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Study on Soil Moisture Depletion Pattern of Wheat Under Different IW/CPE Ratio

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Abstract

Wheat is one of the most important cereal crops and staple food of nearly 35 percent of the world population. In climatologically approaches, irrigation is scheduled on IW/CPE ratio. In IW/CPE approach, known amount of irrigation water is applied when cumulative pan evaporation reaches predetermined level. The experiment was conducted in randomized block design with irrigation scheduling on climatological approach i.e. on IW/CPE ratios of IW/CPE=0.6, IW/CPE=0.8, IW/CPE=1.0, IW/CPE=1.2 and control treatment with six irrigations at critical growth stages of wheat. Seasonal water requirement of wheat was found to be highest (570 mm) under irrigation scheduling at control treatment (I_4). Favorable soil moisture was maintained in the irrigation scheduling treatment of IW/CPE=1.2 (I_4) throughout the growing period and it was always maintained in allowable depletion regime. However, soil moisture was inadequate in irrigation scheduling at IW/CPE=0.6 (I_1). Highest water use efficiency was recorded in treatment I2 which may due to lowest water use, followed by I_3, I_4, I_1 and I_5.

Key words : Irrigation Scheduling, IW/CPE, Water requirement, Water use efficiency, Soil Moisture.

Wheat (*Triticum aestivum* L.) is the first important and strategic cereal crop for the majority of world's populations. Efficient water management requires a thorough study of plant water relationship, climate, agronomic practices and economic assessment. In Wheat, different growth stages such as crown root initiation, tillering, late jointing, boot flowering, milk and dough could be well delineated. Experiments conducted to study the important stages critical in their demand for water have clearly indicated that some stages can tolerate moisture stress to a certain extent. 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. Irrigation scheduling depends on soil, crop, atmospheric, irrigation systems and operational factors. Irrigation scheduling techniques can be based on soil water depletion approach, plant basis or plant indices, climatic approaches, critical growth stage approaches and plant water status itself. In soil water depletion approaches, the available soil moisture in the root zone is a good criterion for scheduling irrigation. When the soil moisture in a specified root zone depth is depleted to a particular level (which is different for different crops) it is too replenished by irrigation. In plant basis or plant indices, as the plant is the user of water, it can be taken as a guide for scheduling irrigation. In critical growth approaches, irrigation scheduling at growth stage of crop at which moisture stress level reaches to irrevocable yield loss. These stages are known as critical period or moisture sensitive period. In plant water status approaches, water content in plant itself is considered for scheduling irrigation however, it is yet common use for wants of standard low cost techniques. Whereas, in

1. and 2. Research Scholar.

climatological approaches, the amount of water lost by evapotranspiration is estimated from climatological data. 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. For practical purpose, irrigation should be started when allowable depletion of available moisture in the root zone reaches. The available water is soil moisture which lies between field capacity and permanent wilting point.

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 will be conducted to assess the water need of wheat crop throughout the growing season using different levels of IW/CPE ratio, by determining the irrigation interval, number of irrigations, moisture depletion pattern.

Materials and Methods

A field experiment on "Performance of wheat under different IW/CPE ratio" was conducted during winter of 2013-14 at the Farm of Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The climate of Akola is subtropical semi-arid characterized by three distinct seasons namely summer becoming hot and dry from March to May. The warm and rainy monsoon fall from June to Oct. and winter with mild cold from November to Feb. Akola is situated in the subtropical zone 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 and average annual precipitation is 750 mm The normal mean monthly maximum temperature during the hottest month (May) is 42°C while the normal mean monthly minimum temperature in the coldest month (December) is 10.7°C. The mean daily evaporation reaches as high as 19.0 mm in the month of May and as low as 3.00 mm in the month of August. The physical and chemical properties are determined are showed in Table 1.

