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RESEARCH ARTICLE :

Water use efficiency, consumptive use and soil moisture extraction pattern of wheat as influenced by irrigation schedules and genotypes

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SUMMARY : An investigation was carried out to study the effect of irrigation schedules and wheat (*Triticum aestivum* L.) genotypes on yield, consumptive use of water, soil moisture depletion pattern and water use efficiency at the University of Agricultural Sciences, Dharwad (Karnataka) in the year 2001-02. The design of the experiment was split plot with three replications. The wheat crop irrigated six times (I_7 irrigation schedule) recorded significantly highest grain yield (2669 kg ha^{-1}) compared to other irrigation schedules. Among the wheat genotypes, DWR-1006 (durum wheat) recorded significantly higher yield (2390 kg ha^{-1}) as compared to DWR-162 (aestivum wheat). The maximum consumptive use (485.5 mm) was found with frequently irrigated treatment (I_7) while the least consumptive use was registered with I_1 irrigation schedule. Similarly, among the different wheat genotypes, DWR-1006 showed higher consumptive use of water (335.1 mm). The maximum water use efficiency was found with I_2 irrigation schedule and with DWR-162. Wheat is a surface feeder, the maximum amount of moisture was depleted in shallow depth than deeper layer of soil.

KEY WORDS :
Water use efficiency, Consumptive use, Soil moisture depletion pattern, Irrigation schedule, Wheat genotypes

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BACKGROUND AND OBJECTIVES

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops of the world on account of its wide adaptability to agroclimatic conditions and different soil. Among major cereals, wheat ranks first in area and production at the global level and it contributes more calories and proteins to the world's human diet than any other cereals. It is the main staple food of nearly 35 per cent of the world population. In India, wheat is the second most important food crops, next only to rice. Water for irrigation is a scarce resource, therefore, water use 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. Efficient water management requires a thorough study of plant water relationships, climate, agronomic practices and economic assessment. Emphasizing on this, several researches have been conducted in the past years with the focus on consumptive use of water, water use efficiency and soil moisture extraction pattern. Pratibha *et al.* (1994) observed the highest (330 mm) consumptive use of water of wheat on sandy clay loam soil at Hyderabad with eight irrigations as compared to six and four irrigations (183 and 141 mm), respectively. At Ranchi (Jharkhand) on sandy loam soil, Pal *et al.* (1996) reported progressively increased consumptive use of water with increased irrigation frequencies. Consumptive use of water varied from (272 mm) when two irrigations were applied at crown root initiation and boot stage to 346 mm with four irrigations applied at crown root initiation, maximum tillering, boot and milk stages. At Akola (Maharashtra), a field experiment was conducted in vertisols by Deshmukh *et al.* (1997), they observed highest WUE (8.64 kg ha^{-1} mm^{-1}) when one irrigation was applied at crown root initiation stage. Lower values for WUE were recorded when irrigation frequency increased from one to five (7.65 kg ha^{-1} mm^{-1}). Soni and Lehria (1999) carried out an experiment on silty loam soil at Jammu (Jammu and Kashmir) and they reported the highest WUE (10.58 kg ha^{-1} mm^{-1}) when no irrigation was applied. Lower values of WUE of 8.47, 8.32, 8.35 kg ha^{-1} mm^{-1} were noticed when one irrigation at crown root initiation, one irrigation at flowering and two irrigation at crown root initiation and flowering stages were applied, respectively. Mishra *et al.* (1994) reported that the wheat crop extracted more (77%) moisture from top 60 cm than 60-120 cm depth of soil profile in irrigation schedule at 1.0 IW/CPE ratio compared to IW/CPE ratio of 0.5 and 0.75. It was noticed that the top 0-15 cm soil layer contributed 46.8, 41.7 and 31.0 per cent soil moisture in eight, six and four irrigations, respectively. This calls for immediate attention towards the judicious application of water and this is possible only by following some scientific basis for water application to the crop. One such scientific approach particularly in water scarcity areas is critical growth stages approaches for scheduling irrigation.

