Agrometeorological Indices Requirement for Wheat Crop under Different Irrigation Levels

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ABSTRACT

The field experiment was conducted at Agronomy Farm, Anand Agricultural University, Anand (Lat.: 22°35' N, Log.: 72°55' E & 45.1 m above ms) during rabi season in 2011-2012. The treatment comprised of five levels of irrigation schedule Viz., I1 (CRI, TL, BT, FL, ML, SD), I2 (0.4 IW: CPE ratio), I3 (0.6 IW: CPE ratio), I4 (0.8 IW: CPE ratio) and I5 (1.0 IW: CPE ratio) in randomized block design (RBD) within four replications. The main aim is to quantify the agrometeorological indices of wheat crop. The different agrometeorological indices were evaluated i.e. growing degree Days (GDD), Heliothermal Unit (HTU), Photothermal Unit (PTU) and Relative temperature Disparity (RTD). The results revealed that the different irrigation level was found alter the agrometeorological indices and its efficiency at different phenophases of wheat crop. The higher GDD (3532°C day), HTU (32759°C day), and PTU (38652°C day) were found with I1 (CRI, TL, BT, FL, ML, SD) irrigation level. The relative temperature disparity (RTD) was found higher under I3 (0.6 IW: CPE ratio) irrigation level and photothermal index (PTI) was found varying as fluctuating trend among all irrigation levels.

Keywords: Wheat, Irrigation levels, GDD, HTU, PTU, PTI.

Introduction

Agrometeorological indices requirement of wheat crop was varies in different irrigation application and weather conditions. Wheat (Triticum aestivum L.) is one of the most important cereal crops globally. India covers about 30.2 million hectares area with total production of 93.5 million tonnes and productivity of 30.9 q/ha (Anonymous, 2016). Gujarat ranks sixth in wheat production in country and area, production and productivity, averaged are 0.85 million ha, 2.4 tonnes and 2.9 tonnes ha⁻¹, respectively (Anonymous, 2016). The minimum growth temperature for is 3-4 °C, the optimum temperature about 25 °C, and the maximum from about 30-32 °C.

The day and night temperature played vital role to completion the primary requirement of degree day. The minimum temperature quite high value was promoted the higher respiration and ultimately increases the water requirement and lowers the assimilation rate. Changes in climatic variables like rise in temperature and decline in rainfall may be more frequent in future as suggested by the Intergovernmental Panel on Climate Change
Pre anthesis and post-anthesis high temperature and heat may have huge impacts upon wheat growth, and stress reduced the photosynthetic efficiency of crop (Wang et al., 2011). You et al., (2009) observed significant reduction in economical yield due to rise in temperature and concluded that a 1.8°C rise in temperature caused 3-10% reduction in wheat yields. Winter crops are vulnerable to high temperature during reproductive stages especially night temperature (Tmin) and differential response of temperature change (rise) to various crops has been noticed under different production environments (Kalra, 2008). Crop is exposed to a variety of weather conditions during its different phenophases of growth, resulting in large variations in growth rate and yield. For quantifying the thermal relation of crops, thermal units approach is widely used (Ramteke et al., 1996) and has been further modified to include photothermal units and heliothermal units (Rao et al., 1999). Water is essential at every developmental phase of crop growth starting from seed germination to crop maturity for harvesting the maximum potential yield of wheat. There is a positive correlation between grain yield and irrigation frequencies at the critical phases Irrigation missing at some critical growth stage sometime drastically reduces grain yield (Chauhan et al., 2008) due to not proper drought stage attained and resulted were found to lower test weight. Similarly, over irrigation also sometimes tends to decrease grain yield instead of increasing yield (Kahlown and Azam, 2002).

