a
		L.S. D.	1.321	0.7543	1.343	1.108	0.6255	0.6146
Main of irrigation values at 2APE			21.01 a	9.468 a	25.41 a	29.85 a	18.50 a	16.12 a
1APE	V1	Cont.	12.01 f	5.887 h	14.04 f	14.79 j	8.721 j	7.347 i
		KS	16.05 de	7.926 efg	16.50 e	20.86 i	11.018 h	8.804 g
		Chito.	18.0 c	8.924 d	17.69 e	24.89 f	12.019 g	10.110 f
	V2	Cont.	15.58 e	7.689 fg	16.80 e	15.80 j	9.617 i	8.056 h
		KS	17 .21 cd	8.498 de	19.55 d	23.55 g	12.652 f	10.012 f
		Chito.	20.58 b	10.476 bc	19.92 d	29.70 d	13.839 e	11.653 e
		LSD	1.321	0.7543	1.343	1.108	0.6255	0.6146
Main irrigation values at 1APE			16.58 b	8.233 b	17.42 b	21.60 b	11.31 b	9.33 b
Irrigation treatments LSD			1.758	0.9217	1.272	0.5994	0.2004	1.156
Mean overall		V1	17.90 b	8.327 b	20.59 b	24.29 b	14.38 b	12.02 b
		V2	19.69 a	9.375 a	22.24 a	27.16 a	15.43 a	13.43 a
Barely varieties of LSD			0.4523	0.3751	0.6633	0.6701	0.2829	0.3686
Mean overall		Cont.	15.57 c	7.228 c	23.05 a	19.39 c	12.62 c	10.42 c
		KS	18.68 b	8.858 b	22.20 b	26.04 b	15.59 b	12.83 b
		Chito.	22.13 a	10.467 a	23.05 a	31.74 a	16.51 a	14.92 a
Ant-transpiration substance LSD			0.6605	0.3772	0.6717	0.5542	0.3128	0.3073
Interaction of IR X V		F Test	*	ns	*	ns	*	ns
Interact. of IR X Ant. trans.		F Test	*	ns	.	.	ns	***
Interact. of V X Anti-trans.		F Test	.	ns	ns	***	*	**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1'

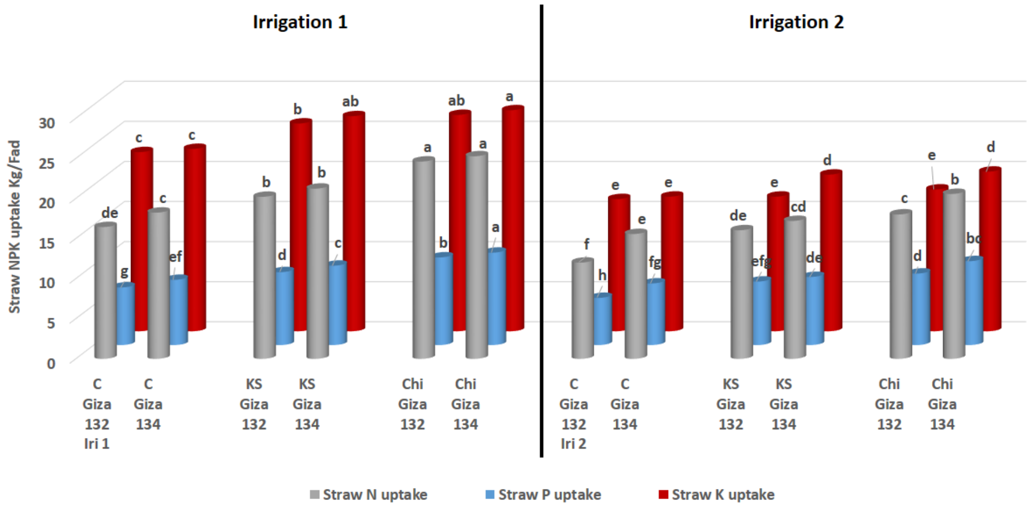

Figure 3. Effect of irrigation intervals and anti-transpiration substances on straw NPK uptake in barley varieties

