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Influence of sowing dates and zinc levels on yield and yield components of wheat (*Triticum aestivum*)

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In South-West of Iran, terminal heat stress, occurring during anthesis and grain filling period, is an important environmental stress that limits spring bread wheat grain yield up to 40% in 10% of the total cultivated area (Jalal Kamali and Duveiller 2008). In Khuzestan Province, late sowing is responsible for a significant wheat yield loss compared with cooler regions, as temperature often exceed 30°C during the grain filling period. Terminal heat stress, often occurring during the last phases of spring wheat development, (booting, heading, anthesis and grain filling period) is considered as one of the major environmental limiting factors that drastically reduces grain number per spike, grain weight and final grain yield of wheat (Reynolds *et al.* 2001 and Rane *et al.* 2007).

The inadequacy of zinc in soils and plants may disturb the essential photosynthetic activity, carbon assimilation and several growth parameters. Also, it makes the plants susceptible to several kinds of stresses such as drought, heat, chilling, high light intensity etc. (Cakmak *et al.* 1999). Ma *et al.* (2017) found that zinc application in the field increased grain yield under both adequate water supply and rain-fed conditions and zinc plays a role in alleviating wheat plant under drought stress by zinc-mediated increase in photosynthesis pigment and active oxygen scavenging substances, and reduction in lipid peroxidation. Graham and McDonald (2001) reported that elevated temperatures cause deleterious changes in a number of physiological processes, including disruption of membranes, while zinc deficiency also reduces membrane integrity. Peck and McDonald (2010) showed that low levels of Zn nutrition can exacerbate the adverse effects of short periods of heat stress on kernel growth and chloroplast function of wheat. This research was designed to evaluate the effect of zinc levels on grain yield and yield components of wheat under terminal heat stress of Ahwaz climatic conditions.

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The experiment was conducted in the research field of Agricultural Sciences and Natural Resources University of Khuzestan (31º N, 48º Eand 34 m above sea level) situated in South-West of Iran during 2015-2016 growing season. Experimental factors were included three sowing dates (29 Nov (timely), 14 Dec (late) and 30 Dec (very late)) as main plots and five zinc levels (0 (control), 10, 20, 30 and 40 kg/ha) in sub plots in split plot design with three replicates. Zinc was soil applied as $ZnSO_4$ at tillering stage in wheat cultivar Chamran. The soil texture was clay loam, pH 7.5 and EC=3 dS/m. Each plot had 10 rows with 2 m length and 20 cm row spacing. The seeds were sown manually at plant density of 400 seeds per square meter. The plots were fertilized for each sowing date using 150 kg/ha Nitrogen (N) supplied from urea and 75 kg/ha phosphorus (P_2O_5) supplied from triple superphosphate. Urea was applied in two halves, the first half on sowing time of each sowing date and the rest at the beginning of stem elongation phase. The experiment was optimally managed to avoid any stresses, especially water stress. Weeds were controlled manually and chemically. Grain yield (GY) and biological yield (BY) were determined at physiological maturity by harvesting 1 m^2 of each plot. The spike number per m^2 (SM2) was recorded from the harvested area. The average number of grains per spike (GPS) was calculated based on 20 spikes. The thousand grain weight (TGW) was determined by counting the grains using an electronic seed counter. Harvest index (HI) was calculated as the ratio of grain yield to the total above ground biomass yield. Analysis of variance was performed by using general linear model (GLM) procedure of statistical analysis system (SAS version: 9.4). The comparison of means was carried using LSD test, LS means and physical slicing method (Soltani 2006).

In this experiment late sowing (terminal heat stress) significantly reduced grain yield and its components. The comparison of means showed that the highest spike number/m^2, grains per spike, thousand grain weight, grain yield, biological yield and harvest index was in the first sowing date (Table 1). Appropriate climate condition and low temperatures during growing period allowed to producing the highest amount of all measured traits for the sowing

Table 1 Mean comparison of measured traits in sowing dates

Sowing date	SM2i	GPS	TGW (g)	GY (kg/ha)	BY (kg/ha)	HI (%)
29 Nov.	450.6[a]	33.1[a]	37.6[a]	5590[a]	16173[a]	35.5[a]
14 Dec.	442.6[a]	26.9[b]	34.5[b]	4160[b]	14950[b]	28.6[b]
30 Dec.	385.7[b]	26.6[b]	30.8[c]	3120[c]	11513[c]	27.6[b]

In each column, means with the same letter are not significantly different at the 5% probability level-using LSD. SM2, spike per M2; GPS, grain per spike; TGW, thousand grain weight; GY, grain yield; BY, biological yield and HI, harvest index.