**Materials and Methods**

The field experiment was conducted at Agronomy Farm, Anand Agricultural University, (AAU), Anand, Gujarat (Lat.: 22°35’ N, Log.: 72°55’ E and 45.1 m above msl) during *rabi* season in 2011-2012. The treatment comprised of five levels of irrigation schedule *viz.*, I₁ (CRI, TL, BT, FL, ML, SD), I₂ (0.4 IW: CPE ratio), I₃ (0.6 IW: CPE ratio), I₄ (0.8 IW: CPE ratio) and I₅ (1.0 IW: CPE ratio) in randomized block design (RBD) within four replications. The number of days to attain various phenophases was determined from randomly selected five plants (with followed the sampling method) in all the plots visually by the number of days taken from the sowing date to attain respective phenophases up to maturity. Maximum and minimum temperatures used for study were taken from agro meteorological observatory that is near from the experimental site. The growing degree days (GDD) and heliothermal unit (HTU) was calculated according to the formula of Rajput (1980) and photothermal and relative temperature disparity (RTD) unit was calculated by using the formula of Major et al., (1975) for different phenophases of wheat [viz. Crown root initiation (CRI), tillering (TL), booting (BT), anthesis (AT), milking (ML), dough stage (DS) and physiological maturity (PM)].

\[
\text{GDD} = \sum_{i=1}^{n} \left[ \frac{T_{\text{max}} + T_{\text{min}}}{2} - T_{\text{b}} \right]
\]

Where

- \( T_{\text{max}} \) = Maximum Temperature (°C)
- \( T_{\text{min}} \) = Minimum Temperature (°C)
- \( T_{\text{b}} \) = Base Temperature

\[
\text{HTU} = \sum_{i=1}^{n} \text{GDD} \times \text{SSH}
\]

\[
\text{PTU} = \sum_{i=1}^{n} \text{GDD} \times \text{Daylength}
\]

\[
\text{RTD} = \sum_{i=1}^{n} \frac{T_{\text{max}} - T_{\text{min}}}{T_{\text{max}}} \times 100
\]

\[
\text{PTI} = \text{GDD} \div \text{Growing days}
\]
GDD | Growing Degree Days (°C day)
---|---
HTU | Heliothermal Units (°C day)
PTU | Photothermal Units (°C day)
RTD | Relative Temperature Disparity
PTI | Photothermal index (°C day)
Tmax | Maximum temperature (°C)
Tmin | Minimum temperature (°C)
Tb | Base temperature (°C)
SSH | Bright sunshine hours (hrs/day)

Results and Discussion

Growing degree day (GDD)

The results were revealed that the agrometeorological indices i.e. growing degree day (GDD) from date of CRI to physiological maturity (PM) accounted higher with \( I_1 \) (CRI, TL, BT, FL, ML, DS) than \( I_4 \) (0.8IW: CPE) irrigation level while lowest GDD observed when crop irrigated with \( I_2 \) (0.4 IW: CPE) and \( I_3 \) (0.6 IW: CPE) irrigation level. Moreover from anthesis to physiological maturity higher GDD were recorded with \( I_1 \) irrigation level than the rest of treatments. At physiological maturity of the crop highest GDD (3532 °C day) was accounted with \( I_1 \) irrigation level than \( I_4 \) (3500 °C day) while lowest GDD were recorded in case of \( I_2 \) (3168 °C day) irrigation level (Table 1).

The different irrigation application during critical phenophases was very much influencing on grain size and its comparative economical weight along with boldness in size of grain in \( I_1 \) irrigation level treatment. The regular irrigation applied treatment (II) were observed the vigorous plant with dark green in colour with quite higher leaf area index as well chlorophyll contain in the leaves and less reflectivity of PAR wave length at advance phases was observed in \( I_1 \). In the Table 1 showed the various phenophases attained the degree day. The higher GDD was observed at physiological maturity stage in all the irrigation levels.

Heliothermal units (HTU)

Heliothermal units (HTU) were gradually increased from CRI to physiological maturity in all the irrigation level. During the period of study among all the irrigation level maximum HTU was recorded with \( I_1 \) (CRI, TL, BT, FL, ML, DS) irrigation level 32759 °C day while the lowest HTU were recorded (29563 °C day) in case of irrigation level \( I_2 \) (Table 2). The HTU were found at par during different phenophases with all irrigation level. The slandered deviation were observed quite increasing trend from CRI to physiological maturity (PM) in all irrigation levels.

