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Effect of Deficit Irrigation and Nano Fertilizers on Yield and some Morphological Traits of Cotton

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ABSTRACT: In order to study the response of cotton to nano fertilizers, under low irrigation condition, a split plot randomized complete block design with three replications was used at the Agricultural Research Center of Birjand branch, Islamic Azad University, Birjand, Iran in 2014. Irrigation treatments(including 50% and 100% of crop water requirement) and fertilizer treatments (including control, ZnO, SiO_2, ZnO + SiO_2, nano ZnO, nano SiO_2 and nano ZnO + nano SiO_2) were as main plots and sub plots, respectively. Results revealed that low irrigation regime led to reduction of yield, yield components and morphological traits. Seed cotton (lint + seed) and lint yield at 50% of crop water requirement decreased 29.7 and 26.5% that control treatment, respectively. Fertilizer treatment had no effect on any measured traits but ZnO led to 12.5% increase in cotton lint yield that control. According to the results of the study, it is better to irrigate cotton based on 100% of crop water requirement if water is available, and in limited water condition it would be better to irrigate on 50% of crop water requirement along with ZnO application to alleviate the negative effects of drought stress.

Keywords: water stress, ZnO, SiO_2, boll, lint yield

INTRODUCTION

After soya, cottonseed is considered as the second oilseed in terms of oil production rate (Naseri, 1994). This product is called White Gold due to its high commercial and economic value, and, with public awareness increase, the need for cotton textiles is rising. Given that cotton comprises the feedstock of textile industries and these industries create jobs, the significance of cotton is clear in current conditions of the country. Numerous factors play a role in acquiring optimum yield of the cotton plant among them water and nutrient elements needed by plants, have profound impact on yield and yield components of cotton. Therefore, irrigation management and nutrient elements are two very substantial and crucial issues in optimal production of cotton (Li *et al.,* 2002). The extensive researches have indicated that if cotton is irrigated with abundant water, it will grow as a large shrub and signs of delay in reproductive growth will appear in it; nevertheless, under mild and prolonged moisture stress, it has less vegetative growth period and enters flowering and boll stage faster (Kanber *et al.,* 1990).

Although cotton is known as an adaptable plant, the different amounts of irrigation water have a significant effect on cotton yield (Onder *et al.,* 2009). Some researchers believe that despite the rise in falling boll caused by increasing irrigation, a linear relationship is simultaneously seen between lint yield and the number of produced boll on the one and hand, and irrigation on the other hand (Ernest *et al.,* 2006). Geerts and Raes (2009) indicated that deficit irrigation in various products leads to enhancing the water use efficiency without having to drastically reduce yield. Since drought tolerance in plants varies with cultivar and phenological stages, deficit irrigation needs careful study of plant responses to drought stress. Water stress reduces quickly plant growth, height and cotton leaf area and results in the reduction of lint yield. Sever water stress in the early growth period to mid flowering period causes slower growth, plant shrinkage, less nodes and prolific branches and less leaf area index (Burke and Omahony, 2001). In the experiment, Akbari Nodehi (2011) investigated the effect of different levels of zero, 25, 50, 75, 100 and 125 percent of water requirement on the production of cotton; the results indicated that zero and 75 percent treatments of water requirement had the lowest and the highest yield per unit area with 1679 and 3099 kilograms per hectare, respectively. Fathi *et al.* (2011) examined irrigation water amounts 0, 33, 66, 100 and 133 percent of plant water requirements in cotton; the results revealed that cotton yield was under the effect of different irrigation water treatments and the highest cotton yield was related to 66 percent treatment of irrigation water with 1996/6 kg of cotton per hectare. Different levels of irrigation also had significant effect on all components of yield except the number of seeds per boll.

Zinc deficiency in soils, especially in arid and semi-arid regions, is considered as a limiting factor (Takkar and Walker, 1992).