Table 1. Mechanical-chemical composition of experimental soil

Particulars	Values	Analytical method used
A. Mechanical composition		
Sand (%)	14.78	Bouycous hydrometer method
Silt (%)	33.69	
Clay (%)	51.53	
Textured class	Clayey	
B. Chemical composition		
Soil organic carbon (%)	0.63	Walkyey and Black method
Available nitrogen (kg ha^{-1})	238.3	Modified Kjeldahl Method
Available phosphorus (kg ha^{-1})	14.6	Olsen's Method
Available potassium (kg ha^{-1})	266.0	Flame photometric
pH	7.84	Beckman's Glass electrode pH meter
EC (ds m^{-2})	0.77	Conductivity bridge from 1:2:5 soil water ratio
C. Single value soil moisture constant		
Bulk density (gm cm^{-3})	1.18	Core sampler method
Field Capacity (%)	38.25	Pressure plate and pressure membrane apparatus
Permanents wilting point (%)	17.21	Pressure plate and pressure membrane apparatus

Experimental details : The field experiment was laid out in randomized block design, with four replication and five treatments. In four treatments out of five, irrigation was scheduled on the basis of various IW/CPE ratios and in one control treatment irrigation was scheduled at critical growth stages of wheat. The details of treatments are given in Table 2.

Table 2. Treatment details

Treat.	Treatment details
I_1	IW/CPE ratio = 0.6
I_2	IW/CPE ratio = 0.8
I_3	IW/CPE ratio = 1.0
I_4	IW/CPE ratio = 1.2
I_5	Control with six irrigations at Crown Root Initiation (CRI), Maximum Tillering, Late Jointing, Flowering, Milking Stage and Dough Stage.

Table 3. Experimental details

Particulars	Specification
Crop	Wheat
Scientific name	*Triticum aestivum* L.
Variety	AKAW - 4627
Experimental design	Randomized Block Design
Number of replications	Four
Number of treatments	Five
Number of plots	20
Plot size	6m x 1.8m
Inter-space between replications per plots	2 m
Season	Winter 2012
Crop spacing	18 cm (row to row)
Seed rate	140 kg ha^{-1}
Recommended fertilizer dose	80:40:40 (N:P:K)
Date of sowing	14th December 2013
Date of harvesting	25th March 2014

Details of irrigation scheduling : For the purpose of irrigation scheduling the irrigation in various treatments, predetermined soil moisture constants were used. Following equations were used for irrigation scheduling.

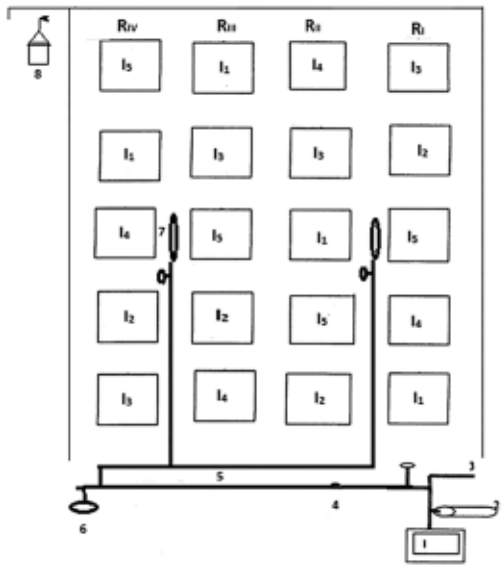

Fig. 1. Layout

Total available water (TAW) : Total available water is the amount of water that is available for plant use. It is actually the difference of soil moistures between field capacity and permanent wilting point. The total available water was calculated using following formulae.

$$TAW = \frac{\theta_{FC} - \theta_{PWP}}{100} \times \gamma \times Z_{\gamma} \times 1000 \quad ...(1)$$

where, TAW = Total available water, (mm), θ_{FC} = Moisture content at field capacity, (%), θ_{PWP} = Moisture content at Permanent wilting point, (%), γ = Bulk density, (gm cm^{-3}) and Z_{γ} = Effective root zone depth, (m).

Using soil moisture constants, firstly total available 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.

$$IW = 0.50 \times TAW \quad \ldots(2)$$

Where, IW = Depth of irrigation to be applied in one irrigation, (mm).

