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Effect of Selenium spraying on yield and growth indices of Wheat (*Triticum aestivum* L.) under drought stress condition

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ABSTRACT

An experiment was conducted in order to evaluate the effects of Se spraying on yield and growth indices of wheat under drought stress condition, in agriculture and natural resource research center of Tehran province in 2011-12. A split plot layout within randomized complete block design with three replications were used. main plots were three irrigation treatments (normal irrigation, non-irrigation at 50% stem elongation stage and non-irrigation at 50% flowering stage) and sub plots were three levels of Se (Na_2O_3Se) spraying (pure water, 18 and 36 mg/l Se concentration). The greatest grain yield was belonged to normal irrigation with 6425 kg/ha. It decreased to 5375 kg/ha and 3979 kg/ha for light and severe stress by 16.3% and 38% respectively. Light stress has not a significant effect on LAI and CGR, but it was significant at severe stress treatment. All traits except no. of fertile tiller, plant height and HI influenced by selenium spraying. Grain yield was increased by using selenium but was significant for low level of Se spraying. Se spraying at drought stress conditions had desirable effect on RWC, LAI and CGR and increased them.

Key words: Wheat, Drought stress, Se spraying, Growth indices, Yield.

INTRODUCTION

Water deficit stress is one of the most important limiting factors of agricultural products which decreases land use efficiency in semi-arid regions. Increasing population and growing demand for agricultural and livestock products as well as the limitation of water and soil resources severely worsens the problem of water deficit. Drought is a yield-decreasing factor even when its damages are not visible. Therefore, it is crucially important to figure out methods for increasing crops yield (Kafi*et al*., 2000). Water stress is a major environmental problem which affects agricultural land in Iran. Because of water deficit in most arid regions, tolerance of crops to drought has always been of great importance for the plant breeder (Alizadeh, 2004). According to Lessani and Mojtahedi (2006), one of the main aspects of drought tolerance is the ability of plant cells to survive severe water loss without suffering deleterious damages. After its discovery in the early 1800s, selenium (Se) was most notable forits harmful effects to animals. Perceptions changed in the late 1950s when Schwarz and Foltz(1957), reported that Se prevented liver necrosis in vitamin E deficient rats. Its role in human health was established when Se, the last of 40 nutrients proven to be essential, was shown to be a required cofactor for the enzyme glutathione peroxidase, which protects against oxidative cell damage[Gupta, and Gupta, 2000). Dietary deficiencies exist in many countries throughout the world(Reilly, 1998) because low soil Se can give rise to low Se in the food chain (Levander and Beck, 1995). Inverse associations exist between nutritional Se status and cancerrisks(Combs and Gray, 1998), cardiovascular disease (Oldfield, 1991), and immune system functions (Baum, 1997), with low Se resulting in increased disease. The use of Se fertilization of vegetable crops has been used to increase dietary Se levels in humans and other animals (Eurola, 1989). Breeding of plants that are enriched with Se could be an effective way to reduce dietary deficiencies and increase health benefits (Farnham, 1999 ;Grusak and DellaPenna, 1999).Selenium can be absorbed by plants as selenate ($SeO4^{-2}$), selenite ($SeO3^{-2}$), or as organic Se compounds such as selenomethionine (Mikkelsen et al. 1989).Selenium has not been classified as a plant essential element, but its role as a beneficial element in plants able to accumulate large amountsof Se has been considered (Terry and Zayed, 1994). Uptake and accumulation of Se by plants isdetermined by Se form and concentration, the identity and presence ofcompeting ions, and the affinity of a species to absorb and metabolize Se (Zayed et al., 1998).In several countries, there are regions with Se deficiency in the human diet, due to lack of Se available for plants in the soil. One solution to this problem is to use Se dietary supplements (Tinggi, 2003). Until the role and migration of Se in the biosphere is clearly established, it is appropriate to enhance Se content in edible plants by agricultural measures which have less irreversible consequences for the environment, for example foliar application of Se compounds. Even in this case, however, safety measures must be taken, such as protecting agricultural workers applying the spray, and applying foliar fertilization before the edible parts of the plants develop, to exclude the possibility of food pollution. Foliar application of Se has been used to enhance the Se content in potato (Poggi et al., 2000), rice (Chen et al., 2002) and soybean (Yang et al., 2003). Selenium is not evenly distributed in plant tissues. Actively growingtissues usuallycontain the highest amounts of Se (Kabata-Pendias and Pendias 1992). Many plant species accumulate higher amounts of Se in shoot or leaf tissues than root tissues,but there are exceptions in the literature. Selenium is also unevenly distributed within seeds. In barley (Hordeum vulgare L.),Se accumulated in dried grains in the husk and pericarp (0.6 ppm), in the scutellum (0.4 ppm), in the embryo (0.3 ppm), and in the aleurone layer, embryonic leaves, and root initials (0.2 ppm) (Huang and Clausen, 1994).In different studies, a relation between total dry matter of crop plants and applied Selenium level has been reported which indicates the resistance of the crop to water deficit stress. Water deficit severely affects Selenium transport ratio, i.e. the ratio of Selenium content of vegetative organs to that of grain, and Selenium use efficiency (Jackson, 2000). At present, there is no method for increasing atmospheric precipitation during drought periods. Therefore, the best way for counteracting drought is to use suitable cultivation operations and drought-tolerant cultivars (Rahba and Uprety, 1998).

