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Effect of irrigation scheduling and zinc fertilization on growth and soil chemical properties under irrigated wheat (*Triticum aestivum* L.) cultivation

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Abstract
A field experiment was conducted to assess the effect of irrigation scheduling and zinc fertilization on growth and yield of wheat. The experiment was conducted at agricultural farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India during 2014-2015 and 2015-2016, respectively. The treatments consisted of four irrigation scheduling intervals (I_1 - CRI + Late Tillering + Flowering, I_2- CRI + Late Jointing + Milking, I_3- CRI + Flowering + Dough and I_3- CRI + Milking + Dough) and five zinc fertilization doses at different stages of crop growth. The results indicated that irrigation scheduling and zinc fertilization significantly influenced plant height, crop growth rate (CGR), ear length and test weight. There was no significant variation in pH, EC, organic carbon and zinc with the irrigation scheduling interval. Application of zinc had significant increase in zinc content in soil. However, there was non-significant effect of irrigation scheduling and zinc fertilization on relative growth rate (RGR), net assimilation rate (NAR). On the basis of findings of two years experimentation, irrigation scheduling at CRI + Late Jointing+ Milking and zinc fertilization @ 10 kg Zn ha^{-1} as basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% spray at Z 71 stages of wheat is recommended for wheat growth.

Keywords: Irrigation scheduling, zinc fertilization, growth, wheat

Introduction

Irrigation scheduling becoming more important in recent years due to continuous decrease in available fresh water for agricultural production (Cai and Rosegrant, 2003) [6]. The low water productivity in farmer's fields compared with well-managed experimental sites also indicates the need more efforts to transfer water saving technologies to the farmers (Singh *et al.* 2014) [19, 22]. Proper irrigation scheduling is essential for the efficient use of water, energy and other production inputs. There are various approaches for scheduling irrigation, however, critical growth stage is one of the easy and simple approach of irrigation scheduling. Further it has been reported that skipping irrigation at different growth stages of wheat affect its yield components, yield as well as chemical properties (El-Gawad *et al.* 1993 and Sharaan *et al.* 2000) [8, 21]. In terms of quality, skipping irrigation at milk and grain filling stage decreased moisture, fat and carbohydrate contents but gave the highest values of protein, ash and fibre contents in wheat (Mehasen *et al.* 2014) [16]. Thus proper irrigation scheduling neither decrease neither yield nor quality of wheat, but improve the growth, development and production of wheat (Muhammad *et al.* 1997) [17]. Hence, there is a need to refine irrigation scheduling to wheat by forcing a shift from plentiful to limited water.

About 30% of the cultivated soils of the world are Zn deficient and about 50% of the soils used for cereal crop production have low levels of Zn available for plants (Welch 1993) [24]. It is estimated; more than 40% of the wheat crop is cultivated on severely low Zn soils (Alloway 2008) [3], which produces grain yields with poor Zn content. About two billion of the world population is affected by Zn deficiency (Cakmak *et al.* 2010a) [7] which is associated with low dietary intake. Since cereal grains have inherently low Zn concentrations compared to legume, growing them on these potentially Zn-deficient soils further decreases grain Zn concentration. It is, therefore, not surprising that the well-documented Zn deficiency problem in humans occurs predominantly in the countries/regions such as India, China, Pakistan and Turkey where soils are low in available Zn and cereals are the major source of calorie intake (Alloway, 2008) [3]. Increasing Zn concentration in wheat, staple food crop, is therefore, an important humanitarian challenge to world.

Enrichment of seeds with Zn benefits both crop production and health of the consumers, especially those whose Zn intake comes primarily from cereal grains. In wheat, it was found that the highest Zn concentration in seed was achieved when foliar Zn was applied after the flowering stage (Zadoks scale 7; Zadok *et al*. 1974) [25] compared to the applications before the flowering stage (Cakmak *et al*. 2010a) [7]. But foliar Zn applications of Zn are also used, usually at the mid tillering or at early anthesis stages of growth (Cakmak *et al*. 2010a) [7]. Foliar application of Zn fertilizers is an effective agronomical practice in crop production, with substantial influence on both yield and particularly grain quality (Khoshgoftarmanesh *et al*. 2010) [15]. Owing to the above points a study was conducted to assess the effect of irrigation scheduling and zinc fertilization on growth and protein yield of wheat.

