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## Influence of irrigation scheduling on growth and yield of Wheat (*Triticum aestivum* L.)

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#### ABSTRACT

The field experiment entitled “Influence of irrigation scheduling on growth and yield of Wheat (*Triticum aestivum* L.)” was conducted at the Research farm of the Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat (M.P.), during Rabi season of year 2024-25. The experiment was laid out in RBD Design with 8 treatment combinations, comprising of different irrigation schedules viz. (T1) CRI, (T2) CRI + T, (T3) CRI + T, (T4) CRI + J + F, (T5) CRI + T + M, (T6) CRI + T + F + M, (T7) CRI + T + J + F + M and (T8) CRI + T + J + F + M + D. Eight treatment combinations were replicated three times.

The data concluded that among irrigation schedules, six irrigations T8 (CRI + T + J + F + M + D) produced maximum all the growth and yield traits studied, particularly grain yield (46.78 qt ha<sup>-1</sup>) as compared to five irrigations and four irrigations. Hence, six irrigations at different stages were found most suitable for obtaining the maximum grain yield of wheat.

**Keywords:** Irrigation, Tillers, CRI, Grains, Ear head, Seed index, Straw yield

#### Introduction

Wheat is the second staple food crop of India after rice. India has a total production of 95.91 million tonnes which is 12 % of the world food production from 31.34 million hectares of land with productivity of 30.61 q/ha during *Rabi* 2021-22 (Anonymous, 2022) [1]. According to an estimate, India will have to produce at least 109 million tons of wheat by 2020 [2] AD to feed its 1.3 billion population. It contains about 70% carbohydrate, 12% protein, 1.7% fats, 2.7% minerals and 2% fiber. Madhya Pradesh is an equally important wheat-growing states of India. Madhya Pradesh occupied about 5001.5 thousand hectares under wheat in 2021-22. The total production of wheat was 13130.2 thousand tonnes in same year. The average yield of wheat in the State, in that year was 26.25 quintal per hectare. The recent data shows that Madhya Pradesh occupied more than 5000 thousand hectares under wheat in 2014-15 with total production was more than 13000 thousand tonnes and average yield was about 26.00 quintals per hectare (Anonymous, 2022) [1].

The irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper irrigation scheduling is essential for the efficient use of water, energy and other production inputs. Three major considerations influencing the irrigation schedule are: (a) the water needs of crop; (b) availability of water for irrigation; and (c) capacity of the root zone to store water. Water needs of crop are of paramount importance in determining the time of irrigation during the crop-growing season.

Water is a precious and scarce input that plays a vital role in assured crop production since it is essential for the maintenance to turgidity, absorption of nutrients and the metabolic process of the plants. Therefore, it becomes imperative to develop an optimum irrigation schedule to maintain sufficient available soil moisture throughout the crop period for the best exploitation of crop yield potential. Among the several recognized criteria of irrigation scheduling, the climatological approach is very scientific and widely accepted among scientists and research workers throughout the world. It is well known that evapotranspiration by a full crop cover is closely associated with evaporation from an open pan (Dastane, 1972) [3]. Parihar *et al.* (1976) [4] suggested a relatively more practical meteorological approach of IW/CPE, which is a ratio between a fixed amount of irrigation water (IW) and cumulative pan evaporation minus rains. This IW/CPE approach merits on account of its simplicity of operation and high water use efficiency. Therefore, the climatological approach of scheduling irrigation by evaluating different IW/CPE ratios in wheat crop has been proposed in this study. It is a fact that in future, less and less of water will be available for agriculture on account of increasing water demand for domestic, industrial and other purposes. It is estimated that even after achieving the full irrigation potential, nearly 50% of the total cultivated area will remain rain-fed (Vision, 2020) [2].