RESOURCES AND METHODS

A field experiment was conducted during *Rabi* season of 2001-02 at Agriculture College Farm, Dharwad (Karnataka), to study the response of bread wheat (cv. DWR-162) and durum wheat (cv. DWR-1006) to irrigation schedules based on critical growth stages in vertisols of Northern Karnataka. Mean values of field capacity, permanent wilting percentage and bulk density of the soil at different depths are given in Table A. The water table depth during experimentation was below three meters throughout the growing period. The study included seven irrigation schedules *viz.*, I_1 (two irrigations at crown root initiation stage + tillering stage), I_2 (two irrigations at CRI + flowering stage), I_3 (three irrigations at CRI + jointing stage + flowering stage), I_4 (three irrigations at CRI + tillering stage + milky stage), I_5 (four irrigations at CRI + tillering stage + flowering stage + milky stage), I_6 (five irrigations at CRI + tillering stage + jointing stage + flowering stage + milky stage) and I_7

Table A : Field capacity, bulk density and permanent wilting point values

Physical constants	Depth (cm)		
	0-15	15-30	30-60
Field capacity (%)	32.30	32.65	33.48
Bulk density (Mg m^{-3})	1.24	1.28	1.32
Permanent wilting point (%)	15.80	16.14	16.47

Table B: Total number of irrigation and depth of irrigation water (cm) applied to wheat genotypes

Irrigation treatments	Number of irrigations	Total depth of irrigation applied (cm)
Common irrigation	1	6
I_1: Irrigations at CRI + tillering stage	2	18
I_2: Irrigations at CRI + flowering stage	2	18
I_3: Irrigations at CRI + jointing + flowering stage	3	24
I_4: Irrigations at CRI + tillering + milky stage	3	24
I_5: Irrigations at CRI + tillering + flowering + milky stage	4	30
I_6: Irrigations at CRI + tillering + jointing + flowering + milky stage	5	36
I_7: Irrigations at CRI + tillering + jointing + flowering + milky + dough stage	6	42

(six irrigations at CRI + tillering stage + jointing stage + flowering stage + milky stage + dough stage) as main plots and two wheat genotypes *viz.*,DWR-162 (aestivum) and DWR-1006 (durum) as sub plots. The study was conducted in Split Plot Design in three replications. The irrigation water of 60 mm depth was applied at each irrigation with the help of parshall flume. The soil moisture content was determined gravimetrically. The moisture percentages obtained were used to calculate the consumptive use of water (Dastane, 1967). The irrigation depths applied in various treatments are given Table B.

OBSERVATIONS AND ANALYSIS

The results obtained from the present investigation on yield of wheat genotypes, consumptive use and water use efficiency are given in Table 1. The different irrigation schedule had significant influence on the yield of wheat. I_7 irrigation schedule recorded significantly highest grain yield (2669 kg ha^{-1}) over I_1 (1626 kg ha^{-1}), I_4 (2128 kg ha^{-1}), I_2 (2150 kg ha^{-1}) and I_3 (2240 kg ha^{-1}) but was at par with I_5 (2463 kg ha^{-1}) and I_6 (2580 kg ha^{-1}). The significant increase in grain yield is attributed to yield contributing characters *viz.*, weight of grains per ear,

Table 1 : The mean weight of grain yield (kg ha^{-1}), consumptive use (mm) and water use efficiency (kg ha^{-1} mm^{-1}) of wheat as influenced by irrigation schedules and genotypes

Treatments	Grain yield (kg ha^{-1})	Consumptive use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
Irrigation Schedules			
I_1- CRI + T	1626	231.0	7.03
I_2- CRI + F	2150	233.8	9.19
I_3- CRI + J + F	2240	299.9	7.46
I_4- CRI + T + M	2128	304.6	6.98
I_5- CRI + T + F + M	2463	359.5	6.85
I_6- CRI + T + J + F + M	2580	419.3	6.15
I_7- CRI + T + J + F + M + D	2669	485.5	5.49
S.E.±	85.42	-	-
C.D (P=0.05)	263.30	-	-
Wheat genotypes			
V_1-DWR 162	2140	331.16	6.45
V_2-DWR 1006	2390	335.1	7.31
S.E.±	47.85	-	-
C.D. (P=0.05)	145.14	-	-
Interaction (I X V)			
S.E.±	123	-	-
C.D. (P=0.05)	NS	-	-

CRI - Crown root initiation stage, T- Maximum tillering stage, J- Late jointing stage, F- Flowering stage, M- Milky stage, D- Dough stage
NS = Non-significant

Table 2: The soil moisture extraction pattern (%) of wheat as influenced by irrigation schedules and genotypes