Materials and Methods

Study area

Field experiments were conducted during 2014-15 and 2015-16 (*rabi*) at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The geographical position of the farm lies at $25^0$18'N latitude, $88^0$36'E latitude and at an altitude of 128.93 meter above the mean sea level. The climate of the study site was semi-arid to sub humid with moisture deficit index between 20-40. The total rainfall of 131.30 mm was received during the wheat crop growth period of first (2014-15) year, was higher (46.30 mm) than second (2015-16) year. The weekly mean maximum temperature ranged from 27.8 to 36.6^0C with an average of 25.8^0C in 2014-15, and 28.4 to 41.4^0C with an average of 28.8-^{0}C in 2015-16, during wheat growth seasons, respectively. The weekly mean minimum temperature was ranged from 6.2 to 20.9^0 C with an average of 12.8 ^{0}C in 2014-15 and 7.2 to 23.1^0C with an average with an average of 13.6 ^{0}C in 2015-16 during wheat crop season, respectively. The experimental field was typically a medium soil, suitable for wheat crop in *Rabi* season with homogeneously fertile with even topography and uniform textural make up. For timely and regular irrigation, the experimental field was connected to main channel of the tube well. Proper drainage facility was also provided in order to remove excess water during experimental period.

Experimental material

Wheat crop variety for experiment was used of HUW-234 (Malaviya Wheat). It was suitable for late sown irrigated conditions, having 90-100 cm height. It is mostly grown for bread purpose with protein content of 10-11%. It completes its life cycle in 125-135 DAS. Average yield potential is 30-35 qtl ha^{-1}.

Experimental design and treatments

Field experiments were set up in randomized block design (RBD) taking 20 treatment combinations and three replications. Treatments included four irrigation schedule and five levels of zinc fertilization

Table 1: Irrigation scheduling and Zinc fertilization

A	**Irrigation scheduling**	
1	CRI + Late tillering + Flowering	I_1
2	CRI + Late Jointing + Milking	I_2
3	CRI + Flowering + Dough	I_3
4	CRI + Milking + Dough	I_4
B	**Zinc fertilization**	
1	0 kg Zn ha^{-1} (control)	Zn_1
2	5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z_{45} + 0.25% at Z_{71}	Zn_2
3	5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z_{60} + 0.25% at Z_{83}	Zn_3
4	10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z_{45} + 0.25% spray at Z_{71}.	Zn_4
5	10 kg Zn ha^{-1}at basal + 0.25% $ZnSO_4$ foliar spray at Z_{60} + 0.25% spray at Z_{83}.	Zn_5

Note: Z = Zadok's scale, Z45 = Boot swollen, Z_{60} = Pollination (Anthesis), Z_{71} = Dough stage, Z83 = Early dough

A plot having uniform fertility and uniform topography were selected for running of field trials in both years. The crop stubbles of previous crop and weeds were removed and destroyed from the field at the time of land preparation. The recommended rate of nutrients (N, P, and K @ 150, 60, and 60 kg ha^{-1}) were applied through urea, DAP and MoP. DAP and MoP were applied at the time of sowing whereas, nitrogen in two splits *i.e.* ½ at sowing and ½ at 30 days after sowing. Zinc was applied as a basal dose according to treatments through zinc sulphate (monohydrate) just prior to sowing of wheat. Line sowing was followed in furrows, opened by wooden marker at 22.5 cm as row spacing by using 125 kg seeds ha^{-1} and furrow were covered immediately after sowing. Quantity of water applied in field was measured with parshall flume by properly placing in water channel and delivered to the respective plots as per the irrigation schedule. Volume method was used to measure the irrigation water. The depth of irrigation was 6±2 cm. Irrigations were scheduled at predetermined critical growth stages of crop in respective treatments.

Collection of experimental data

Plant height (cm.)

Height of five randomly selected plants were recorded at 30, 60, 90 DAS and at harvesting stage from base of the plant to tip of the crop.

