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Productivity of wheat (*Triticum aestivum* L.) in relation to hydrogel as influenced by different irrigation regimes and nutrient levels

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Abstract
The field experiment entitled "Productivity of wheat (*Triticum aestivum* L.) in relation to hydrogel as influenced by different irrigation regimes and nutrient levels" was conducted at the Research Farm of the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana during *rabi* 2013-14. The soil of the experimental field was loamy sand, slightly alkaline in reaction, low in available nitrogen and medium in phosphorus and potassium. The experiment was conducted in split plot design with 24 treatments *viz.* four irrigation levels in main plots and six levels of nutrient and hydrogel doses in sub plots with three replications. Increase in the irrigation frequency significantly increased the dry matter accumulation and leaf area index at 120 DAS. Significantly higher plant height, tiller density and effective tillers were recorded with four irrigations as compared to no and two irrigations and were statistically at par with three irrigations. The highest tiller count was recorded under three irrigations which was statistically at par with four irrigations. The highest biological yield was recorded with four irrigations and was significantly better than three, two and no irrigations. Grain yield recorded was highest under four irrigations and was statistically at par with grain yield under three irrigations. The higher yield attributes (viz. tiller density and effective tillers), dry matter accumulation, biological and grain yield were recorded under 100% RDF with 5.0 kg/ha hydrogel ($RDF_{100}H_5$) which was statistically at par with 100% RDF with 2.5 kg/ha hydrogel ($RDF_{100}H_{2.5}$) and 75% RDF with 5 kg/ha hydrogel ($RDF_{75}H_5$). Application of hydrogel improved the nutrient uptake by the crop. The highest leaf area and plant height were recorded with $RDF_{75}H_5$ which were at par with 100% RDF with 2.5 kg/ha hydrogel $RDF_{100}H_5$ and $RDF_{100}H_{2.5}$.

Keywords: hydrogel, Irrigation, Nutrition, Fertilizer, Productivity, Wheat and Yield

Introduction

Wheat (*Triticum aestivum* L.) is the world's most widely cultivated food crop. Wheat grain contains about 12% protein which is more than that in other cereals and is of special significance to maintain the good bread making quality, due to the presence of a characteristic substance called 'gluten'. It has also a relatively high content of niacin and thiamine. Wheat is the second most important grain crop after rice in India. India has ever growing population, it has been projected that to feed 1.3 billion population and for diversified uses, India will have to produce at least 109 million tonnes of wheat by 2020 A.D. which might be only possible through elevating the national productivity up to 40.0 q ha^{-1} (Nagarajan and Rana 2002) [8]. Water availability is one of the most important factors influencing the growth and productivity of wheat. 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 Water requirement of wheat vary from 180-420 mm depending upon the duration of the crop (Balasubramaniyan and Palaniappan 2001) [1]. Thus, there is a sufficient scope to carry out what minimum amount of water should be applied to have maximum yield per unit of water applied. Irrigations are recommended at the times corresponding to the specific growth stages (crown root initiation, early tillering, late jointing/boot and heading/flowering) of wheat. Depending upon the soil type 4-5 irrigations are generally required to get optimum yield of wheat under normal climatic conditions in North-West India (PAU 2013) [13]. The chemical fertilizers, no doubt, are the important source, which can meet the nutrients requirement but their imbalanced and continuous use lead to environmental pollution and deterioration of soil physico-chemical properties. Fertilizers constitute an integral part of improved crop production technology. Supply of adequate amounts of nutrients and its management is one of the most important factors in influencing the yield of not only wheat but other crops as well. 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 systems that optimize yield, reduce losses and improve N uptake and water use efficiency are important in sustainable agriculture. Water absorbing materials have been reported to be effective tools in increasing water holding capacity. Water conservation is a key step to attain sustainable agriculture growth, development and productivity. There is a strong need for plant growth media with increased water and nutrient holding capacity. In addition, to reducing the frequency of irrigation during crop production, such hydration strategies are essential for minimizing post production crop loss in retail outlets. Hydrogel is one of the most popular, having also been used to reduce water runoff and increase infiltration rates in field agriculture, in addition to increasing water holding capacity for agricultural applications (Sharma 2004) [20]. The hydrogel provides a range of environmental benefits like decreased erosion, reduced sediment and nutrient losses and absorb the nutrients to gradually release them. The influence of hydrogels depends on soil structure, concentration of salts and fertilizers, and the type of plant cultivated (Narjary *et al* 2012) [9]. The use of hydrophilic polymers, to improving soil water and fertilizer retention properties and thus crop productivity is attracting considerable interest. Keeping these considerations in view, the present study entitled "Productivity of wheat (*Triticum aestivum* L.) in relation to hydrogel as influenced by different irrigation regimes and nutrient levels" was planned.