MATERIALS AND METHODS

An experiment was conducted in order to evaluate the effects of Se spraying on yield and growth indices of wheat under drought stress condition, in agriculture and natural resource research center of Tehran province during 2011-12. A split-plot based on randomized complete block design with three replications were used. main plots were three irrigation treatments (normal irrigation (I1), non-irrigation at 50% flowering stage (I2) and non-irrigation at 50% stem elongation stage (I3), and sub plots were three levels of Se (Na_2O_3Se) spraying (pure water (Se0), Se spraying with 18 $g.ha^{-1}$ concentration (Se1), and Se spraying with 36 $g.ha^{-1}$ concentration (Se2).Wheat cultivar evaluated in this test was WS-82-9, a new promising line tolerant to drought. Fertilizer recommendations were based on soil test results (Table 1).The Soil Se concentrations in the area was less than the limit of 0.6 mg Se kg considered deficient for production of crops with an adequate Se level (Gupta and Gupta 2002). 80 kg $ha^{-1}$of triple superphosphate and 50 kg ha^{-1}potassium sulfate and 200 kg ha^{-1}urea was applied. Phosphorus and potassium and half of urea fertilizers were applied at sowing and the remaining was applied during plants rapid growth stage. Each subplot consists of four 6m in length farrow, each 60 cm wide and three lines on each. Between two sub-plots one line gap were implanted. Also two meters distance was placed between main plots to prevent water leakage. Weeds were controlled in the trial using registered herbicides as required for the

weed spectrum present.Grain yield was measured at maturity using a plot combine, by harvesting the center two farrows of each plot with deleting 0.5 m from both sides. To calculate total dry weight, after harvesting, the samples were transferred to laboratory and their total dry matter was weighed after oven-drying for 24 hours. Harvest index was calculated by the following equation:
Harvest Index = (Total Grain Weight / Total Plant Weight) * 100

To measure1000-kernel weight, three 100-kernel replicationswere chosen from each treatment and their averageweight was regarded as 1000-kernel weightafter weighing them with precise electronic scale.To calculate grain number/spike, all grains in 1.5m2 were counted and then divided into harvestedear number (10 spikes).In order to calculate physiological indices during growing season, every 30 days interval, destructive sampling was done for seven times. In each sampling, about 0.25 m2/plot was harvested. During the growth, CGR was calculated with formula 1.

$$\text{Formula 1: } CGR = \frac{W2 - W1}{GA(t2 - t1)}$$

Leaf surface was measured with a portable leaf surface measurement and LAI was calculated by using formula 2.

$$\text{Formula2 :} LAI = \frac{LA1 + LA2}{2} * \frac{1}{GA}$$

Were LA1 and LA2 are surface of each stage (m2) and GA surface of sample area (m2). MS Excel was used for graphics.Relative water content (RWC) was recorded at booting stage of wheat growth period according to Schonfeld *et al.* (1988), where fresh weight from three youngest fully expanded leaves (flag leaves) were determined within 2 hrs after excision. Turgid weight was obtained after soaking the leaves for 16 to 18 hrs in distilled water. After soaking, leaves were quickly and carefully blotted dry with tissue paper prior to determine of turgid weight. Dry weight was obtained after drying the leaves sample for 72 hrs at 70°C. Relative water content was calculated from the following equation:
RWC = [(fresh weight – dry weight) / (turgid weight – dry weight)] × 100

Data analysis of variance was done with SAS 9.1 statistical software and Duncan's Multiple Range Test (DMRT) at 5% probability was used for means comparison.

