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STUDY THE EFFECT OF CHITOSAN ON SOME GROWTH AND YIELD PARAMETERS IN WHEAT GROWN UNDER WATER STRESS CONDITION

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Abstract

This investigation was conducted during two winter successive seasons 2015/5016 and 2016/2017 seasons on wheat cultivar Sakha 93 (*Triticum aestivum* L.). The investigation aimed to improve wheat growth and yield under different levels of water stress (100, 75 and 50% of evapotranspiration ETc) by spraying application with different concentrations of chitosan (0, 250 and 500 ppm) as anti-transpiration agent under sprinkler irrigation system. The data showed that, wheat cultivar Sakha 93 could gained commercial growth and yield parameters under water stress reached to 75% of ETcby spraying application with 500 ppm concentration of chitosan.

***Key words*:** wheat cultivar Sakha 93, water stress, sprinkler irrigation, chitosan, anti-transpiration.

Introduction

Drought is one of the greatest abiotic stress to agriculture, inhibiting plant growth and reducing productivity. Wheat is the most widely planted in the main crop zone (crop zones are mostly known as hardiness zones), about 70% of which are droughty, or semiarid areas, the demand for crop supply has increased correspondingly (Zeng and Luo, 2012). Wheat is one of most important cereal crop in Egypt with total production of about 8 million tons, not enough to feed the increasing population being about of 100 million inhabitants (Hassan *et al*., 2017).

Kahlown *et al*. (2003) reported that wheat require about 400 to 650 mm water, where optimum yields observed with the application of 650 mm in depending upon weather, length of growing period, soil and irrigation supplies. Increasing water stress level is detrimental to plant growth and may result in marked alteration in its morphological features including significantly reduction in shoot and root lengths, leaf area and total biomass production (Aldesuquy *et al*., 2012). Moreover, Zareian *et al*. (2014) found that the reduction of grain yield and its components of wheat plant along with emergence and grain filling under impact of water stress through withholding at the ear. So, it is urgent to improve wheat yield grown underwater stress conditions, depending on different statuses of soil water, biochemical changes to various extents, occurred in wheat grains.

Chitosan and its derivatives from aquatic products such as waste shrimp, crab shells were mainly inexhaustible marine resources. It is a member of the polysaccharides that which is considered a useful natural polymer and is produced by alkaline *N*-deacetylation of chitin. Chitosan is the second most abundant natural polymer on earth. It has become a hot issue to elucidate the possible responses and adaptation of plants to drought. Report indicated that chitosan reduced plant transpiration in pepper plants, resulting in 26–43% reduction in water use without reduction in dry matter yield. The obtained results suggested that chitosan might be an effective antitranspirant for reducing the consumption of irrigation water in agriculture (Bistgani *et al*., 2017).

The present study aimed to improve wheat growth and yield parameters under water stress condition by using chitosan.

Materials and Methods

This investigation was conducted during two winter successive seasons 2015/2016 and 2016/2017 seasons on wheat cultivar Sakha 93 (*Triticum aestivum L.*). The investigation aimed to improve wheat growth and yield under different levels of water stress (100, 75 and 50% of evapotranspiration ETc) by spraying application with different concentrations of chitosan (0, 250 and 500 ppm) as anti-transpiration agent under sprinkler irrigation system. The wheat plants grown in sandy loam soil under water stress condition ata private orchard at Belbeis region – El Sharkia Governorate, Egypt.

All wheat plants under this study received the same applied agricultural practices except those of the experimental treatments. The experimental design was split plot arrangement of complete randomized block design (factorial experiment -split plot design) with three replicates and 10.50 m^2 (3.00×3.50 m) for each replicate area. The main plot contained 100, 75, 50 % of ETc and the sub-plot comprised three chitosan concentrations (0, 250 and 500 ppm).Wheat seeds were

sown manually in mid-November with 80 kg per feddan. Chitosan treatments were applied three times at the required rates in mid-December, mid-January and mid-February (after 30, 60 and 90 days from planting). The experiment remained until the end of April, but irrigation stopped at the end of March. Irrigation was for short periods until germination twice a week and after germination the irrigation period 10 days before harvesting.

The tested irrigation levels were based on different rates of irrigation water i. e. 1154, 867 and 578 m^3 /fed./season, according to the FAO – Penman - Moteith equation (1998) using meteorological data of the region as in the following tables:

Table 1: Reference crop evapotranspiration rate (ETo) calculated using CROPWAT V.8.00computer program from meteorological data under Sharkia Governorate conditions using FAO – Penman - Moteith equation (Average of two years 2015 & 2016).