Irrigation scheduling is the process of determining the optimal timing and quantity of water to apply to crops, ensuring that they receive adequate moisture at each stage of their growth. It is particularly crucial in dryland farming systems or regions with unreliable rainfall patterns. For wheat (*Triticum aestivum*), an essential cereal crop grown worldwide, the role of irrigation scheduling in optimizing growth and maximizing

yield is critical. Proper irrigation management can significantly influence wheat productivity, grain quality, and resource use efficiency, especially in areas facing water scarcity.

Wheat, as a water-sensitive crop, requires careful irrigation management, especially during its reproductive stages (flowering and grain filling), where water stress can lead to considerable reductions in yield. The need for precise irrigation scheduling arises from the fact that both over-irrigation and under-irrigation can harm the crop. Over-irrigation leads to waterlogging, which can stunt root development and decrease oxygen availability in the soil, while under-irrigation leads to water stress, which negatively impacts physiological processes, grain formation, and ultimately, yield (Hossain *et al.*, 2021) [5].

Irrigation scheduling directly influences several key aspects of wheat growth and yield. Proper water management ensures that plants have access to sufficient moisture during critical growth phases, such as germination, tillering, heading, and grain filling. During these phases, water stress can lead to reduced tiller formation, decreased grain number, and smaller grain size, all of which result in lower yields (Gao *et al.*, 2020) [6].

Optimal irrigation practices, on the other hand, enhance water use efficiency (WUE) by ensuring that crops receive water only when necessary. This reduces water wastage, improves soil structure, and promotes healthy plant growth. Additionally, with rising concerns about climate change and limited freshwater resources, efficient irrigation scheduling helps conserve water while ensuring that wheat production remains sustainable and economically viable (Bouman *et al.*, 2020) [7].

Various methods for irrigation scheduling exist, including soil moisture-based scheduling, weather-based scheduling, and evapotranspiration (ET)-based scheduling. Soil moisture sensors are used to monitor the moisture levels in the soil and determine when irrigation is required, while weather-based scheduling uses local weather conditions to estimate the crop's water needs. The ET-based approach uses the crop's evapotranspiration rates to calculate irrigation requirements, offering an accurate way to meet the water needs of wheat at different growth stages (Allen *et al.*, 1998) [8].

Additionally, technologies such as drip irrigation and sprinkler systems, which deliver water directly to the root zone, are being used more widely in wheat farming to improve the precision of water application and reduce wastage (Wang *et al.*, 2020) [9]. Despite its importance, effective irrigation scheduling faces challenges, especially in areas with uncertain rainfall or poor soil-water retention capacity. Climate variability, such as unexpected droughts or excessive rainfall, can complicate scheduling decisions. Moreover, the cost of implementing advanced irrigation technologies, such as automated soil moisture sensors or evapotranspiration models, can be prohibitive for smallholder farmers (Tavakkol *et al.*, 2018) [10].

## Materials and Methods

The experiment was carried out at the Research farm of the Department of Agronomy, School of Agriculture Science, Technology & Research, Sardar Patel University, Balaghat (M.P.). The experiment was conducted in a randomised complete block design eight treatments with three replications. Different irrigation schedule will be allocated to the plots as per treatments. The seed rate used as 100 kg/ha for sowing with 22.5 × 10.0 cm row-to-row and plant-to-plant distance. The treatments were viz. (T1) CRI, (T2) CRI + T, (T3) CRI + T, (T4) CRI + J + F, (T5) CRI + T + M, (T6) CRI + T + F + M, (T7) CRI + T + J + F + M and (T8) CRI + T + J + F + M + D. The gross and net plot size was 5.00 m × 3.00 m and 4.00 m × 3.00 m, respectively. The irrigation was applied as per the treatments. All the other agronomic practices were applied uniformly to all the treatments. The experiment will consist of the following factors, along with their respective levels.

## Results and Discussion

Plant height increases progressively with increase in age up to 90 days with a slight decline thereafter. The abrupt increase in height from 30 to 90 DAS shows grand growth period of the crop. The different treatments of irrigation scheduling had not significantly influenced the plant height at 30 DAS. The plant height recorded at 60 DAS, 90 DAS, and at harvest was influenced significantly with increasing the irrigation schedules from one to six irrigations.

