Journal of Crop Nutrition Science
ISSN: 2423-7353 (Print) 2538-2470 (Online)
Vol. 3, No. 4, 2017
http://JCNS.iauahvaz.ac.ir
OPEN ACCESS

Assessment Effect of Chitosan Foliar Application on Total Chlorophyll and Seed Yield of Wheat (*Triticum aestivum* L.) Under Water Stress Conditions

Mohammad Hadi Masjedi, Arash Roozbehani* and Mahdi Baghi

Department of Agronomy and Plant Breeding, Roudehen Branch, Islamic Azad University, Roudehen, Iran.

RESEARCH ARTICLE

ARTICLE INFO.
Received Date: *18 Aug. 2017*
Received in revised form: *14 Sep. 2017*
Accepted Date: *21 Oct. 2017*
Available online: *31 Dec. 2017*

To Cite This Article: Mohammad Hadi Masjedi, Arash Roozbehani and Mahdi Baghi. Assessment Effect of Chitosan Foliar Application on Total Chlorophyll and Seed Yield of Wheat (*Triticum aestivum* L.) Under Water Stress Conditions. ***J. Crop. Nut. Sci.,*** *3(4): 14-26, 2017.*

ABSTRACT

Crop show morphological and physiological responses to microbial, physical or chemical factors which are known as elicitors. Chitosan is a natural biopolymer modified from chitin, which is the main structural component of squid pens, cell walls of some fungi and crab shells. Water stress is one of the most important abiotic stresses that affect plant physiological and morphological traits. In order to study the effects of chitosan foliar spraying on total chlorophyll, seed yield and its components of wheat under water stress conditions a split plot experiment based on randomized complete block design with three replications was conducted at Agricultural Research Center of Roudhen Islamic Azad University in 2017. The main plots included different irrigation regime at three levels (I_1: normal irrigation, I_2: water stress at heading stage, I_3: water stress in grain filing period) and chitosan foliar application at tillering and stem elongation stages by three concentrations (C_1:0, C_2: 0.05%, C_3: 0.1% chitosan in acetic acid is 1%) was belonged to sub plots. The results of analysis of variance showed that yield and its components in normal irrigation conditions have the best result and drought causes damage to the plant. The use of chitosan in the form of spraying had positive effects on some of the important characteristics of the wheat. Lowering the plant height, total chlorophyll, yield and yield components, as well as growth and development under drought stress conditions, are partially offset by the use of various concentrations of chitosan. The effect of chitosan on growth and yield of plant can be attributed to the production of plant hormones. The results of mean comparison showed that the highest economic yield was related to consumption of chitosan 0.1% in normal irrigation (6495.199 $kg.ha^{-1}$) and The largest reduction of economic yield was observed under water stress in seed filing stage and in the absence of chitosan application (1511.49 $kg.ha^{-1}$). The use of chitosan and normal irrigation has increased 76% to economic yield than control. It is concluded that foliar application of chitosan at vegetative stage enhanced the plant growth and development, which resulted from increased fruit yield in wheat. Among the concentrations, 0.1 percentages had superiority for plant growth, yield components and seed yield than the others. Finally recommend that in the region under drought stress conditions, foliar application chitosan will be useful.