Meteorological factor	November	December	January	February	March
Min Temp °C	13.00	8.60	6.60	7.10	9.20
Max Temp °C	25.70	21.20	19.70	21.00	23.60
Humidity %	69.00	73.00	71.00	66.00	62.00
Wind km/day	104.00	124.00	136.00	139.00	139.00
Sun hours	7.70	6.90	6.90	7.40	8.60
Rad MJ/m²/day	13.40	11.40	12.10	14.90	19.30
ETcmm/day	2.48	1.88	1.93	2.50	3.42
ETc(100%)	2.48	1.88	1.93	2.50	3.42
ETc (75%)	1.86	1.41	1.45	1.88	2.57
ETc (50%)	1.24	0.94	0.97	1.25	1.71

Water requirements = Kc × ETo Kc = crop coefficient

Table 2 : The first irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate (m^3/ feddan/ season) from mid-November to March according to the monthly data as shown in the following table.

Water requirements (W.R)	November	December	January	February	March
ETc (100%)	2.48	1.88	1.93	2.5	3.42
crop coefficient	0.35	0.75	1.05	1.20	0.67
W.R (mm/m^2/day)	0.87	1.41	2.03	3.00	2.29
W.R (m^3/fed./day)	3.65	5.92	8.51	12.60	9.62
W.R (m3/ fed. Month)	109.37	177.66	255.34	378.00	288.72

ETc = 1154 m^3/ feddan/ season

Table 3 : The second irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate (m^3/ feddan/ season) from mid-November to March according to the monthly data as shown in the following table.

Water requirements (W.R)	November	December	January	February	March
ETc (75%)	1.86	1.41	1.45	1.88	2.57
crop coefficient	0.35	0.75	1.05	1.20	0.67
W.R (mm/m^2/day)	0.65	1.06	1.52	2.26	1.72
W.R (m^3/fed./day)	2.73	4.44	6.39	9.48	7.23
W.R (m3/ fed. Month)	82.03	133.25	191.84	284.26	216.96

ETc = 867 m^3/ feddan/ season

Table 4: The third irrigation level of total water requirement (W. R.) was calculated by theoretical irrigation rate (m^3/ feddan/ season) from mid-November to March according to the monthly data as shown in the following table.

Water requirements (W.R)	November	December	January	February	March
ETc (50%)	1.24	0.94	0.97	1.25	1.71
crop coefficient	0.35	0.75	1.05	1.20	0.67
W.R (mm/m^2/day)	0.43	0.71	1.02	1.50	1.15
W.R (m^3/fed./day)	1.82	2.96	4.28	6.30	4.81
W.R (m3/ fed. Month)	54.68	88.83	128.33	189.00	144.36

ETc = 578 m^3/ feddan/ season

Table 5 : Chemical constituents of the used irrigation water.

pH	TDS ppm	Soluble cations meq /L				Soluble anions meq /L			Boron (ppm)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCo_3^{-}	Cl^{-}	SO_4^{--}	
7.12	300	0.10	0.70	0.64	3.25	0.10	0.06	4.53	0.02

Table 6 : Soil chemical characteristics of the tested experimentsite.

Depth (cm)	PH	TDS ppm	$Ca_2(CO)_3$ %	Soluble cations meq /100 g soil				Soluble anions meq /100 g soil				Major elements (ppm)			Minor elements (ppm)			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCo_3^{-}	Cl^{-}	SO_4^{--}	N	P	K	Fe	Mn	Zn	Cu
0-60	8.33	326	2.90	0.20	0.06	3.84	1.00	-	0.05	0.30	4.75	30.0	7.50	150.0	0.15	0.24	0.18	0.11

- TDS = total dissolved salts

Table 7 : Soil physical properties of the soil under experimental site.

Depth	Particle size distribution (%)				Moisture content (%)			
(cm)	Coarse sand	Fine sand	Silt	Clay	Saturation point (S.P.)	Field capacity (F. C.)	Available water (Av. W.)	Wilting point (W.P.)
0 - 60	43.20	19.50	24.00	13.30	28.60	14.30	7.15	7.15

The tested treatments were evaluated through the following parameters:

Growth and yield parameters : At the end of every experimental season (harvest time)plant height, plant numbers per m^2, number of tillers per plant, number of leaves per plant, leaf area m^2, shoot dry weight, root dry weight, spike weight, spike length, number of grains per spike and grain yield ton per feddan were determined and recorded.

Leaf photosynthetic pigments and proline contents : The photosynthetic pigments contents were determined in fresh samples of leaf by SPAD device. Moreover, the proline content of fresh leaves (µ moles/g fresh weight) was determined following the method adopted by Bates *et al*., 1973.

Leaf chemical composition : The dried leaves were finely grinded and digested using micro-Kjeldahl unit. The percentage of nitrogen content was determined according to Naguib, 1969. Phosphorus percentage was determined according to AOAC, 1985. Potassium percentage was determined according to Brown and Lilliland, 1964.