Irrigation scheduling could not show a significant effect on plant height during early stages but it produced a significant difference at later stages. Tallest plants were observed under Irrigation scheduling (T<sub>8</sub>) CRI + T + J + F + M + D which has significant difference with T<sub>7</sub> (CRI + T + J + F + M). The Irrigation scheduling i.e. (T<sub>1</sub>) CRI produced significantly shorter plants. Increase in plant height is a function of cell expansion and depends upon cell water potential. Significant increase in plant height brought by irrigation at (T<sub>8</sub>) CRI + T + J + F + M + D was due to optimum moisture supplies during the vegetative and reproductive phases which maintained good establishment of roots and various metabolic processes and resulted into profuse and vertical growth of the plants. The highest plant height could be attributed to the fact that due to proper supply of moisture which affects the solubility of nutrients resulted in increment of plant height. The finding were in close conformity with Deo *et al.* (2017) [11], Jat *et al.* (2015) [12], Dangar *et al.* (2017) [13] Nayak *et al.* (2015) [14], Kaur *et al.* (2016) [15].

Number of tillers per meter row length increases progressively with increase in age up to 90 days with a slight decline thereafter. The abrupt increase in number of tillers per meter row length from 30 to 90 DAS shows grand growth period of the crop. The different treatments of irrigation scheduling could not influence the number of tillers per meter row length at 30 DAS. The number of tillers per meter row length recorded at 60 DAS, 90 DAS, and at harvest was influenced significantly with increasing the irrigation schedules from one to six irrigations. Similar finding also reported by Shorna *et al.*, (2020) [16].

The Number of tillers (m<sup>-2</sup>) was influenced at 30 DAS due to various irrigation scheduling. This might be due to non-application of variable irrigation up to this stage. The higher number of tillers was found under irrigation T<sub>8</sub> (CRI + T + J + F + M + D) which was followed by with T<sub>7</sub> (CRI + T + J + F + M). This might be owing to adequate moisture level at all growth stages increases photosynthetic activities thereby increasing number of tillers. The result is near those of Saren *et al.* (2004) [17], Atikullah *et al.* (2014) [18] and Kumar *et al.* (2016) [19].

Number of leaves per plant increases progressively with increase in age up to 90 days with a slight decline thereafter. The abrupt increase in number of leaves per plant from 30 to 90 DAS shows grand growth period of the crop. The different treatments of irrigation scheduling could not influence the number of leaves per plant at 30 DAS. The number of leaves per plant recorded at 60 DAS, 90 DAS, and at harvest was influenced significantly with increasing the irrigation schedules from one to six irrigations. The results are in agreement with findings of Saren *et al.* (2004) [17], Brahma *et al.*, (2007) [20], Kumar *et al.*, (2016) [19], Kenedy *et al.* (2018) [21].

An examination of data showed at 45 DAS a positive effect of different irrigation scheduling applications on the fresh weight of plant. The irrigation scheduling increase significantly enhances the fresh weight of crops as compared to decreasing irrigation scheduling at these crop growth stages. The treatment combination consisting of T<sub>6</sub> (CRI + T + F + M) produced the fresh weight of plant (34.06 g), followed by T<sub>8</sub> (CRI + T + J + F + M + D) (33.00 g), as compared to all the remaining treatment combinations. The lowest fresh weight of plant (9.36 g) was noticed under only one irrigation application (at CRI stages), the T<sub>1</sub> treatment combination and dry weight of plant. The irrigation scheduling increase significantly enhances the dry weight of plant as compared to decreasing irrigation scheduling at these crop growth stages. The treatment combination consisting of T<sub>6</sub> (CRI + T + F + M) produced the highest dry weight of plant (7.45 g),