Crop growth rate (CGR)

It is the rate of the dry matter production per unit ground area per unit time and it was computed by using formula suggested by Watson 1952. It was expressed in g dm^{-2}day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where

W1 = Dry weight of plant (g) per m row length at time t1

W2 = Dry weight of plant (g) per m row length at time t2

A = Land area (dm²)

Relative growth rate (RGR)

Relative growth rate ($g^{-1}m^2day^{-1}$) was estimated by using the following formula suggested by Hoffmann and Poorter (2002) [12].

$$RGR = \frac{\log W2 - W1}{t2 - t1}$$

Where

Log = natural logarithm
t_1 = time one (in days)
t_2 = time two (in days)
W_1 = Dry weight of plant at time t1 (in grams)
W_2 = Dry weight of plant at time t2 (in grams)
Log_e value = 0.4342945

Net assimilation rate (NAR)

Indirectly it shows the rate of net photosynthesis was estimated at different intervals of period and expressed in gram of dry matter per meter row length per day by using the following formula given by Gregory (1917) [11].

$$NAR = (W_2 - W_1)(\log_e L_2 - \log_e L_1)/(t_2 - t_1)\ (L_2 - L_1)$$

Where

L_1 = Leaf area at a time one
L_2 = Leaf area at a time two
W_1 = Dry weight of plant at time one (in grams)
W_2 = Dry weight of plant at time two (in grams)
t_1 = Time one (in days)
t_2 = Time two (in days)
W_1 = Dry weight of plant at time one (in grams)
W_2 = Dry weight of plant at time two (in grams)

Ear length (cm.)

Five ears were randomly selected from the sampled plants at harvest and length was measured from the base to the tip of the ear, including awn.

1000 grain weight (g)

From the grain sample of each net plot, 1000 grains were selected at random and their weight was recorded in grams (g).

Soil analysis after harvest of crop

Random soil samples were collected from each experiment plot from depth of 0-15 cm after harvest of crop during both years. These soil samples further brought in lab followed by oven drying, crushed and passed through 2.0 mm sieve. These samples were used for analyzing pH, EC, OC, N, P, K, and Zn by following their standard procedure.

Statistical analysis

The analysis and interpretation of data was done using the Fischer's method of analysis of variance technique as described by Gomez and Gomez (1984) [10]. The level of significance used in 'F' and 't' test was P-0.05 and critical difference values were calculated wherever the 'F' test as significant.

Results and Discussion

Crop growth rate (g m^{-2} day^{-1})

Irrigation scheduling

It is apparent from 2014-15 data presented in Table 1 that, crop growth rate (CGR) had shown mixed response to irrigation schedules during both the years. CGR at 30 DAS was found non-significant. Highest CGR (2.29 g m^{-2} day^{-1}) was recorded in I_2 at 60 DAS was significantly superior over other treatments. At harvest, highest CGR (2.67 g m^{-2} day^{-1}) was recorded in I_2 treatment.

During second year (2015-16), highest CGR (0.59 g m^{-2} day^{-1}) at 30 DAS, was found I_2 over other treatments. Same trend was found at 60 DAS. CGR at 90 DAS and harvest was found non-significant.

Zinc fertilization

Significant variation in crop growth rate was observed in response to different zinc fertilization treatment during both the years of experiments.

During 2014-15, highest CGR (0.66 g m^{-2} day^{-1}) at 30 DAS was recorded in Zn_4 (10 kg Zn ha^{-1} as basal +0.25% $ZnSO_4$ foliar spray at Z45+ 0.25% spray at Z 71) which was at par to Zn_3 and Zn_5. Same trend was found at 60 DAS with highest CGR (2.20 m^{-1} day^{-1}) in Zn_4. At 90 DAS highest CGR (2.92 g m^{-2} day^{-1}) was recorded in Zn_4 and it was at par with Zn_5. CGR at harvest was recorded non-significant.

Same trend was observed during succeeding year also for CGR as influenced by zinc fertilization. Highest CGR (0.62 g m^{-2} day^{-1}) at 30 DAS was recorded in Zn_4 which was at par to Zn_2, Zn_3 and Zn_5 treatments. At 60 DAS, highest CGR (2.18 g m^{-1} day^{-1}) was found in Zn_4 treatment. But at harvest CGR was found non-significant. Meanwhile lowest CGR was found in Zn_1 (control) during all stages in both years of experiments.