Physcio-chemical parameters : Physcio-chemical parameters such as fat, ash, protein and gluten were determined according to methods described in Anonymous, 2000.

Statistical analysis: The experimental design was split plot design of complete randomized block design with three replicates and 10.5 m^2 (3X3.5) for each replicate area. The main plot contained 100, 75, 50% of ETc and the sub-plot comprised three chitosan concentration (0, 250 and 500 ppm).The data obtained were statistically analyzed using the analysis of variance method as reported by Snedecor and Cochran, 1980. The differences between means were differentiated by using Duncan's range test (Duncan, 1955).

Results

Plant height, plant numbers per m^2 and number of tillers per plant

The data in Table (8) showed that, decreasing irrigation water amount from 100% to 50% of ETc decreased significantly plant height from 90.07 and 92.40to 72.13and 73.33 cm in the first and the second season, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 89.00 and 90.60 cm compared to 69.60 and 70.80 for chitosan 0 ppmin the first and the second seasons, respectively. At the same time, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation attained the highest values, which reached to 99.00 and 101.4 cm in the first and the second seasons, respectively. Also, chitosan 500 ppm with 75 % ETc of water irrigation attained 84.00

and 86.20 cm, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation (80.20 and 81.60 cm) in the first and the second seasons, respectively.

In the same trend, the plant numbers per m^2reached minimum values 428.20 and 434.07 with 50% ETc compared to 534.13 and 546.33 with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 528.27 and 536.00 compared to chitosan 0 ppm, which recorded 413.00 and 418.73 in the first and the second seasons, respectively. Meanwhile, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values reached to 586.60 and 599.40in the first and the second seasons, respectively. Also, chitosan 500 ppm with 75% ETc of water irrigation gained 498.60 and 509.40, which exceeded the (control) chitosan 0 ppm with 100% ETc of water irrigation, which recorded 477.00 and 483.60 in the first and the second seasons, respectively.

Similarly, data illustrated that decrease in the amount of irrigation water (50% ETc) decreased number of tillers per plant (5.40 and 5.40) compared to (6.80 and 6.90) with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 6.60 and 6.60 compared to chitosan 0 ppm in the first and the second seasons, respectively. Moreover, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values7.20 and 7.20in the first and the second seasons, respectively. Also, chitosan 500 ppm with 75 % ETc of water irrigation gained 6.30 and 6.30, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 6.30 and 6.30 in the first and the second seasons, respectively.

Number of leaves per plant, leaf area, shoot and root dry weight

Values given in Table (9) showed that, decreasing the amount of irrigation water from 100% to 50% ETc caused a significant reduction in the number of leaves per plant, leaf area, shoot and root dry weight.

Decreasing irrigation water amount from 100% to 50% of ETc decreased significantly number of leaves per plant from 4.72 and 4.72 to 3.81 and 3.86 in the first and the second season, respectively. In addition, spraying chitosan 500 ppm attained the highest values, which reached to 4.68 and 4.72 compared to 3.64 and 3.64 for chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation attained the highest values, which reached to 5.20 and 5.20in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 4.42 and 4.55, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation (4.16 and 4.16) in the first and the second seasons, respectively.

On the other hand, the leaf area cm^2 reached minimum values 38.11 and 37.47cm^2 with 50% ETc compared to 42.19 and 41.88cm^2 with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 42.97 and 42.38cm^2 compared to chitosan 0 ppm, which recorded 35.33 and 34.73 cm^2in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values reached to 44.83 and 44.62 cm^2in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 40.58 and 40.38cm^2, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 39.33 and 38.66 cm^2 in the first and the second seasons, respectively.

Table 8 : Effect of irrigation water levels and spraying with different concentrations of chitosan on plant height, plant numbers per m^2 and numbers of tillers per plant of wheat c.v. Sakha 93.

Parameters / Treatments	Plant height (cm)		Plant numbers per m^2		Number of tillers per plant	
	First season (2015-2016)					
100% ETc	90.07	A	534.13	A	6.80	A
75% ETc	76.47	B	454.00	B	5.70	B
50% ETc	72.13	C	428.20	C	5.40	C
chitosan 0ppm	69.60	C	413.00	C	5.40	C
chitosan 250ppm	80.07	B	475.07	B	5.90	B
chitosan 500ppm	89.00	A	528.27	A	6.60	A
100% ETc × chitosan 0ppm (control)	80.20	d	477.00	d	6.30	b
100% ETc × chitosan 250ppm	91.00	b	538.80	b	6.90	b