Keywords*:* *Different irrigation regime, Grain weight, Plant height.*

***Corresponding Author:** Arash Roozbehani ✉ roozbahani@riau.ac.ir

INTRODUCTION

Abiotic stress is the major cause of crop loss worldwide (Xiong *et al.,* 2002). Water deficit affects every aspect of plant growth by modifying the anatomy, morphology, physiology, biochemistry and finally the productivity of a crop. Moisture stress during spike emergence and anthesis has been reported to reduce grain yield up to 20% mainly through reduction of individual grain weight. Other study number of grains per spike which results in the reduction of grain yield crop during growth stages is known to have cumulative effects expressed as a reduction in total biomass as compared to well-watered conditions by 20% mainly due to 16% reduction in individual grain weight measure of plant productivity per unit of water used, depends on the unit with which productivity (photosynthesis or biomass accumulation) and WU (transpiration, evapotranspiration plant or canopy level (Shamsi and Kobraee, 2013). The limitation of water resources in arid and semi-arid areas was the main reason that we considered water as the most important material in the production lines, although people often do not obey the irrigation water consumption rules and regulations (Cakir, 2004). Drought is one of the greatest abiotic stresses to agriculture, inhibiting plant growth and reducing productivity (Zhang *et al.,* 2008). Drought is a long period with precipitates less than average, with no sufficient moisture for maximum potential growth of the plant (Blum, 2012). Drought stress is one of the most common environmental stresses and almost every year affects about 25 percent of global crop production (Liang *et al.,* 2003). Iran with average 250 millimeters of rainfall per year is considered as the arid region of the world (Ghamarnia and Gowing, 2005). Bittelli *et al*. (2001) reported that occasional or episodic drought events can be counteracted through the use of anti-transpirants, compounds applied to foliage to limit the water loss. They include both film-forming and stomata closing compounds, able to increase leaf resistance to water vapor loss, thus improving plant water use in assimilating carbon, and, in turn, producing biomass or yield (Tambussi and Bort 2007). Another approach to reducing water loss due to transpiration is by increasing the reflection of sunlight from leaves, through reflecting types of anti-transpirants, thus limiting water loss from evaporative leaf cooling (Gaballah and Moursy 2004). Among anti-transpirant compounds, chitosan has previously proved to be effective in pepper (Bittelli *et al.,* 2001). After drought stress is the most important and most common environmental stress throughout the world, including Iran. Now many compounds are used in order to reduce the damaging effects of stress on plants. The use of biological elicitorin many plants is one of the ways to reduce the harmful effects of abiotic stresses. Biological elicitors include polysaccharides, proteins, glycoproteins or parts of the cell wall of fungi, plants (cellulose and pectin) and micro-organisms (chitin and glucan) is (Esma'ilzadeh Behabadi and Sharifi, 2013). Chitosan is one of the incentives including incentives that stimulate plant defense mechanisms in response to stress (Kowalski *et al*., 2006). It can also greatly affect the reduction of salinity and increased plant growth (Esma'ilzadeh Behabadi and Sharifi, 2013). Chitosan works as a biostimulant that came through the induction of plant defense systems and alters and enhances the production of secondary metabolites in medicinal plants (Cheng *et al*., 2006). Chitosan is a polysaccharide resulting from the deacetylation of chitin, the linear polymer of (1-4)-β-linked N-acetyl-D-glucosamine. It is obtained from the outer shell of crustaceans such as crabs and shrimps (Ruiz-García and Gómez-Plaza, 2013). In plants, the chitosan is largely used to mimic biotic and abiotic stresses (Sharif *et al*., 2018). Chitosan is harmless to crops, animals and humans, and is biodegradable and friendly to the environment (Dzung *et al*., 2011). Chitosan is a cationic polysaccharide, a derivative of chitin obtained from waste materials from seafood processing (Ye and Lou, 2009). They have been introduced as a material to improve grain yield under unfavorable conditions due to their bioactivities to plants such as inducing the plants resistance against a wide range of diseases through antifungal, antibacterial, antivirus activities (Wang *et al*., 2006); stimulating the growth of plants and seed germination (Chandrkrachang, 2002); improving soil fertility and enhancing the mineral nutrient uptake of plant (Dzung, 2005; Dzung, 2007); increasing the content of the chlorophylls, photosynthesis and the chloroplast enlargement, escalating nitrogen fixing nodes of species of leguminous plants and reducing the effects of abiotic stress on plants (Song *et al*., 2006). Chitosan is an anti transpirant compound that has proved to be effective in many crops (Karimi *et al.,* 2012). It was used to protect plants against oxidative stress (Guan *et al.,* 2009) and to stimulate plant growth (Farouk *et al.,* 2011). Chitosan is a natural, low toxic and inexpensive compound that is biodegradable and environmentally friendly with various applications in agriculture. Chitosan is a natural, low toxic and inexpensive compound that is biodegradable and environmentally friendly with various applications in agriculture; it is obtained by the deacetylation of chitin. In agriculture, chitosan has been used in seed, leaf, fruit and vegetable coatings, as fertilizer and in controlled agrochemical release, to increase plant productivity (New *et al.,* 2004), to protect plants against microorganisms (Farouk *et al*., 2011) and against oxidative stress (Guan *et al.,* 2009) and to stimulate plant growth (Farouk *et al.,* 2011). Chitosan and their derivatives are non-toxic, biodegradable, and friendly to the environment and have a great potential for agricultural application and enhancing crop production (Chandrkrachang, 2002; Sharath chandra *et al*., 2004). Also, due to its cationic character, chitosan presents a wide variety of physicochemical and biological properties, including antimicrobial, antioxidant and antihypertensive properties (Aranaz *et al*., 2009). It has proved to be effective in many crops to protect plants against oxidative stress (Teran and Singh, 2002) and to stimulate plant growth (Gornik *et al*., 2008). Some researchers reported that chitosan has been widely used as growth stimulator, germination acceleration, and yield enhancement in many crop species such as orchid (Nge *et al*., 2006), faba bean (El-Sawy *et al*., 2010) and corn (Lizarraga-Paulin *et al*., 2011). Finally, Saharan *et al*. (2015) stated that Cu-chitosan NPs improved growth, seed germination, seedling length, fresh and dry weight of tomato at 0.08, 0.10 and 0.12% levels. Underwater stress, plants can avoid drought harm through several ways such as stomatal closure, leaf rolling, osmotic adjustments, reductions and consequently decreases in the cellular expansion, and alterations of various essential physiological and biochemical processes by use of chitosan (Farouk and Amany, 2012). In this respect, Bittelli *et al*. (2001) reported that occasional or episodic drought events can be counteracted through the use of compounds such as chitosan. Chitosan is a natural polysaccharide derived by *N* deacetylation of chitin, and a major component of the shells of a crustacean such as a crab, shrimp, and crawfish (Orgaz *et al*., 2011). Recently, the use of chitosan has been considered as a non-toxic, biodegradable and compatible with various stresses such as drought stress (Dzung *et al.,* 2011). In the latter studies, a positive effect of chitosan was observed on the growth of roots, shoots and leaves of various plant species Polysaccharide was a more effective way to improve the capacity of drought resistance (Bautista-Banos, 2006). The existing results (Shu, 2007) showed that certain concentration of polysaccharide can enhance the capacity of cold, salt and drought resistance for crops. Chitosan and its derivatives from aquatic products such as waste shrimp, crab shells were mainly inexhaustible marine resources. Moreover, plants treated with chitosan may be less prone to stress evoked by un-favorable conditions, such as drought, salinity and low or high temperature (Jabeen and Ahmad, 2013). Abdel-Meng *et al*. (2008) on strawberry showed that chitosan application improved plant height, number of leaves, fresh and dry weights of the leaves and yield components. Sheikha and AL-Malki (2011) indicate that application of different concentrations of chitosan enhanced bean shoot and root length, fresh and dry weights of shoots, root and leaf area as well as the level of chlorophyll in leaves. The role of chitosan in alleviating the harmful effect of water stress on yield may be due to an increase in stomatal conductance and net photosynthetic CO_2-fixation activity under water stress (Khan *et al.,* 2002), and to its role in reducing transpiration to save water. Abdel-Aziz *et al*. (2018) investigated the effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains and reported nano chitosan-NPK fertilizers could be used to improve the chemical composition of wheat grains (accumulation of carbohydrates). The least concentration (Nano 10) was the best to obtain better wheat grains and the best type of soil was clay-sandy soil. The mechanism by which nano chitosan fertilizer improves wheat grain quality should be further elucidated with special emphasis on human safety of such application. Salehi *et al*. (2017) by evaluate effect of foliar application of chitosan on yield and essential oil of savory under salt stress reported application of chitosan as a biological stimulus can adjust such stress via inducing the herb's defense routes. Moreover, chitosan treatment caused changes in the amount of metabolites of savory and such changes can be affected by chitosan concentration. However, the beneficial effect of chitosan is generally depending on its concentration, application methods, environmental condition and growth status. Although conducted some research about influences of chitosan application on different plants, but low information available about how chitosan foliar application alleviate growth trend and yield of wheat crop under different irrigation regime in semi-arid environments. The purpose of this study was to investigate the ability of chitosan to decrease the deleterious effects of water stress condition on wheat crop grown in Iran.