Relative growth rate (g m^{-2} day^{-1})

Irrigation scheduling

The summary of data on relative growth rate (RGR) at different days of observation is presented in Table 1. In general, relative growth rate was decreased as the growth progressed up to harvest during both the years. The RGR found non-significant at all stages of intervals, except at 60 - 90 DAS interval during 2014-15 in response to irrigation scheduling and highest RGR (0.011 g m^{-2} day^{-1}) was recorded in I_4 (CRI + Milking + Dough) irrigation treatment. It was further at par to I_1 and I_3 irrigation treatments.

During 2015 and 2016 also, RGR was found non-significant in all treatments at all observation intervals.

Zinc fertilization

In contrast to irrigation scheduling, marked variation in RGR was observed due to different zinc fertilization management practices.

Significantly higher RGR (0.026 g m^{-2} day^{-1}) was found in control (Zn_1) treatment at 30 – 60 duration during 2014 and 2015 years. Meanwhile at 60- 90 DAS and at 90- at harvest interval, it was found non- significant during both years. Meanwhile interaction effect between irrigation scheduling and zinc fertilization was found significant during 30-60 DAS interval of 2016 year and during both years at 60-90 DAS and 90- at harvest intervals.

Net assimilation rate (g m^{-2} day^{-1})

Irrigation scheduling

The summary of data on net assimilation rate (NAR) at different days of observation is presented in Table 3. In general, NAR was decreased as the growth progressed up to harvest during both the years. The net assimilation found non-significant at all the stages of the growth during both the years.

Zinc fertilization

Marked variation in net assimilation rate was not observed due to different zinc fertilization practices and NAR was found non-significant at all the growth stages during both the years of experiment.

Ear length (cm)

Irrigation scheduling

From the scanning of data on ear length, presented in Table 2 reveals that, longest ear length (11.78 cm) was recorded in I_2 (CRI + Late Jointing + Milking) treatment of irrigation scheduling and was at par to I_1 (10.86 cm). Lowest value of ear length was recorded in I_4 (9.93 cm) during 2014-15.

During second year, 2015-16, highest value of ear length (13.09 cm) was recorded in I_2 treatment of irrigation scheduling followed by I_3 and I_4. Lowest ear length (10.84 cm) was recorded in I_1.

Zinc fertilization

It is evident from the data that, application of 10 kg Zn ha $^{-1}$ at basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% at Z 71 (Zn_4) produced longest ear length (11.91 cm) which was at par to Zn_2 and Zn_3 during 2014-15. Lowest ear length (9.56 cm) was recorded in control treatment.

Same trend was also found during 2015-16 year. Highest ear length (12.70 cm) was recorded in Zn_4 treatment while lowest value (10.76 cm) was found in control.

Thousand grain weight (g)

Data pertaining to 1000 grain weight as influenced by different treatments are summarized in Table no 3. Close scanning of data revealed that, significant variation in 1000 grain weight due to irrigation schedules and zinc fertilization was recorded during both the years.

During 2014-15 year of experiment, 1000 grain weight (32.01 g) of wheat obtained from irrigation scheduling at CRI + Late Jointing + Milking was significantly superior over other treatments. Lowest 1000 grain weight (27.12 g) was recorded in irrigation scheduling at CRI + Milking+ Late Jointing stages.

Same trend was also repeated during successive year of experiment. Highest 1000 grain weight (32.04 g) was recorded in I_2 treatment. Lowest value of 1000 grain weight (28.08 g) was found in I_4 treatment.

Zinc fertilization

In general the zinc management practices produced significantly highest 1000 grain weight. In treatment of 10 kg Zn ha^{-1} at basal +0.25% $ZnSO_4$ foliar spray at Z45+ 0.25% spray at Z 71 (Zn_4) produced maximum 1000 grain weight (31.38 g) which was at par to Zn_2, Zn_3 and Zn_5 during 2014-15 year.. Lowest 1000 grain weight (25.49 g) was found in control.