Although plant need for the zinc element is small, if sufficient amounts of this element are not available, plants will suffer from physiological stresses caused by the inefficiencies of multiple enzyme systems and other fertility related metabolic acts (Baybordi, 2006). Banks (2006) stated that zinc foliar application in soya led to the enhancement of seed yield, the amount of protein and the amount of seed oil but this increase was not significant. Cakmak (2009) believes that zinc foliar application, especially in drought stress conditions, creates a special role in plant protection against stress. The enhancement of plant growing ability due to zinc efficacy in the plant leads to the expansion of tillering and the conversion of tiller to spike and reduces the number of infertile tillers and spikes in wheat (Lotfollahi *et al.,* 2007). Silica is also known as an unnecessary element in most plants yet the absorption of this element by the plant is accompanied by several beneficial effects such as increased resistance to pests and diseases (Hossain *et al.,* 2007), tolerance to abiotic stresses (Liang, 1999), and improvement of the product performance and quality (Kamenidou *et al.,* 2010). Ma and Yamaji (2006) stated that by sedimenting in the cuticle layer and its wax, silicon induces the reduction of transpiration in the leaf area under drought stress conditions. In Liang *et al.* (2005), it was stated that silicon consumption has led to the expansion of corn plant yield.

Supplying of chemical fertilizers in the form of nanoparticles has recently received considerable attention. The results of available studies indicate different response of various species of plants to materials in the shape of nano (Zhu *et al.,* 2008). Because of the use of nano fertilizers, the time and speed for the release of elements coincide and match plant nutritional requirements, thus the plant can absorb maximum amount of nutritional elements and, as a consequence, while reducing leaching of elements, the product yield increases as well (Tavan *et al.,* 2014).

Therefore, due to the significance of zinc and silica elements in crop growth and production and their positive role in creating drought resistance, the objective of this experiment is to assess the impact of the use of normal zinc oxide and silica elements and their nano form in deficit irrigation conditions in the cotton plant.

MATERIALS AND METHODS

A split plot randomized complete block design with three replications was used at the Agricultural Research Center of Birjand branch, Islamic Azad University, Birjand, Iran in 2014. The irrigation treatment was considered in two levels (50 and 100 percent plant water requirement) as the main plot and the zinc oxide (Zn) fertilizers, silicon oxide (Si), zinc oxide + silicon oxide (Si + Zn), with the rate of 6000 ppm and nano zinc oxide (Nz), nano silicon oxide (Ns), Ns + Nz at a rate of 500 ppm and the control treatment (C) as the sub plot.

Water requirement was determined with FAO method.

ET_{ref} (mm) = Evaporation from the pan (millimeter) × pan coefficient (0.7)

$ET_{crop} = ET_{ref} \times K_c$ (crop coefficient)

After selecting the land, tillage and land leveling was performed. Each plot includes 4 three meter cultivation line. Sowing was done on both sides of 50 cm ridges and at a distance of 30 cm row. The date of sowing was May 31. Before planting, cotton seeds were, first, disinfected with Benomyl fungicide. From the time of planting seeds, in order to germinate uniformly, irrigation was similar in all the treatments. After the crop establishment, a pressurized system with hose and contour was used for irrigating the plots. Weed control was done during the growing season by weeding twice during the growing season. No pest or disease was observed in the growth season. Foliar application treatment was employed in two stages (August 1, 2014 and September 1, 2014). The first harvest of bolls was done on 10/22/14, and the second and final harvest on 11/21/14 when the shoot had been completely dried. Considering the border effect, sixteen plants were harvested, randomly from each plot. Plant height, length the first reproductive branches, number of lateral branches, number of bolls per unit area, number of bolls per plant, number of seeds per unit area, seed weight, lint weight, hundred grain weight, and seed yield were determined.

The software used for statistical analysis of this study are SAS and MSTATC statistical software. The means were compared using Duncan's multi-domain test at 5% probability level.

RESULTS AND DISCUSSION

A. Morphological traits

The effect of irrigation on traits of plant height and the number of lateral branches and length of the first reproductive branch was significant, yet the impact of fertilizer was not significant in any (Table 2). The results of means comparison indicated that, in 100% water requirement treatment, the plant height (56.7 cm), length of the first reproductive branch (18.1 cm) and number of lateral branches (10 branches per bush) were more and compared with that, in 50% water requirement treatment, the amounts of these traits revealed 28.2, 39.8 and 18 percent reduction, respectively (Table 3). The growth phenomenon is the consequence of vital activities in conditions where the plant has sufficient water; in the absence of the required water supply, height reduction will occur, due to the reduction of turgor pressure of growing cells and acting on length of cells (Ahmadi and Beaker, 2000). Burke and Omahony (2001) also demonstrated that exacerbating water shortages in the cotton growing season results in slow growth, lower nodes number and plant shrinkage.