Table 1. Soil physical and chemical characteristics of the experimental site

Variable		Variable	
Texture	Clay-loam	P (ppm)	10.6
pH	7.6	K (ppm)	350
Ec	3 dSm^{-1}	Fe (ppm)	4.4
OC %	0.72	Zn(pmm)	0.42
N %	0.027	Mn (ppm)	11.5
Se ($mg.kg^{-1}$)	0.37		

RESULTS AND DISCUSSION

Grain number per spike

Both drought stress treatments (S1 and S2), showed the decrease in grain number/Spike compared with normal irrigation treatment (S0), but it was only significant for S2. Considering that before applying water stress, the plants received enough water up to 50% flowering stage and then, they were encountered with drought stress, i.e. when reproductive organs started to form, this stress decreased grain number/ear. Gevrek and Atasoy (2012), reported thatKernel number per spike decreased by 20.8 % as a result of drought effect after post anthesis. The control treatment was 32.2 per spike while 25.5 in the drought treatment. Fisher (2008), also reported that water stress causes a decrease in kernel number per spike in wheat at the flowering stage. Generally, number of grains per spike is one of the most important determinant of the yield which is affected by various factors.Some other studies also showed that drought stress at flowering and grain emergence stage harms the plant more than that at other stages (Deepak and Wattal, 1995). In the current study, no compensation process in grain number/ear under water deficit stress was observed. According to Wright *et al*. (2003), the effect of stress on grain number/spike was quite minor.

Table 2. Analysis of variance of measured traits

SOV	df	Mean Square						
		Grainper Spike	TKW	Biological yield	Grain yield	RWC	LAI	CGR
Rep	2	22.343	76.93	595793.5	120400	1.742	0.005	0.013
S	2	815.39 *	359.59 *	31540261 *	13554844**	2.445 *	0.915 **	3.866 **
E (a)	4	235.99	52.31	224666	81921	2.484	0.004	0.005
Se	2	16.67 *	40.15*	1081795 *	329540 *	31.754 *	0.048 *	0.027 *
S × Se	4	5.36 ns	7.37 ns	35466.7 ns	72714 *	0.563 ns	0.013 *	0.001 *
E (b)	12	20.45	3.24	92922.9	54469	0.982	0.001	0.001
C.V		9.6	13.3	12.4	14.4	11.3	10.7	10.7

ns:non-significant; *and**significant at $p<0.05$ and $p<0.01$ respectively. Rep: replication; S: Stress, Se: Selenium

As shown in Table 2, applying Se with 36 g ha^{-1} concentration (Se2) significantly affected number of grains per spike and produced the highest number of grains (51.0 grain per spike). Increase in number of grains per wheat spike with applying micronutrients is reported by other researches. In a study about effects of drought stress and Selenium application on maize cultivars, Nejata et al. (2009), reported that selenium application with 18 g.ha^{-1} caused a significant effect on number of grain per spike. They stated that number of grain per spike increased from 271 to 287 by 5.9% in Se application treatment.Tahir *et al.* (2009) recorded significant increase in number of grains per spike with the foliar application of boron.

