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PRODUCTIVITY AND WATER USE EFFICIENCY OF BREAD WHEAT (*TRITICUM AESTIVUM* L.) AS INFLUENCED BY IRRIGATION SCHEDULE, MULCHING AND HYDROGEL IN EASTERN INDO-GANGETIC PLAINS OF INDIA

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Abstract

A field experiment was conducted to evaluate the influence of limited and adequate irrigation and moisture conservation practices (rice straw mulch and hydrogel) on yield and water use efficiency in wheat. Though, maximum wheat yield (3.92 t/ha) and water use efficiency (15.72 kg/ha/mm) was recorded with four irrigations at crown root initiation stage, tillering, late jointing, and milk stage, two irrigations applied at tillering and flowering and soil mix drilling of 7.5 kg/ha hydrogel (a synthetic polymer) at sowing produced comparable yield (3.34 t/ha) with less water use, enhancing the water use efficiency (15.45 kg/ha-mm). The higher net return and B : C ratio were found in the treatment 2.5 kg/ha hydrogel. Thus, from present study it may be concluded that under limited irrigation conditions, water conservation practices like soil mix drilling of hydrogel and rice-straw mulching are beneficial for maintaining optimum moisture in soil to enhance wheat yield and water use efficiency.

Introduction

Wheat (*Triticum aestivum* L.) is widely grown crop of the world and satiates the food security and wide adaptability in different agro-climatic conditions. The issue of water management has assumed paramount importance and occupied the centre stage of politico-economic debates in the world. India has already entered the shadow of the zone of physical and economic water scarcity. Scheduling of irrigation based on phenological stages (crown root, tillering, booting, anthesis, soft dough and hard dough stage) in wheat has been practical approach to the farmers in different wheat growing zones in India. Wheat response to water stress from stem elongation to booting, followed by anthesis and grain-filling stages (Zhang *et al.*1999). Application of limited irrigation gets maximum yield and saves water compared to more irrigation schedules on wheat (Khokhar *et al.* 2010).

Effect of mulching in conserving moisture and increasing productivity of wheat has been reported (Sarwar *et al.* 2013). Combination of irrigation with mulch is advocated to improve water uptake and to reduce number of irrigation in the spring wheat (Li *et al.* 2004). Hydrogel a semi-synthetic super absorbent polymer has shown the potential to realize more yield per drop of water (Jalilian and Mohsennia 2013) and reduces the leaching of herbicides, fertilizer and irrigation requirement of crops (Mehr and Kourosh 2008). Research is limited on combined effect of mulch, hydrogel and irrigation scheduling in wheat under semi-arid environment of Eastern Indo-Gangetic Plains of India. In the present study attempts were made to evaluate the effect of adequate and limited irrigation scheduled at critical stages with moisture conservation practices *viz.*, mulching and hydrogel on yield and consumptive use of water and WUE in wheat.

