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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 (I_1), 0.8 (I_2), 1.0 (I_3), 1.2 (I_4) and Control treatment with six irrigations at critical growth stages of wheat (I_5). Irrigation scheduling at IW/CPE = 1.2 (I_4) 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 I_3i.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 I_1, I_2, I_4 and I_5. The results showed that themaximum yield of wheat was obtained in treatment I_3(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 evapotranpiration is estimated from climatological data.Evapotranspiration is the sum of evaporation and plant transpiration. Evaporationis the process whereby liquid water is converted into water vapour fromevaporating surface while in transpiration, vaporization of liquid water containedin 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 predetermine level (Ahlawat and Gongaiah, 2010).

The Mohammod 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. Microsprinkler, 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 established viz., no irrigation (I_0), irrigation at IW:CPE of 0.6 (I_1), irrigation at IW:CPE of 0.8 (I_2), irrigation at IW:CPE of 1.0 (I_3) and irrigation at IW:CPE of 1.2 (I_4). 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 points 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 20º 42' North and longitude of 77º 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 Tillering, 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)

$$TAW \quad \frac{FC \quad PWP}{100} \quad Z_r \quad 1000 \text{ ....(1)}$$

Where,

TAW = Total Irrigation water, (mm)

θ_{FC} = Moisture content at field capacity, (%)

θ_{pwp} = Moisture content at Permanent wilting point,(%)

γ = Bulk density, (gm/cm^3)

Z_r = 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 X TAW...(2)

Where,

IW- 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).

$$CPE = \frac{IW}{Ratio} \text{ ....(3)}$$

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).

$$WUE = \frac{Y}{WR} \quad \ldots (4)$$

Where,

WUE = Water use efficiency, (kg/ha-cm)

Y = Grain yield, (kg)

WR = Total water requirement, (ha-cm)

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 I_3, I_4 & I_5; irrigations were scheduled in all growth stages, whereas in case treatment I_2 irrigation was not scheduled during maximum tillering stage. Similarly in case of treatment I_1, irrigation was not scheduled during three growth stages i.e. maximum tillering, flowering and dough stage. It shows that treatments I_1 and I_2 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 (I_4) even 6% more than control treatment followed by I_5 (Control) (606.4 mm), I_3 (IW/CPE = 1.0) (565 mm) and I_2 (IW/CPE = 0.8) (490 mm). In next year 2012-13 it was 552.5 mm under irrigation scheduling at (I_5) Control treatment followed by I_4 (IW/CPE = 1.2) (532.5 mm), I_3 (IW/CPE = 1.0) (457.5 mm) and I_2 (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 (I_1). Hence highest saving of water over control treatment was achieved in

Table 1: Physico-chemical properties of soil at experimental site

Soil depth cm	Sand%	Silt %	Clay%	Textural class	Bulk density gcm^{-3}	Soil moisture constant (%)		Saturated moisture content, cm^{3}cm^{-3}	ECdS/m	pH
						FC	PWP			
0-60	14.8	33.7	51.5	Clay	1.18	38.25	17.21	0.40	0.77	7.78

Table 2: Irrigation scheduling details

Sr. No.	Particulars	Observation	
1	Total available water (TAW), mm		149
2	Depth of irrigation (IW), mm		75
3	Cumulative Pan Evaporation at which irrigation scheduled treatment wise (CPE), mm	I_1 (IW/CPE = 0.6)	125
		I_2 (IW/CPE = 0.8)	93.8
		I_3 (IW/CPE = 1.0)	75
		I_4 (IW/CPE = 1.2)	62.5

Table 3: Crop growth stage wise water requirement

Sr.No.	Crop growth stage	Water requirement under different irrigation scheduling									
		I_1		I_2		I_3		I_4		I_5	
		11-12	12-13	11-12	12-13	11-12	12-13	11-12	12-13	11-12	12-13
1	After sowing	115	82.5	115	82.5	115	82.5	115	82.5	115	82.5
2	Crown root Initiation (14 DAS)	75	-	75	-	75	-	75	-	64.8	60.1
3	Maximum tillering(28 DAS)	-	-	-	75	75	75	75	75	83.6	85.2
4	Late Jointing (36 DAS)	75	75	75	-	75	-	150	75	71.9	77.7
5	Flowering (57 DAS)	-	-	75	75	75	150	75	75	105.3	96.9
6	Milking stage (75 DAS)	75	75	75	75	75	75	75	150	100.8	93.7
7	Dough stage (82 DAS)	-	75	75	75	75	75	75	75	65	57
*	Seasonal water requirement	340	307.5	490	383.5	565	457.5	640	532.5	606.4	552.7

Table 4: Total water requirement of wheat

Treatment	Number of irrigations		Total water requirement (mm)		Saving of water over control treatment (%)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
I_1 (IW/CPE = 0.6)	3	3	340.0	307.5	44	44.36
I_2 (IW/CPE = 0.8)	5	4	490.0	382.5	19	30.79
I_3 (IW/CPE = 1.0)	6	5	565.0	457.5	7	17.22
I_4 (IW/CPE = 1.2)	7	6	640.0	532.5	(-) 6	3.67
I_5 (Control)	6	6	606.4	552.7		