100% ETc × chitosan 500ppm	99.00	a	586.60	a	7.20	a
75% ETc × chitosan 0ppm	68.40	g	405.20	g	5.40	c
75% ETc × chitosan 250ppm	77.00	e	458.20	e	5.40	c
75% ETc × chitosan 500ppm	84.00	c	498.60	c	6.30	b
50% ETc × chitosan 0ppm	60.20	h	356.80	h	4.50	d
50% ETc × chitosan 250ppm	72.20	f	428.20	f	5.40	c
50% ETc × chitosan 500ppm	84.00	c	499.60	c	6.30	b
	Second season (2016-2017)					
100% ETc	92.40	A	546.33	A	6.90	A
75% ETc	79.00	B	467.07	B	6.00	B
50% ETc	73.33	C	434.07	C	5.40	C
chitosan 0ppm	70.80	C	418.73	C	5.40	C
chitosan 250ppm	83.33	B	492.73	B	6.30	B
chitosan 500ppm	90.60	A	536.00	A	6.60	A
100% ETc × chitosan 0ppm (control)	81.60	d	483.60	e	6.30	b
100% ETc × chitosan 250ppm	94.20	b	556.00	b	7.20	a
100% ETc × chitosan 500ppm	101.40	a	599.40	a	7.20	a
75% ETc × chitosan 0ppm	69.60	f	411.00	g	5.40	c
75% ETc × chitosan 250ppm	81.20	d	480.80	e	6.30	b
75% ETc × chitosan 500ppm	86.20	c	509.40	c	6.30	b
50% ETc × chitosan 0ppm	61.20	g	361.60	h	4.50	d
50% ETc × chitosan 250ppm	74.60	e	441.40	f	5.40	c
50% ETc × chitosan 500ppm	84.20	c	499.20	d	6.30	b

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

At the same time, data illustrated that decrease the amount of irrigation water (50% ETc) decreased shoot dry weight (4.93 and 4.87 g) compared to (6.07 and 6.13 g) with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 6.13 and 6.07 g compared to chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values 6.80 and 6.80g in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 5.80 and 5.80 g, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 5.40 and 5.40 g in the first and the second seasons, respectively.

Moreover, data illustrated that decrease the amount of irrigation water (50% ETc) decreased root dry weight (5.93 and 5.87 g) compared to (7.27 and 7.20 g) with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 7.20 and 7.00 g compared to chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values 8.00 and 7.80g in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 6.80 and 6.60 g, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 6.40 and 6.40 g in the first and the second seasons, respectively.

Table 9 : Effect of irrigation water levels and spraying with different concentrations of chitosan on number of leaves per plant, leaf area, shoot and root dry weight of wheat c.v. Sakha 93.

Parameters / **Treatments**	**Number of leaves per plant**		**Leaf area cm^2**		**Shoot dry weight (g)**		**Root dry weight (g)**	
	First season (2015-2016)							
100% ETc	4.72	A	42.19	A	6.07	A	7.27	A
75% ETc	4.03	B	38.18	B	5.20	B	6.20	B
50% ETc	3.81	C	38.11	B	4.93	C	5.93	B
chitosan 0ppm	3.64	C	35.33	C	4.73	C	5.60	C
chitosan 250ppm	4.25	B	40.18	B	5.33	B	6.60	B
chitosan 500ppm	4.68	A	42.97	A	6.13	A	7.20	A

100% ETc × chitosan 0ppm (control)	4.16	b	39.33	e	5.40	c	6.40	c
100% ETc × chitosan 250ppm	4.81	b	42.40	c	6.00	b	7.40	b
100% ETc × chitosan 500ppm	5.20	a	44.83	a	6.80	a	8.00	a
75% ETc × chitosan 0ppm	3.51	c	35.59	g	4.80	d	5.40	d
75% ETc × chitosan 250ppm	4.16	b	38.37	f	5.00	c	6.40	c
75% ETc × chitosan 500ppm	4.42	b	40.58	d	5.80	b	6.80	c
50% ETc × chitosan 0ppm	3.25	d	31.07	h	4.00	e	5.00	d
50% ETc × chitosan 250ppm	3.77	c	39.77	e	5.00	c	6.00	c
50% ETc × chitosan 500ppm	4.42	b	43.50	b	5.80	b	6.80	c
	Second season (2016-2017)							
100% ETc	4.72	A	41.88	A	6.13	A	7.20	A
75% ETc	4.07	B	37.90	B	5.33	B	6.13	B
50% ETc	3.86	C	37.47	C	4.87	C	5.87	B
chitosan 0ppm	3.64	C	34.73	C	4.73	C	5.60	C
chitosan 250ppm	4.29	B	40.14	B	5.53	B	6.60	B
chitosan 500ppm	4.72	A	42.38	A	6.07	A	7.00	A
100% ETc × chitosan 0ppm (control)	4.16	b	38.66	e	5.40	c	6.40	b
100% ETc × chitosan 250ppm	4.81	b	42.37	b	6.20	b	7.40	b
100% ETc × chitosan 500ppm	5.20	a	44.62	a	6.80	a	7.80	a
75% ETc × chitosan 0ppm	3.51	d	34.99	f	4.80	d	5.40	c
75% ETc × chitosan 250ppm	4.16	b	38.35	e	5.40	c	6.40	b
75% ETc × chitosan 500ppm	4.55	b	40.38	c	5.80	b	6.60	b
50% ETc × chitosan 0ppm	3.25	e	30.54	g	4.00	e	5.00	c
50% ETc × chitosan 250ppm	3.90	c	39.70	d	5.00	d	6.00	b
50% ETc × chitosan 500ppm	4.42	b	42.15	b	5.60	c	6.60	b