During second year of experiment, same trend was also recorded. Highest value of 1000 grain weight (32.02 g) was recorded in Zn_4, which was at par to Zn_2 and Zn_3. Meanwhile, Zn_1 recorded lowest value of 1000 grain weight (26.43).

Longest ear length (11.78 and 13.90 cm), highest grain count (45.35 and 46.08) and 1000 grain weight (32.01 and 32.04 g) were recorded during 2014-15 and 2015-16 year, respectively in irrigation schedule of CRI + Late Jointing + Milking. It might be increased due to irrigation scheduled at Late Jointing stage of wheat. Formation of ear is related to number of productive or effective tillers and favourable condition for the formation of more number of productive tillers. It includes, increase in CO_2 assimilation rate, late senescence of flag leaf and translocation of photosynthates (Bhat *et al*., 2004) [5] from source to sink, whose cumulative effect resulted in production of higher number of longer spike length, number of grains per spike and test weight. Higher weight of grains per ear is attributed mainly to more number of grains per ear and 1000 grain weight. Irrigation at milking might be helped to accumulate more photosynthates in sink (grain) and more 1000 grain weight (32.01 and 32.04 g respectively). These findings are also supported by Singh *et al*., 1980 [19, 22]. Besides, it might also be due to irrigation scheduling at CRI + Late Jointing + milking caused increase of dry matter production under higher moisture regimes and its further partitioning into spikes. It may turns into heavier spike, hence, more number of grains spike^{-1} (Idnani and Kumar, 2012) [13].

Application of zinc showed varied significant response to different yield parameters, although mostly controlled by genetic factors. Zinc applied @ 10 kg Zn ha^{-1} at basal +0.25% $ZnSO_4$ foliar spray at Z 45+ 0.25% spray at Z 71 resulted longest length of ear (11.91 and 12.70 cm), highest number of grains per ear (44.86 and 45.23) and 1000 grain weight (31.58 and 32.02 g) during 2014-15 and 2015-16 year, respectively. The increase in length of ear in response to zinc management might be correlated to better nutrition of panicle primordia (Ali *et al*, 2011, Shah *et al*, 2011, Basit *et al.* 2005 and Jan *et al*, 2013) [1, 2, 4, 20] which may results in improvement in yield parameters. Similar results related to improvement in spike length, effective tillers plant^{-1} and number of grains plant^{-1} in response to application of zinc have been reported by Ali *et al*. (2009) [1], Reddy and Bhardwaj (1989) [18], Islam *et al* (1999) [14] and Genc *et al* (2006) [9]. Meanwhile, lowest length of ear (9.56 and 10.76 cm), highest number of grains per ear (34.29 and 37.33) and 1000 grain weight (25.49 and 26.43 g) were recorded during 2014-15 and 2015-16 year, respectively.

Soil pH, EC and organic carbon after harvest of crop

The data related to pH, EC and organic carbon in soil as influenced by irrigation scheduling and zinc fertilization has been presented in Table 4.40

Irrigation scheduling

Among chemical properties, pH, EC and organic carbon were found non-significant by the irrigation scheduling during both the years of experimentation.

Zinc fertilization

The perusal of data revealed that, zinc fertilization had also found non-significant effect on pH, EC and organic carbon during 2015-16 and 2015-16 seasons of crop growth.

Zn content in soil after harvest of crop

The data pertained to Zn content in soil was influenced by irrigation scheduling and zinc fertilization has been presented in Table 4.

Irrigation scheduling

Non-significant effect was found for Zn content in soil during both years in response to irrigation scheduling.

Zinc fertilization

From scrutiny of the data it revealed that, effect of zinc fertilization on Zn content in soil was recorded statistically significant on during 2014-15. Highest soil Zn (0.52 mg kg^{-1}) was found in Zn_5 (10 kg Zn ha^{-1} at basal +0.25% $ZnSO_4$ foliar spray at Z 60+ 0.25% spray at Z 83) treatment, followed by

Zn_4 (0.46 mg kg^{-1}). However; lowest Zn (0.40 mg kg^{-1}) content in soil was found in Zn_1 (control) treatment.
Similar trend was also found during 2015-16 season with highest soil Zn (0.50 mg kg^{-1}) was found in Zn_5 treatment. Meanwhile, lowest soil Zn (0.39 mg kg^{-1}) was recorded in Zn_1.