Table 1: Properties of the soil in the experiment location.

Parameters	Values	Parameters	Values
pH	8.07	OC (%)	0.13
EC (ms/cm)	2.97	Sand (%)	40
SP (%)	39.2	Silt (%)	50
SAR	6.61	Clay (%)	10
Ca (meq/lit)	7.5	Texture	clay
Mg (meq/lit)	5.4	N (total) (%)	0.019
Na (meq/lit)	16.3	P (ava)ppm	3.17
K (meq/lit)	0.3	K (ava)ppm	185
Cl (meq/lit)	17.1	Fe (mg.kg^{-1})	2.23
SO_4^{-2} (meq/lit)	3.5	Cu (mg.kg^{-1})	0.44
CO_3(meq/lit)	0	Zn (mg.kg^{-1})	0.51
HCO_3(meq/lit)	8.5	Mn (mg.kg^{-1})	4.89
$CaCo_3$ (%)	16.2	B (mg.kg^{-1})	0.22
GYP (%)	10.9	TDS	19.1

Table 2: The result of analysis of variance for the effect of irrigation and fertilizer on some traits of cotton.

Source of variation	Df	Mean-square									
		Boll number per m^{-2}	**Boll numb er per**	**Seed number per m^{-2}**	**100-Seed weight**	**Lint yield**	**Lint percent age**	**Seed Yield**	**Plant height**	**Length of the first sympodial**	**Number of monopo**
Replication	2	56.95	0.277	133300.0	0.078	3739.1	13.91	1254.9	93.10	16.989	14.16
Factor A (irrigation)	1	14065.38*	55.08*	14143651.9*	0.191 ^{ns}	34040.4*	50.38 ^{ns}	133081.9*	2702.09*	529.944**	33.46*
Error a	2	734.97	2.92	530469.8	0.406	380.8	13.51	4993.6	29.93	1.481	0.95
Factor B (fertilizer)	6	322.99 ^{ns}	1.27 ^{ns}	435495.6 ^{ns}	0.222 ^{ns}	1485.6 ^{ns}	18.42 ^{ns}	4096.3 ^{ns}	19.78 ^{ns}	3.872 ^{ns}	0.53 ^{ns}
(Irrigation × fertilizer)	6	227.85 ^{ns}	0.91 ^{ns}	285202.9 ^{ns}	0.208 ^{ns}	2517.4 ^{ns}	15.71 ^{ns}	2683.1 ^{ns}	13.18 ^{ns}	4.487 ^{ns}	0.34 ^{ns}
Error b	24	231.35	0.89	238862.7	0.206	2203.5	23.29	2247.8	9.19	5.466	0.46
CV (%)	-	15.39	15.31	15.84	4.66	25.21	12.59	15.84	6.23	16.26	7.44

ns,* and ** are non-significant, and significant at the 0.05 and 0.01 level of probability, respectively.

B. Yield and Yield Components

The effect of irrigation on the number of bolls per unit area, boll number per plant, seed number per m^{-2}, lint weight and the seed yield per unit area was significant, but the impact of fertilizer treatment and the interaction between these two treatments did not become significant on any of the yield traits or yield components (Table 2).

The results indicated that, in 100% plant water requirement supply treatment, the number of produced bolls (117.1 bolls per square meter) was more than in 50% water requirement supply treatment (80.5 bolls per square meter), indicative of 30.2 percent reduction in the number of bolls per square meter in stress conditions (Table 3). Furthermore, the number of bolls per plant in 100% water requirement treatment (7.3) was more compared with 50% water requirement treatment (Table 3). The formation and growth of bolls is dependent on the continued availability of assimilates. Any stress which reduces the availability of assimilates causes the reduction of the number of bolls by increasing their abortions. In severe water stress conditions, loss of flowers and bolls results in the reduction of the number of bolls (Fathi and Navabi, 2008). In 100% water requirement treatment, the number of seeds per m^{-2} (3665 seeds) was 36.6 percent more than 50% plant water requirement treatment (Table 3). Lack of supply of photosynthetic materials, required for the growth of embryo and the seed development, is one of the main reasons for the reduction of seed number in drought stress conditions. By reducing the leaf areas and their loss, the incidence of drought stress leads to the reduction of plant photosynthetic source and loss of enzyme activity effective on this process. Vilalobos *et al.* (1996) also indicated that the number of seeds is relative to the environment conditions occurred during the time prior to pollination and a little after that.