Thousand kernel weight

Thousand kernel weight decreased significantly as a result of drought stress in both flowering and stem elongation stages (Table 1). TKW was 46.7 g in the control whereas 43.4 and 34.8 g in non-irrigation at 50% flowering and 50% stem elongation treatments respectively (table 2). Eskandari and Kasemi (2010) also found negative effect of water stress on thousand kernel weight in wheat. However Se applications had significant effects on thousand grain weight only in high concentration.In current research the plants received enough water until 50% flowering stage and then, at this stage when the reproductive organs started to form, the drought stress was applied, and TKW decreased under stress.According to the results, TKW was 7.1 and 25.5% higher under S1 and S2irrigationtreatments than that irrigationconditions. Plant Selenium spraying increasedthis trait under both stress and normal conditions,so that it increased TKW by 5% and 10.5%under 18 and 36 g.ha^{-1} Se spraying.These results coincide with the findings of Bayoumi *et al.* (2008) who observed that drought caused reductions in 1,000-kernel weight by 16.4%. In this study, the reason for the decrease in TKW under water deficit condition could be related to the occurrence of drought stress at two important growth stages (stem elongation and flowering stage) and the decrease in the absorption of water and minerals and consequently, the decrease in leaf photosynthesis and sap production. It may be due to disturbed nutrient uptake efficiency and photosynthetic translocation within the plant (Farshadfar et al. 2013) that produced shriveled grains due to hastened maturity. This is likely due to the shortage of moistures which forces plant to complete its grain formation in relatively lesser time (Riaz and Chowdhrv, 2003). Under drought conditions the availability of current assimilates for extending seed filling will often be severely reduced. In such circumstances, a variety that can mobilize reserves of carbohydrates in the stem will be able to maintain better seed filling. Water deficit condition brought about the loss of reproductive organs and as a result, increased the susceptibility of grain formation on spike. Nejata et al. (2009) reported that Thousand kernel weights decreased significantly by 5.6% as a result of drought stress in the post anthesis stage. Effect of selenium spraying on TKW of wheat was significant at 95% level (table 1). TKW was increased from 39.9 g in normal irrigation treatment to 41.9 g in Se1 treatment and 44.1 g in Se2 treatment by 5 and 10.5% respectively (table 2).Nejat et al.(2009), in a study about effects of drought stress and Selenium application on yield and yield components of two maize cultivars, reported that 1000-grain weight was about 217 and 288 g with and withoutleaf Selenium spraying, respectively. Undernormal condition, it was 276 g without leaf Seleniumspraying and 291 g with that. It can be said that the difference betweentwo Selenium treatments for 1000-grainweight was not as much as that for grain number/spike. In other words, the increase in 1000-grain weight compensated the decrease in grainnumber/spike. Hence, higher mean 1000-grainweight was what made the Selenium applicationsuperior in grain yield. The difference betweenmaximum and minimum 1000-grain weight inthe studied cultivars was about 15 g. but even this small difference had a considerable effect on final yield.

Table 3. Mean comparison of traits

Treatment	Grain per Spike	TKW (gr)	Biological Yield (Kg ha^{-1})	Grain Yield (Kg ha^{-1})	RWC (%)	LAI	CGR g $m^{-1}d^{-1}$
Irrigation							
S0	56.0 a	46.7 a	14070 a	6425 a	71.0 a	3.75 a	4.45 a
S1	53.2 a	43.4 b	13370 a	5375 b	66.6ab	3.68 a	4.39 a
S2	39.9 b	34.8 c	10530 b	3979 c	61.5 b	3.17 b	3.24 b
Se							
Se0	47.8 a	39.9 b	12280 b	5044 b	66.5 b	3.45 b	3.94 b
Se1	50.3 ab	41.9 ab	12740 ab	5326 a	69.6ab	3.56 a	3.99 b
Se2	51.0 b	44.1 a	12950 a	5409 a	71.9 a	3.59 a	4.05 a
S * Se							
S0Se0	53.9 b	45.7 ab	13680 b	6382a	71.3 a	3.72 ab	4.39 b
S0Se1	56.2 a	47.3 a	14120 ab	6460 a	70.5ab	3.76 ab	4.44 b
S0Se2	57.9 a	47.0 a	14400 a	6435 a	71.1 a	3.78 a	4.52 a
S1Se0	52.4 b	38.7 c	12880 c	5155c	68.1 b	3.63 c	4.24 d
S1Se1	54.6 ab	43.3 bc	13550 b	5439bc	70.3ab	3.70 b	4.29 cd
S1Se2	52.6 b	48.3 a	13690 b	5532 b	70.5 ab	3.72 ab	4.33 c
S2Se0	37.3 d	32.3 e	10280 d	3596e	66.1 c	3.0 e	3.20 f
S2Se1	40.2 c	35.0 de	10550 d	4080d	68.0 b	3.24 d	3.23 f
S2Se2	42.3 c	37.0 d	10770 d	4261d	68.5 b	3.27 d	3.30 e

Means in a column by the same letter are not significantly different at $P < 0.05$.S: Stress, Se: Selenium