C: Control Treatment, KS: Potassium silicate Treatment, Chi: Chitosan

Different letters represent a significant difference at p<0.05 according to the LSD

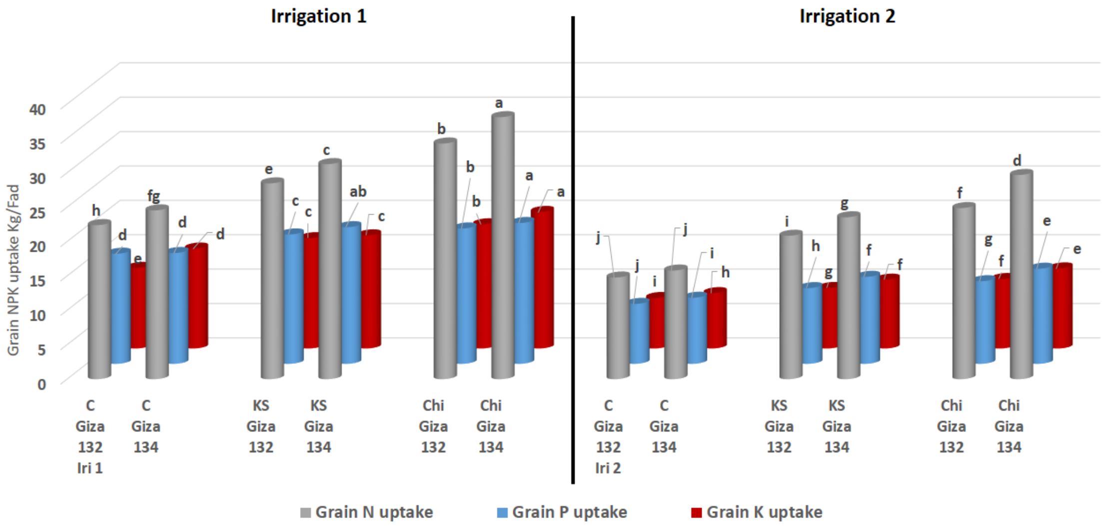

Figure 4. Effect of irrigation intervals and anti-transpiration substances on grain NPK uptake in barley varieties

C: Control Treatment, KS: Potassium silicate Treatment, Chi: Chitosan

Different letters represent significant difference at p<0.05 according to the LSD

The data in Figure 3 and Figure 4 show the effect of interaction between irrigation intervals, barley varieties, and anti-transpiration on NPK uptake demonstrating that the highest results in straw and grain NPK uptake were produced with irrigation at short periods (IR1) and chitosan application (chito.) for barley Giza 134(V2), followed by barley Giza 132(V1). The irrigation (IR1), barley Giza 134(V2) or (V1), and KS were ordered second in straw and grain NPK contents. But long irrigation intervals (IR2) and untreated substance (control) for barley Giza 132(V1) produced the lowest straw and grain NPK uptakes.

Soil macro nutrients availability (g kg^{-1})

Figure 5 and Figure 6 show the mean values of soil NPK available (mg.kg^{-1}) affected by irrigation intervals based on (APE) and anti-transpiration for barley varieties (V) after harvesting during the winter season 2022/2023 and the two winter seasons 2023/2024, respectively. The mean values of soil NPK availability increased by (18.03% and 17.31%), (15.02%-11.78%), and (11.52%-11.94%) under short irrigation intervals (IR1) compared with long irrigation intervals (IR2) at two seasons, respectively. Generally, anti-transpiration treatments enhanced the soil NPK available. The results showed that the effect of chitosan on NPK availability was greater than that of potassium silicate and the control treatment. Similar results were found by Ali *et al.* (2023).