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Spike weight, spike length, number of grains per spike and grain yield ton per feddan

The data in Table (10) noticed that, decreasing irrigation water amount from 100% to 50% of ETc decreasing significantly spike weight from 3.02 and 3.24 g to 2.54 and 2.75 g in the first and the second season, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 2.88 and 3.08 g compared to 2.52 and 2.72 g for chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100% ETc of water irrigation gained the highest values, which reached to 3.24 and 3.47 g in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 2.74 and 2.93 g, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation (2.59 and 2.77 g) in the first and the second seasons, respectively.

In addition, spike length cm reached minimum values 9.97 and 10.55 cm with 50% ETc compared to 11.56 and 12.13cmwith 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 11.45 and 12.19 cm compared to chitosan 0 ppm, which recorded 9.69 and 10.19 cm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values reached to 12.24 and 12.91 cm in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 11.05 and 11.82 cm, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 10.88 and 11.10 cm in the first and the second seasons, respectively.

For number of grains per spike, data illustrated that decrease the amount of irrigation water (50% ETc) decreased number of grains per spike (45.53 and 46.67) compared to (56.80 and 58.67) with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 56.07 and 57.67 compared to chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100 % ETc of water irrigation gained the highest values 62.20 and 64.40 in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 53.00 and 54.80, which exceeded the (control) chitosan 0 ppm with 100%

ETc of water irrigation, which recorded 50.80 and 51.80 in the first and the second seasons, respectively.

In the same trend, data illustrated that decrease the amount of irrigation water (50% ETc) decreased grain yield ton per feddan (1.06 and 1.08 ton) compared to (1.99 and 2.10 ton) with 100% ETc in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm gained the highest values, which reached to 1.92 and 1.98 ton compared to chitosan 0 ppm in the first and the second seasons, respectively. In addition, spraying chitosan 500 ppm combined with 100% ETc of water irrigation gained the highest values 2.59 and 2.71 ton in the first and the second seasons, respectively. At the same time, chitosan 500 ppm with 75 % ETc of water irrigation gained 1.59 and 1.66 ton, which exceeded the (control) chitosan 0 ppm with 100 % ETc of water irrigation, which recorded 1.39 and 1.42 ton in the first and the second seasons, respectively.

Table 10 : Effect of irrigation water levels and spraying with different concentrations of chitosan on spike weight, spike length, number of grains per spike and grain yield ton per feddan of wheat c.v. Sakha 93.