Total dryweight

Drought stress showed a significant decrease in total dry weight compared with normal irrigation (table 1). Total dry weight was 14070 kgha^{-1} in the control whereas 13370 and 10530 kgha^{-1} in non-irrigation at 50% flowering and 50% stem elongation treatments respectively (table 2). This was significant for drought stress at stem elongation treatment but was not for drought stress at 50% flowering stage. For I2 water stress treatment, stress was induced after vegetative growth so it had not significant effect on plant growth and decrease of dry matter accumulation. In the other word, vegetative characteristics are determined before flowering stage and after this period these characteristics will not changes due to water deficit stress. Non-irrigation at 50% stem elongation decreased TDM by 25.1% andit can be concluded that total dryweight is strongly affected by water deficit stress during vegetative growth period. These results coincide with the findings of Bayoumi*et al.* (2008) who observed that drought caused reductions in biological yield 32.9%.Significant differences were observed at 95% level in total dry weight among Se application treatments.

Grain yield

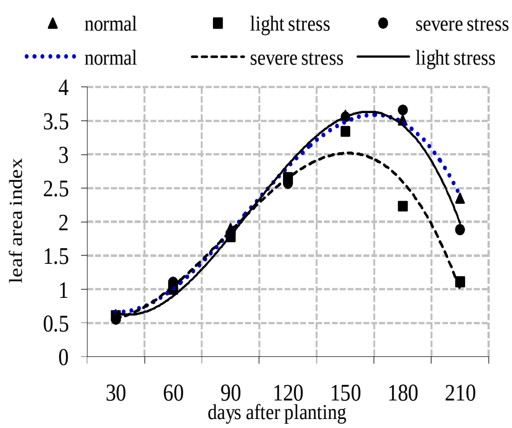
Crop productivity is the rate at which a crop accumulates organic matter which depends primarily on the rate of photosynthesis and conversion of light energy to chemical energy by green plants (Reddy,2004). According to analysis of variance (Table2) significant differences was observed for irrigation treatments ($P<0.01$), various Se spraying treatments ($P<0.05$) and interactions between irrigation and Se spraying ($P<0.05$) on grain yield. The highest grain yield was produced with normal irrigation and 36 g.ha^{-1}Se spraying (S0Se2) with 6435 kg.ha^{-1}, and the least was belonged to non-irrigation at 50% flowering stage and pure water spraying treatment (S2Se0) with 3596 kg.ha^{-1} grain yield.Se application at both stress treatment (S1Se1,S1Se2 and S2Se1,S2Se2) caused a significant decrease in grain yield compared with no Se treatments (S1Se0 and S2Se0) which indicates the importance of Se in compensation of drought damages during plant growth and its role in increasing grain yield. The higher grain yield in Se treated plots was because of more number of grain per spike as well as TKW and LAI. Several reports indicated that either soil or foliar application of micronutrients had positive correlation with wheat yield (Habib, 2009; Wroble, 2009). The yield of wheat is composed of three components i.e. number of spikes, kernels per spike and kernels weight. Though, kernel weight does exert an influence on grain yield but its effect is lower than spikes and kernels per spike. According to the results is showed by nejata et al. (2009), maize grain yield was 27%lower under stress than irrigation conditions and Seleniumspraying increased grain yield by 27.1and 5% under stress and normal conditions, respectively. Under stress, the grain yieldof SC700 was 6.925 t.ha^{-1} without Selenium sprayingand 8.524 t/ha with Selenium spraying. Under normal condition, the grain yield of SC700 was 15.828 t.ha^{-1} without Selenium spraying and 16.894 t.ha^{-1} with Selenium spraying which was the highest.Chandler and Singh (2008), observed that grain yield and biological yield particularly showed maximum sensitivity to moisture stress.It is reported that Leaf spraying with Selenium at flowering stage and shortly afterward significantly increases yield, so that under drought stress, yield and thousand-grain weight increased but grain number/head decreased (Visic, 2006). The experiments shows that under stress condition, Selenium spraying increases the activities of the enzymes superoxide dismutase and catalase as well as lipid level of peroxidase. Other studies showed that plant treatment with Selenium could improve its drought-tolerance, so that it could be due to the increase in activity level of antioxidant enzymes (Timothy, 2001). It was found that the peroxidaseactivity in soil decreased due to the uptakable selenium content. The lowestselenium dose significantly (by 10%) increased the catalase activity (Nowak et al. 2004).