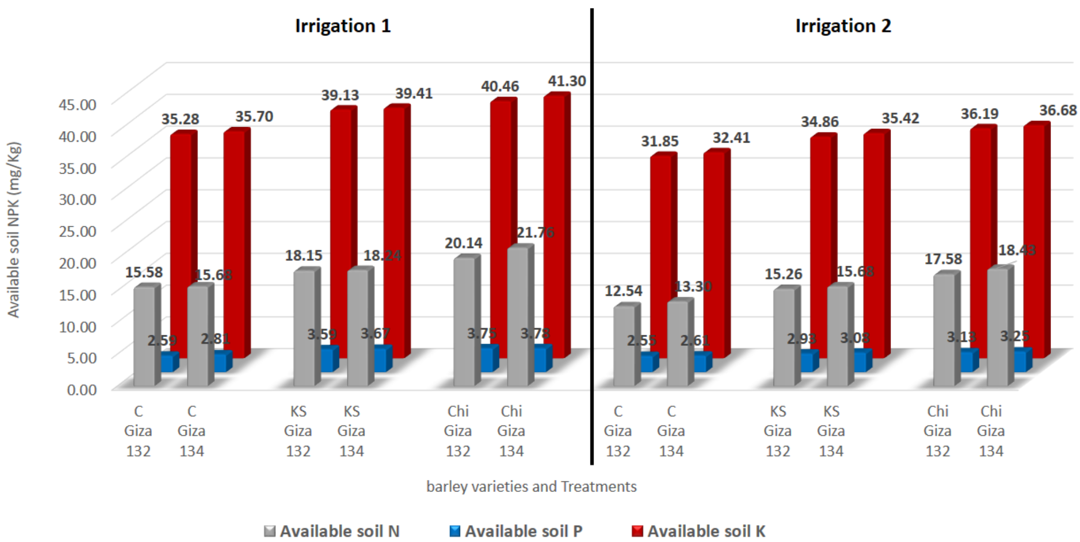

Figure 5. Effect of irrigation intervals and anti-transpiration substances on soil available NPK (First Season, winter 2022/2023)

C: Control Treatment (T1), KS: Potassium silicate Treatment (T2), Chi: Chitosan (T3)

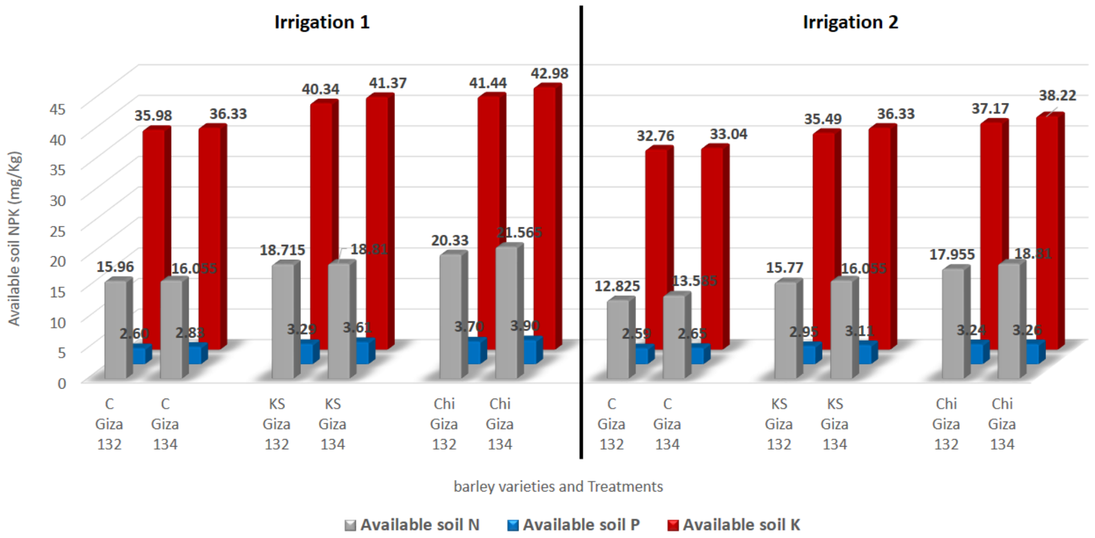

Figure 6. Effect of irrigation intervals and anti-transpiration substances on soil available NPK (Second Season, winter 2023/2024)