Parameters / Treatments	Spike weight g		Spike length cm		Number of grains per spike		Grain yield ton per feddan	
	First season (2015-2016)							
100% ETc	3.02	A	11.56	A	56.80	A	1.99	A
75% ETc	2.59	B	10.31	B	48.27	B	1.23	B
50% ETc	2.54	B	9.97	C	45.53	B	1.06	C
chitosan 0ppm	2.52	C	9.69	C	44.00	C	0.94	C
chitosan 250ppm	2.76	B	10.71	B	50.53	B	1.41	B
chitosan 500ppm	2.88	A	11.45	A	56.07	A	1.92	A
100% ETc × chitosan 0ppm (control)	2.59	b	10.88	c	50.80	b	1.39	d
100% ETc × chitosan 250ppm	3.24	a	11.56	b	57.40	b	2.00	b
100% ETc × chitosan 500ppm	3.24	a	12.24	a	62.20	a	2.59	a
75% ETc × chitosan 0ppm	2.52	c	9.52	e	43.20	c	0.85	e
75% ETc × chitosan 250ppm	2.52	c	10.37	d	48.60	c	1.23	d
75% ETc × chitosan 500ppm	2.74	b	11.05	b	53.00	b	1.59	c
50% ETc × chitosan 0ppm	2.45	d	8.67	f	38.00	d	0.58	f
50% ETc × chitosan 250ppm	2.52	c	10.20	d	45.60	c	1.00	e
50% ETc × chitosan 500ppm	2.66	b	11.05	b	53.00	b	1.60	c
	Second season (2016-2017)							
100% ETc	3.24	A	12.13	A	58.67	A	2.10	A
75% ETc	2.77	B	10.97	B	50.20	B	1.31	B
50% ETc	2.75	B	10.55	C	46.67	C	1.08	C
chitosan 0ppm	2.72	C	10.19	C	44.93	C	0.96	C
chitosan 250ppm	2.95	B	11.28	B	52.93	B	1.55	B
chitosan 500ppm	3.08	A	12.19	A	57.67	A	1.98	A
100% ETc × chitosan 0ppm (control)	2.77	c	11.10	c	51.80	b	1.42	d
100% ETc × chitosan 250ppm	3.47	a	12.37	b	59.80	b	2.16	b
100% ETc × chitosan 500ppm	3.47	a	12.91	a	64.40	a	2.71	a
75% ETc × chitosan 0ppm	2.70	d	10.19	e	44.20	c	0.87	d
75% ETc × chitosan 250ppm	2.70	d	10.91	d	51.60	b	1.40	d
75% ETc × chitosan 500ppm	2.93	b	11.82	c	54.80	b	1.66	c
50% ETc × chitosan 0ppm	2.70	d	9.28	f	38.80	d	0.59	e
50% ETc × chitosan 250ppm	2.70	d	10.55	d	47.40	c	1.08	d
50% ETc × chitosan 500ppm	2.85	c	11.82	c	53.80	b	1.56	c

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Chemical composition, pigments and proline leaf contents

Regarding Table (11), leaves chemical composition have been affected by 50%ETc, which reached to 0.592, 0.054 and 1.45 % compared to 100% ETc, which reached 0.897, 0.071and 1.93% for N, P, and K, respectively.

In addition, leaves chemical composition have affected by chitosan 500 ppm application, which reached 0.816, 0.074 and 1.90 % N, P, and K, respectively. It is clear that spraying chitosan 500 ppm with 100% ETc of irrigation water gained the highest values for N, P, and K, which were 0.996, 0.084 and 2.16 %, respectively. Also, using spraying chitosan 500 ppm with 75% ETc of irrigation water gained 0.766 , 0.074, and 1.79 % for N, P and K, respectively, which were statistically over than or equal to (control), spraying chitosan 0 ppm with 100% ETc of irrigation water, which were 0.788, 0.064 and 1.63 % for N, P and K, respectively. The leaves pigments had the same trend. This was true in both seasons.

Table 11: Effect of irrigation water levels and spraying with different concentrations of chitosan chemical composition, pigments and proline leaf contents of wheat c.v. Sakha 93.

Parameters / Treatments	N%		P%		K%		SPAD chll		Proline (µm/F.W.g)	
	First season (2015-2016)									
100% ETc	0.897	A	0.071	A	1.93	A	49.40	A	6.56	C
75% ETc	0.690	B	0.061	B	1.54	B	42.00	B	9.83	B
50% ETc	0.592	C	0.054	C	1.45	C	40.00	C	13.35	A
chitosan 0ppm	0.625	C	0.054	B	1.37	C	37.60	C	11.91	A
chitosan 250ppm	0.738	B	0.057	B	1.64	B	44.53	B	9.44	B
chitosan 500ppm	0.816	A	0.074	A	1.90	A	49.27	A	8.39	C
100% ETc × chitosan 0ppm (control)	0.788	c	0.064	b	1.63	c	43.40	b	7.52	d
100% ETc × chitosan 250ppm	0.906	b	0.064	b	2.01	b	50.00	a	6.39	e
100% ETc × chitosan 500ppm	0.996	a	0.084	a	2.16	a	54.80	a	5.76	f
75% ETc × chitosan 0ppm	0.606	c	0.054	c	1.31	f	37.00	c	11.28	b
75% ETc × chitosan 250ppm	0.698	c	0.054	c	1.51	d	42.40	b	9.59	c
75% ETc × chitosan 500ppm	0.766	c	0.074	b	1.79	c	46.60	b	8.63	d
50% ETc × chitosan 0ppm	0.480	d	0.044	d	1.19	g	32.40	d	16.92	a
50% ETc × chitosan 250ppm	0.610	c	0.054	c	1.40	e	41.20	b	12.35	b
50% ETc × chitosan 500ppm	0.686	c	0.064	b	1.75	c	46.40	b	10.78	c
	Second season (2016-2017)									
100% ETc	0.921	A	0.075	A	2.01	A	49.13	A	6.49	C
75% ETc	0.711	B	0.063	B	1.64	B	41.67	B	9.74	B
50% ETc	0.576	C	0.055	C	1.52	C	37.73	C	14.26	A
chitosan 0ppm	0.625	C	0.054	C	1.44	C	36.40	C	12.22	A
chitosan 250ppm	0.755	B	0.063	B	1.74	B	43.87	B	9.71	B
chitosan 500ppm	0.827	A	0.075	A	1.98	A	48.27	A	8.55	C
100% ETc × chitosan 0ppm (control)	0.788	c	0.062	b	1.77	d	42.20	b	7.72	d
100% ETc × chitosan 250ppm	0.954	b	0.072	b	2.09	b	50.80	a	6.10	e
100% ETc × chitosan 500ppm	1.022	a	0.090	a	2.18	a	54.40	a	5.65	f
75% ETc × chitosan 0ppm	0.608	d	0.052	c	1.34	f	35.60	c	11.58	c
75% ETc × chitosan 250ppm	0.736	c	0.062	b	1.67	e	43.20	b	9.15	d
75% ETc × chitosan 500ppm	0.788	c	0.074	b	1.90	c	46.20	b	8.48	d
50% ETc × chitosan 0ppm	0.480	f	0.048	d	1.21	g	31.40	d	17.37	a
50% ETc × chitosan 250ppm	0.576	e	0.056	c	1.48	e	37.60	c	13.89	b
50% ETc × chitosan 500ppm	0.672	d	0.062	b	1.87	c	44.20	b	11.53	c