Photothermal units (PTU)

Photothermal units (PTU) from CRI to booting (BT) stage accounted higher with \( I_1 \) (CRI, TL, BT, FL, ML, DS) and \( I_5 \) (1.0 IW: CPE) irrigation level while lowest PTU were recorded with \( I_2 \) (0.4 IW: CPE) irrigation level. From anthesis to physiological maturity higher PTU were recorded with \( I_1 \) than rest of the treatments. At physiological maturity of wheat highest PTU (38652 °C days) with \( I_1 \) irrigation level while the lowest PTU were observed in case of wheat crop \( I_2 \) (34632 °C days) irrigation level. PTU decreased as irrigation level (IW: CPE) decreased (Table 3).
Table 1: Growing degree days (°C day) required for various phenophases of wheat as affected by different irrigation levels

| Irrigation levels | Phenophases |
|-------------------|-------------|
|                   | CRI | TL  | BT  | AT  | ML  | SD  | PM  |
| I (CRI, TL, BT, FL, ML, DS) | 732 | 1325 | 1685 | 2081 | 2553 | 3055 | 3532 |
| I2 (0.4 IW: CPE)  | 732 | 1263 | 1557 | 2001 | 2460 | 2800 | 3168 |
| I3 (0.6 IW: CPE)  | 732 | 1294 | 1609 | 2032 | 2523 | 2952 | 3426 |
| I4 (0.8 IW: CPE)  | 732 | 1294 | 1635 | 2058 | 2523 | 3020 | 3500 |
| I5 (1.0 IW: CPE)  | 732 | 1325 | 1660 | 2058 | 2553 | 3020 | 3463 |
| Mean              | 732 | 1300 | 1629 | 2046 | 2522 | 2969 | 3418 |
| S.D.              | 0.00 | 25.94 | 49.29 | 30.55 | 37.97 | 101.79 | 145.18 |
| C.V.              | 0.00 | 0.02 | 0.03 | 0.01 | 0.02 | 0.03 | 0.04 |

Table 2: Heliothermal units (°C day) required for various phenophases of wheat as affected by different irrigation levels

| Irrigation levels | Phenophases |
|-------------------|-------------|
|                   | CRI | TL  | BT  | AT  | ML  | SD  | PM  |
| I (CRI, TL, BT, FL, ML, DS) | 6684 | 12232 | 15182 | 18788 | 23310 | 28247 | 32759 |
| I2 (0.4 IW: CPE)  | 6684 | 11678 | 14255 | 18064 | 22401 | 25748 | 29563 |
| I3 (0.6 IW: CPE)  | 6684 | 11979 | 14607 | 18327 | 23025 | 27222 | 31809 |
| I4 (0.8 IW: CPE)  | 6684 | 11979 | 14760 | 18576 | 23025 | 27900 | 32467 |
| I5 (1.0 IW: CPE)  | 6684 | 12232 | 14945 | 18576 | 23310 | 27900 | 32140 |
| Mean              | 6684 | 12020 | 14750 | 18466 | 23014 | 27403 | 31748 |
| S.D.              | 0.00 | 229.2 | 350.1 | 277.9 | 371.2 | 997.3 | 1271.9 |
| C.V.              | 0.000 | 0.019 | 0.024 | 0.015 | 0.016 | 0.036 | 0.040 |
Table 3 Photothermal units (°C day) required for various phenophases of wheat as affected by different irrigation levels

| Irrigation levels | Phenophases | CRI | TL | BT | AT | ML | SD | PM |
|-------------------|-------------|-----|----|----|----|----|----|----|
| I1 (CRI, TL, BT, FL, ML, DS) |             | 7890 | 14197 | 18035 | 22287 | 27466 | 33126 | 38652 |
| I2 (0.4 IW: CPE)  |             | 7890 | 13534 | 16661 | 21424 | 26435 | 30231 | 34632 |
| I3 (0.6 IW: CPE)  |             | 7890 | 13869 | 17220 | 21755 | 27130 | 31945 | 37406 |
| I4 (0.8 IW: CPE)  |             | 7890 | 13869 | 17496 | 22038 | 27130 | 32729 | 38275 |
| I5 (1.0 IW: CPE)  |             | 7890 | 14197 | 17763 | 22063 | 27466 | 32729 | 37841 |
| Mean              |             | 36.6 | 35.0 | 33.4 | 31.7 | 30.8 | 30.5 | 30.8 |
| S.D.              |             | 0.00 | 0.09 | 0.31 | 0.09 | 0.01 | 0.05 | 0.22 |