Cumulative pan evaporation (CPE) : Different moisture regimes were created by different irrigation schedules based on IW/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 2.3.

$$CPE = \frac{IW}{Ratio} \quad \ldots(3)$$

Pan evaporation data were recorded daily and cumulative figures were calculated subtracting the rainfall.

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 and using following equation 4.

$$TAW = \frac{\theta_{FC} - \theta_{BI}}{100} \times \gamma \times Z_{\gamma} \times 1000 \quad \ldots(4)$$

Where, IW = Irrigation water, (mm), θ_{FC} = Moisture content at field capacity, (%), θ_{BI} = Moisture content before irrigation, (%), γ = Bulk density, (gm cm^{-3}) and Z_{γ} = Effective root zone depth, (m).

First common irrigation was given to all treatments just after sowing to bring the experimental plots to field capacity. For this purpose soil moisture content was determined before sowing to calculate the depth of irrigation of first common irrigation. In all plots water was conveyed through pipeline and measured quantity of water was applied using water meter.

Result and Discussion

Soil Moisture depletion studies : Soil moisture observations were taken by gravimetric method before and after every irrigation, in each treatment to observe the moisture depletion pattern. The soil moisture depletion patterns of wheat as influenced by different irrigation scheduling treatment are discussed in this section.

Treatment I_1 : Soil moisture depletion observation are presented in Table 4 and pattern is depicted in Fig 2.

Table 4. Soil moisture depletion as influenced by treatment I_1

Days after sowing	Soil moisture (%) at depth				Average soil moisture content (%)	Depletion before next irrigation (%)
	0-15 cm	15-30 cm	30-45 cm	45-55 cm		
2	41.63	38.84	35.98	36.16	38.15	
30	27.29	24.94	24.41	22.47	24.78	64.02
33	39.34	36.72	34.95	28.95	34.99	
58	25.70	22.53	22.53	20.60	23.31	71.00
61	35.14	33.34	31.35	28.71	32.73	
80	24.45	23.05	21.40	19.96	22.15	76.52
84	36.93	34.22	32.54	29.21	33.23	

(FC=38.25%, PWP=17.21%, MAD=27.73%)

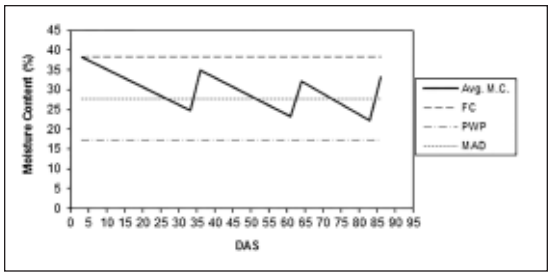

Fig. 2. Soil moisture depletion pattern as influenced by treatmen I_1.

It is seen from Table 4 that soil moisture depletion before each irrigation in treatment I1 was more than 50%, which shows the inadequacy of moisture available to crop. It is also observed from Fig. 1 that soil moisture was inadequate in treatment I_1, as it was depleted below maximum allowable depletion level before each irrigation. Therefore sufficient amount of soil moisture was not maintained throughout of growing period of wheat crop.

Treatment I_2 : Soil moisture depletion observations in respect of treatment I_2 are presented in Table 5 and pattern is depicted in Fig 3.

It is seen from Table 5. that soil moisture depletions before three irrigation in treatment (I2) were depleted slightly below maximum allowable depletion, which shows the inadequacy of soil moisture in later stages of crop.

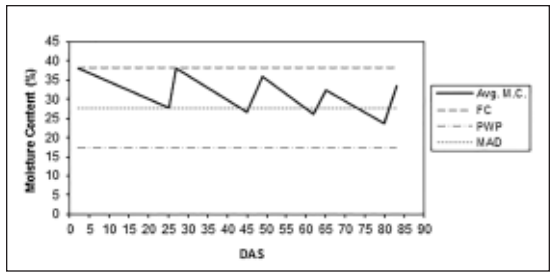

Fig. 3. Soil moisture depletion pattern as influenced by treatment I_2.