Materials and methods

The field experiment was conducted at the Punjab Agricultural University, Ludhiana (30^0 56/N latitude and 75° 52/E longitude and at an altitude of 247 m above m.s.l), Punjab during *rabi* 2013-14. The soil type was deep alluvial loamy sand, Typic Ustochrept, low in organic carbon (4.2 g C/kg at 0-15 cm), EC 0.12 dS/m normal in pH (pH 7.6), low in available N 183.4 kg/ha, medium in available P (13.8 kg/ha) and ammonium acetate extractable K (145.1). The rainfall of 177 mm was received during the wheat growing season. The experiment was conducted in a split plot design with four levels of irrigation at various physiological growth stages of wheat crop i.e. I_0 - no irrigation, I_2 -two irrigations at crown root initiation [CRI (20-25 DAS)] and boot stage (90-95 DAS), I_3 -three irrigations at CRI, tillering (50-60 DAS) and milk stage (105-115 DAS) and I_4 -four irrigations at CRI, tillering, boot stage and milk stage in main plots and six levels of nutrient and hydrogel doses (100% RDF 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) in sub plots with three replications. Hydrogel developed by Indian Agricultural Research Institute (IARI), New Dehli was used and was applied with last ploughing before sowing of the wheat crop. The crop was sown on flat bed with row spacing of 20 cm. The recommended dose of fertilizers (RDF) of nitrogen in the form of urea (46% N) was used at the rate of 150 kg N/ha (3 split doses: 1/2 at sowing, 1/4 at Ist irrigation and 1/4 at 2nd irrigation). Phosphorus (P_2O_5) at the rate of 62.5 kg/ha in the form of Di-ammonium phosphate (DAP- 18% N, 46 % P_2O_5) and Potassium (K_2O) at the rate of 30 kg/ha in the form of Muriate of Potash (MOP- 60 % K_2O) fertilizers were applied at the time of sowing. The data on yield was collected at harvest and presented as q/ha and observation on growth and yield attributers were recorded from ten randomly selected tagged plants from each plot. Analysis of variance (ANOVA) was performed using CPCS 1 statistical software at 0.05% level of probability was used to test the significance of differences among treatment means.

Result and Discussions

Growth characters

Plant height

The plant height (Table 1) was influenced significantly by different irrigation levels at all the observation intervals. The treatment I_4 being significantly better than I_0 and I_2 treatments but statistically at par with I_3 treatment except at 30 days after sowing where I_4 was statistically at par with I_2 and I_3 treatments, which were significantly better than I_0 treatment. Similar results were recorded by Sarma *et al* (2007) [16] in an experiment conducted at Hissar (Haryana).

On the other hand nutrient and hydrogel levels also had significant effect on the plant height of wheat crop at all the observation times. The treatment $RDF_{75}H_5$ resulted in significantly higher plant height and was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{100}H_5$ except at 30 days after sowing where it was significantly better than $RDF_{75}H_0$ only and was at par with all other treatments. This can be due to the fact that hydrogel retains more soil moisture, reduces the leaching losses of nutrients thus, provides the favourable soil conditions which enhance the crop growth. These results are in agreement with the findings of Ifhtikar *et al* (2002) [3] from Pakistan, who reported increasing plant height with increase in nutrient levels. Application of hydrogel ($H_{2.5}$/H_5) recorded significantly higher plant height than H_0 irrespective of nutrient levels. A similar effect of hydrogel on plant height was also reported by Rehman *et al* (2011) [15] on rice crop.

Tillers m^{-2}

Four irrigations led to the highest tiller count (Table 2) at all the observations except 30 days after sowing where irrigation had non-significant effect. The irrigation treatment of I_4 was statistically at par with I_3 at 90 and 120 days after sowing and was significantly better than I_2 and I_0 treatments. At 60 days of sowing I_3 treatment recorded the highest tillers and was at par with I_4 which were significantly better than I_2 and I_0 treatments. This can be due to better soil moisture conditions under increased irrigation levels. These results are in agreement with the results reported by Ngwako and Mashiqa (2013) [10].

The nutrient and hydrogel levels also had a significant effect on tillering of wheat crop except at 30 days after sowing. Application of $RDF_{75}H_5$ treatment resulted in significantly higher tiller count which was at par with $RDF_{100}H_5$ and $RDF_{100}H_5$ while, significantly better than all other treatments at 60, 90 and 120 days after sowing. This can be attributed to increased soil moisture and nutrient availability by increasing the hydrogel levels. Tillers were significantly increased with application of hydrogel in both the treatments. These results are supported by the Rehman *et al* (2011) [15], they reported increased number of tillers by rice crop with increase in hydrogel levels on sandy loam soils. Higher number of tillers with 100% nutrients of wheat crop was also reported by Sepeyha *et al* (2012) [19]. Tillers were significantly increased with application of hydrogel in both the nutrient levels.