C: Control Treatment (T1), KS: Potassium silicate Treatment (T2), Chi: Chitosan (T3)

CONCLUSION

Increasing the irrigation from 1 APE to 2 APE significantly increased the morphological parameters, yield, yield characteristics, water use efficiency, and yield content of nitrogen, phosphorus, and potassium (NPK) uptake for the two studied barley cultivars. Moreover, the application of anti-transpiration substances significantly elevates all the previous measurements compared to the control. Irrigation at 2 APE and chitosan for barley Giza 134 showed the highest significant values. So, it is recommended to irrigate at 2 APE and to use chitosan with barley Giza 134 cultivar in sandy soil under sprinkler irrigation in the North-East of Egypt.

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تأثير فترات الري وسيلكات البوتاسيوم والشيتوزان على الإنتاجية والعلاقات المائية لبعض أصناف الشعير المزروعة في التربة الرملية في مصر

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الملخص العربي

يعتبر محصول الشعير واحد من المحاصيل الحبوب الأربعة من حيث الإنتاج والاستهلاك على مستوى العالم. استخدم الشعير كغذاء للإنسان في الماضي. بينما الان يستخدم كغذاء للحيوانات وفي بعض المشروبات الصناعية. وقد اجريت هذه الدراسة لتوضيح تأثير فترتي ري معتمده على بخر الوعاء التراكمي وتأثير مواد مضادات النتح المضافة ورقيا: سيليكات البوتاسيوم والشيتوزان على صنفي الشعير جيزة ١٣٢ و١٣٤. وقد تمت زراعة الشعير بأرض المزرعة البحثية لمحطة البحوث الزراعية بالإسماعيلية، مصر خلال موسمي شتوي ٢٠٢٣/٢٠٢٢ و٢٠٢٤/٢٠٢٣. وبعد ذالك تم تقديرالتأثير الناتج من المعاملات على للمواد المضافة على العلاقات المائية والنمو والمحصول ومكوناته وكذلك التحليل الكيماوي للأرض والنبات.

أوضحت النتائج أن الاستهلاك المائي الحقيقي لمحصول الشعير ما بين ١١٢٢,٠٧ م٣/فدان الى ١٥٨٦,٧٦ م٣/فدان خلال الموسم الأول وما بين ١١٥٢,٢٧ م٣/فدان الى ١٦١٤,٨م٣/ فدان خلال الموسم الثاني لصنفى الشعير تحت الدراسة على الترتيب

أظهرت نتائج التحليل الإحصائي القطع المنشقة مرتين المجمع الى أن هناك زيادة معنوية لكل القياسات المورفولوجية والمحصول وخصائص المحصول وكفاءة استخدامه للماء والتحليل الكيماوي (نيتروجين، فوسفور، بوتاسيوم) لمحصول الشعير صنفي جيزة ١٣٢ و١٣٤ عند زيادة معامل البخر من ١-٢. كما أثرت معاملات مضادة النتح الى زيادة معنوية لجميع عوامل الدراسة السابقة مقارنة بمعاملة الكنترول. تم الحصول على أعلى القيم المقاسة عند الري بمعامل بخر تراكمي (٢) مع إضافة الشيتوزان لصنف الشعير جيزة ١٣٤. لذلك يوصى بالري بمعامل بخر تراكمي (٢) مع إضافة الشيتوزان لصنف الشعير جيزة ١٣٤ المنزرع بالأرض الرملية تحت نظام الري بالرش في شمال شرق مصر.