Table 3 Mean comparison of grain yield (kg/ha) in sowing dates and zinc levels

Zinc (kg/ha)	29 Nov.	14 Dec.	30 Dec.
0	5120b	3550c	2740b
10	5210b	4400ab	2770b
20	5770b	4200abc	3280a
30	6720a	4710a	3310a
40	5110b	3920bc	3520a

In each column, means with the same letter are not significantly different at the 5% probability level-using LS means.

date of 29 Nov. But, late sowing and high temperatures in March, April, and May and consequently terminal heat stress during reproductive phase and grain filling period significantly decreased all measured traits at third sowing date (30 Dec). The highest grain yield was in the sowing date of 29 Nov and the lowest grain yield was in the sowing date of 30 Dec In the other word, late sowing or terminal heat stress resulted in about 44% decrease in grain yield. Based on these findings, it is clear that the best sowing date was 29 of Nov and late sowing beyond the optimum window would considerably decrease grain yield and yield components mostly due to high temperature during flowering and grain filling period in Ahvaz region. However, late-sown crops were severely affected by heat damage during April and May. Several authors have reported that heat stress is responsible for reduced crop stand, shortened life cycle, reduced tiller number, suppressed biomass production, decreased fertilization and grain development, reduced spike size, spike number/m^2 and grain number per spike as well as grain weight, so that all these changes are translated into reduction in final grain yield (Rane *et al.* 2007, Modhej *et al.* 2008 and Moshatati *et al.* 2017).

The comparison of means (Table 2) showed that the effect of zinc levels was significant on grain per spike, grain yield, biological yield and harvest index but there was no significant effect on spike/m^2 and thousand grain weight. The highest grain per spike, grain yield and harvest index were in 30 kg/ha zinc, but the maximum biological yield was in 20 kg/ha zinc. On the other hand, the lowest amounts of above traits were in 0 kg/ha zinc. These results indicate that

Table 2 Mean comparison of measured traits in zinc levels

Zinc (kg/ha)	SM2i	GPS	TGW (g)	GY (kg/ha)	BY (kg/ha)	HI (%)
0	411.3a	26.9b	34.3a	3800c	13914b	28.6b
10	435.0a	27.8b	33.8a	4130bc	14247ab	29.8b
20	434.5a	29.7ab	34.6a	4410b	14986a	30.5b
30	425.5a	33.4a	34.8a	4910a	14907a	34.6a
40	425.2a	29.2ab	34.0a	4180bc	14517ab	29.3b

In each column, means with the same letter are not significantly different at the 5% probability level-using LSD

SM2, spike per M2; GPS, grain per spike; TGW, thousand grain weight; GY, grain yield; BY, biological yield and HI, harvest index.

zinc application leads to producing a higher yield. In this study grain yield increase with increasing zinc application. One reason of increase in grain yield is that zinc acts a cofactor in the enzymes directly involved in the process of photosynthesis (e. g. carbonic anhydrase and rubisco) which may have led to accumulate more photosynthates in the grain and thereby increasing grain yield (Peck and McDonald 2010 and Ma *et al.* 2017).

The mean comparison of zinc levels in each sowing date for grain yield (Table 3) showed that in the first sowing date, the highest grain yield was observed in 30 kg/ha zinc application and the lowest in 40 kg/ha zinc. In the second sowing date, the maximum grain yield was observed in 30 kg/ha zinc application and the minimum 0 kg/ha zinc. In the last sowing date, the maximum grain yield was observed in 30 kg/ha zinc application and the minimum in 0 kg/ha zinc. According to these results, in the late sowing date (terminal heat stress), zinc application (30 kg/ha) increase the grain yield about 15 percent. These results demonstrated that the detrimental effects of terminal heat stress and low zinc availability on the grain yield will be most damaging when these stresses occur in combination. Also, the results suggested that zinc fertilization could preserve grain yield under terminal heat stress.

In general, it can be concluded that zinc fertilization increased grain yield of wheat in all sowing dates especially under terminal heat stress condition in late sowing date. If sowing date due to previous crop, water and equipment's limitations delayed until after best time (30 Dec), zinc application (30 kg/ha) could be recommended. While the responses to terminal heat stress and low zinc were largely additive effects, this result demonstrated that high levels of zinc nutrition has the potential to improve the adverse effects on grain yield of wheat under terminal heat stress condition. This experiment represents a contribution to the understanding of the relationships between zinc applications and grain yield of wheat under terminal heat stress.

SUMMARY

In order to evaluate the influence of sowing dates and zinc levels on yield and yield components of wheat (*Triticumaestivum* L.) in Ahwaz, a split-plot experiment including three sowing dates (29 Nov, 14 and 30 Dec) in main plots and five zinc levels (0 (control), 10, 20, 30

and 40 kg/ha) in sub plots were implemented with three replicates in research farm of Agricultural Sciences and Natural Resources University of Khuzestan, Ahwaz, Iran. The mean comparison of sowing dates showed that the maximum grain yield was related to sowing date of 29 Nov and the minimum was obtained from 30 Dec. The mean comparison of zinc levels showed that the highest grain yield was in 30 kg/ha zinc and the lowest was in 0 kg/ha zinc. The mean comparison of interaction effect showed that the maximum grain yield was produced from 29 Nov and 30 kg/ha zinc and the minimum amount was related to 30 Dec and 0 kg/ha zinc. In general, in all sowing dates, zinc application increased grain yield of wheat.

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