Interaction effect was found non-significant by different irrigation, nutrient and hydrogel levels.

Dry matter accumulation

It was noticed that dry matter accumulation (Table 3) was not significantly influenced by increasing irrigation levels from I_2

to I_4 at 30 days after sowing but recorded significantly better dry matter accumulation than I_0 treatment. Application of I_4 resulted in significantly better dry matter accumulation than I_0, I_2 and I_3 treatments at 120 days after sowing. At 60 and 90 days after sowing I_4 was at par with I_3 but were significantly better than I_0 and I_2 treatments. This can be due to the better crop growth, plant height, tiller count under increased irrigation conditions. These results were in conformation with the results obtained by Jana *et al* (2001) [4]. The nutrient and hydrogel levels also had a significant effect on dry matter accumulation by the crop. At 30 days after sowing $RDF_{75}H_0$ resulted in significantly lower dry matter accumulation while all the other treatments were at par with each other. At 60 days after sowing $RDF_{75}H_5$ recorded highest dry matter accumulation and was statistically at par with $RDF_{75}H_5$ and $RDF_{75}H_5$. While, the treatment $RDF_{100}H_5$ recorded the highest dry matter accumulation at 90 and 120 days after sowing this was at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. This can be attributed to higher moisture conditions and higher nutrient uptake by the crop with increased hydrogel levels. Yangyuoru *et al* (2006) [24] also reported increased dry matter accumulation in maize crop with the application of hydrogel. Higher dry matter accumulation with optimum NPK levels was also reported by Mojid (2012) [6]. Interaction effect of irrigation, nutrient and hydrogel were found to be non-significant.

Periodic leaf area index

The data for leaf area index at 30, 60, 90 and 120 days after sowing have been presented in Table 4, increasing irrigation from I_2 to I_4 showed non-significant results at 30 days after sowing and was at par with each other but was significantly better than I_0 treatment. The treatment of I_4 recorded the highest leaf area index at 120 days after sowing which was significantly better than I_0, I_2 and I_3. At 60 and 90 days after sowing leaf area index was significantly better in I_3 and I_4 treatments than I_0 and I_2 treatments, I_3 and I_4 were at par with each other. This can be due to better absorption of moisture and nutrients from the soil under higher moisture availability. These results are supported by results obtained by Pandey *et al* (1997) [12]. Nutrient and hydrogel levels also showed significant results. At 30 days after sowing $RDF_{75}H_0$ recorded significantly lower yields than all the other treatments. At 60, 90 and 120 days after sowing $RDF_{75}H_5$ recorded the highest leaf area which was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{100}H_5$ and was significantly better than other treatments. These results are in agreement with results reported by Sayyari and Ghanbari (2012) [18], they reported higher leaf area of Sweet Pepper with hydrogel application. Interaction effect was non-significantly effected by irrigation, nutrient and hydrogel treatments.

Yield attributing characters and yield

Tiller density m^{-2}

The data regarding tiller density have been presented in Table 5. It was observed that irrigation, nutrient and hydrogel levels had a significant effect on the tiller density. The treatment of I_4 irrigation gave significantly higher number of total tillers than I_0 and I_2 treatments while, it was statistically at par with I_3 treatment of irrigation. This can be attributed due to application of irrigation at CRI and tillering stage. These results are in agreement with the results reported by Pal *et al* (2000b) [11] and Ram *et al* (2013) [14]. $RDF_{75}H_0$ recorded significantly lower total tillers than all the other treatments. Nutrient and hydrogel level with $RDF_{100}H_5$ recorded higher number of total tillers and was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. This can be due to the adequate moisture and higher nutrient absorption during the CRI and tillering stage. These results are in agreement with results of Rehman *et al* (2011) [15] they reported higher tiller density of rice crop with hydrogel application. Higher number of tiller density with increased levels of NPK was supported by Singh *et al* (2007) [16, 22]. Interaction effect of irrigation, nutrient and hydrogel was found to be non-significant.