MATERIALS AND METHODS

Field and Treatment Information

In order to study the effects of chitosan foliar spraying on total chlorophyll, seed yield and its components of wheat under water stress conditions a split plot experiment based on randomized complete block design with three replications was conducted at Agricultural Research Center of Roudhen Islamic Azad University in 2017. The main plots included different irrigation regime at three levels (I_1: Normal irrigation, I_2: water stress at heading stage, I_3: water stress in grain filing period) and chitosan foliar application at tillering and stem elongation stages by three concentrations (C_1:0, C_2: 0.05%, C_3: 0.1% chitosan in acetic acid is 1%) was belonged to sub plots. The Farms located in Roudhen city, Tehran province (Iran) (35º73 Lat. N; 51º9 Long. E, 1690 m above sea level). The soil properties are shown in Table 1.

Table 1. Soil properties of the field site

Depth (cm)	0-30	**Fe (PPM)**	3.7
Silt (%)	50	**K (PPM)**	378
Clay (%)	24	**Mn (PPM)**	6.75
Sand (%)	26	**Zn (PPM)**	55.58
Cu (PPM)	1.13	**pH**	7.2
P (PPM)	20.9	**EC ($ds.m^{-1}$)**	4.5

Farm Management

Agronomic practices including tillage operations, leveling, nitrogen and phosphorus fertilizers, organic manure, and weed and pest managements were done. The wheat cultivar used in this experiment is Sivand was obtained from Seed and Plant Improvement Institute in Karaj. Land preparation began in the second half of October. The necessary fertilizer according to land soil test and recommendations of soil and water department is given to the land. Experimental cultivation in the second half of November was conducted by means of cereal seeder experiment. Each sub plot was consisted of four stacks with a width of 60 cm and on each stacks 20 lines planting and the length of 4.2 m.

Measured Traits

To determine the yield and its components, the two side rows and half a meter of the beginning and end of each plot were eliminated as the marginal effects and finally the ultimate samples were taken from an area of 1 m^2. In order to determine the number of spikes per area unit, the spikes were taken from an area of 1 m^2 of then three middle lines of each plot after considering half a meter of beginning and end of each line as the margin and after counting the spikes their mean was considered as the number of spikes per area unit. As many as 10 spikes were randomly selected from the middle lines of each plot and the number of seeds was counted carefully and their mean was recorded. Two 500-seed samples were randomly selected from the produced seeds by each plot and if the weight difference of the two samples was less than 5%, the total weight of the two samples was considered as weight of 1000-seed. After full maturity of seeds, spikes were taken from three middle lines of each plot in area of 1 m^2 and the seed yield of each plot with moisture of 14% was calculated per area unit and then was recorded. Chlorophyll content was determined by froze and Archioze method (Ferus and Arkosiva, 2001).

Statistical Analysis

Data were analyzed via SAS software (Ver.9). Means were compared by LSD (least significant difference) test at 5% probability level.

RESULTS AND DISCUSSION

Plant height

The ANOVA results showed effects of irrigation regime and chitosan on plant height was significant at 1% probability level but interaction effect of treatment was not significant (Table 2).

