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Consumptive Use, Water Use Efficiency, Moisture Depletion Pattern of Wheat under Semi-arid Eastern Plain Zone of Rajasthan

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ABSTRACT

Background: India has the largest area under wheat cultivation but variability in climate is one of the major environmental threat to agriculture particularly wheat crop. The growth and yield of wheat crop is adversely affected by environmental stresses such as soil moisture deficit, high temperature, low light intensity *etc*. Among these stresses irrigation water is a scare resource, it's optimization is fundamental to water resources use. It permits better utilization of all other production factors and thus leads to increased yields per unit area and 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. Thus, an assessment of the potential for reducing water needs and increasing production is the need of time. The current study aimed to study of this province in order to manage and control related problems.

Methods: In this context a field experiment was conducted during *Rabi* season 2016 and 2017, Soil moisture studies were started right from sowing and continued up to maturity of wheat crop. The soil moisture content under all the treatments of three replications was determined just before irrigation and twenty four hours after irrigation from 0-15, 15-30, 30-45 and 45-60 cm soil depths and calculate consumptive use of water, soil moisture depletion pattern and water use efficiency.

Result: Results revealed that the maximum consumptive use (350.01 mm) of water found with irrigation schedule at 1.2 ETc and highest water use efficiency (15.32 kg ha^{-1} mm^{-1}) obtained with irrigation schedule at 1.0 ETc. Among the different wheat cultivars Raj-4120 registered higher consumptive use (332.57 mm) and Raj- 4238 obtained highest water use efficiency (16.13 kg ha^{-1} mm^{-1}) while crop sown on 15th November recorded higher consumptive use (333.04 mm) and water use efficiency (15.69 kg ha^{-1} mm^{-1}). Wheat is a surface feeder with fibrous root system, the maximum amount of moisture was depleted in shallow depth (0-15 cm) than deeper layers of soil.

Key words: Consumptive use, Date of sowing and irrigation scheduling, Moisture depletion pattern, Water use efficiency, Wheat cultivars.

INTRODUCTION

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

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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 60120 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.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* season 2016 and 2017 at Research farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Durgapura, Jobner, Rajasthan (75° 47′ East longitudes, 26° 51′ North latitude and at altitude of 390 m above mean sea level). The soil of experimental field was loamy sand in texture, slightly alkaline in reaction containing 0.25% organic C, with *pH* 8.2, EC 0.15ds m^{-1}, available nitrogen 136.5 kg ha^{-1}, phosphorous 33.30 kg ha^{-1} and potassium 195.45 kg ha^{-1}. The meteorological data was recorded daily from sowing to harvest from meteorological observatory situated near the experimental farm. The experimental site characterized by aridity of the atmosphere and extremity of temperature both in summer (45.5°C) and winter (4°C). Under semi-arid climatic conditions, the area receives 500-700 mm per annum rainfall which is mostly occurring during July to September. Rainfall received during the wheat growing season (Nov. to April) was 22.9 mm. The mean monthly maximum and minimum temperatures during the wheat growing season (Nov. to April) varied from 21.55 to 38.32 and 6.05 to 23.25°C, respectively. The cumulative bright sunshine hours during the growing season varied between 6.70 to 10.05 hrs. The experiment was laid out in Split plot design with three replications. Thirty six treatment combinations were investigated. Treatments comprises four irrigation levels: I_1 (0.6 ETc), I_2 (0.8 ETc), I_3 (1.0 ETc) and I_4 (1.2 ETc), three cultivars: C_1 (Raj-4120), C_2 (Raj-4079) and C_3 (Raj-4238) and three dates of sowing: D_1 (15th Nov.), D_2 (30th Nov.) and D_3 (15th Dec.). In the recommended irrigation treatments applied at different irrigation intervals according to ET_C level with the help of water meter. Standard crop production practice and methods were followed for weeding, fertilizer application and crop protection management to grow the crop.The irrigation water of 60 mm depth was applied at each irrigation with the help of water meter. Crop was harvested manually in the end week of March and First week of April when 80% of the grains turned to golden colour. Grain and biological yield were recorded at the harvest. Least significant difference at 0.05% level of probability was used to test the significance of differences among treatment means. Soil moisture depletion, consumptive use and water use efficiency were calculated with the following formulas:

Soil moisture analysis

Soil moisture

Soil moisture studies were started right from sowing and continued up to maturity of wheat crop. The soil moisture content under all the treatments of three replications was determined just before irrigation and twenty four hours after irrigation from 0-15, 15-30, 30-45 and 45-60 cm soil depths.

Sampling techniques

The soil samples for soil moisture studies were taken with the help of screw auger. Soil samples were taken around fixed spot selected at random in net plot area of each treatment of three replications. Then the samples were transferred immediately to aluminum soil moisture boxes and covered with moist gunny bag to avoid moisture loss from the soil samples. The moisture boxes containing soil samples were shifted immediately to laboratory for weighing and drying.