Relative Water Content

Drought stress had a significant effect on RWC (table 1). The analysis of data showed that with the increase in the duration of water stress period there was a progressive decrease in the relative water content of flag leaves. RWC decreased by 6.1 and 13.4% for non-irrigation at 50% flowering and 50% stem elongation stages (table 2). The intensity of theresponse to water stress depends on the stress severityand its duration, as well as the plant developmentalstage. Wheat crop needs water for the entire period ofgrowth, but some stages are more vulnerable to watershortage and moisture stress during this period mayresult in significant yield losses, noteworthy in this regardare the phases of crown root initiation, booting and earlygrain fill period (Iqbal and Bano, 2009). Khakwani *et al*., (2011) in a study about Drought tolerance screening of wheat varieties by inducing water stress conditions, reported that RWC of all varieties was significantly decreased when subjected to stress conditions as compared to control. They stated that leaf area of all varieties decreased significantly in both drought conditions. Leaf area of plants grown under 35% FC deceased 21-42% and decreased 44-64% when these varieties were grown under 25% FC. Deepak and Wattal (1995) indicated that as moisture stress intensified, leaf water potential and content as well as leaf area growth and development were significantly decreased. Kumar and Singh (1996) showed that moisture stress decreased leaf conductivity and this decrease was larger in lower leaves than in upper ones. On the other hand, transpiration rate was similar between two cultivars and decreased as moisture stress intensified, under which a positive correlation was found between transpiration rate and leaf conductivity which eventually affected leaf relative water content.According to results of Bayoumi*et al*. (2008), RWC maybe attributed to differences in the ability of the variationto absorb more water from the soil and/or the ability tocontrol water loss through stomata.Se spraying at drought stress conditions had desirableeffect on RWC and increased it (table 1 and 2). Dhillon (2002), reported that selenium foliar spraying increases antioxidant enzymes and improve plant drought resistance. It was shown that Se hasthe ability to regulate the water status of plants under conditions of drought (Kuznetsov *et al*., 2003) and thatthe protective effect of Se under drought stress conditionswas achieved by increasing the water uptake capacity of the root system (Kuznetsov *et al*., 2003). Eskandari Zanjani et al. (2012) in a study about Effects of Zeolite and Selenium Application on Pumpkin under Drought Stress, reported that in drought stress treatments the highest amount of RWC and thelowest of WSD were obtained in the presence of zeoliteand Se together.

Leaf Area Index

Fig. 1 shows the effects of normal irrigation and drought stress onthe flow of changes for leaf area index (LAI) during wheatgrowthperiod. All three treatments showed similar LAI increment from start of wheat growth until mid-stem elongation phase, but the LAI reduced for S2 treatment from this time to the end of growth period. It was due to reduction of plant water access that caused to reduce access to water dissolved nutrients, thus, plants reduced their leaf area by shrinking the leaves and the leaves became tube shape and finally losing leaves which dramatically declined LAI. This followed by increase in downward slope of LAI regression curve. Rajala *et al*.(2009), reported that drought reduces photosynthesis, plant water content and leaf area development.



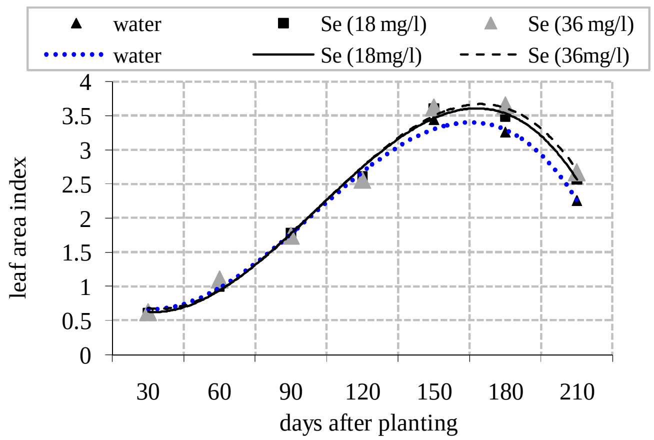
Figur 1. LAI at different levels of drought stress