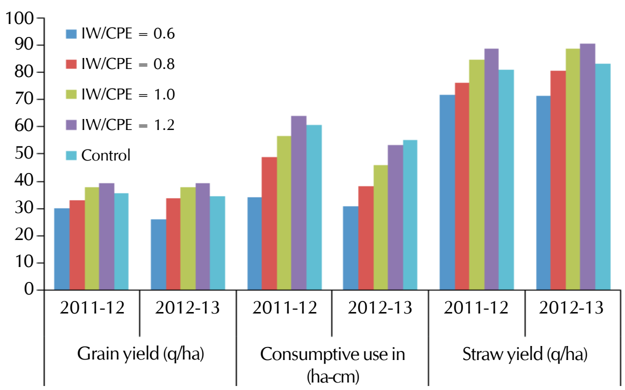

Figure 1: Yield observation of wheat influenced by different treatment

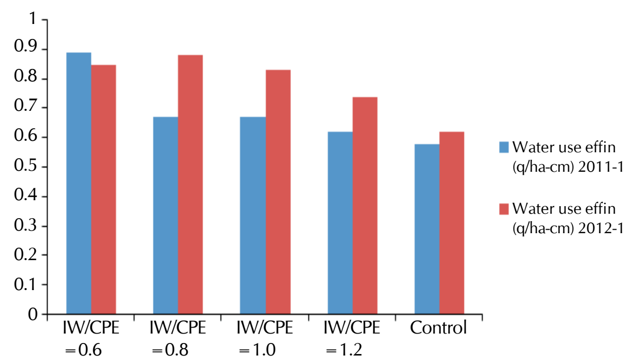

Figure 2: Treatmentwise water use efficiency

treatment I_1 *i.e.* 44 % and 44.36% respectively at 2011-12 and 2012-13.

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 Figure1.Significantly highest average wheat grain yield and straw yield in both year was obtained under treatment I_4 (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 I_1 (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 I_1, which may be due to lowest water use, followed by treatments I_2, I_3, I_4. However, lowest WUE 0.58 q/ha-cm was recorded in treatment I_5 (Control).This may be due that the consumptive use in case of treatment of I_1 was lowest and whereas it was highest in case of treatment I_4. It is also seen that water use in treatment I_4 was more than treatment I_5, still water use efficiency in I_4 was more than I_5. It may be due to higher grain yield recorded in treatment I_4 as compared to treatment I_5 i.e. control treatment.

In next year 2012-13 highest water use efficiency 0.88 q/ha-cm was recorded in treatment I_2, which may be due to lowest water use, followed by treatments I_1, I_3, I_4. However, lowest WUE 0.62 q/ha-cm was recorded in treatment I_5 (Control).This may be due to that, the consumptive use in case of treatment of I_1 was lowest and whereas it was highest in case of treatment I_5. It is also seen that water use in treatment I_4 was negligibly less than treatment I_5, still water use efficiency in I_4 was more than I_5. It may be due to higher grain yield recorded in treatment I_4 as compared to treatment I_5.

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PRINCIPLES OF IRRIGATION SCHEDULING.18 Crop water use .18 What drives crop water use? .Â x Understand the meaning of â€œirrigation efficiencyâ€ x Measure and record how evenly your irrigation system applies water. x Appreciate the benefits of irrigation scheduling and understand the. driving principles. 3 Irrigation Systems V3.doc 01/11/02.Â More detail on the methods for evaluating the various irrigation systems are provided in the following notes. 3 Irrigation Systems V3.doc 01/11/02. Page 17. Principles of irrigation scheduling. Crop water use. For given climatic conditions, crop water use depends on the type of crop and its stage of growth. Efficient water use depends on proper irrigation scheduling. Methods or approaches of irrigation scheduling are dependent on various inputs, and also have some limations. Appropriate scheduling method should be based on technology level available at the locality concerned, availability of inputs and socio-economic condition of the growers. This paper reviews the different approaches of irrigation scheduling. Pan evaporation, stage basis, deficit irrigation concept, ET basis, soil water potential, leaf water potential, stress day index, modelling approach, simple irrigation calendar approach, a The irrigation scheduling techniques fall in the general catego-ries of meteorological and physiological techniques. Meteorologi-cal approach of scheduling irrigation is relating the evapotrans-piration from crop to evaporation from an open pan, as it is well known that the rate of evapotranspiration is related to open pan evaporation. Cumulative pan cumulative pan evaporation and ra-tio between irrigation water and cumulative pan evaporation for scheduling have been used by researches as it is easy for farmers to use and is adoptable. Citation: Avadhesh Kumar Koshal., et al. â€œResponse of Toma Scheduling Irrigation. Water is an important natural resource, and we must do all we can to conserve it, especially as it becomes increasingly scarce. One step we can take is to be sure our irrigation systems are properly scheduled. But there is more to this than simply reduc-ing the watering time.Â Assuming the equipment is functioning correctly, letâ€™s consider the following factors to determine the optimum irrig-ation schedule: evapotranspira-tion rate, precipitation rate, effi-ciency and uniformity, re-stricted hours or days, crop co-efficient, soil texture, root depth, and unusual conditions. Evapotranspiration Rate. Evapotranspiration (ET) is a measure of how much moisture is lost to the atmosphere from plant and soil surfaces (how much they â€œsweatâ€) during the course of the day. Irrigation scheduling is the process used by irrigation system managers to determine the correct frequency and duration of watering. The following factors may be taken into consideration: Precipitation rate of the irrigation equipment â€“ how quickly the water is applied, often expressed in inches or mm per hour. Distribution uniformity of the irrigation system â€“ how uniformly the water is applied, expressed as a percentage, the higher the number, the more uniform.