Table 2: Effect of irrigation scheduling and zinc fertilization on crop growth rate (CGR) of wheat

Treatments	CGR ($gg^{-1}m^{-2}$)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2015	2016	2015	2016	2015	2016	2015	2016
Irrigation scheduling (I)								
I_1	0.55	0.53	2.09	2.08	2.44	2.50	2.04	2.17
I_2	0.61	0.59	2.29	2.19	2.31	2.55	2.67	2.54
I_3	0.53	0.49	1.92	1.87	2.41	2.53	2.00	1.91
I_4	0.54	0.48	1.74	1.72	2.55	2.50	1.90	2.08
S.Em±	0.03	0.03	0.08	0.07	0.16	0.16	0.16	0.23
CD (0.05)	NS	0.53	0.22	0.21	NS	NS	0.44	NS
Zinc fertilization (Zn)								
Zn_1	0.36	0.34	1.79	1.76	2.27	2.27	2.01	2.01
Zn_2	0.54	0.52	2.09	2.07	2.15	2.58	2.42	2.17
Zn_3	0.60	0.54	2.01	1.95	2.26	2.34	2.19	2.27
Zn_4	0.66	0.62	2.20	2.18	2.92	2.94	1.91	2.08
Zn_5	0.62	0.60	1.96	1.87	2.53	2.48	2.15	2.35
S.Em±	0.04	0.04	0.09	0.08	0.18	0.18	0.17	0.26
CD (0.05)	0.11	0.11	0.24	0.24	0.51	2.27	NS	NS
IxZN	NS	NS	NS	NS	S	S	S	S

I_1 - CRI + Late tillering + Flowering
I_2 - CRI + Late Jointing + Milking
I_3 - CRI + Flowering + Dough
I_4 - CRI + Milking + Dough

Zn_1 - 0 kg Zn ha^{-1} (Control)
Zn_2 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z45+ 0.25% at Z 71
Zn_3 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60+ 0.25% spray at Z 83
Zn_4 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 45+ 0.25% spray at Z 71
Zn_5 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60+ 0.25% spray at Z 83

Table 3: Effect of irrigation scheduling and zinc fertilization on relative growth rate (RGR) of wheat

Treatments	RGR ($gg^{-1}day^{-1}$)					
	30-60 DAS		60-90 DAS		90-harvest	
	2015	2016	2015	2016	2015	2016
Irrigation scheduling (I)						
I_1	0.023	0.024	0.010	0.010	0.0050	0.005
I_2	0.024	0.023	0.008	0.009	0.0063	0.006
I_3	0.023	0.023	0.010	0.011	0.0050	0.005
I_4	0.021	0.022	0.011	0.011	0.0048	0.005
S.Em±	0.001	0.001	0.001	0.001	0.0005	0.001
CD (0.05)	NS	NS	0.002	NS	NS	NS
Zinc fertilization (Zn)						
Zn_1	0.026	0.026	0.011	0.011	0.006	0.006
Zn_2	0.023	0.024	0.009	0.010	0.006	0.005
Zn_3	0.021	0.022	0.009	0.010	0.005	0.006
Zn_4	0.022	0.022	0.010	0.010	0.004	0.005
Zn_5	0.021	0.021	0.010	0.010	0.005	0.006
S.Em±	0.001	0.001	0.001	0.001	0.001	0.001
CD (0.05)	0.003	0.003	NS	NS	NS	NS
IxZN	NS	S	S	S	S	S

I_1 - CRI + Late Tillering + Flowering
I_2 - CRI + Late Jointing + Milking
I_3 - CRI + Flowering + Dough
I_4 - CRI + Milking + Dough

Zn_1 - 0 kg Zn ha^{-1} (Control)
Zn_2 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z45 + 0.25% at Z 71
Zn_3 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83
Zn_4 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% spray at Z 71
Zn_5 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83

Table 4: Effect of irrigation scheduling and zinc fertilization on net assimilation rate (NAR) of wheat