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Materials and Methods

An experiment was conducted for 2 years in a sandy loam soil at Banaras Hindu University Varanasi, (25^0.18′ N latitude, 83^0.03′ E longitude and 75.5 meteraltitude), Uttar Pradesh, India, during 2012 - 2014. The area is under subtropical semi-arid climate with moisture deficit index of –20 to –40 % and experiences hot and dry summer (April-June), hot-humid monsoon period (July - September) and mild to cold winter (October - February). The rainfall pattern varied to a great extent during two years of study as shown in Table 1. In 2012 - 2013 the Pan-evaporation during December, January, February, March, April and May were 33.4, 44.9, 56.9, 128.3 and 128.3 mm, respectively. In 2013 - 2014 the PET during December, January, February, March, April and May were 34.7, 37.1, 53.7, 116.3 and 129.9 mm, respectively. The experimental soil was sandy clay loam in texture with a pH of 7.2. It was moderately fertile being low in mean organic carbon 0.35% and available N 206.60 kg/ha, phosphorous 17.67 kg/ha, potash 238.0 kg/ha. Factorial experiment was laid out in a randomized complete block design and replicated thrice. Eighteen treatments combinations comprised of three irrigation schedules *viz.*, no irrigation, one irrigation at crown root initiation and two irrigation at tillering and flowering and six moisture conservation treatments *viz.* without mulch and hydrogel, 4 t/ha mulch, 6 t/ha mulch, 2.5 kg hydrogel/ha, 5.0 kg hydrogel/ha and 7.5 kg hydrogel/ha were compared with recommended irrigation schedule based on phonological stages (crown root initiation, tillering, late jointing and milk stage) of wheat. Quantity of irrigation water was measured with parshall flume to a depth of 5 ± 2 cm and applied as per irrigation schedule. Wheat variety HD 2733 was line sown at a row spacing of 22.5 cm. using 125 kg seeds/ha. A uniform basal rate of 60 kg N/ha, 60 kg P/ha and 40 kg K/ha was applied in all the treatments combinations, except un irrigated crop which received 120 kg N/ha as basal with P and K. Remaining half nitrogen was applied at 30 days after sowing in rest of the treatments. Hydrogel was mixed with soil and applied in the band of seed line at the time of sowing. Rice straw mulch was spread in inter-rows 3 days after sowing. Soil moisture determination was done using gravimetric method. Soil samples were drawn with the help of screw auger from 0 - 15, 15 - 30, 30 - 60 and 90 cm soil depth before sowing and before and after of each irrigation. The moisture percentage from different soil depths was used to calculate consumptive use of water and soil moisture extraction pattern of the crop for irrigation treatments. Soil moisture depletion pattern from different layers were measured at 0 - 15, 15 - 30 and 30 - 60 cm and 90 cm depths by sunflower plant indicator method (Dastane 1972).

Table 1. Rainfall pattern according to irrigation schedules in both years.

Rainfall (mm)	2012-13	2013-14
Before CRI (1 - 21 days)	0	0
CRI to T (22 - 42 days)	0	63.4
T to LJ (43 - 63 days)	0	24.4
LJ to milking (64 - 85 days)	66.8	50
Milking to harvesting (86 - 120 days)	9.6	0
Total	76.4 mm	137.8 mm

CRI = Crown root initiation, T = Tillering, LJ = Late jointing.

$$\textbf{Consumptive use of water (cm)} = \sum_{i=1}^{n} \text{Total moisture depleted} + \text{soil moisture contribution} + \text{ER}$$

$$\text{Water use efficiency (kg/ha/mm)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total consumptive use of water (mm)}}$$

The statistical analysis of variance was done by using the Fischer's method as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was p = 0.05 and LSD values were calculated wherever the 'F' test was significant. Since, the trends in treatment effects on parameters studied were non-significant between years the data were pooled for presentation.

Results and Discussion

The maximum growth parameters were recorded in recommended four irrigations scheduled at CRI, tillering, late jointing, and milk stage which was significantly higher than one irrigation schedule at CRI and no irrigation, but comparable to two irrigations at tillering and flowering (Table 2).

Table 2. Irrigation scheduling and moisture conservation practices on growth parameters at harvest of wheat (mean of 2012-13 and 2013-14).

Treatments	Growth parameters				Physiological characteristics
	Plant height (cm)	LAI at 90 DAS	No. of tillers/m^{-2}	Dry matter/m (g)	Crop growth rate (g/m^2/day)
Irrigation schedules					
I_0 (No irrigation)	94.44	2.26	267.50	194.97	1.19
I_1 (One irrigation)	104.47	2.88	291.46	215.78	1.42
I_2 (Two irrigations)	113.21	2.95	315.24	235.04	1.59
SEm ±	0.63	0.01	0.86	0.38	0.02
CD (p = 0.05)	1.28	0.02	1.73	0.76	0.03
Moisture conservation practices					
M_1 (Nothing used)	98.57	2.54	279.74	205.48	1.36
M_2 (4 t mulch/ha)	102.10	2.66	291.03	216.02	1.39
M_3 (6 t mulch/ha)	106.08	2.73	296.76	216.77	1.41
M_4 (2.5 kg hydrogel/ha)	103.60	2.74	287.07	215.29	1.38
M_5 (5 kg hydrogel/ha)	106.04	2.75	293.75	217.72	1.42
M_6 (7.5 kg hydrogel/ha)	107.86	2.76	300.06	220.31	1.44
SEm ±	1.26	0.02	1.71	0.75	0.03
CD (p = 0.05)	2.55	0.05	3.47	1.52	0.07
I×M	NS	NS	NS	NS	NS
C (Four irrigations)	108.92	3.02	310.00	226.59	1.39
SEm ±	4.75	0.08	6.46	2.83	0.12
CD (p = 0.05)	9.63	0.17	13.09	5.74	0.25