Table 3: Mean comparison for the effect of irrigation and fertilizer on some traits of cotton.

Treatment	Boll number per m^{-2}	Boll number per plant	Seed number per m^{-2}	100-Seed weight (g)	Lint yield ($g.m^{-2}$)	Lint percentage	Seed yield ($g.m^{-2}$)	Plant height (cm)	Length of the first sympodial Branch (cm)	Number of monopodial branch
Irrigation										
100% water requirement	117.1 a	7.3 a	3665.0 a	9.8 a	214.7 a	37.2 a	355.5 a	56.7 a	18.1 a	10.0 a
50% water requirement	80.5 b	5.0 b	2504.4 b	9.7 a	157.7 b	39.4 a	242.9 b	40.7 b	10.9 b	8.2 b
Fertilizers										
Control	102.8 a	6.4 a	3223.3 ab	9.9 a	180.6 a	36.7 a	312.7 ab	47.2 ab	14.6 a	9.1 a
ZnO	104.1 a	6.5 a	3359.2 a	9.6 a	206.4 a	38.8 a	325.8 a	50.3 a	15.3 a	9.3 a
SiO	97.8 a	6.1 a	3010.7 ab	9.5 a	182.0 a	38.4 a	292.0 ab	50.0 a	14.8 a	9.0 a
nano ZnO	105.3 a	6.6 a	3214.5 ab	10.0 a	184.9 a	37.7 a	311.8 ab	50.3 a	15.6 a	9.3 a
nano SiO_2	88.7 a	5.5 a	2693.1 b	9.8 a	159.4 a	37.8 a	261.2 b	48.7 ab	13.6 a	8.9 a
ZnO+SiO_2	104.5 a	6.5 a	3330.9 ab	9.6 a	186.2 a	37.1 a	323.1 ab	49.0 ab	14.2 a	9.3 a
nano ZnO + nano SiO_2	88.7 a	5.5 a	267.8 ab	9.6 a	203.8 a	42.0 a	267.8 ab	45.4b	13.4a	8.5a

Table 4: Mean comparison for the interaction of irrigation and fertilizer on some traits of cotton.

Treatment		Boll number (m^2)	Boll number/plant	Seed number (m^2)	100-Seed weight(g)	Lint weight (g/m^2)	Lint percentage (%)	Seed Yield (g/m^2)	Plant height (cm)	The first Sympodial Length (cm)	Monopodial Number
Irrigation	Fertilizers										
Optimum irrigation (100% water requirement)	Control	126.1ab	7.9ab	3944.0a	10.2a	217.0ab	36.0a	382.6a	54.9ab	19.1a	10.2ab
	ZnO	119.5ab	7.5ab	3901.6a	9.7a	228.3ab	37.3a	378.5a	57.9ab	18.6a	10.2ab
	SiO	112.0abc	7.0abc	3521.8ab	9.7a	213.4ab	38.5a	341.6ab	57.5abc	17.6a	9.7abcd
	nano ZnO	133.6a	8.3a	4147.0a	10.2a	229.0ab	36.4a	402.3a	60.7a	20.1a	10.7a
	nano SiO	98.3bcde	6.1bcde	2912.2bcd	10.0a	151.5b	34.4a	282.5bcd	58.2bcde	16.3a	9.8abc
	ZnO + SiO	124.1ab	7.8ab	3946.1a	9.3a	204.3ab	34.6a	382.8a	56.3ab	16.9a	10.1ab
	nano ZnO + nano SiO	106.4abcd	6.6abcd	3282.4abc	9.6a	259.3a	43.5a	318.4abc	51.5abcd	17.7a	9.2bcde
Drought stress (50% water requirement)	control	79.5de	5.0de	2502.7cd	9.7a	144.3b	37.4a	242.8cd	39.6de	10.1b	8.0e
	ZnO	88.7cde	5.5cde	2816.9bcd	9.6a	184.5ab	40.3a	273.2bcd	42.6cde	12.0b	8.5de
	SiO	83.6cde	5.2cde	2499.6cd	9.3a	150.7b	38.3a	242.5cd	42.5cde	12.1b	8.2e
	nano ZnO	77.1de	4.8de	2282.0d	9.9a	140.8b	38.9a	221.4d	39.8de	11.0b	8.0e
	nano SiO	79.1de	4.9de	2474.1cd	9.7a	167.3b	41.1a	240.0cd	39.1de	10.9b	8.1e
	ZnO + SiO	84.8cde	5.3cde	2715.6bcd	9.9a	168.2b	39.6a	263.4bcd	41.6cde	11.4b	8.6cde
	nano ZnO + nano SiO	71.1e	4.4e	2240.0d	9.7a	148.4b	40.4a	217.3d	39.4e	9.2b	7.9e