The results of mean comparison of different irrigation regime revealed that the highest plant height was related to normal irrigation (110.54 cm) and the lowest one belonged to water stress at heading stage (101.80 cm), normal water consumption increased by 9% to plant height (Table 3). The reason for reducing the plant height is due to decreased cell torsion due to increased stress, decreased growth and cell development, especially in the stem. Water stress leads to increases in abscisic acid levels in roots, which is transported from roots to shoot where it acts in the apical region of the plant as an antagonist of the auxine and cytokinin, responsible for growth and cell division, respectively (Abdalla, 2011) as well as inhibiting DNA synthesis. The results of mean comparison of different concentration of chitosan indicated that the highest plant height was related to 0.1% chitosan (130.93 cm) and the lowest one was related to non chitosan consumption (73.12 cm), so chitosan consumption increased by 43% to plant height (Table 3). Chitosan contains nitrogen in its chemical structure, which is recognized as one of the most important nutrients for plants and soil. When nitrogen is dissolved in chitosan, it gradually penetrates and remains in the soil for longer periods of time and can be effective in this regard. The significant effect of chitosan on plant growth may be attributed to an increase in the key enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and increased photosynthesis which enhanced the plant growth (Gornik *et al.,* 2008).

Table 2. Result of Analysis of variance of measured traits

S.O.V	df	Plant height	Total Chlorophyll	No. of spike per plant	No. of seed per spike	1000-seed weight	Seed yield
Block	2	93.08^{ns}	0.211^{ns}	29.27^{ns}	77.48^{ns}	89.97^{ns}	1060390^{ns}
Irrigation regime (a)	2	203.43**	4.89*	1.24^{ns}	474.03**	957.24**	16244064**
Error I	4	210.65	0.01	1.04	1614	27.41	341824
Chitosan (b)	2	7744.16**	2.48*	51.72**	584.14**	968.69**	14245902**
a*b	4	98.41^{ns}	0.06*	1.19^{ns}	9.14^{ns}	6996.105^{ns}	2737406*
Error II	12	146.19	0.01	3.95	31.09	105.3	173138
CV (%)	-	12.8	15.8	17.3	16.4	21.2	12.4

ns: non-significant, ** and * are significantly at 1% and 5% respectively.

Table 3. Mean comparison effect of irrigation regime and chitosan on measured traits

Treatment	Plant height (cm)	No. of spike per plant	No. of seed per spike	1000 grain weight (g)
Irrigation regime				
I_1	110.54^{*a}	11.43^{a}	37.43^{a}	48.29^{a}
I_2	101.80^{b}	10.88^{ab}	27.43^{ab}	34.06^{b}
I_3	102.94^{ab}	11.56^{a}	23.32^{b}	28.24^{c}
Chitosan				
C_1	73.21^{c}	8.54^{c}	20.54^{c}	25.10^{c}
C_2	111.14^{b}	12.41^{ab}	31.32^{ab}	40.76^{b}
C_3	130.93^{a}	12.92^{a}	36.32^{a}	44.73^{a}

*Values having the same alphabetical letter(s) in each column did not significantly different according to LSD test at 5% probability level.

I_1: Normal irrigation, I_2: water stress at heading stage, I_3: water stress in grain filing period

C_1: 0, C_2: 0.05%, C_3: 0.1% chitosan concentration

Total chlorophyll

The results of analysis of variance showed that the effects of irrigation regime, chitosan and interaction were significant at 5% level (Table 2). The results of the mean comparison interaction effect of treatment showed that the highest total chlorophyll content was related to 0.1% chitosan foliar application and normal irrigation (3.68 $mg.g^{-1}$ fresh leaf weight) and the lowest total chlorophyll content in the absence of chitosan and water stress at seed filling stage (1.06 $mg.g^{-1}$ fresh leaf weight), so the use of chitosan and normal irrigation has increased the total chlorophyll content by 70% (Fig. 1).

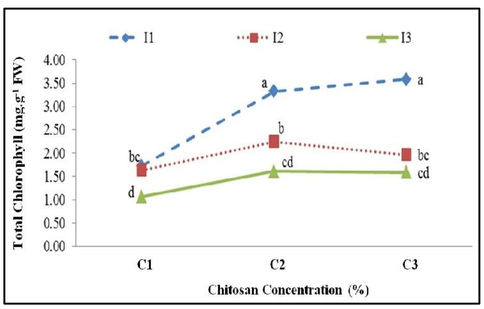

Fig. 1. Interaction effect of irrigation regime and chitosan on total chlorophyll via LSD test at 5% probability level
I_1: Normal irrigation, I_2: water stress at heading stage, I_3: water stress in grain filing period.
C_1: 0, C_2: 0.05%, C_3: 0.1% chitosan concentration.

Drought stress also reduced the uptake of essential elements and photosynthetic capacity (Kandil *et al.,* 2001) as well as increased synthesis of chlorophyll. The decrease in chlorophyll content under drought is a commonly observed phenomenon (Nikolaeva *et al.,* 2010). The decrease in chlorophyll under water stress might be due to reduced synthesis of the main chlorophyll pigment complexes encoded by the cab gene family (Allakhverdiev *et al.,* 2003), or to destruction of the pigment protein complexes which protect the photosynthetic apparatus, or to oxidative damage of chloroplast lipids and proteins (Lai *et al.,* 2007). The effects of chitosan, in increasing chlorophylls and total carbohydrate contents were confirmed in cucumber, radish and cowpea (Farouk *et al.,* 2011). These results are consistent with Khan *et al*. (2002) who reported that application of chitosan increased photosynthesis in leaves of maize and soybean. Chitosan may alleviate the water stress effect on photosynthetic pigments by enhancing endogenous Levels of cytokinins, which stimulate chlorophyll synthesis. Malekpoor *et al.* (2016) by evaluate effect of foliar application of chitosan on morphological and physiological characteristics of basil under reduced irrigation and reported water stress decreased the content of photosynthetic pigments and growth parameters, foliar-applied chitosan, in particular 0.4 $g.L^{-1}$ increased plant growth under stressed or non-stressed conditions compared with untreated plants.

