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Research Communication

Grain yield, nutrient uptake and water-use efficiency of wheat (*Triticum aestivum*) under different moisture regimes, nutrient and hydrogel levels

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2013–14 at Ludhiana, Punjab, to determine the effect of four irrigation regimes (0, 2, 3 and 4 irrigations) and 6 levels of nutrient and hydrogel [100% recommended dose of fertilizer (RDF) 150 kg N: 60 kg P_2O_5 : 30 kg K_2O/ha without hydrogel, 100% RDF with 2.5 kg/ha hydrogel, 100% RDF with 5.0 kg/ha hydrogel, 75% RDF without hydrogel, 75% RDF with 2.5 kg/ha hydrogel and 75% RDF with 5.0 kg/ha hydrogel] on wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.]. Grain yield was the highest under 4 irrigations which was, however, at par with grain yield under 3 irrigations. Using $RDF_{100}H_5$, $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$, similar grain yield was recorded. Consumptive use was highest under 4 irrigations. Water-use efficiency (WUE) decreased with increase in irrigation levels while it showed an increasing trend with increase in hydrogel dose. The highest WUE was found with no irrigations along $RDF_{100}H_5$ which was statistically at par with application of 2 irrigations along $RDF_{100}H_5$ and no irrigation $RDF_{100}H_{2.5}$.

Key words *:* Hydrogel, Irrigation, Nutrients, Water-use efficiency, Wheat, Yield

Wheat is the world's most widely cultivated food crop. It is eaten in various forms by more than 1,000 million human beings in the world and is grown mostly under irrigated conditions. Water is an important input for realizing high wheat productivity; however, it is becoming the most limiting factor for crop production in most of the north-western parts of India where rice–wheat (R–W) is the major cropping system. More than 90% of R–W area is irrigated and is facing irrigation water shortage and declining ground watertable (Hira, 2009). Poor crop nutrition and imbalanced use of fertilizers are also important factor responsible for low wheat productivity. Balanced fertilizer use is not only the first requirement; rather it is a prerequisite for improving the efficiency of conventionally applied major nutrients. Crop-production practices that optimize yield, reduce losses and improve nutrient uptake and water-use efficiency (WUE) are important in sustainable agriculture. So, there is a strong need for plant-growth media with increased water and nutrient-holding capacity. Hydrogel is a polymer used to increase water-holding capacity for agricultural applications (Sharma, 2004), to reduce erosion and nutrient losses and absorb the nutrients to gradually release them. The use of hydrophilic polymers, to improving soil water and fertilizer-retention properties and thus crop productivity is attracting considerable interest.

The field experiment was conducted at the Punjab Agricultural University, Ludhiana (30° 56' N and 75° 52' E and at an of 247 m above mean sea-level), Punjab, during the winter (*rabi*) season of 2013–14. The soil type was deep alluvial loamy sand, Typic Ustochrept, low in organic carbon (4.2 g C/kg), electrical conductivity (EC) 0.12 dS/m, normal in *p*H (7.6), low in available N 183.4 kg/ha, medium in available phosphorus (13.8 kg P_2O_5/ha) and ammonium acetate-extractable K (145.1 kg K_2O/ha). The rainfall of 177 mm was received during the wheat-growing season. The experiment was conducted in a split-plot design with 4 levels of irrigation at various physiological growth stages of wheat crop, i.e. no irrigation, 2 irrigations at crown-root initiation [CRI 20–25 days after sowing (DAS)] and boot stage (90–95 DAS), 3 irrigations at CRI, tillering (50–60 DAS) and milk stage (105–115 DAS) and 4 irrigations at CRI, tillering, boot stage, and milk stage in main plots and 6 levels of nutrient and hydrogel [100% recommended dose of fertilizer (RDF) without

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hydrogel ($RDF_{100}H_0$), 100% RDF with 2.5 kg/ha hydrogel ($RDF_{100}H_{2.5}$), 100% RDF with 5.0 kg/ha hydrogel-($RDF_{100}H_5$), 75% RDF without hydrogel ($RDF_{75}H_0$) 75% RDF with 2.5 kg/ha hydrogel ($RDF_{75}H_{2.5}$) and 75% RDF with 5.0 kg/ha hydrogel ($RDF_{75}H_5$)] in sub-plots with 3 replications. Hydrogel developed by the Indian Agricultural Research Institute (IARI), New Delhi, was used in study and was applied with the last ploughing by broadcast method before sowing of the wheat crop. The crop was sown on flat beds with row spacing of 20 cm. The recommended dose of fertilizers, i.e. 150 kg N/ha, 60 kg P_2O_5/ha and 30 kg K_2O/ha in form of urea (46%N), diammonium phosphate (DAP 18%N 46% P_2O_5) and muriate of potash (60% K_2O) fertilizers were applied at the time of sowing. Data on yield attributes and yield were collected at harvesting. Soil-moisture determination was done by FOM/mts-handheld meter, which is based on TDR (Time Domain Reflectometry) up to 150 cm. Wheat was harvested manually in the third week of April. Grain and straw samples were analysed for total N, P and K using standard methods. Nutrient uptake was calculated by multiplying grain and straw yield by nutrient content. Test weight (1,000-grain weight), protein content, grain hardness and gluten content (%) was also determined. Consumptive use of water (CU) and water-use efficiency (WUE) were computed by using standard formula. The data were analysed at a 0.05 level of probability.