followed by T<sub>8</sub> (CRI + T + J + F + M + D) (7.28 g), as compared to all the remaining treatment combinations. The lowest dry weight of plant (1.76 g) was noticed under only one irrigation application (at CRI stages), the T<sub>1</sub> treatment combination. This might be due to increase in plant height and uptake of nutrients through maintaining adequate moisture supply. All these contributed for full turgidity and opened leaves, which increased the photosynthetic activity of crops, resulting higher dry matter accumulation. The lowest dry matter accumulation might be due to lack of desired moisture, which resulted in reduced plant height and led to reduced photosynthetic activity which ultimately reflected in lowest dry matter accumulation. These results with response of moisture regimes was also reported by Deo *et al.* (2017) [11], Jat *et al.* (2015) [12], Dangar *et al.* (2017) [13], Chouhan *et al.* (2017) [22] and Kumar *et al.* (2018) [23].

Yield attributes are the function of vegetative development. The major yield attributing characters, which determine the yield in wheat are number of spikes (m<sup>-2</sup>), length of spike, number of grains spike<sup>-1</sup> and test weight. The highest values of all yield attributes were obtained under irrigation scheduling at T<sub>8</sub> (CRI + T + J + F + M + D) which followed by at (T<sub>7</sub>) CRI + T + J + F + M during investigation. This might be the outcome of maintained adequate moisture in the root zone throughout the crop growth period that maintained the chlorophyll content in leaves of plant and crop remained green for longer period of time.

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest length of spike of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on length of spike of wheat. The highest length of spike (18.08 cm) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M which was significantly better than T<sub>1</sub> (at CRI stages, 10.77 cm). Similar result has also been reported by Rehman *et al.* (2000) [24], Dangar *et al.* (2017) [13], Kumar *et al.* (2018) [23].

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest Number of grains/spike of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on Number of grains/spike of wheat. The highest Number of grains/spike (40.27 cm) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (38.06) which was significantly better than T<sub>1</sub> (at CRI stages, 29.59 cm).

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest test weight of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on test weight of wheat. The highest test weight (44.86 g) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (44.07 g) which was significantly better than T<sub>1</sub> (at CRI stages, 34.80 g). Higher weight of grains per ear is attributed mainly to higher number of grains per ear and 1000 grain weight. These findings are in agreement with Singh *et al.* (1980) [25].

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest Grain yield per ha of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on Grain yield per ha of wheat. The highest Grain yield per ha (46.78 q/ha) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (35.61 q/ha) which was significantly better than T<sub>1</sub> (at CRI stages, 16.50 q/ha). These results are in agreement with the results of Watson *et al.* (1958) [26] and Krishnamurthy *et al.* (1973) [27]. More accumulation of dry matter in leaves help the photosynthetic area to remain active for longer period and is responsible for overall growth of plant.

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest Straw yield per hectare of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on Straw yield per hectare of wheat. The highest Straw yield per hectare (56.25 q/ha) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (48.35 q/ha) which was significantly better than T<sub>1</sub> (at CRI stages, 36.05 q/ha). Similar research finding were also reported by Khatri *et al.* (2002) [28], Nadeem *et al.* (2007) [29] and Behera *et al.* (2014) [30].

Based on application of irrigation schedule at (T<sub>8</sub>) CRI + T + J + F + M + D produced significantly highest protein content of wheat. An examination of data showed positive effect of different irrigation schedule in combination with growth stages on protein content of wheat. The highest protein content (10.69 %) was recorded with the application of treatment, (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (10.39 %) which was significantly better than T<sub>1</sub> (at CRI stages, 7.22 %).

The perusal data revealed that highest B:C ratio (3.25:1) was recorded under different irrigation scheduling treatment (T<sub>8</sub>) CRI + T + J + F + M + D followed by (T<sub>7</sub>) CRI + T + J + F + M (2.37:1), while it was minimum (0.57:1) with T<sub>1</sub> (at CRI stages). These finding are well supported by Jat *et al.* (2015) [12], Singh *et al.* (2012) [31], Tripathi *et al.* (2012) [32] and Yadav *et al.* (2014) [33].