Increase in growth parameters at higher moisture regime might be due to maintenance of adequate and continuous moisture to plant which maintained good establishment of roots and various metabolic processes. Moisture conservation produced significant variation in plant height, LAI, number of tillers/m, dry matter accumulation and crop growth rate at harvest stage during both years. These findings are in accordance with the findings of Ahmad (2002). Among moisture conservation treatments, hydrogel at 7.5 kg/ha was significantly superior to the rest of treatments, except mulching at 6 t /ha, in plant height, number of tillers/m, and dry matter accumulation by crop (Table 2). Mulching is known to increase moisture storage in soil which increases absorption and utilization of nutrients from soil, thus increasing the size of source and increase the activity of cell division,cell expansion and cell elongation, ultimately leading to an increased growth parameters (Al-Harbi *et al.*1996).

The maximum grain yield was recorded with two irrigation schedules at tillering and flowering and was significantly superior to irrigation applied only at CRI (I_1) and no irrigation (I_0), but on par to four irrigations. Similarly, I_1 was significantly superior over I_0 (Table 3).Yield is the function of vegetative development; it might be due to maintained adequate available soil moisture (ASM) in the root zone throughout the crop growth period. The present findings are similar with the findings of Mubeen *et al.* (2012).

Table 3. Effect of irrigation scheduling and moisture conservation practices on yield attributes, total consumptive use, and WUE at harvest and economics of wheat (mean of 2012-13 and 2013-14).

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Total consumptive use (mm)	Water use efficiency (kg/ha-mm)	Net returns (Rs./ha)	B:C ratio
Irrigation schedules							
I_0 (No irrigation)	2.51	2.88	5.39	206.08	12.36	17438	0.6
I_1 (One irrigation)	3.27	3.74	7.05	212.89	15.51	30663	1.1
I_2 (Two irrigations)	3.92	4.49	8.42	227.14	17.31	42063	1.4
SEm ±	0.17	0.18	0.35	0.09	0.09	287.08	0.0099
CD (p = 0.05)	0.35	0.36	0.70	0.19	0.17	823.38	0.029
Moisture conservation practices							
M_1 (Nothing used)	2.88	3.34	6.25	214.21	13.44	28838	1.2
M_2 (4 t mulch/ha)	3.23	3.71	6.94	214.91	15.09	29933	1.0
M_3 (6 t mulch/ha)	3.33	3.79	7.12	215.20	15.51	29627	0.9
M_4 (2.5 kg hydrogel/ha)	3.31	3.77	7.17	215.92	15.38	33367	1.2
M_5 (5 kg hydrogel/ha)	3.32	3.79	7.13	215.95	15.49	30813	1.0
M_6 (7.5 kg hydrogel/ha)	3.34	3.82	7.14	216.03	15.45	27750	0.8
SEm ±	0.35	0.36	0.69	--	--	574.15	0.0198
CD (p = 0.05)	0.71	0.73	1.41	0.37	0.35	1646.76	0.057
I×M	NS	NS	NS	--	NS		
C (Four irrigations)	3.92	4.54	8.47	249.37	15.72	45996.92	1.7
SEm ±	1.32	1.36	2.62	0.69	0.64	1722.46	0.0594
CD (p = 0.05)	2.67	2.75	5.32	1.40	1.31	4940.28	0.196

