OPTIMIZATION OF IRRIGATION SCHEDULING ON THE BASIS OF IW/CPE RATIOS FOR WHEAT

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ABSTRACT
The research was conducted at the Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to optimize different IW/CPE irrigation schedules with optimum water use efficiency of wheat crop (variety AKAW-4627). The experiment was carried out in 2011-12 and 2012-13 during December to March in randomized block design with five irrigation treatments and four replications. Treatments includes irrigation at IW/CPE ratios at 0.6 (I1), 0.8 (I2), 1.0 (I3), 1.2 (I4) and Control treatment with six irrigations at critical growth stages of wheat (I5). Irrigation scheduling at IW/CPE=1.2 (I4) recorded significantly highest grain yield 39.37 q/ha and 39.44 q/ha in 2011-12 and 2012-13 respectively compared to rest of treatment. Water use efficiency recorded in treatment I4, i.e. 0.67 q/ha-cm and 0.83 q/ha-cm in 2011-12 and 2012-13 respectively was found optimum as compared to I1, I2, I3 and I5. The results showed that maximum yield of wheat was obtained in treatment I4 (IW/CPE = 1.0) i.e. 37.89 q/ha and 37.9 q/ha in 2011-12 and 2012-13 respectively compared to rest of treatment with only average marginal yield reduction 1.51 q/ha in both yearunder 12.11% water saving irrigation strategy over control treatment.

INTRODUCTION
As water for irrigation is a scare resource, its optimization is fundamental to water resource use. It permits better utilization of all other production factors and thus leads to increased yields per unit area and time. The objective of irrigation is to maintain the soil moisture at optimum levels in the plant root zone, so that root will have a constant supply of moisture with adequate aeration. Efficient water management requires a thorough study of plant-water relationship, climate, agronomic practices and economic assessment.

About 75 to 80% of the available freshwater resource in many parts of the world is used for agriculture. Global population by 2025 will likely increase to 7.9 billion, more than 80 % of people will live in developing countries (Singh, 2012). Around 36% of the 2025 world population is projected to be living in India and China alone (Dam and Malik, 2003). Management practices for conservation of water have been increasingly emphasized because of scare natural precipitation, high evapotranspiration and excessive depletion of limited ground water resources. The irrigated area should be increased by more than 20% and the irrigated crop yield should be increased by 40% by 2025 to secure the food for 8 billion people (Lascano and Sojka, 2007). Thus, an assessment of the potential for reducing water needs and increasing production is the need of time. The higher requirement of food to feed the increased population with reduced water availability for crop production forces the irrigation researchers and managers to use water-saving irrigation strategies to improve the water productivity (WP) in recent years.

Wheat is one of the most important cereal crops of the world on account of its wide adaptability to different agro-climatic and soil conditions. Among major cereals, wheat ranks first in area and production at the global level and it is the staple food of nearly 35 per cent of the world population. Wheat is the leading source of protein in human food, having higher protein content than either maize (corn) or rice and the other major cereals. Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles, couscous and for fermentation to make beer, other alcoholic beverages or biofuel. The area, production and yield of wheat in India in year 2011-12 is 29.5 m-ha, 93.9 m-tones and 31.86 q/ha, respectively. The area, production and yield of wheat in Maharashtra in year 2011-12 was 0.88 m-ha, 1.5 m-tones and 17.07 q/ha, respectively. However in Vidarbha, area and production of wheat was 0.23 m-ha and 0.35 m-tones respectively with yield of 15.47 q/ha, during 2011-2012. Thus productivity of wheat in Vidarbha is lower than its potential yield.

Irrigation scheduling is the systematic method by which producer can decide on when to irrigate and how much water to apply. The goal of effective scheduling programs is to supply the plants with sufficient water while minimizing losses to deep percolation or runoff. Mandal and Roy (2012) observed in pulse crops extremely vulnerable to climate factors viz. temperature, humidity, rainfall and photoperiod at flowering stage. Therefore for irrigation scheduling many techniques are present, among them in climatological approach the amount of water lost by evapotranspiration is estimated from climatological data. Evapotranspiration is the sum of...
evaporation and plant transpiration. Evaporation is the process whereby liquid water is converted into water vapor from evaporating surface while in transpiration, vaporization of liquid water contained in plant tissues (Meena H. M. et al., 2015). When ET reaches in a particular level, irrigation is scheduled. The amount of irrigation given is either equal to ET or fraction of ET. Different methods of climatic approaches are IW/CPE ratio method and pan evaporation method. In IW/CPE approach, known amount of irrigation water is applied when cumulative pan evaporation reaches predetermined level (Ahlawat and Gongaiah, 2010).