Treatments	NAR ($gm^{-2}day^{-1}$)					
	30 DAS		60 DAS		90 DAS	
	2015	2016	2015	2016	2015	2016
Irrigation scheduling (I)						
I_1	0.054	0.057	0.039	0.039	0.030	0.031
I_2	0.059	0.064	0.042	0.044	0.029	0.030
I_3	0.060	0.063	0.037	0.037	0.030	0.032
I_4	0.063	0.065	0.035	0.035	0.029	0.030
S.Em±	0.005	0.006	0.001	0.002	0.002	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS

Zinc fertilization (Zn)						
Zn_1	0.050	0.054	0.038	0.039	0.029	0.029
Zn_2	0.057	0.062	0.040	0.040	0.028	0.030
Zn_3	0.067	0.068	0.039	0.039	0.029	0.029
Zn_4	0.060	0.062	0.039	0.041	0.032	0.033
Zn_5	0.061	0.065	0.036	0.036	0.031	0.032
S.Em±	0.005	0.007	0.001	0.003	0.002	0.001
CD (0.05)	NS	NS	NS	NS	NS	NS
IxZN	NS	NS	NS	NS	S	S

I_1 - CRI + Late Tillering + Flowering
I_2 - CRI + Late Jointing + Milking
I_3 - CRI + Flowering + Dough
I_4 - CRI + Milking + Dough

Zn_1 - 0 kg Zn ha^{-1} (Control)
Zn_2 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z45 + 0.25% at Z 71
Zn_3 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83
Zn_4 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% spray at Z 71
Zn_5 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83

Table 5: Effect of irrigation scheduling and zinc fertilization on soil chemical properties after harvest of crop

Treatment	**pH**		**EC**		**OC (%)**		**Zn (mg kg^{-1})**	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Irrigation scheduling (I)								
I_1	7.03	7.05	0.143	0.144	0.34	0.34	0.45	0.44
I_2	6.97	6.99	0.143	0.144	0.34	0.34	0.44	0.43
I_3	6.85	6.89	0.143	0.143	0.35	0.35	0.45	0.43
I_4	6.95	6.93	0.143	0.144	0.33	0.33	0.46	0.44
S.Em±	0.10	0.09	0.001	0.001	0.01	0.01	0.01	0.01
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Zinc fertilization (Zn)								
Zn_1	7.12	7.14	0.145	0.146	0.35	0.35	0.40	0.39
Zn_2	6.98	6.97	0.141	0.142	0.33	0.33	0.43	0.43
Zn_3	7.08	7.13	0.142	0.143	0.33	0.33	0.43	0.41
Zn_4	6.90	6.93	0.142	0.143	0.34	0.34	0.48	0.46
Zn_5	6.67	6.67	0.143	0.144	0.35	0.35	0.52	0.50
S.Em±	0.11	0.10	0.001	0.001	0.01	0.01	0.01	0.01
CD (0.05)	NS	NS	NS	NS	NS	NS	0.02	0.02
IxZN	NS	NS	NS	NS	NS	NS	S	S

I_1 - CRI + Late Tillering + Flowering
I_2 - CRI + Late Jointing + Milking
I_3 - CRI + Flowering + Dough
I_4 - CRI + Milking + Dough

Zn_1 - 0 kg Zn ha^{-1} (Control)
Zn_2 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z45 + 0.25% at Z 71
Zn_3 - 5 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83
Zn_4 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% spray at Z 71
Zn_5 - 10 kg Zn ha^{-1} at basal + 0.25% $ZnSO_4$ foliar spray at Z 60 + 0.25% spray at Z 83

Conclusion

The results indicated that irrigation scheduling and zinc fertilization significantly influenced plant height, crop growth rate (CGR), ear length and test weight. There was no significant variation in pH, EC, organic carbon and zinc with the irrigation scheduling interval. Application of zinc had significant increase in zinc content in soil. However, there was non-significant effect of irrigation scheduling and zinc fertilization on relative growth rate (RGR), net assimilation rate (NAR). On the basis of findings of two years experimentation, irrigation scheduling at CRI + Late Jointing+ Milking and zinc fertilization @ 10 kg Zn ha^{-1} as basal + 0.25% $ZnSO_4$ foliar spray at Z 45 + 0.25% spray at Z 71 stages of wheat is recommended for wheat growth.

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