Amongst moisture conservation practices, maximum grain, straw and biological yield were recorded with M_6 (7.5 kg hydrogel/ha) which was at par with M_3 (6 t mulch/ha) and M_5 (5 kg hydrogel/ha). These treatments were significantly superior to M_1 (no moisture conservation practice) and M_2 (4 t mulch/ha). Hydrogel hade been reported to increase the growth attributes that lead to increased yield attributes and crop yield (Sendur *et al.* 2001). Mulch being a barrier to evaporation loss, maintained more moisture in the soil which supported more number of ear heads and enabled them to bear more grains and finally crop yields (Huang *et al.* 2005).

Application of mulch and hydrogel affected net return and benefit cost ratio B : C ratio markedly. The net return and benefit cost ratio were numerically higher in treatment four irrigation (45997 Rs./ha and 1.7) and followed by two irrigation (42063 Rs./ha and 1.4) and 2.5 kg hydrogel/ha (33367Rs./ha and 1.2). This might be due to the increase in grain yield with frequent irrigations applied in this treatment.

Table 4. Interaction effect of irrigation scheduling and moisture conservation practices on grain yield of wheat.

Treatments	Grain yield						Mean
	M_1	M_2	M_3	M_4	M_5	M_6	
I_0 (No irrigation)	2.19	2.51	2.61	2.58	2.55	2.57	2.50
I_1 (One irrigation)	2.88	3.29	3.33	3.33	3.36	3.38	3.26
I_2 (Two irrigation)	3.56	3.89	4.02	4.02	4.04	4.03	3.93
Mean	2.88	3.23	3.32	3.31	3.32	3.32	
CD (p = 0.05)	NS						

Table 5. Interaction effect of irrigation scheduling and moisture conservation practices on total consumptive use of water on wheat.

Treatments	Total consumptive use (mm)						Mean
2012-13	M_1	M_2	M_3	M_4	M_5	M_6	
I_0 (No irrigation)	173.83	178.45	178.80	180.12	179.14	180.02	178.39
I_1 (One irrigation)	184.05	184.18	186.70	187.52	187.86	188.68	186.50
I_2 (Two irrigation)	210.35	210.50	211.10	210.33	211.16	211.17	210.77
Mean	189.46	190.99	192.20	192.66	192.72	193.29	

The total consumptive water use was maximum in control, but WUE was maximum with two irrigation schedules at tillering and flowering (Table 5). This might be due to sufficient and continued supply of water for high evapo-transpiration from vegetation (Tadayon *et al.* 2012). Amongst moisture conservation practices, total consumptive use and water use efficiency were higher in M_6 (7.5 kg hydrogel/ha) followed by M_5 (5 kg hydrogel/ha) and M_3 (6 t mulch/ha) for water use efficiency. Minimum total consumptive use and WUE in M_1 (no moisture conservation practice). WUE increased due to mulching because evapo-transpiration becomes less in inter rows. Whereas, application of hydrogel to the soil helped in retaining more moisture in the soil, increased water holding capacity of soil and decreased infiltration rate of soil (Vizaylaxmi *et al.* 2012). Consequently, better crop growth and yield were obtained under hydrogel at higher rates than lower rate and also the alone application of mulch. The treatment combinations of I_2M_6 (two irrigations with 7.5 kg hydrogel/ha) recorded maximum consumptive use of water than all other combinations of irrigation schedules and moisture conservation treatments. However, I_2 in combination with all the moisture conservation practices recorded higher consumptive use than other combination of irrigation and moisture conservation practices. Hydrogel improved water holding capacity and nutrient supplying capacity because it retains larger amount of water and increased the size 500 - 1000 times. Thus, it reduces the losses and provide water slowly to plant. Similar finding was also observed by Rostampour (2013).

From the present study, it may be inferred that under limited water availability two irrigations at CRI and flowering stages of wheat and 7.5 kg hydrogel/ha be applied for higher growth yield and water use efficiency of wheat.

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