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

On the contrary, proline leaf content increased with decreasing irrigation water level from 100 ETc% to ETc50% of water irrigation, it is interesting to mention that, decreasing water irrigation quantity increased proline content.

Proline content increased with 50 % ETc reached to 13.35µg / moles of leaf fresh compared to 6.56µg / moles of leaf fresh for 100 %ETc, respectively. In addition, proline content get low values with chitosan 500 ppm application, which reached to 8.39 µg / moles of leaf fresh. Thus, spraying chitosan 500 ppm with 100% ETc of irrigation water gained the lowest values for proline content, which was5.76 µ g / moles of leaf fresh. Also, chitosan 500 ppm with 50% ETc of irrigation water gained 10.78µg / moles of fresh leaf. This was true in both seasons.

Seed Quality Characters

Data in Table (12) revealed that, seed quality characters have been affected by 50% ETc, which reached to 11.16 and 1.81% compared to100% ETc, which reached to 11.62 and 2.20 % in the first season for moisture and fat content, respectively. In addition, moisture and fat content have been affected by chitosan 500 ppm application, which reached to 11.54 and 2.15%, respectively. It is clear that spraying chitosan 500 ppm with 100% ETc of irrigation water gained the highest values for moisture and fat content which were 11.78 and 2.31%, respectively. Also, using spraying chitosan 500 ppm with 50% ETc of irrigation water gained 11.32and 1.99 %. This was true in both seasons.

Additionally, the parameters of ash, protein, dry gluten content and zeleny values opposed to moisture and fat content in both seasons. The ash, protein, dry gluten content and zeleny values were decreased when the water irrigation level or chitosan concentration increased. Also, the highest values for those parameters were obtained with spraying chitosan 0 ppm with 50% ETc of irrigation water, where the lowest values were obtained with spraying chitosan 500 ppm with 100% ETc of irrigation water.

Discussion

In this respect, our results showed that, the leaf water content reflects the water status in plant, which was subjected to soil moisture and metabolism. Chitosan coating can improve the leaf water content in plant. The experimental results showed that chitosan significantly increased the concentration of chlorophyll compared with the control under drought stress, which illustrates chitosan can enhance the photosynthesis performance (El-Tantawy, 2009). Under the drought condition, a well developed root system absorbs more water to keep the moisture stable. Chitosan coating can reduce the inhibition of roots and stem growth under drought stress, which shows chitosan effectively promotes the development of root system and strengthens the capability of water absorption, so as to enhance drought resistance of wheat plants (Zeng and Luo, 2012).

Others researched influences of chitosan on rape resistance, the tests showed that chitosan could raised up the active ties of those protection enzymes and hence to strengthen the ability of drought tolerance of plants. Chitosan considered to protect membrane system, reduce the damage of drought stress and strengthen drought resistance of plant (Zhang *et al*., 2002). In addition, the stimulating effect of chitosan on plant growth may be attributed to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure, and reducing the accumulation of harmful free radicals by increasing antioxidants and enzyme activities (Guan *et al*., 2009). Lee *et al*. (1999) found that chitosan has the similar function with abscisic acid (ABA) as an important plant hormone, and plays an important role in plant resistance to adverse environment.