Weighing and drying of samples

The soil samples collected in the boxes were weight (W_1) immediately and then transferred to a hot electrically heated oven with thermostat control. The samples were dried at 105°C temperature for eight to ten hours till constant weight (W_2) was obtained. Moisture percentage was worked out by using following formula (Dastane, 1972).

$$\text{Moisture percentage (Oven dry weight basis)} = \frac{W_1 - W_2}{W_2} \times 100$$

Consumptive use of water (mm)

The consumptive use of water under different treatments was computed by using the procedure suggested by (Dastane, 1972).

$$d = \sum_{i=1}^{n} \frac{M^i_1 - M^i_2}{100} \times AS_i \times D_i$$

Water use efficiency

Water Use Efficiency (WUE) was estimated by dividing the yield (kg ha^{-1}) 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 (Michael, 1978).

$$\text{WUE (kg ha}^{-1}\text{ mm}^{-1}\text{)} = \frac{Y}{CU}$$

Soil moisture depletion pattern (%)

The soil moisture depletion is the relative amount of moisture extracted from different depths within the crop root zone. Soil moisture depletion from four layers *viz*., 0-15, 15-30, 30-45 and 45-60 cm depth was computed. Moisture depleted from each layer was calculated by adding all the short period depletion at the respective depth till maturity of the crop and the percentage depletion at various depths to the total was worked out.

Table 1: Effect of irrigation scheduling, cultivars and varying sowing dates on soil moisture depletion pattern (%) of wheat.

Treatment	Depletion pattern at 0-15 cm			Depletion pattern at 15-30 cm			Depletion pattern at 30-45 cm			Depletion pattern at 45-60 cm		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Irrigation scheduling												
I_1 (Etc 0.6)	36.21	36.69	36.45	29.38	29.21	29.30	20.29	20.41	20.35	12.57	13.16	12.87
I_2 (Etc 0.8)	37.39	37.10	37.25	29.59	29.47	29.53	20.71	20.85	20.78	12.67	13.28	12.98
I_3 (Etc 1.0)	37.43	37.15	37.29	29.78	29.68	29.73	21.09	21.25	21.17	12.71	13.36	13.04
I_4 (Etc 1.2)	37.48	37.21	37.35	29.85	29.77	29.81	21.19	21.29	21.24	12.75	13.39	13.07
SEm±	0.11	0.12	0.08	0.10	0.11	0.08	0.10	0.11	0.07	0.10	0.11	0.07
CD(P= 0.05)	0.37	0.40	0.24	0.35	0.39	0.23	0.34	0.38	0.23	NS	NS	NS
Cultivars												
V_1 (Raj 4120)	37.23	36.72	36.98	29.48	29.40	29.44	20.71	20.77	20.74	12.56	13.17	12.87
V_2 (Raj 4079)	37.49	37.27	37.38	29.77	29.64	29.71	20.92	21.07	21.00	12.77	13.39	13.08
V_3 (Raj 4238)	37.42	37.12	37.27	29.71	29.57	29.64	20.82	21.01	20.92	12.70	13.32	13.01
SEm±	0.07	0.06	0.04	0.06	0.06	0.04	0.06	0.06	0.04	0.06	0.05	0.04
CD(P= 0.05)	0.20	0.18	0.13	0.18	0.18	0.12	0.17	0.17	0.12	0.17	0.16	0.11
Date of sowing												
D_1 (15th NOV.)	37.46	37.28	37.37	29.87	29.70	29.79	20.92	21.10	21.01	12.76	13.41	13.09
D_2 (30th NOV.)	37.41	37.14	37.28	29.50	29.50	29.50	20.82	20.99	20.91	12.70	13.32	13.01
D_3 (15th DEC.)	37.27	36.70	36.99	28.58	29.41	29.00	20.72	20.76	20.74	12.56	13.20	12.88
SEm±	0.05	0.05	0.04	0.05	0.05	0.04	0.05	0.05	0.04	0.05	0.05	0.04
CD(P= 0.05)	0.15	0.15	0.10	0.14	0.15	0.15	0.14	0.15	0.10	0.14	0.15	0.10

RESULTS AND DISCUSSION

Effect of irrigation scheduling

Moisture depletion pattern (Table 1) showed that the soil moisture depletion decreased progressively with the depth of soil in all irrigation schedules. Higher amount of irrigation water (I_4) to wheat crop extracted more soil moisture from upper soil layers as compared to less amount of irrigation water applied to the crop probably due to more availability of moisture in soil profile which increased the potential and greater stomatal conductance. Under limited water supply (I_1), moisture availability from upper layers decreased which compelled the plants to extract more moisture from deeper layers. These results are in close proximity with those of (Jana *et al*., 2001, Kibe and Singh, 2003 and Zaman *et al*., 2006).

Results showed (Table 2) that treatment I_4 (Irrigation at 1.2 ETc) exhibited maximum value of consumptive use (332.48, 367.54 and 350.01 mm) over all other treatments which was found at par with I_3 (Irrigation at 1.0 ETc) with the respect values (311.18, 342.48 and 326.8 mm) while the minimum consumptive use was brought about by I_1 (Irrigation at 0.6 ETc) in the tune of (273.85. 305.44 and 289.65 mm) in 2016-17, 2017-18 and pooled analysis, respectively. Thus consumptive use of water increased with increasing in quantity of irrigation water. This might be due to more amount of irrigation water which increased consumption of water due to better growth of crop and simultaneously the loss of water through evaporation under treatment. Inadequate moisture supply to the crop under I_1 resulted in the lowest consumptive use of water. These findings are analogous to those reported by (Bandyopadhyay and Mallick, 2003, Parihar and Tiwari, 2003 and Singh *et. al*., 2012).

