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 (I1 - CRI + Late Tillering + Flowering, I2 - CRI + Late Jointing + Milking, I3 - CRI + Flowering + Dough and I4 - 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) [3]. 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) [13]. 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°18'N latitude, 88°36'E latitude and at an altitude of 128.93 meter above the 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°C with an average of 25.8°C in 2014-15, and 28.4 to 41.4°C with an average of 28.8°C in 2015-16, during wheat growth seasons, respectively. The weekly mean minimum temperature was ranged from 6.2 to 20.9°C with an average of 12.8 °C in 2014-15 and 7.2 to 23.1°C with an average of 13.6 °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                         | **B** Zinc fertilization |
| 1 CRI + Late tillering + Flowering                  | 1 0 kg Zn ha⁻¹ (control) |
| 2 CRI + Late Jointing + Milking                     | Zn₁                         |
| 3 CRI + Flowering + Dough                           | Zn₂                         |
| 4 CRI + Milking + Dough                             | Zn₃                         |
| 5 CR₄ + Milking + Dough                             | Zn₄                         |

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⁻²day⁻¹.

\[
\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{X}{A}
\]

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
X = Plant height (cm)
A = Land area (dm²)

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

\[ \text{RGR} = \frac{\log W_2-W_1}{t_2-t_1} \]

Where
\[ \log = \text{natural logarithm} \]
\[ t_1 = \text{time one (in days)} \]
\[ t_2 = \text{time two (in days)} \]
\[ W_1 = \text{Dry weight of plant at time t1 (in grams)} \]
\[ W_2 = \text{Dry weight of plant at time t2 (in grams)} \]
\[ \log_e \text{value} = 0.4342945 \]

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].

\[ \text{NAR} = (W_2 - W_1)(\log_e L_2 - \log_e L_1)/((t_2 - t_1) (L_2 - L_1)) \]

Where
\[ L_1 = \text{Leaf area at a time one} \]
\[ L_2 = \text{Leaf area at a time two} \]
\[ W_1 = \text{Dry weight of plant at time one (in grams)} \]
\[ W_2 = \text{Dry weight of plant at time two (in grams)} \]
\[ t_1 = \text{Time one (in days)} \]
\[ t_2 = \text{Time two (in days)} \]
\[ W_1 = \text{Dry weight of plant at time one (in grams)} \]
\[ W_2 = \text{Dry weight of plant at time two (in grams)} \]

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 I1 at 60 DAS was significantly superior over other treatments. At harvest, highest CGR (2.67 g m^{-2} day^{-1}) was recorded in I1 treatment. During second year (2015-16), highest CGR (0.59 g m^{-2} day^{-1}) at 30 DAS, was found I1 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 Zn5 (10 kg Zn ha^{-1} as basal +0.25% ZnSO4 foliar spray at Z45+ 0.25% spray at Z71) which was at par to Zn0 and Zn5. Same trend was found at 60 DAS with highest CGR (2.20 m^{-3} day^{-1}) in Zn6. At 90 DAS highest CGR (2.92 g m^{-2} day^{-1}) was recorded in Zn4 and it was at par with Zn5. 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 Zn4 which was at par to Zn0, Zn5 and Zn6 treatments. At 60 DAS, highest CGR (2.18 g m^{-2} day^{-1}) was found in Zn4 treatment. But at harvest CGR was found non-significant. Meanwhile lowest CGR was found in Zn1 (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 I1 (CRI + Milking + Dough) irrigation treatment. It was further at par to I1 and I3 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 (Zn0) treatment at 30 – 60 duration during 2014 and 2015 years. Meanwhile at 60-90 DAS and at 90-120 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 90-120 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 I1 (CRI + Late Jointing + Milking) treatment of irrigation scheduling and was at par to I1 (10.86 cm). Lowest value of ear length was recorded in I1 (9.93 cm) during 2014-15. During second year, 2015-16, highest value of ear length (13.09 cm) was recorded in I1 treatment of irrigation scheduling followed by I3 and I4. Lowest ear length (10.84 cm) was recorded in I1.

Zinc fertilization
It is evident from the data that, application of 10 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 45 + 0.25% at Z 71 (Zn₄) produced longest ear length (11.91 cm) which was at par to Zn₂ and Zn₃ 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 Zn₄ 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 I₃ treatment Lowest value of 1000 grain weight (28.08 g) was found in I₄ 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% ZnSO₄ foliar spray at Z45+ 0.25% spray at Z 71 (Zn₄) produced maximum 1000 grain weight (31.38 g) which was at par to Zn₂, Zn₃ and Zn₄ 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 Zn₄ which was at par to Zn₂ and Zn₃. Meanwhile, Zn₁ 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 CO₂ assimilation rate, late senescence of flag leaf and translocation of photosynthates (Bhat et al., 2004) 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% ZnSO₄ 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 pertaining 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 Zn₅ (10 kg Zn ha⁻¹ at basal +0.25% ZnSO₄ foliar spray at Z 60+ 0.25% spray at Z 83) treatment, followed by
Zn₂ (0.46 mg kg⁻¹). However, lowest Zn (0.40 mg kg⁻¹) content in soil was found in Zn₁ (control) treatment. Similar trend was also found during 2015-16 season with highest soil Zn (0.50 mg kg⁻¹) was found in Zn₅ treatment. Meanwhile, lowest soil Zn (0.39 mg kg⁻¹) was recorded in Zn₁.