Four irrigation gave significantly higher number of effective tillers than no irrigation and 2 irrigations, while it was statistically at par with 3 irrigations (Table 1). The treatment $RDF_{100}H_5$ recorded higher number of effective tillers which were statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. Singh *et al.* (2007) also reported increased tillers with increased NPK doses. Irrigation levels did not influence number of grains/ear and 1,000-grain weight in the present study. There was a progressive increase in wheat grain yield with every increase in irrigation level with 4 irrigations resulted in significantly higher yield than no irrigation and 2 irrigations, while it was statistically at par with 3 irrigations. Ram *et al.* (2013) also reported the similar results. Treatment $RDF_{100}H_5$ recorded the higher grain yield than the treatments $RDF_{100}H_0$, $RDF_{75}H_0$ and $RDF_{75}H_{2.5}$ and was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$ treatments. Application of 75% RDF resulted in significantly lower grain yield than 100% RDF. Hydrogel @ 5 kg/ha along with 75% RDF showed similar grain yield as that of 100% RDF. This might be owing to fact that hydrogel improved the soil-moisture conditions in

Table 1. Yield attributes and yield, quality characters, nutrient uptake and consumptive use of water of wheat crop in relation to hydrogel under different irrigation regimes and nutrient levels

Treatment	Yield attributes and yield				Quality characters		Nutrient uptake (kg/ha)			Consumptive use (cm)
	Effective tillers/m²	1,000-grain weight (g)	Grains/ ear	Grain yield (t/ha)	Protein content (%)	Gluten content (%)	N	P	K	
Irrigation level										
No irrigation (I_0)	250	41.8	51.1	4.16	12.4	8.6	127.0	23.4	91.5	30.4
Two irrigation (I_2)	322	41.9	51.2	5.11	11.7	9.0	153.2	31.7	119.4	39.4
Three irrigation (I_3)	352	40.9	51.7	5.80	11.6	9.3	166.7	34.9	130.6	48.5
Four irrigation (I_4)	356	41.7	51.8	5.83	11.4	9.1	167.7	36.4	134.0	54.1
SEm±	4.4	0.8	1.10	0.07	0.06	0.12	1.50	0.40	1.4	-
CD (P=0.05)	14	NS	NS	0.23	0.2	0.4	4.8	1.3	4.5	-
Nutrient and hydrogel level										
$RDF_{100}H_0$	315	41.3	51.4	5.10	11.9	9.4	148.2	31.5	115.6	44.8
$RDF_{100}H_{2.5}$	332	40.8	51.8	5.41	12	9.2	161.9	34.2	122.7	43.1
$RDF_{100}H_5$	339	42.9	51.8	5.58	12.2	9.3	170.6	36.8	126.8	41.8
$RDF_{75}H_0$	271	41.8	51.2	4.44	10.4	8.5	118.3	22.8	100.7	44.4
$RDF_{75}H_{2.5}$	325	40.9	51.3	5.24	11.7	8.6	153.9	30.0	120.8	43.0
$RDF_{75}H_5$	338	41.6	51.4	5.57	12.3	9.0	172.1	35.2	126.4	41.8
SEm±	4.1	1.0	1.9	0.6	0.17	0.17	1.9	1.6	3.2	-
CD (P=0.05)	12	NS	NS	0.18	0.5	0.5	5.6	4.6	9.3	-
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	-

I_0 No rrigation; I_2, 2 irrigations; I_3, 3 irrigations; I_4, 4 irrigations; $RDF_{100}H_0$, 100% RDF without hydrogel; $RDF_{100}H_{2.5}$, 100% RDF with 2.5 kg/ha hydrogel; $RDF_{100}H_5$, 100% RDF with 5.0 kg/ha hydrogel; $RDF_{75}H_0$, 75% RDF without hydrogel; $RDF_{75}H_{2.5}$, 75% RDF with 2.5 kg/ha hydrogel and $RDF_{75}H_5$, 75% RDF with 5.0 kg/ha hydrogel addition to reducing the leaching losses of nutrients. Rehman *et al.* (2011) also reported similar effect of hydrogel on rice and Das *et al.* (2013) on sorghum crop.