Treatment I_3 : Soil moisture depletion observations in respect of treatment I_3 are presented in Table 6. and pattern is depicted in Fig 4.

It is seen from Table 6 that soil moistures before three irrigation in treatment I_3 were slightly depleted moisture allowable depletion limit i.e. 50 % which shows favourable soil moisture was maintained throughout the growing season of crop. It is seen from Fig 4. that favourable soil moisture was maintained in treatment I_3 before two irrigation as the depletion of moisture were within allowable limit.

Table 5. Soil moisture depletion as influenced by treatment I_2

Days after sowing	Soil moisture (%) at depth				Average soil moisture content (%)	Depletion before next irrigation (%)
	0-15 cm	15-30 cm	30-45 cm	45-55 cm		
3	41.63	38.85	35.98	36.17	38.16	
25	31.25	28.88	26.32	27.77	27.77	49.80
27	41.54	39.45	37.09	33.58	37.91	
45	29.53	27.42	25.42	24.35	26.68	54.99
49	40.39	37.66	37.66	31.02	35.88	
62	29.38	27.32	24.68	22.62	26.00	58.22
65	36.02	33.76	30.83	28.64	32.31	
80	26.38	24.47	22.53	20.09	23.59	69.67
83	38.73	35.13	31.80	27.84	33.37	

(FC=38.25%, PWP=17.21%, MAD=27.73%)

Table 6. Soil moisture depletion as influenced by treatment I_3

Days after sowing	Soil moisture (%) at depth				Average soil moisture content (%)	Depletion before next irrigation (%)
	0-15 cm	15-30 cm	30-45 cm	45-55 cm		
2	41.63	38.85	35.98	36.17	38.16	
20	31.84	27.43	27.79	25.46	28.13	48.09
23	42.86	39.05	36.98	33.34	38.01	
38	30.07	28.54	26.64	25.51	27.69	50.19
41	41.44	38.73	36.29	33.22	37.42	
53	30.35	28.43	26.57	25.07	27.60	50.61
56	41.90	38.93	36.30	34.48	37.90	
66	30.44	28.54	26.54	24.43	27.44	51.37
69	42.36	38.99	36.29	34.14	37.95	
80	31.46	28.97	27.40	25.79	28.40	46.81
83	40.95	38.45	36.01	33.10	37.13	

(FC=38.25%, PWP=17.21%, MAD=27.73%)

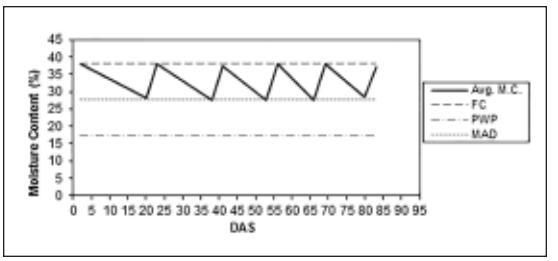

Fig. 4. Soil moisture depletion pattern as influenced by treatment I_3.

It is seen from Table 5 that soil moistures before three irrigation in treatment I_3 were slightly depleted moisture allowable depletion limit i.e. 50% which shows favourable soil moisture was maintained throughout the growing season of crop. It is seen from Fig 4. that favourable soil moisture was maintained in treatment I_3 before two irrigation as the depletion of moisture were within allowable limit.

Treatment I_4 : Soil moisture depletion observations in respect of treatment I_4 are presented in Table 7 and pattern is depicted in Fig 5.

It is observed from Table 7 that soil moisture depletions before each irrigation in treatment I_4 were always less than maximum allowable depletion that shows the adequacy of soil moisture throughout the growing season of crop

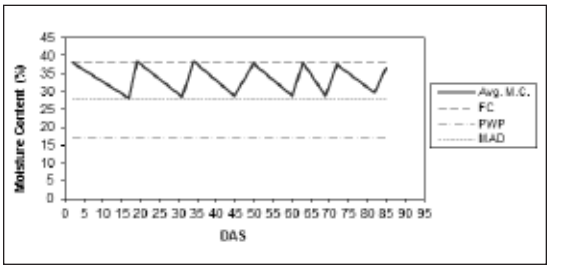

Fig. 5. Soil moisture depletion pattern as influenced by treatment I_4.