Number of spikes per plant

The results of analysis of variance revealed that the effects of different concentration of chitosan on number of spikes per plant was significant at 1% probability level but effect of irrigation regime and interaction effect of treatments was not significant (Table 2). The results of mean comparison of different concentration of chitosan showed that the highest number of spikes per plant was related to consumption of 0.1% chitosan (12.92) and the lowest number of spikes per plant (8.53) belonged to not consumption chitosan. The use of chitosan caused 33% increase in the number of spikes per plant (Table 3). El-Tantawy (2009) reported that application of chitosan increased photosynthetic pigment thereby the photosynthesis and reproductive growth increased. In this concern, Ghoname *et al*. (2010) observed that foliar application of chitosan on sweet pepper significantly increased the number of fruits per plant and the mean weight of fruit, as well as fruit quality characteristics.

Number of seeds per spike

The results of analysis of variance showed that the effect of irrigation regime and chitosan on the number of seeds per spike were significant at 1% probability level, but interaction effect of treatments was not significant (Table 2). The results of mean comparison of different irrigation regime showed that the highest number of seeds per spike was related to normal irrigation (37.43) and lowest one belonged to water stress in grain filing period (23.32), normal water consumption increased by 37% to the number of seeds per spike (Table 3). Leaf injury and reduction of number of seeds per spike from water deficit stress is correlated with vulnerability to oxidative stress, accompanied by chlorophyll loss changes in the ratio of chlorophyll a:b (Farouk *et al*., 2011). The mean comparisons results of different concentration of chitosan indicated that the highest number of seeds per spike was related to 0.1% chitosan foliar application (36.32) and the lowest one (20.54) was related to control, so the use of chitosan caused 44% increase in the number of seeds per spike (Table 3). The increases in plant biomass may be due to improving photosynthetic machinery so yield components will increase (Khan *et al*., 2002).

1000- Seed weight

The results of analysis of variance showed that the effect of irrigation regime and chitosan consumption on 1000-seed weight was significant at 1% probability level but interaction effect of treatments was not significant (Table 2). The results of mean comparison showed that the highest 1000 seed weight was related to the application of normal irrigation (48.28g) and the lowest one belonged to water stress in grain filing period (28.23g), so the consumption of ordinary water resulted in 41% increase in the weight of one thousand seeds (Table 3). Song *et al*. (1998) showed that water stress induced swollen pollen and filament development, decreased filament fertility and resulted in reductions in seed number and weight per ear. The results of mean comparison of chitosan consumption revealed that the highest 1000 seed weight was related to the consumption of 0.1% chitosan foliar application (44.73 gr) and the lowest one (25.10 gr) belonged to control, so chitosan consumption increased by 43% to 1000 seed weight (Table 3). Recently, some researchers reported that chitosan enhanced plant growth and development (Khan *et al*., 2002; Gornik *et al*., 2008). They reported that application of chitosan increased key enzymes activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and improved the transportation of nitrogen (N) in the functional leaves which enhanced plant growth and development. The increase in cowpea yield due to chitosan application may be due to its effects in stimulating physiological processes, improving vegetative growth, followed by active translocation of photo assimilates from source to sink tissues, increasing leaf-blade thickness as well as the dimensions of the vascular bundles, as indicated in our results.

Seed yield

The results of analysis of variance indicated that the effect of irrigation regime and chitosan on seed yield were significant at 1% probability level, also interaction effect of treatments was significant at 5% probability level (Table 2). The results of mean comparison of interaction effect of treatments showed that the highest seed yield was related to consumption of chitosan 0.1% in normal irrigation (6495 $kg.ha^{-1}$) and the lowest one was observed under water stress in seed filing stage and in the absence of chitosan application (1511 $kg.ha^{-1}$), so the use of chitosan and normal irrigation has increased 76% to seed yield than to control (Fig. 2).

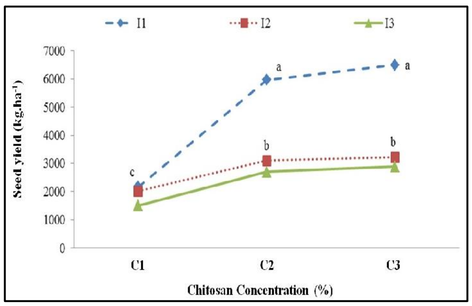

Fig. 2. Interaction effect of irrigation regime and chitosan on seed yield via LSD test at 5% probability level.
I_1: Normal irrigation, I_2: water stress at heading stage, I_3: water stress in grain filing period
C_1: 0, C_2: 0.05%, C_3: 0.1% chitosan concentration