The maximum LAI for S0 and S1 irrigation treatments was greater than S2 treatment and it occurred much later. For S1 treatment (non-irrigation at 50% of flowering stage), regression curve of LAI was similar trend to normal irrigation treatment until 50% flowering stage, but from this time, LAI regression curve dropped due to shrinking and early defoliation of leaves. Regression equations of LAI curves for different levels of irrigation has showed at table 3. R^2 coefficients were 0.992, 0.997 and 0.955 for S0, S1 and S2 irrigation treatments, respectively and showed a desirable precision for this assessment. The main and significant difference between irrigation treatments was duration and survivance of leaf area. Leaf area and the vertical leaf area profile influence the interception and utilization of solar radiation of crop canopies and consequently, dry matter accumulation and grain yield.

Table 4. Regression equations and R2coefficients of LAI curve for irrigation treatments

treatment	regression equation	*R2*
Normal	$y = -0.065x^3 + 0.645x^2 - 1.127x + 1.207$	*0.992*
Light stress	$y = -0.082x^3 + 0.816x^2 - 1.622x + 1.532$	*0.977*
Severe stress	$y = -0.063x^3 + 0.553x^2 - 0.741x + 0.818$	*0.955*

The effect of selenium application on the trend of changes for LAI regression curves during wheat growth period has showed in Fig. 2. The trend was different for Se application treatments compared with test from stem elongation stage until the end of wheat growth period.



Figur 2. LAI at different levels of Se spraying

An important factor of this difference was effect of selenium on duration and growth rate of wheat leaves. The maximum LAI for both two Se1 and Se2 treatment was greater than test (Se0). Availability of sufficient nutrients resulted in higher leaf area, which in turn boosted the photosynthetic activity and ultimately higher dry matter accumulation. There was no significant difference between Se1 and Se2 treatment for LAI. Our data indicated that Se foliar application increased physiological growth indices and highest TKW, Total dry weight, grain yield and LAI were achieved by Se spraying with 36 g ha^{-1} concentration. There was not a significant difference between Se2 and Se1 treatments.Regression equations of LAI curves for different levels of selenium application has showed at table 5. R^2 coefficients were 0.982, 0.994 and 0.990 for S0, S1 and S2 irrigation treatments, respectively and showed a desirable precision for this assessment.

Table 5. Regression equations and R2 coefficients of LAI curve for irrigation treatments

treatment	regression equation	R2
Pure water	$y = -0.062x^3 + 0.618x^2 - 1.108x + 1.219$	*0.982*
Se spraying (18 $mg.l^{-1}$)	$y = -0.065x^3 + 0.653x^2 - 1.194x + 1.234$	*0.994*
Se spraying (36 $mg.l^{-1}$)	$y = -0.066x^3 + 0.675x^2 - 1.301x + 1.374$	*0.990*

Crop Growth Rate

The aim of growth indices studies is evaluation of plant response to different factors during growth period. This indices use to estimate the plant growth and development based on time. Crop growth rate (CGR) shows plant photosynthesis efficiency and state by dry matter accumulation over a period of time. As Fig. 3 shows, the trend of CGR changes for three irrigation treatments was similar until 50% stem elongation stages but hereafter, slope of CGR curve for severe stress (S2) treatment dropped due to start of shrinking and early defoliation of leaves and thereafter decrease CGR. The maximum CGR for this treatment, was also less than two normal (S0) and light stress (S1) treatments because of low accumulation period. So, Minimum growth period length and grain yield was obtained from this treatment.