Among quality characters, the highest 1,000-grain weight was recorded in 4 irrigations. Protein content recorded in no irrigation was significantly higher than all other irrigation levels. Coventry *et al.* (2011) reported similar irrigation effects on protein content. Gluten content was recorded the highest under I_3 irrigation treatment (3 irrigations) which was statistically at par with I_4 (4 irrigations) and I_2 (2 irrigations) treatments and significantly better than I_0 treatment (no irrigation) of irrigation. On the other hand, protein and gluten content was influenced significantly by nutrient and hydrogel levels, while effect on 1,000-seed weight was found non-significant. The highest protein content was obtained with $RDF_{75}H_5$ which was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{100}H_5$ but significantly better than all the other nutrient and hydrogel levels, whereas $RDF_{100}H_0$ recorded the highest gluten content which was statistically at par with all other treatments except $RDF_{75}H_0$ and $RDF_{75}H_{2.5}$.

The N, P, K uptake were found highest with I_4 treatment and was statistically at par with I_3 treatments which were significantly better than I_0 and I_2 treatments. The nitrogen uptake was 32.04% higher with 4 irrigations than treatments received no-irrigation. Singh *et al.* (2013) from Pantnagar also reported the same results. Treatment $RDF_{75}H_5$ recorded significantly higher nitrogen uptake which was statistically at par with $RDF_{100}H_{5.}$ $RDF_{75}H_5$ recorded 45.47% higher nitrogen uptake than $RDF_{75}H_{0.}$ In terms of P and K, $RDF_{100}H_5$ recorded the highest and was at par $RDF_{100}H_{2.5}$ and $RDF_{75}H_{.5}$ and significantly better than all the other treatments. Application of hydrogel significantly improved the nutrient uptake by the wheat crop

Table 2. Interactive effect of irrigation, nutrient and hydrogel on water-use efficiency (kg grain/ha/mm) of wheat

Nutrient and hydrogel rates	Irrigation levels				
	No	Two	Three	Four	Mean
$RDF_{100}H_0$	13.0	11.4	11.7	10.4	11.6
$RDF_{100}H_{2.5}$	14.7	13.3	12.1	11.0	12.8
$RDF_{100}H_5$	15.6	14.8	12.9	11.4	13.7
$RDF_{75}H_0$	11.6	11.0	9.8	8.6	10.2
$RDF_{75}H_{2.5}$	13.1	12.8	12.2	11.1	12.3
$RDF_{75}H_5$	14.4	14.2	12.8	11.2	13.2
Mean	13.7	12.9	11.9	11.4	

		SEm±	CD (P=0.05)
Irrigation levels	:	0.19	0.6
Nutrient and hydrogel rates	:	0.14	0.4
Interaction	:		0.9

Details of treatments are given under table 1

at both levels of nutrients. This could owing to the higher moisture availability and reduced leaching losses under hydrogel application. Four irrigation treatment recorded the highest consumptive use of water. Lowest consumptive use of water was recorded in no irrigation. The consumptive use of water under 4 irrigations was 77.8% higher than that of no-irrigation treatment. Increase in hydrogel levels decreased the consumptive use at both the nutrient levels. These results support the findings of by Narjary *et al.* (2012) from Dehli, India, who reported the increased water availability to growing crops in hydrogel-amended sandy soils.

The water-use efficiency (WUE) was the highest (13.7 kg grain/ha/mm) in no irrigation mainly due to conservative water use, which indicates the efficient water use at no irrigation, although its yield was less (Table 2). The lowest WUE was recorded under 4 irrigations which was statistically at par 3 irrigations. The WUE with 4 irrigations was 20.17% lower than that of no irrigation. Among nutrient and hydrogel treatments, the highest WUE was obtained under $RDF_{100}H_5$ and the lowest under $RDF_{75}H_0$ treatment. This indicates the beneficial role of hydrogel in saving the irrigation water available in limited water-supply conditions. The highest WUE was found with no irrigations along with $RDF_{100}H_5$ which was statistically at par with application of 2 irrigation along with $RDF_{100}H_5$ and no irrigations along with $RDF_{100}H_{2.5}$. With 2 irrigations treatment hydrogel 5 kg/ha was found significantly better than 2.5 kg/ha and the control where no hydrogel was applied. However, with 3 and 4 irrigations hydrogel @ 2.5 and 5 kg/ha were found statistically at par with each other but significantly better than the control. So hydrogel was found more effective under no or restricted irrigation treatment. These results support the findings of El-Hardy *et al.* (2009).

Hence application of hydrogel at the rate of 5 kg/ha can reduce the nutrient by 25% without decreasing the yield of crop, and irrigations levels could be restricted to 3 instead of 4 irrigations without reducing the yield of wheat crop. Consumptive use of water increased with the increase in irrigation levels, while increase in hydrogel level decreased the consumptive use of water. With 3 irrigations by using 2.5 or 5.0 kg/ha hydrogel, water-use efficiency is similar but significantly higher than no hydrogel.

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