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

| Treatments | 30 DAS | 60 DAS | 90 DAS | At harvest |
|------------|--------|--------|--------|------------|
|            | 2015   | 2016   | 2015   | 2016   |
| Irrigation scheduling (I) | |
| I₁ | 0.55 | 0.53 | 2.09 | 2.08 | 2.44 | 2.50 | 2.04 | 2.17 |
| I₂ | 0.61 | 0.59 | 2.29 | 2.19 | 2.31 | 2.55 | 2.67 | 2.54 |
| I₃ | 0.53 | 0.49 | 1.92 | 1.87 | 2.41 | 2.53 | 2.00 | 1.91 |
| I₄ | 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) | |
| Zn₁ | 0.36 | 0.34 | 1.79 | 1.76 | 2.27 | 2.27 | 2.01 | 2.01 |
| Zn₂ | 0.54 | 0.52 | 2.09 | 2.07 | 2.15 | 2.58 | 2.42 | 2.17 |
| Zn₃ | 0.60 | 0.54 | 2.01 | 1.95 | 2.26 | 2.34 | 2.19 | 2.27 |
| Zn₄ | 0.66 | 0.62 | 2.20 | 2.18 | 2.92 | 2.94 | 1.91 | 2.08 |
| Zn₅ | 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 | 0.27 | NS | NS |

I₁ - CRI + Late tillering + Flowering
I₂ - CRI + Late Jointing + Milking
I₃ - CRI + Flowering + Dough
I₄ - CRI + Milking + Dough

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

| Treatments | 30-60 DAS | 60-90 DAS | 90-harvest |
|------------|-----------|-----------|------------|
|            | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Irrigation scheduling (I) | |
| I₁ | 0.023 | 0.024 | 0.010 | 0.011 | 0.0050 | 0.005 |
| I₂ | 0.024 | 0.023 | 0.008 | 0.009 | 0.0063 | 0.006 |
| I₃ | 0.023 | 0.023 | 0.010 | 0.011 | 0.0050 | 0.005 |
| I₄ | 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) | |
| Zn₁ | 0.026 | 0.026 | 0.011 | 0.011 | 0.006 | 0.006 |
| Zn₂ | 0.023 | 0.024 | 0.009 | 0.010 | 0.006 | 0.005 |
| Zn₃ | 0.021 | 0.022 | 0.009 | 0.010 | 0.005 | 0.006 |
| Zn₄ | 0.022 | 0.022 | 0.010 | 0.010 | 0.004 | 0.005 |
| Zn₅ | 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 |
| I₁ - CRI + Late Tillering + Flowering | Zn₁ - 0 kg Zn ha⁻¹ (Control) |
| I₂ - CRI + Late Jointing + Milking | Zn₂ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z45 + 0.25% at Z 71 |
| I₃ - CRI + Flowering + Dough | Zn₃ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 60 + 0.25% spray at Z 83 |
| I₄ - CRI + Milking + Dough | Zn₄ - 10 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 45 + 0.25% spray at Z 71 |
| I₅ - CRI + Milking + Dough | Zn₅ - 10 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ 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 | 30 DAS | 60 DAS | 90 DAS |
|------------|--------|--------|--------|
|            | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Irrigation scheduling (I) | |
| I₁ | 0.054 | 0.057 | 0.039 | 0.039 | 0.030 | 0.031 |
| I₂ | 0.059 | 0.064 | 0.042 | 0.044 | 0.029 | 0.030 |
| I₃ | 0.060 | 0.063 | 0.037 | 0.037 | 0.030 | 0.032 |
| I₄ | 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 |
Table 5: Effect of irrigation scheduling and zinc fertilization on soil chemical properties after harvest of crop