## Conclusion

The study concluded that six irrigations scheduled at CRI, tillering, jointing, flowering, milking, and dough stages (T<sub>8</sub>) significantly enhanced wheat growth and yield, with the highest grain yield recorded at 46.78 q/ha. To strengthen these findings, future research should focus on validating this irrigation strategy across diverse agro-climatic zones and under varying soil and weather conditions. Incorporating economic analyses will help determine the cost-effectiveness of the six-irrigation approach compared to reduced schedules. Additionally, the integration of precision irrigation methods such as drip or sensor-based systems could enhance water use efficiency without compromising yield. Further studies examining the interactions between irrigation timing, fertilizer regimes, and wheat genotypes may refine best practices. Lastly, considering the impacts of climate change is essential to assess the long-term viability and sustainability of intensive irrigation strategies.

**Table 1.** Influence of irrigation scheduling on growth and yield of Wheat (*Triticum aestivum* L.)

| Treatment               | Plant height (cm) | Number of tillers/m <sup>2</sup> | Number of leaves per plant | Fresh weight of plant (g) | Dry weight of plant (g) | Length of spike (cm) | Number of grains/spike | Test weight (g) | Grain yield per hectare (q/ha) | Harvest index (%) | Protein content (%) | B: C ratio |
|-------------------------|-------------------|----------------------------------|----------------------------|---------------------------|-------------------------|----------------------|------------------------|-----------------|--------------------------------|-------------------|---------------------|------------|
| CRI                     | 70.48             | 65.02                            | 34.67                      | 9.36                      | 1.76                    | 10.77                | 29.59                  | 34.80           | 16.50                          | 26.75             | 7.22                | 0.57       |
| CRI + T                 | 76.37             | 93.67                            | 42.01                      | 31.51                     | 6.99                    | 13.10                | 34.24                  | 36.85           | 18.61                          | 31.57             | 8.91                | 0.97       |
| CRI + F                 | 78.47             | 116.60                           | 50.80                      | 18.67                     | 2.13                    | 14.68                | 36.00                  | 40.20           | 24.50                          | 36.28             | 9.21                | 1.49       |
| CRI + J + F             | 82.06             | 121.21                           | 53.91                      | 18.67                     | 2.25                    | 15.45                | 37.33                  | 41.91           | 26.17                          | 36.31             | 9.90                | 1.66       |
| CRI + T + M             | 82.06             | 126.87                           | 54.73                      | 30.40                     | 7.05                    | 15.61                | 37.50                  | 42.50           | 32.56                          | 41.44             | 10.08               | 2.17       |
| CRI + T + F + M         | 82.86             | 129.93                           | 56.27                      | 34.06                     | 7.45                    | 15.62                | 37.56                  | 43.67           | 33.36                          | 41.42             | 10.17               | 2.21       |
| CRI + T + J + F + M     | 83.67             | 138.33                           | 57.80                      | 32.50                     | 6.89                    | 16.22                | 38.06                  | 44.07           | 35.61                          | 42.15             | 10.39               | 2.37       |
| CRI + T + J + F + M + D | 86.49             | 163.53                           | 64.00                      | 33.00                     | 7.28                    | 18.08                | 40.27                  | 44.86           | 46.78                          | 45.04             | 10.69               | 3.25       |
| S. Em±                  | 1.14              | 3.58                             | 0.99                       | 1.69                      | 0.55                    | 0.61                 | 1.06                   | 1.25            | 3.37                           | 2.52              | 0.39                | -          |
| C.D. (P = 0.05)         | 3.33              | 10.44                            | 2.90                       | 5.13                      | 1.66                    | 1.78                 | 3.10                   | 3.64            | 9.84                           | 7.34              | 1.18                | -          |

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