The Mohammad Neem et al. (2002) concluded that irrigation scheduling was done on the basis of cumulative pan evaporation (CPE) wheat grain at seed rates of 100:125 and 150 kg/ha was irrigated using IW:CPE ratio of 0.70, 0.90, 1.10 and 1.3. It inferred that to obtained the maximum production of wheat it should be sown at the rate of 125 kg/ha and should be irrigated at IW:CPE ratio of 0.9. Kumar et al. (2009) studied that feasibility of using micro-sprinkler drip irrigation system for vegetable production in a canal command area. These systems were compared with the existing flood irrigation method for onion production with four irrigation levels viz., 0.60, 0.80, 1.00 and 1.20 of irrigation water to cumulative pan evaporation ratio (IW/CPE). Microirrigation systems resulted in higher onion yield and greater profitability than surface irrigation at each irrigation schedule. However microsprinkler indicated better economics than a drip irrigation system. Microirrigation, drip and surface irrigation system with 1.20 IW/CPE of irrigation produced maximum crop yields of 34.34, 33.10 and 22.57 t ha⁻¹, respectively.

Alam et al. (2010) conducted an experiment to determine the appropriate irrigation schedule for carrot production in hill valley. The experiment consisted of five treatments of irrigation after plant establishment viz., no irrigation (I₀), irrigation at IW:CPE of 0.6 (I₁), irrigation at IW:CPE of 0.8 (I₂), irrigation at IW:CPE of 1.0 (I₃) and irrigation at IW:CPE of 1.2 (I₄). The amount of irrigation water (IW) was fixed at 4 cm. The experiment was laid out in RCBD with 3 replications. The treatments significantly influenced the growth, yield contributing characters and yield of carrot. Among the treatments, irrigation at IW: CPE of 1.2 gave the maximum yield (51.47 t/ha) which received 4 irrigations. Irrigation water use efficiency was obtained 1705.63 kg/ha/cm by this treatment.

Thus irrigation scheduling provides information to the managers to develop irrigation strategies for each plot of field on the farm. Keeping these point in view experiment was conducted to determine irrigation water requirement and the productivity response of wheat under different irrigation schedules.

MATERIALS AND METHODS

Experimental site

The experiment was laid out on the farm of Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during rabi season of 2011-12 and 2012-13. Akola is situated at the latitude of 20° 42’ North and longitude of 77° 02’ East. Altitude of the place is 307.41 m above the mean sea level. The climate of Akola is subtropical semi-arid. The meteorological data during the period of experimentation was obtained from Agro-Meteorological Observatory, Dr. P.D.K.V., Akola. Physico-chemical properties of soil at experimental site were presented in Table 1.

Experimental details

The field experiment was laid out in randomized block design, with four replications and five treatments. In four treatments out of five, irrigation was scheduled on the basis of various IW/CPE ratios like 0.6, 0.8, 1 and 1.2 respectively. (Parihar and Tiwari, 2003) and in one control treatment irrigation was scheduled at Crown Root Initiation (CRI), Maximum Tilling, Late Jointing, Flowering, Milking Stage and Dough Stage. (Choudhary and Kumar, 2004) Recommended fertilizer dose 80:40:40 (N:P:K) were applied by broadcasting method. Pest and disease control by chemical was carried out as per requirement. During the weeding, soil earthing up was done for the development of plant roots and breaking of crust formed during the irrigation.

Details of Irrigation scheduling

Flood irrigation was applied in all plots, water was conveyed through pipeline and measured quantity of water was applied using water meter. For the purpose of irrigation scheduling the irrigation in various treatments, predetermined soil moisture constants were used. Following equations were used for irrigation scheduling. The total available water was calculated using following formulae described in book of Irrigation Theory and Practices. (Michael A.M. 1983)

\[ TAW = \frac{FC - PWP}{100} Z_r 1000 \]

Where,

\[ TAW = \text{Total Irrigation water, (mm)} \]
\[ \theta_c = \text{Moisture content at field capacity, (%)} \]
\[ \theta_{pwp} = \text{Moisture content at Permanent wilting point,()}\]
\[ \gamma = \text{Bulk density, (gm/cm}^3)\]
\[ Z_r = \text{Effective root zone depth, (m)} \]

Using soil moisture constants, firstly available irrigation water was determined for the experimental soil. For the purpose depth of effective root zone was taken 60 cm for wheat crop.

Depth of irrigation (IW)

After determining TAW, depth of irrigation was determined considering the maximum allowable depletion of 50 percent and using following equation 2 (Michael A.M. 1983).

\[ IW = 0.50 \times TAW \]

Where,

\[ IW= \text{Depth of irrigation to be applied in one irrigation, (mm)} \]

Cumulative pan evaporation (CPE)

For this purpose cumulative pan evaporation for respective treatments of IW/CPE ratios were determined using predetermined IW and values of ratios by using following equation 3 (Michael A.M. 1983).

\[ CPE = \frac{IW}{\text{Ratio}} \]

Pan evaporation data were recorded daily and cumulative
figures were calculated subtracting the rainfall. Total available water (TAW) was determined using soil moisture constants of the soil. Depth of irrigation water (IW) per irrigation was calculated considering 50% maximum allowable depletion. Then cumulative pan evaporation (CPE) at predetermined IW and at different IW/CPE ratios, were calculated. Accordingly irrigation scheduling details were calculated and are given in Table 2.