Table 4 Relative temperature disparity (RTD) required for various phenophases of wheat as affected by different irrigation levels

| Irrigation levels | Phenophases | CRI | TL | BT | AT | ML | SD | PM |
|-------------------|-------------|-----|----|----|----|----|----|----|
| I1 (CRI, TL, BT, FL, ML, DS) |             | 47.8 | 55.7 | 59.5 | 63.4 | 62.1 | 61.9 | 59.3 |
| I2 (0.4 IW: CPE)  |             | 47.8 | 55.3 | 60.8 | 61.6 | 62.5 | 62.1 | 61.1 |
| I3 (0.6 IW: CPE)  |             | 47.8 | 55.7 | 60.4 | 63.0 | 63.3 | 60.9 | 61.7 |
| I4 (0.8 IW: CPE)  |             | 47.8 | 55.7 | 59.9 | 62.3 | 62.9 | 60.5 | 59.3 |
| I5 (1.0 IW: CPE)  |             | 47.8 | 55.7 | 59.9 | 62.8 | 62.7 | 61.7 | 59.5 |
| Mean              |             | 47.8 | 55.6 | 60.1 | 62.6 | 62.7 | 61.4 | 60.2 |
| S.D.              |             | 0.00 | 0.18 | 0.50 | 0.69 | 0.45 | 0.69 | 1.14 |
| C.V.              |             | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
Table 5. Photo thermal index (°C day) required for various phenophases of wheat as affected by different irrigation levels

| Irrigation levels | Phenophases |          |          |          |          |          |          |
|-------------------|-------------|----------|----------|----------|----------|----------|----------|
|                   | CRI | TL | BT | AT | ML | SD | PM |
| I₁(CRI, TL, BT, FL, ML, DS) | 36.6 | 34.9 | 33.0 | 31.5 | 30.8 | 30.6 | 31.0 |
| I₂ (0.4 IW: CPE) | 36.6 | 35.1 | 33.8 | 31.8 | 30.8 | 30.4 | 30.5 |
| I₃ (0.6 IW: CPE) | 36.6 | 35.0 | 33.5 | 31.8 | 30.8 | 30.4 | 30.9 |
| I₄ (0.8IW: CPE) | 36.6 | 35.0 | 33.4 | 31.7 | 30.8 | 30.5 | 31.0 |
| I₅ (1.0 IW: CPE) | 36.6 | 34.9 | 33.2 | 31.7 | 30.8 | 30.5 | 30.9 |
| Mean | 36.6 | 35.0 | 33.4 | 31.7 | 30.8 | 30.5 | 30.8 |
| S.D. | 0.00 | 0.09 | 0.31 | 0.09 | 0.01 | 0.05 | 0.22 |
| C.V. | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |

Relative temperature disparity (RTD)

The effect of relative temperature disparity (RTD) was found no significant with different irrigation levels. Among irrigation levels values of RTD were increased from CRI to anthesis (AT) thereafter decreased up to physiological of crop but standard deviation higher at PM. Irrigation level I₃ and I₂ was accredited more RTD values than I₅, I₄ and I₁ irrigation level during the study period. The value of RTD increases with growing of the crop up to vegetative stage thereafter reduction in RTD was observed with physiological maturity of the crop; it might be due to lower value of night temperature and quite increased the day temperature. The high values of RTD were signal of higher mean temperature and comparatively low mean temperature (Table 4).

Photo thermal index (PTI)

Photo thermal index (PTI) for consecutive phenophases was computed and presented in table 5. PTI is expressed as degree days per growth day (Sastry and Chakravartty, 1982). Photo thermal index gradually decreased from emergence to physiological maturity (Kingra and Kaur 2012). Among the irrigation level the highest PTI value was found for I₁ (CRI, TL, BT, FL, ML, DS) and I₄ (0.8IW: CPE) and lowest value for I₂ (Table 5).

It was concludes that I₁ (CRI, TL, BT, FL, ML, DS) irrigation level was recorded maximum GDD, HTU, PTU and PTI as compare to other irrigation levels for wheat crop. Delayed irrigation application reduced the wheat production. So amount and time of irrigation water should be kept in mind for higher yield. I₁ irrigation level proved to be beneficial for farmers to keep good harvest. The potential yield of any variety can attain where provided the efficient irrigations at critical growth stages without the situation of stress at Anand conditions.

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