Treatment I_5 : Soil moisture depletion observations in respect of treatment I_5 are presented in Table 8 and pattern is depicted in Fig 6.

It is seen from Table 8 that, in control treatment I5, soil moisture was depleted below maximum allowable limit i.e. 50% before four irrigations. It may be due to that the interval of these stages of crop were more enough to deplet

Table 7. Soil moisture depletion as influenced by treatment I_4

Days after sowing	Soil moisture (%) at depth				Average soil moisture content (%)	Depletion before next irrigation (%)
	0-15 cm	15-30 cm	30-45 cm	45-55 cm		
2	41.63	38.85	35.98	36.17	38.16	
17	30.64	28.82	27.41	25.63	28.13	48.09
19	41.27	39.42	37.70	35.52	38.47	
31	31.21	29.61	27.62	25.31	28.44	46.62
34	41.97	39.53	37.04	34.62	38.29	
45	31.84	29.61	27.47	26.37	28.82	44.81
50	41.90	39.04	36.33	33.95	37.81	
60	31.82	29.71	27.48	26.37	28.84	44.72
63	41.94	39.05	37.10	33.82	37.98	
69	31.90	29.76	28.00	26.09	28.94	44.24
72	42.13	39.26	36.58	32.44	37.60	
82	33.36	30.46	28.54	26.11	29.62	41.01
85	41.07	38.34	35.36	31.71	36.62	

(FC=38.25%, PWP=17.21%, MAD=27.73%)

Table 8. Soil moisture depletion as influenced by treatment I_5

Days after sowing	Soil moisture (%) at depth				Average soil moisture content (%)	Depletion before next irrigation (%)
	0-15 cm	15-30 cm	30-45 cm	45-55 cm		
3	41.63	38.85	35.98	36.17	38.16	
12	31.20	24.27	29.51	28.66	28.41	46.76
16	42.07	38.83	35.03	32.06	37.00	
26	30.21	27.82	26.42	23.95	27.10	52.99
31	43.18	39.70	36.43	32.03	37.83	
34	33.85	31.13	28.73	26.58	30.07	38.87
39	43.69	40.43	37.73	34.48	39.08	
55	29.01	26.90	24.57	21.72	25.55	60.36
60	39.94	37.11	34.25	30.73	35.51	
73	30.90	28.64	26.56	23.87	27.49	51.14
77	41.01	38.18	35.53	31.93	36.66	
80	30.65	28.56	26.46	24.37	27.51	51.04
84	41.82	38.73	34.85	31.29	36.67	

(FC=38.25%, PWP=17.21%, MAD=27.73%)

the soil moisture below allowable limit. Fig 6. shows that in control treatment I_5, soil moisture depleted below allowable depletion before four irrigation.

Summary and Conclusions

Favorable soil moisture was maintained in the irrigation scheduling treatments of IW/CPE=1.2 (I_4) throughout the growing period and it was always maintained in allowable

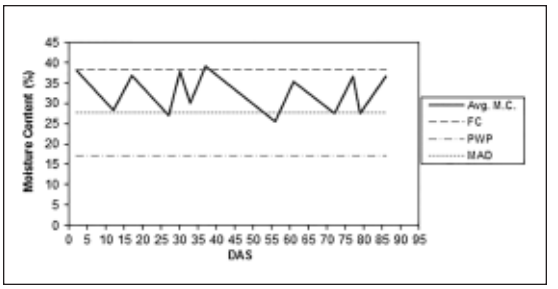

Fig. 6. Soil moisture depletion pattern as influenced by treatment I_5.

depletion regime. However, soil moisture was inadequate in irrigation scheduling at IW/CPE=0.6 (I_1). Whereas in irrigation scheduling treatments I_2 and I_5, soil moistures were slightly depleted below allowable limit.

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