The reduced yield may by due to the negative effect of water stress on the yield components resulting in a reduction in the supply of carbon assimilate and photosynthetic rate by plants and consequently less biomass produced as well as decreased translocation of assimilates towards the developing fruits (Kumar *et al.,* 1994). Chibu and Shibayama (2003) reported that application of chitosan at early growth stages increased plant growth and development, thereby increased seed yield in rice and soybean. Chitosan induce to synthesize plant hormones such as gibberellins. Furthermore, it enhances growth by some signaling pathways related to auxin biosynthesis via a tryptophan independent pathway (El-Bassiony *et al.,* 2014). Also, 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). Behboudi *et al.* (2018) by evaluate of chitosan nanoparticles effects on yield and yield components of barley under late season reported drought stress drought stress affected the biomass, enzyme activity, leaf color, RWC, harvest index, yield and yield components of barley plants; whereas, using chitosan nanoparticles, especially 60 and 90 ppm, decreased the harmful effects of drought stress. Also they suggested that chitosan NPs can be applied to barley plants either through soil or foliar application with different doses in both irrigation regimes to get desired results. Janmohammadi *et al.* (2014) by investigated influences of chitosan solutions on morphological characteristics, growth and yield components of lentil (*Lens culinaris*) under rainfed conditions reported that chitosan application could significantly improve the number of pods per plant, 100-seed weight, grain yield per plant and harvest index in comparison to control plants. They suggest that application of chitosan as agronomic management strategy be further investigated for an efficient technique to induce resistance in lentil plants against biotic and drought stress in semi arid regions, in other hand foliar application of chitosan during reproductive stage could be effective; however, its effect depends on genotypes.

CONCLUSION

All plant growth characters, yield components and seed yield significantly decreased due to water stress in growing seasons. The largest reduction was observed under water stress in seed filing stage. Foliar application of chitosan, improved all plant growth measures compared to untreated control plants. It is concluded that foliar application of chitosan at vegetative stage enhanced the plant growth and development, which resulted from increased fruit yield in wheat. Among concentrations, 0.1 % had superiority for plant growth, yield components and seed yield than others. It can be concluded that wheat plants treated with chitosan induced ability to grow under water stress conditions, perhaps because they can produce various metabolites which cause closure of stomata, resulting in a reduction in transpiration. In other hand chitosan may play an important role in growth and productivity of basil plants grown under water deficit stress conditions, perhaps because they can produce various metabolites, which cause a reduction in transpiration and thus more water becomes available to plants for better growth and production. Overall, it is possible to propose that chitosan could be promising material used to reduce harmful effect of water deficit on growth of basil plants and as a whole, treatment with chitosan partly could alleviate effect of water deficit. In conclusion, it is suggested that chitosan could be used to reduce the harmful effect of water stress on growth of wheat crop. However, more experiments should be conducted in different locations and seasons to draw a valid conclusion regarding chitosan foliar application for fruit yield improvement of wheat.

REFERENCES

Abdalla, M. M. 2011. Beneficial effects of diatomite on growth, biochemical contents and polymorphic DNA in *L. albus* grown under water stress. Agri. Biol. J. North Am. 2: 207-220.

Abdel-Aziz, H. M. M., M. N. Abdel-Ghany Hasaneen. and A. M. Omer. 2018. Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of Wheat grains. Egypt. J. Bot. 58(1): 87-95.

Allakhverdiev, I., H. Hayashi, Y. Nishiyama, A. G. Ivanov, J. A. Aliev, V. V. Klimov, N. Murata. and R. Carpentier. 2003. Glycine betaine protects the D1/D2/Cytb559 complex of photosystem II against photo-induced and heat-induced inactivation. J. Plant Physiol. 160: 41-49.

Aranaz, I., M. Mengibar, R. Harris, I. Panos, B. Miralles. and N. Acosta. 2009. Functional characterization of chitin and chitosan. J. Current Chemical Biol. 3(2): 203-30.

Bautista-Banos, S., A. N. Hemandez-Lauzardo. and M. G. Velazquez-del Valle. 2006. Chitosan as a potential natural. Crop Protection. J. 2: 456-459.

Behboudi, F., Z. Tahmasebi Sarvestani, M. Zaman Kassaee, S. A. M. Modares Sanavi, A. Sorooshzadeh. and S. B. Ahmadi. 2018. Evaluation chitosan nanoparticles effects on yield and yield components of barley (*Hordeum vulgare* L.) under late season drought stress. J. Water Environ. Nanotechnol. 3(1): 22-39. DOI: 10.22090/jwent.2018.01.003.

Bittelli, M., M. Flury, G. S. Campbell. and E. J. Nichols. 2001. Reduction of transpiration foliar application of chitosan. J. Agric. Meteorol. 107(3): 167-75.

Blum, A. 2010. Plant breeding for water-limited environments. Springer Pub. New York. USA.

Cakir, R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops. J. 89: 1-16.

Chandrkrachang, S. 2002. The applications of chitin and chitosan in agriculture in Thailand. J. Adv. Chitin Sci. 5: 458–462.

Cheng, X., U. Zhou. and X. Cui. 2006. Improvement of phenyl ethanoid glycosides biosynthesis in (*Cistanche deserticola*) cell suspension cultures by chitosan elicitor. Biol. J. 121: 253–260.

Chibu, H. and H. Shibayama. 2003. Effects of chitosan application on the growth of several crops. *In*: Chitin and chitosan in life science. T. Uragami, K. Kurita. and T. Fukamizo (Eds.). Yamaguchi. Japan. pp. 235-239.

Dzung, N. A. 2005. Application of chitin, chitosan and their derivatives for agriculture in Vietnam. J. Chitin and Chitosan Sci. 10: 109-113.

Dzung, N. A. 2007. Chitosan and their derivatives as prospective biosubstances for developing sustainable eco-agriculture (Eds. S. Senel, K. M. Varum, M. M. Sumnu, A. A. Hincal). J. Adv. Chitin Sci. X. pp. 453-459.