Irrigation treatments	Wheat genotypes						Mean soil layers (cm)		
	V_1- DWR 162 Soil layers (cm)			V_2- DWR 1006 Soil layers (cm)					
	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
I_1- CRI + T	36.95	33.25	29.80	38.00	33.01	29.00	34.47	33.13	29.40
I_2- CRI + F	35.02	34.52	30.46	39.38	33.85	26.77	37.20	34.18	28.61
I_3- CRI + J + F	38.58	34.48	26.94	37.02	35.50	27.48	37.80	34.99	27.21
I_4- CRI + T + M	39.93	33.53	26.54	39.27	34.14	26.59	39.60	33.83	26.56
I_5- CRI + T + F + M	41.89	32.88	25.23	40.00	36.00	24.02	40.94	34.44	24.62
I_6- CRI + T + J + F + M	43.66	33.80	22.54	44.01	36.03	20.05	43.83	34.91	21.29
I_7- CRI + T + J + F + M + D	44.49	35.40	20.11	45.03	37.00	18.01	44.76	36.20	19.06
Mean	40.07	33.98	25.94	40.38	35.07	24.56	40.22	34.52	25.25

CRI - Crown Root Initiation stage, T- Maximum tillering stage, J- Late jointing stage, F- Flowering stage, M- Milky stage, D - Dough stage ear length, number of grains per ear, effective tillers and 100 grain weight. Significantly highest (1.75 g) weight of grain per ear head was recorded by I_7 irrigation schedule over I_1 (1.42 g), I_2 (1.58 g), I_4 (1.58 g) but was at par with I_3, I_5 and I_6 (1.63, 1.63 and 1.72 g), respectively. Significantly higher weight of grains per ear is attributed mainly to significantly higher number of grains per ear and 1000 grain weight. Theses findings are in agreement with Singh *et al.* (1980). The increase in yield components is attributed to significantly higher growth parameters like effective tillers (94.66), total dry matter production (217.58 g m^{-1} row length), leaf area (49.31 dm^2 m^{-1} row length), and leaf area index (2.18). This increase is attributed to higher consumptive use of water (485.5 mm) in I_7 irrigation schedule compared to I_1 irrigation schedule (231.0 mm). These results are in conformity with the findings of Pratibha *et al*. (1994) and Pal *et al*. (1996) who recorded higher consumptive use of water with increase in the irrigation frequencies. Among the wheat genotypes, DWR-1006 gave significantly higher yield (2390 kg ha^{-1}). This increase in yield is attributed to increase in yield components which in turn are attributed to the higher consumptive use of water (335.1 mm) by DWR-1006 genotypes as compared to DWR-162 (331.6 mm).

Highest (9.19 kg ha^{-1} mm^{-1}) water use efficiency (WUE) was noticed in I_2 irrigation schedule and lowest (5.49 kg ha^{-1} mm^{-1}) in I_7 irrigation schedule (Table 1). WUE is mainly dependent on two factors *viz.*, grain yield and consumptive use of water. The highest WUE in I_2 irrigation schedule was mainly due to low consumptive use of water (233.8 mm) indicating the efficient water use at lower frequencies of irrigation. The lower WUE under frequently irrigated (I_7 irrigation schedule) condition resulting in higher losses of water from surface soil (485.5 mm) leading to the lower water use efficiency. Similar findings were reported by Deshmukh *et al*. (1997) and Jana *et al*. (2001).

The percentage of soil moisture depletion by wheat genotypes at different depth of soil as influenced by irrigation schedules is presented in Table 2. Wheat extracted 44.76, 36.20 and 19.06 per cent moisture from the soil depth of 0-15, 15-30 and 30-60 cm, respectively in I_7 irrigation schedule. Among the wheat genotypes DWR-1006 extracted more water from the different soil depths (40.38, 35.07 and 24.56 per cent from 0-15, 15-30 and 30-60 cm layers, respectively) as compared to DWR-162.

The interaction effect between irrigation schedules and wheat genotypes was non-significant with regard to yield and growth parameters.

Conclusion :

Thus, irrigating the wheat crop at all critical stages produced higher grain yield and net returns. Under scarcity of water, four irrigations schedules at crown root initiation (CRI) stage, tillering stage, flowering stage and milky stages recorded at par grain yield resulting in saving two irrigations. Wheat genotypes DWR-1006 performed better than DWR-162.

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