Means, each column, followed by similar letter(s) are not significantly different at the 5% probability level - using Duncan's Multiple Range Test

The effect of nano fertilizers treatment was not significant on any of the yield traits and yield components (Table 3). Incanola, plant nutrition with zinc resulted in enhance the storage of carbohydrates in the pollen grain, the enhancement of pollen grain longevity and the number of pollen grain (Sharma *et al.*, 1990). On the other hand, zinc element participates in protein synthesis of the pollen tube during pollination, which leads to increase the seed number (Marschner, 1995). Seed weight and cotton lint, in 50% water requirement treatment, displayed reductions of 29.7 and 26.5 percent, respectively, compared with the desirable irrigation treatment (Table 3). Ritchie *et al.* (2004) reported that by reducing the amount of moisture in soil and enhancing drought stress in plant, the amount of cotton lint decreases.

Moreover, by evaluating different factors on qualitative traits of cotton lint, Johnson *et al*. (2002) reported that excessive irrigation also causes the reduction of the lint yield. Regarding seed cotton weight, it was also observed that zinc oxide caused the 5.7 percent expansion of seed cotton compared with the control. In this trait as well, nano silica resulted in the reduction of 14.7 percent seed cotton compared with the control treatment (Table 3). Zinc oxide (with the mean 206.4 grams per square meter) also caused the 12.5 percent increase of cotton lint yield compared with the control (with the mean 180.6 grams per square meter); this expansion was definitely not significant statistically. In this trait as well, silica nano fertilizer led to the approximately 11.7 percent reduction of seed cotton compared with the control (Table 3). Numerous reports have been proposed regarding positive effects of zinc on yield and yield components of different plants (Thalooth *et al.,* 2006; Bukvic *et al.,* 2003). Furthermore, there are reports concerning the increase of the yield of various plants due to the consumption of nano fertilizers (Feizi *et al.,* 2010).

Under water stress conditions, seed yield per square meter decreased considerably. The results indicated that seed yield in 100 percent water requirement treatment (with the mean 355.5 grams per square meter) contained 31.7 percent increase compared with 50 percent water requirement treatment (with the mean 242.9 grams per square meter) (Table 3). Radin *et al.,* (1992), Chu *et al.,* (1995) and Dagdelen *et al.,* (2006) have obtained similar results on cotton as well. By reducing green leaf area duration in the final stages of development, drought stress can induces a sever reduction in production of assimilates by photosynthetic organs (Emam, 2004). Seed yield was not affected significantly by nano fertilizers (Table 2).

The result of analysis of variance indicated that the traits of 100 seed weight and lint percentage (lint to seed cotton yield ratio × 100) were not affected by irrigation treatment (Table 2). Lint percentage represents the share of produced lint in total economic product of the plant (seed cotton). It seems that lint and seed cotton have had similar response to water shortage and, as a consequence, lint percentage was not significantly affected by irrigation treatment. Qorbani Nasrabadand Hezar Jaribi (2006) also found that, in cotton with increasing drought stress lint percentage was enhanced.

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