| Treatment                      | pH 2015 | pH 2016 | EC 2015 | EC 2016 | OC (%) 2015 | OC (%) 2016 | Zn (mg kg⁻¹) 2015 | Zn (mg kg⁻¹) 2016 |
|--------------------------------|---------|---------|---------|---------|-------------|-------------|-------------------|-------------------|
| Irrigation scheduling (I)     |         |         |         |         |             |             |                   |                   |
| I₁ - CRI + Late Tilling + Flowering | Zn₁ - 0 kg Zn ha⁻¹ (Control) | 7.12    | 7.14    | 0.145   | 0.146       | 0.35         | 0.35              | 0.40              |
| I₂ - CRI + Late Jointing + Milking | Zn₁ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z45 + 0.25% at Z 71 | 6.98    | 6.97    | 0.141   | 0.142       | 0.33         | 0.33              | 0.43              |
| I₃ - CRI + Flowering + Dough   | Zn₁ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 60 + 0.25% spray at Z 83 | 7.08    | 7.13    | 0.142   | 0.143       | 0.33         | 0.33              | 0.43              |
| I₄ - CRI + Milking + Dough     | Zn₁ - 10 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 45 + 0.25% spray at Z 71 | 6.90    | 6.93    | 0.142   | 0.143       | 0.34         | 0.34              | 0.48              |
| S.Em±                          | 0.11    | 0.10    | 0.001   | 0.001   | 0.01        | 0.01        | 0.02              | 0.02              |
| Cd (0.05)                      | NS      | NS      | NS      | NS      | NS          | NS          | NS                | NS                |
| Zn₁                            | 7.12    | 7.14    | 0.145   | 0.146   | 0.35        | 0.35        | 0.40              | 0.39              |
| Zn₂                            | 6.98    | 6.97    | 0.141   | 0.142   | 0.33        | 0.33        | 0.43              | 0.43              |
| Zn₃                            | 7.08    | 7.13    | 0.142   | 0.143   | 0.33        | 0.33        | 0.43              | 0.41              |
| Zn₄                            | 6.90    | 6.93    | 0.142   | 0.143   | 0.34        | 0.34        | 0.48              | 0.46              |
| Zn₅                            | 6.67    | 6.67    | 0.142   | 0.143   | 0.35        | 0.35        | 0.52              | 0.50              |
| S.Em±                          | 0.11    | 0.10    | 0.001   | 0.001   | 0.01        | 0.01        | 0.02              | 0.02              |
| Cd (0.05)                      | NS      | NS      | NS      | NS      | NS          | NS          | NS                | NS                |
| I₁ - CRI + Late Tilling + Flowering | Zn₁ - 0 kg Zn ha⁻¹ (Control) | 7.12    | 7.14    | 0.145   | 0.146       | 0.35         | 0.35              | 0.40              |
| I₂ - CRI + Late Jointing + Milking | Zn₁ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z45 + 0.25% at Z 71 | 6.98    | 6.97    | 0.141   | 0.142       | 0.33         | 0.33              | 0.43              |
| I₃ - CRI + Flowering + Dough   | Zn₁ - 5 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 60 + 0.25% spray at Z 83 | 7.08    | 7.13    | 0.142   | 0.143       | 0.33         | 0.33              | 0.43              |
| I₄ - CRI + Milking + Dough     | Zn₁ - 10 kg Zn ha⁻¹ at basal + 0.25% ZnSO₄ foliar spray at Z 45 + 0.25% spray at Z 71 | 6.90    | 6.93    | 0.142   | 0.143       | 0.34         | 0.34              | 0.48              |
| S.Em±                          | 0.11    | 0.10    | 0.001   | 0.001   | 0.01        | 0.01        | 0.02              | 0.02              |
| Cd (0.05)                      | NS      | NS      | NS      | NS      | NS          | NS          | NS                | NS                |
| Zn₁                            | 7.12    | 7.14    | 0.145   | 0.146   | 0.35        | 0.35        | 0.40              | 0.39              |
| Zn₂                            | 6.98    | 6.97    | 0.141   | 0.142   | 0.33        | 0.33        | 0.43              | 0.43              |
| Zn₃                            | 7.08    | 7.13    | 0.142   | 0.143   | 0.33        | 0.33        | 0.43              | 0.41              |
| Zn₄                            | 6.90    | 6.93    | 0.142   | 0.143   | 0.34        | 0.34        | 0.48              | 0.46              |
| Zn₅                            | 6.67    | 6.67    | 0.142   | 0.143   | 0.35        | 0.35        | 0.52              | 0.50              |
| S.Em±                          | 0.11    | 0.10    | 0.001   | 0.001   | 0.01        | 0.01        | 0.02              | 0.02              |
| Cd (0.05)                      | NS      | NS      | NS      | NS      | NS          | NS          | NS                | NS                |

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% ZnSO₄ foliar spray at Z 45 + 0.25% spray at Z 71 stages of wheat is recommended for wheat growth.