Dzung, N. A., V. T. Phuong Khanh. and T. T. Dzung. 2011. Research on impact of chitosan oligomers on biophysical characteristics, growth, development and drought resistance of coffee. J. Carbohydrate Polymers. 84: 751–755.

El-Bassiony, A. M., Z. F. Fawzy, M. A. El-Nemr. and L. I. Yunsheng. 2014. Improvement of growth, yield and quality of two varieties of kohlrabi plants as affected by application of some bio stimulants. Middle East J. Agric. Res. 3(3): 491-498.

El-Sawy, N. M., H. A. Abd El-Rehim, A. M. Elbarbary. and E-S. A. Hegazy. 2010. Radiation-induced degradation of chitosan for possible use as a growth promoter in agricultural purposes. J. Carbohydr Polym. 79(3): 555-62.

El-Tantawy, E. M. 2009. Behavior of tomato plants as affected by spraying with chitosan and aminofort as natural stimulator substances under application of soil organic amendments. Pak. J. Biol. Sci. 12: 1164-1173.

Esma'ilzadeh Behabadi, S. and M. Sharifi. 2013. Increase secondary metabolite production plants using biological Alysytvrhay. J. Cells Tissues. 20: 119-128.

Farouk, S. and A. R. Amany. 2012. Improving growth and yield of cowpea by foliar application of chitosan under water stress. Egyptian J. Biol. 14(1): 14-6.

Farouk, S., A. A. Mosa, A. A. Taha, M. Ibrahim Heba. and A. M. El-Gahmery. 2011. Protective effect of humic acid and chitosan on radish (*Raphanus sativus* L. var. sativus) plants subjected to cadmium stress. J. Stress Physiol. Biochem. 7(2): 99-116.

Feruse, P. and M. Arkosiova. 2001. Variability of chlorophyll content under fluctuating environment. Acta fytotechnica et zootechnica. Special Number. Proc. Intl. Sci. Conf. Occasion of the 55th Anniv. Slovak Agric. Univ. Nitra. Slovakia.

Gaballah, M. S. and M. Moursy. 2004. Reflectants application for increasing wheat plant tolerance against salt stress. Pak. J. Biol. Sci. 7: 956-962.

Ghamarnia, H. and J. W. Gowing. 2005. Effect of water stress on three wheat cultivars. ICID 21st European Regional Conf. 15-19 May. Frankfurt (Oder) and Slubica. Germany and Poland.

Ghoname, A. A., M. A. El-Nemr, A. M. R. Abdel-Mawgoud. and W. A. El-Tohamy. 2010. Enhancement of sweet pepper crop growth and production by application of biological, organic and nutritional solutions. Res. J. Agric. Biol. Sci. 6(3): 349-355.

Gornik, K., M. Grzesik. and B. Romanowska-Duda. 2008. The effect of chitosan on rooting of grapevine cuttings and on subsequent plant growth under drought and temperature stress. J. Fruit Ornam Plant Res. 16: 333-343.

Guan, Y., H. Jin, W. Xian-ju. and S. Chen-xia. 2009. Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. J. Zhejiang Univ. Sci. B. 10(6): 427-33.

Jabeen, N. and R .Ahmad. 2013. The activity of antioxidant enzymes in response to salt stress in safflower (*Carthamus tinctorius* L.) and sunflower (*Helianthus annuus* L.) seedlings raised from seed treated with chitosan. J. Sci. Food Agric. 93(7): 1699-1705.

Janmohammadi, M., H. Mostafavi, H. Kazemi, Gh. R. Mahdavinia. and N. Sabaghnia. 2014. Nitra, Slovaca Universitas Agriculturae Nitriae. J. Acta Technologica Agri. 4: 86-90. DOI: 10.2478/ata-2014-0020.

Kandil, S. A., M. S. A .Abo–El–Kheir. and H. A. El–Zeiny. 2001. Response of some wheat cultivars to water stress imposed at certain growth stages. Egyptian J. Appl. Sci. 16: 82–98.

Karimi, S., H. Abbaspour, J. M. Sinaki. and H. Makarian. 2012. Effects of water deficit and chitosan spraying on osmotic adjustment and soluble protein of cultivars castor bean (*Ricinus communis* L.). J. Physiol. Biochem. 8: 160-69.

Khan, M. H., K. L. B .Singha. and S. K. Panda .2002. Changes in antioxidant levels in *Oryza sativa* L. roots subjected to NaCl salinity stress. Acta Physiologia Plantarum. 24: 145-148.

Kowalski, B., F. Jimenez, L. Herrera. and D. Agramontepenalver. 2006. Application of soluble chitosan in vitro and in the greenhouse to increase yield and seed quality of potato mini tubers. J. Potato Res. 49: 167-176.

Kumar, A., D. P. Singh. and P. Singh. 1994. Influence of water stress on photosynthesis, transpiration, water use efficiency and yield of *Brassica juncea* L. J. Field Crops Res. 37: 95-101.

Lai, Q., B. Zhi-Yi, Z. Zhu-Jun, Q. Qiong-Qiu. and M. Bi-Zeng. 2007. Effects of osmotic stress on antioxidant enzymes activities in leaf discs of PSAG12-IPT modified gerbera. J. Zheijang Univ. Sci. 8(7): 458-464.

Liang, Y., Q. Chen, Q. Liu, W. Zhang. and R. Ding. 2003. Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (*Hordeum vulgare* L.). J. Plant Physiol .160: 1157-1164.