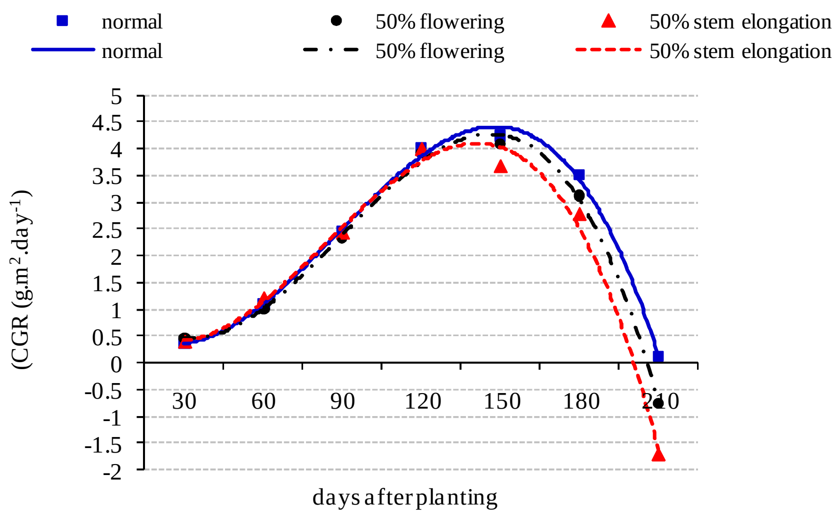


Fig 3. Crop growth rate for different irrigation levels

Maximum CGR for normal irrigation (S0) treatment was 4.25 $g.m^{-2}.day^{-1}$ at fully flowering stage (almost simultaneously with maximum LAI) while, in S1 treatment, it reduced to 4.1 $g.m^{-2}.day^{-1}$. The higher water availability, during flowering and grain filling stages, determined differences in the biomass accumulation trends for normal irrigation. The CGR higher values, the slower and gradual reduction of the growth rates, after the achievement of the maximum speed of accumulation, also explain the higher values of yield for S0 treatment. R^2 coefficients were 0.997, 0.997 and 0.988 for normal, light stress and severe stress, respectively.

Table 5. Regression equations and R2 coefficients of LAI curve for irrigation treatments

treatment	regression equation	R2
Normal	$y = -0.1233x^3 + 1.0786x^2 - 1.6367x + 1.0429$	*0.997*
Light stress	$y = -0.1419x^3 + 1.2699x^2 - 2.2696x + 1.6043$	*0.997*
Severe stress	$y = -0.1364x^3 + 1.1514x^2 - 1.7786x + 1.1871$	*0.988*

Various factors including temperature, solar radiation, age of cultivar and water/nutrient supply affect the CGR. In numerous studies, Crop Growth Rate (CGR) reduction has been reported as the result of water stress. Water deficit stress through the reduction in the LAI and plants photosynthetic capacity reduces CGR and eventually Total Dry Matter (Moradpour et al. 2014). Fig. 4 shows the CGR variation in different Se application treatments. Changes in CGR regression curves for all three treatments was similar. Maximum CGR obtain almost synchronous with maximum leaf surface. The positive effects of selenium application on duration and survivance of leaves and reduction of drought stress damages caused to plant performance and CGR improvement specially for Se application with 36mg/l. more rapid leaf area development and greater plant height due to Se application increased upward slope of CGR.

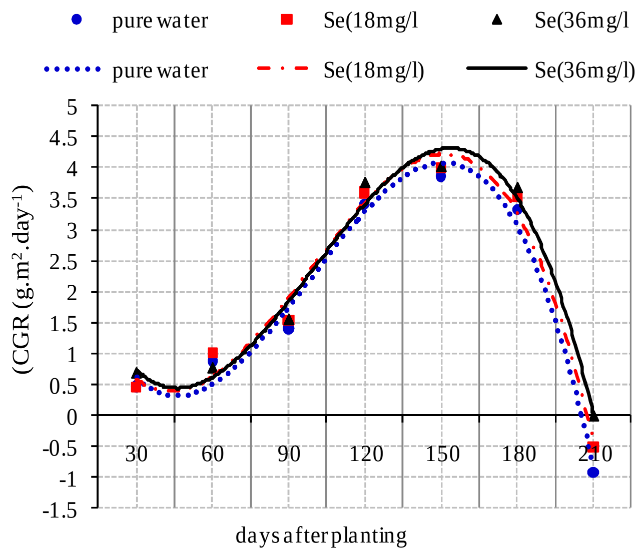


Fig 4. Crop growth rate for Se application levels

CONCLUSIONS

This study was conducted to introduce Se as an essential microelement for increasing grain yield and physiological growth indices. It was also designed to determine whether Se increases wheat drought tolerance. Grain yield is greatly affected by stress at 50% stem elongation stage and also flowering stage. Grain number/spike and TKW were the most effective traits on yield under optimum irrigation as well as water stress conditions. Our results demonstrates that Se foliar sprayingon wheat could not only increased physiological growth indices which is the most important parameter in wheat,but also under water deficit in stem elongation and flowering stages.

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