References
1. Ali A, Ahmad A, Syed WH, Khalqi T, Asif M, Aziz M, Mubeen M. Effects of nitrogen on growth and yield components of wheat. Science International (Lahore) 2011;23:331-332.
2. Ali S, Shah A, Arif M, Miraj G, Ali I, Sajjad M et al. Enhancement of wheat grain yield and yield components through foliar application of zinc and boron. Sarhad Journal of Agriculture 2009;25:15-19.
3. Alloway BJ. Zinc in soils and crop nutrition (2nd ed.). Brussels: International Zinc Association; Paris: International Fertilizer Industry Association 2008.
4. Basit A, Faisal MI, Gul A, Jaffari AK, Ahmad N. Studies of nitrogen use efficiency in wheat (Triticum aestivum L.) by split application at different growth Stages. Journal of Applied. Environmental. Science 2005;1:39-42.
5. Bhat NR, Al Messaie H, Suleiman HK, Al Mulla L, Christopher A, Ferin J, Thomas B. Polymer effectiveness at different temperature regimes under arid environmental conditions. World Journal of Agricultural Science 2004;2:429-434.
6. Cai X, Rosegrant M. World water productivity: current situation and future options. In: Kijne, J.W., Barker, R., Molden, D. (Eds.), Water productivity in agriculture: limits and opportunities for improvement. International Water Management Institute (IWMI), Colombo, Sri Lanka 2003, P163-178.
7. Cakmak I, Pfeiffer WH, McClafferty B. Biofortification of durum wheat with zinc and iron. Cereal Chemistry 2010;87:10-20.
8. El-Gawad A, EL-Habbal A, Edris A, Elham A, Dorgham. Effect of water stress during grain filling period and nitrogen fertilization on yield and its attributes of two wheat genotypes. Egypt Journal of Agronomy 1993;18:211-227.
9. Genc Y, McDonald GK, Graham RD. Contribution of different mechanisms to zinc efficiency in bread wheat during early vegetative stage. Plant Soil 2006;281:353-67.
10. Gomez KA, Gomez AA. Statistical Procedures for Agricultural research, 2nd edition, A Wiley-Inter Science Publication, New York (USA) 1984, P196-211.
11. Gregory FG. Third annual report, experimental and research station, Chesnut 1917.
12. Hoffmann WA, Poorter H. Avoiding Bias in Calculations of Relative Growth Rate. Annals of Botany 2002;90:37.
13. Idnani LK, Kumar A. Performance of wheat (Triticum aestivum) under different irrigation schedules and sowing methods. Indian Journal of Agricultural Sciences 2012;83:37-40.
14. Islam MR, Islam MS, Jahiruddin M, Hoque MS. Effect of sulphur, zinc and boron on yield, yield components and nutrients uptake of wheat. Pakistan Journal Sci Indus Research 1999;42:137-40.
15. Khoshgoftaranesh AH, Schulin R, Chaney RL, Daneshbakhsh B, Afyuni M. Micronutrient-efficient genotypes for crop yield and nutritional quality in sustainable agriculture. A review. Agronomy for Sustainable Development 2010;30:83-107.
16. Mehasen S, Gizawy N, Sharoba A, Soliman S, Khalil T. Yield and chemical composition of bread wheat cultivars as affected by some skipping irrigation. Minufiya Journal of Agriculture Research 2014;39:1-4.
17. Muhammad A, Haji K, Muhammad S. Performance of different wheat (Triticum aestivum L.) varieties under the agro-climatic conditions of Dera Ismail Khan. Sarhad Journal of Agriculture 1997;13:527-528.
18. Reddy, Bhardwaj RBL. Effect of nitrogen and phosphorous on growth and yield of wheat under limited and adequate irrigation. Indian Journal of Agronomy 1989;29:505-09.
19. Singh Y, Kukal S, Jat M, Sidhu H. Improving Water Productivity of Wheat-Based Cropping Systems in South Asia for Sustained Productivity. Sparks, D. (Ed.), Advances in Agronomy. Academic Press, Elsevier Inc 2014;127:157-258.
20. Shah WA, Khan HU, Anwar S, Nawab K. Yield and yield components of wheat as affected by different seed rates and nitrogen levels. Sarhad Journal of Agriculture 2011;27:17-25.
21. Sharaan A, Abd EL-Samie, Gawad. Response of wheat varieties to some environmental influences. II-Effect of planting date and drought at different plant stages on yield and its components. 9th Conf. of Agronomy Menofiya, Egypt 2000;2(3):1-16.
22. Singh RP, Dhiman SD, Sharma HC. Performance of wheat varieties under limited water supply. Indian Journal of Agronomy 1980;25:259-262.
23. Watson DJ. The physiological basis of variation in yield. Advances in Agronomy 1952;4:101-145.
24. Welch RM. Zinc Concentrations and Forms in Plants for Humans and Animals, Kluwer, Dordrecht, The Netherlands 1993.
25. Zadoks J, Chang T, Konzak C. A decimal code for the growth stages of cereals. Weed Research 1974;6:415-421.