Lizarraga-Paulin, E. G., I. Torres-Pacheco, E. Moreno-Martinez. and S. P. Miranda-Castro. 2011. Chitosan application in maize (*Zea mays* L.) to counteract the effects of abiotic stress at seedling level. Af. J. Biotech. 10(34): 6439-6446.

Malekpoor, F., A. Ghasemi Pirbalouti. and A. Salimi. 2016. Effect of foliar application of chitosan on morphological and physiological characteristics of basil under reduced irrigation. J. Res. on Crops. 17(2): 354-359.
Doi: 10.5958/2348-7542.2016.00060.7.

New, N., S. Chandrkrachang. and W. F. Stevens. 2004. Application of chitosan in Myanmar's agriculture sector, *In*: Proceedings of the Sixth Asia Pacific Chitin and Chitosan Symposium, May 23–26. The National Univ. Singapore.

Nge, K. L., N. Nwe, S. Chandrkrachang. and W. F. Stevens. 2006. Chitosan as a growth stimulator in orchid tissue culture. Plant Sci. J. 170(6): 1185-90.

Nikolaeva, M. K., S. N. Maevskaya, A. G. Shugaev. and N. G. Bukhov. 2010. Effect of drought on chlorophyll content and antioxidant enzyme activities in leaves of three wheat cultivars varying in productivity. Russian J. Plant Physiol. 57: 87–95.

Orgaz, B., M. M. Lobete, C. H. Puga. and C. San Jose. 2011. Effectiveness of Chitosan against Mature Biofilms

Formed by Food Related Bacteria. Intl. J. Mol. Sci. 12(1): 11-20.

Ruiz-García. Y. and E. Gómez-Plaza. 2013. Elicitors: A Tool for Improving Fruit Phenolic Content. Agric. 3: 33-52.

Saharan, V., G. Sharma, M. Yadav, M. K. Choudhary, S. S. Sharma. and A. Pal. 2015. Synthesis and in vitro antifungal efficacy of Cu–chitosan nanoparticles against pathogenic fungi of tomato. Intl. J. Biol. Macromol. 75(Supplement C): 346-53.

Salehi, S., Z. Rezayatmand. and A. Ghasemi Pirbalouti. 2017. The effect of foliar application of chitosan on yield and essential oil of savory (*Satureja isophylla* L.) under salt stress. J. Herbal Drugs. 8(2): 101-108. Doi: 10.18869/JHD.2017.101.

Shamsi, K. and S. Kobraee. 2013. Effect of different irrigation regimes on yield and water use efficiency of winter wheat. J. Annals Biol. Res. 4(5): 222-227.

Sharathchandra, R. G., S. N. Raj, N. P. Shetty, K. N. Amruthesh. and H. S. Shetty. 2004. A Chitosan formulation Elexa™ induces downy mildew disease resistance and growth promotion in pearl millet. J. Crop Prot. 23(10): 881-888.

Sharif, R., M. Mujtaba, M. Ur. Rahman, A. Shalmani, H. Ahmad, T. Anwar, D. Tianchan. and X. Wang. 2018. The Multifunctional Role of Chitosan in Horticultural Crops; A Review. Molecules. J. 23(872): 1-20. Doi: 10.3390/molecules23040872.

Sheikha, S. A. and F. M. Al-Malki. 2011. Growth and chlorophyll responses of bean plants to chitosan applications. Europ. J. Sci. Res. 50(1): 124-134.

Shu, Y. J., X. Q. Shi. and Z. X. Zhan. 2007. The effect of chitosan on germination of seeds and seedlings of cucumber cold resistance. Seeds. J. 26: 22-25.

Song, F. B., D. J. Ying, Z. Lie, H. G. Kun. and G. Yi-Qing .1998. Effect of water stress on maize pollen vigor and filament fertility. J. Acta Agronomica Sinica. 24: 368-373.

Song, S. Q., Q. M. SANG. and S. R. Guo. 2006. Physiological synergisms of chitosan on salt resistance of cucumber seedlings. J. Acta Botanica Boreali-Occidentalia Sinica. 26: 435-441.

Tambussi, E. A. and J. Bort. 2007. Water use efficiency in C3 cereals under Mediterranean conditions: a review of physiological aspects. J. Annals Appl. Biol. 150: 307–32.

Teran, H. and S. P. Singh. 2002. Comparison of sources and lines selected for drought resistance in common bean published as Idaho Agric. Exp. Stn. J. Article No. 01722. Univ. Idaho. College Agric. Life Sci. Moscow. ID: 83844. J. Crop Sci. 42(1): 64-70.

Wang, Y., H. G. HE. and Y. Zhou. 2006. Effect of different molecular weight chitosan on several physiological and biochemical characteristics related with plant defence reaction. J. Plant Physiol. 42: 1109-1111.

Xiong, L. M., K. S. Schumaker. and J. K. Zhu. 2002. Cell signaling during cold, drought, and salt stress. The Plant Cell. J. 14: 165-183.

Ye, Y. P. and Y. Q. Lou. 2009. Effect of chitosan with different concentration on drought resistance of sugarcane under drought stress. J. Henan Agric. Sci. 11: 47-50.

Zhang, Y. Y., Y. Li. and T. Gao. 2008. Arabidopsis SDIRI Enhance Drought Tolerance in Crop Plant. J. Biosci. Biotech. Bio-Chem. 72(8): 2251-2254.