Results pertaining to WUE (Table 2) revealed that treatment I_3 (Irrigation at 1.0 ETc) recorded significantly highest WUE (15.32 kg ha^{-1} mm^{-1}). While the lowest WUE (11.94 kg ha^{-1} mm^{-1}) was registered under treatment I_1 (Irrigation at 0.6 ETc) according to pooled analysis. Water use efficiency refers largely to the production per unit of water consumed by a crop. The highest WUE in the treatment I_3 might be due to the fact that crop was supplied with adequate soil moisture without moisture stress during reproductive phase. Hence, proportionately higher yield with the judicious use of limited water resulted to significantly highest WUE. The least WUE in treatment I_1 might be the result of moisture stress experienced by the crop during both vegetative and reproductive phases which ultimately reduced the yield. Nautiyal *et al*. (1999) and Bikrmaditya *et al*. (2011) were also of the same opinion.

Effect of wheat cultivars

Among the wheat genotypes Raj 4079 extracted more water from different soil depths (37.38, 29.71, 21.00 and 13.08 per cent from 0-15, 15-30 and 30-45 and 45-60 cm layers, respectively) as compared to Raj 4238 and Raj 4120 according to pooled analysis. These results were in closed conformity with (Ahmad, 2016). The pattern of soil moisture depletion revealed that maximum utilization of moisture was from surface soil (0-15 cm layer) and gradually decreased with increasing depth of soil. This might be due to maximum concentration of roots in the upper 0-15 cm layer, (Bandyopadhyay, 1997).

Wheat cultivar Raj 4120 (332.57 mm) consumed more water throughout the crop season than Raj 4079 (325.39 mm) and Raj 4238 (300.16 mm) contrarily water use

Table 2: Effect of irrigation scheduling, cultivars and varying sowing dates on consumptive water use (mm) and water use effiency (Kgha^{-1} mm^{-1}) of wheat.

Treatment	Consumptive use of water			Water use effiency		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Irrigation scheduling						
I_1 (Etc 0.6)	273.85	305.44	289.65	12.49	11.39	11.94
I_2 (Etc 0.8)	295.15	326.48	310.82	15.50	14.25	14.88
I_3 (Etc 1.0)	311.18	342.48	326.83	15.91	14.73	15.32
I_4 (Etc 1.2)	332.48	367.54	350.01	15.30	14.12	14.71
SEm±	4.84	4.84	3.42	0.23	0.22	0.19
CD(P= 0.05)	16.73	16.73	10.54	0.81	0.74	0.63
Cultivars						
V_1 (Raj 4120)	314.65	350.19	332.57	11.82	10.71	11.27
V_2 (Raj 4079)	309.35	341.43	325.39	15.79	14.69	15.24
V_3 (Raj 4238)	285.49	314.83	300.16	16.80	15.46	16.13
SEm±	3.82	3.82	2.70	0.16	0.12	0.10
CD(P= 0.05)	11.45	11.45	7.78	0.48	0.36	0.29
Date of sowing						
D_1 (15th NOV.)	320.50	345.59	333.04	16.11	15.27	15.69
D_2 (30th NOV.)	301.79	334.67	318.23	15.74	14.29	15.01
D_3 (15th DEC.)	287.21	326.20	306.70	12.56	11.31	11.93
SEm±	3.10	3.10	2.19	0.11	0.11	0.08
CD(P= 0.05)	8.81	8.81	6.15	0.30	0.33	0.22

efficiency of Raj 4238 was higher than cultivar Raj 4079 and Raj 4120. However, no significant difference was observed in respect of grain yield between cultivars Raj 4079 and Raj 4238. Similar observations were also made by (Pratibha *et al*., 1994).

Effect of dates of sowing

Dates of sowing influenced the amount and rate of consumptive use. 15th November sown wheat consumed maximum amount of water (333.04 mm) and produced highest yield (5201 kg ha^{-1}) with a water use efficiency of 15.69 kg $ha^{-1}mm^{-1}$. Seasonal consumptive use and water use efficiency decreased with a proportion with delay in sowing time. Consequently 15th November sown crop consumed 3.99 and 7.90 percent more water than that of 30th November (319.73 mm) and 15th December (306.70 mm) respectively according to pooled analysis. Such observations were also reported by (Shivani *et al*., 2003 and Agrawal *et al*., 1997).

15th November sown crop extracted maximum amount of water 37.37 % from surface soil (0-15 cm) and it reduced slightly with delay in sowing as it was 37.28% in 15th December sown crop, whereas the reverse was true from soil surface soil *i.e*., 30-60 cm. These findings are in conformity with the reports of (Verma *et al*., 1997).

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