In total, the spray of chitosan, reduced the negative effects of deficit irrigation on plant. However, the mechanism of chitosan in counteracting the harmful effect of water deficit is not well understood and there are a few reports in the literature and the significant change of the growth of plants, induced by chitosan, is still not well understood.

Our results were in harmony with Lee *et al*., 2005; Farouk *et al*., 2011; Sheikha and Al-Malki, 2011; Malekpoor *et al*., 2016.

Table 12 : Effect of irrigation water levels and spraying with different concentrations of chitosan on seed quality characters of wheat c.v. Sakha 93.

Parameters / Treatments	Moisture (%)		Ash (%)		Fat (%)		Protein (%)		Dry gluten (%)		Zeleny value	
	First season (2015-2016)											
100% ETc	11.62	A	1.62	C	2.20	A	9.92	C	13.97	C	55.16	C
75% ETc	11.39	B	1.73	B	2.03	B	10.65	B	14.72	B	57.80	B
50% ETc	11.16	C	1.88	A	1.81	C	11.27	A	15.57	A	60.31	A
chitosan 0ppm	11.23	C	1.83	A	1.89	C	11.08	A	15.28	A	59.38	A
chitosan 250ppm	11.39	B	1.74	B	2.01	B	10.59	B	14.75	B	57.84	B
chitosan 500ppm	11.54	A	1.66	C	2.15	A	10.16	C	14.23	C	56.05	C
100% ETc× chitosan 0ppm (control)	11.45	d	1.69	f	2.08	d	10.46	f	14.52	f	56.90	f
100% ETc × chitosan 250ppm	11.63	b	1.60	h	2.22	b	9.88	h	13.75	h	54.92	h
100% ETc × chitosan 500ppm	11.78	a	1.57	i	2.31	a	9.42	i	13.63	i	53.66	i
75% ETc × chitosan 0ppm	11.24	g	1.82	c	1.89	g	11.02	c	15.28	c	59.52	c
75% ETc × chitosan 250ppm	11.39	e	1.73	e	2.04	e	10.64	e	14.84	e	58.05	e
75% ETc × chitosan 500ppm	11.53	c	1.64	g	2.16	c	10.29	g	14.05	g	55.83	g
50% ETc × chitosan 0ppm	11.00	i	1.97	a	1.69	i	11.78	a	16.02	a	61.72	a
50% ETc × chitosan 250ppm	11.14	h	1.89	b	1.76	h	11.26	b	15.67	b	60.54	b
50% ETc × chitosan 500ppm	11.32	f	1.77	d	1.99	f	10.78	d	15.00	d	58.66	d
	Second season (2016-2017)											
100% ETc	11.54	A	1.72	C	2.07	A	10.00	C	13.99	C	54.71	C
75% ETc	11.24	B	1.84	B	1.95	B	10.71	B	14.81	B	57.13	B
50% ETc	10.91	C	1.97	A	1.81	C	11.52	A	15.63	A	59.52	A
chitosan 0ppm	11.03	C	1.92	A	1.86	C	11.26	A	15.31	A	58.69	A
chitosan 250ppm	11.23	B	1.85	B	1.94	B	10.78	B	14.82	B	57.11	B
chitosan 500ppm	11.42	A	1.76	C	2.03	A	10.19	C	14.30	C	55.57	C
100% ETc × chitosan 0ppm (control)	11.37	d	1.79	f	1.99	d	10.58	f	14.47	f	56.42	f
100% ETc × chitosan 250ppm	11.58	b	1.74	h	2.06	b	9.93	h	13.90	h	54.37	h
100% ETc × chitosan 500ppm	11.67	a	1.64	i	2.15	a	9.48	i	13.61	i	53.32	i
75% ETc × chitosan 0ppm	10.95	g	1.92	c	1.88	g	11.15	c	15.50	c	58.75	c
75% ETc × chitosan 250ppm	11.23	e	1.83	e	1.96	e	10.79	e	14.85	e	56.96	e
75% ETc × chitosan 500ppm	11.52	c	1.77	g	2.02	c	10.19	g	14.06	g	55.70	g
50% ETc × chitosan 0ppm	10.77	i	2.04	a	1.70	i	12.04	a	15.96	a	60.90	a
50% ETc × chitosan 250ppm	10.88	h	1.99	b	1.80	h	11.61	b	15.71	b	59.99	b
50% ETc × chitosan 500ppm	11.08	f	1.87	d	1.91	f	10.91	d	15.23	d	57.68	d

ETc = Evapotranspiration, mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Conclusion

In conclusion, the results clearly suggest that chitosan 500 ppm obviously improved wheat growth and yield under drought stress reached to 75 % ETc, which could save 25% of water irrigation and gained the same yield and quality without any educed in them.

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