**Irrigation Scheduling in Control Treatment**

In control treatment, six irrigations were scheduled at six critical growth stages of wheat crop, viz. Crown Root Initiation (CRI), Maximum Tillering, Late Jointing, Flowering, Milking Stage and Dough Stage. In this treatment, depth of irrigation was determined by observing actual soil moisture before every irrigation.

**Water use efficiency (WUE)**

Water use efficiency (WUE) was estimated by dividing the yield (kg/ha) with the amount of water consumed by the crop (i.e. Crop evapotranspiration or crop water use, mm) during its growth period under different treatment of irrigation. Water use efficiency in different irrigation treatments was calculated by the equation 4 (Michael A.M. 1983).

\[ WUE = \frac{Y}{WR} \]

Where,

\[ WUE = \text{Water use efficiency, (kg/ha-cm)} \]
\[ Y = \text{Grain yield, (kg)} \]

**RESULTS AND DISCUSSION**

**Crop growth stage wise water requirement of wheat**

Irrigation water was conveyed through pipe and water meter was used to apply the measured amount of water at each irrigation. It is seen from Table 3 that in case of treatments I₁, I₂, & I₃; irrigations were scheduled in all growth stages, whereas in case treatment I₄; irrigation was not scheduled during maximum tillering stage. Similarly in case of treatment I₅; irrigation was not scheduled during three growth stages i.e. maximum tillering, flowering and dough stage. It shows that treatments I₁ and I₂ has low yield but high water saving as compared to rest of the treatments.

**Total water requirement of wheat**

Total water requirement and saving of water as influenced by different treatments was presented in Table 4. It was clear that total water requirement of wheat was found to be highest 640 mm in 2011-12 under irrigation scheduling at IW/CPE=1.2 (I₄) even 6% more than control treatment followed by I₅ (Control) (606.4 mm), I₃ (IW/CPE=1.0) (565 mm) and I₂ (IW/CPE=0.8) (490 mm). In next year 2012-13 it was 552.5 mm under irrigation scheduling at (I₅) Control treatment followed by I₄ (IW/CPE=1.2) (532.5 mm), I₃ (IW/CPE=1.0) (490 mm) and I₂ (IW/CPE=0.8) (382.5 mm). It was found to be lowest 340 mm and 307.5 mm respectively at 2011-12 and 2012-13 under irrigation scheduling at IW/CPE=0.6 (I₁). Hence highest saving of water over control treatment was achieved in

<table>
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<tr>
<th>Table 1: Physico-chemical properties of soil at experimental site</th>
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<tr>
<td>Soil depth cm</td>
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<td>0-60</td>
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<th>Table 2: Irrigation scheduling details</th>
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<td>Sr. No.</td>
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<th>Table 3: Crop growth stage wise water requirement</th>
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<td>Sr.No. Crop growth stage</td>
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<tr>
<td>1 After sowing</td>
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<td>2 Crown root Initiation (14 DAS)</td>
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<td>3 Maximum tillering(28 DAS)</td>
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<td>4 Late Jointing (36 DAS)</td>
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<td>5 Flowering (57 DAS)</td>
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<td>6 Milking stage (75 DAS)</td>
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<td>7 Dough stage (82 DAS)</td>
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<td>8 Seasonal water requirement</td>
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WR = Total water requirement, (ha-cm)
Yield and Water Use Efficiency

In both years, irrigation treatments significantly affected the wheat yield and Water Use Efficiency (Sarwar et al., 2010) and yield parameter were presented in Figure 1. Significantly highest average wheat grain yield and straw yield in both year was obtained under treatment I4 (IW/CPE=1.2) i.e. 39.41q/ha and 89.83 q/ha respectively and found to be superior over rest of the treatments. Same treatment were superior in paddy crop results obtained by Maheshwari et al. (2007), Treatment I1 (IW/CPE=0.6) recorded significantly lowest average grain and straw yield i.e. 28.08 q/ha and 71.75 q/ha respectively as compared to all other treatments.

As figure 2 shows that in year 2011-12 highest Water Use Efficiency 0.89 q/ha-cm was recorded in treatment I1, which may be due to lowest water use, followed by treatments I2, I3, I4. However, lowest WUE 0.58 q/ha-cm was recorded in treatment I5 (Control). This may be due that the consumptive use in case of treatment I1 was lowest and whereas it was highest in case of treatment I5. It is also seen that water use in treatment I4 was more than treatment I5, still water use efficiency in I4 was more than I5. It may be due to higher grain yield recorded in treatment I4 as compared to treatment I5.

In next year 2012-13 highest water use efficiency 0.88 q/ha-cm was recorded in treatment I4, which may be due to lowest water use, followed by treatments I1, I2, I3. However, lowest WUE 0.62 q/ha-cm was recorded in treatment I5 (Control). This may be due to that, the consumptive use in case of treatment I1 was lowest and whereas it was highest in case of treatment I1. It is also seen that water use in treatment I4 was negligibly less than treatment I5, still water use efficiency in I4 was more than I5. It may be due to higher grain yield recorded in treatment I4 as compared to treatment I5.

References