Effective tillers

It was observed that effective tillers follow the same trend as that of the total tillers for irrigation, nutrient and hydrogel treatments. The treatment of I_4 gave significantly higher number of tillers than I_0 and I_2 treatments and was statistically at par with I_3 treatment of irrigation. These results are in agreement with the results obtained by the Wajid *et al* (2002) [23] and Ram *et al* (2013) [14]. Similarly, $RDF_{100}H_5$ recorded higher number of effective tillers and was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. The treatment of $RDF_{75}H_0$ recorded significantly lower effective tillers than all the other treatments. It might be due to better growth and development due to more moisture availability with hydrogel application. These results are supported by Mondal *et al* (2003) [7] they also reported higher effective tillers with increased nutrient levels. Interaction effect was found non-significant by different irrigation, nutrient and hydrogel levels.

Number of grains ear^{-1} and 1000-grain weight

The number of grains per ear and 1000-grain weight is an important component of grain yield. Irrigation, nutrient and hydrogel did not have any significant effect on the number of grains per ear (Table 5) Interaction was also recorded non-significant.

Biological yield

The irrigation, nutrient and hydrogel levels have significant effect on biological yield of wheat crop (Table 5). Among the irrigation treatments I_4 resulted in significantly higher yield than all the other treatments while, it was statistically at par with I_3 treatment of irrigation. The increase in biological yield with four irrigations was over zero, two and three irrigations were found 45.3, 12.7 and 3.1% respectively. This might be due to increased number of total & effective tillers and higher plant height. The irrigation treatment of I_3 was found optimum under well distributed rainfall of more than 170 mm in growing season of crop. Shivani *et al* (2003) [21] also reported an increase in biological yield with increased number of irrigations. These reports are further supported by the findings of Sarwar *et al* (2006) [17]. On the other hand nutrient and hydrogel levels also behaved significantly with $RDF_{100}H_5$ recorded the highest biological yield than $RDF_{100}H_0$, $RDF_{75}H_0$ and $RDF_{75}H_{2.5}$ and were statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. The treatment of $RDF_{75}H_0$ recorded significantly lower biological yield than all the other treatments. Irrespective of hydrogel, application of 100% RDF level results in significantly higher biological yield than 75% RDF level. These results are in agreement with the results of Sepeyha *et al* (2012) [19]. The biological yield of wheat crop was recorded significantly higher with hydrogel levels as compared to control where no hydrogel was applied and it was concluded that with 75% RDF along with 5 kg ha^{-1} hydrogel can be applied instead of 100% RDF without any decrease in biological yield. These results are in agreement

with the results of Yezdani *et al* (2007) [25] they found increased soybean yield with application of hydrogel.
Interaction effect was found to be non-significant under different irrigation, nutrient and hydrogel levels.

Grain yield

Grain yield is the function of effective tillers, 1000-grain weight etc. Irrigation, nutrient and hydrogel levels affected the grain yield significantly. Under irrigation treatments there was a progressive increase in wheat grain yield with every increase in irrigation level (Table 5). The treatment of I_4 resulted in significantly higher yield than I_0 and I_2 treatments while, it was statistically at par with I_3 treatment of irrigation. The increase in grain yield with four irrigations over zero, two and three irrigations were found to be 40.1, 14.0 and 0.5% respectively. It might be due to increased availability of soil moisture to the crop in I_4 and I_3 treatments which resulted in higher yield attributes. Brahma *et al* (2007) [2] also reported the increase in grain yield with increase in irrigations levels. The effect of nutrient and hydrogel levels also behaved significantly, $RDF_{100}H_5$ recorded the higher grain yield than $RDF_{100}H_0$, $RDF_{75}H_0$ and $RDF_{75}H_{2.5}$ and was statistically at par with $RDF_{100}H_{2.5}$ and $RDF_{75}H_5$. Application of 75% RDF resulted in significantly lower grain yield as compared to 100% RDF. These results are in agreement with the results reported by Mondal *et al* (2003) [7]. Similar results were also reported by Singh *et al* (2007) [16, 22] from Ludhiana, India on loamy sand soils. Application of hydrogel @ 2.5 kg ha^{-1} and 5 kg ha^{-1} improved the grain yield significantly as compared to control, irrespective of the nutrient levels. Hydrogel @ 5 kg ha^{-1} along with 75% RDF recorded similar grain yield as that of 100% RDF. This might be due to fact that hydrogel improved the soil moisture conditions in addition to reducing the leaching losses of nutrients. Marques *et al* (2013) [5] also reported similar results of hydrogel on sugarcane crop.
Interaction effect of irrigation, nutrient and hydrogel levels was found to be non-significant.
It is concluded from the study that with application of hydrogel at 5 kg/ha, three irrigations can be applied to the wheat crop without decreasing the yield instead of four or five irrigations. On the other hand decreasing the nutrient application by 25% decreased the yield of wheat. The results revealed that with the application of hydrogel at the rate of 5 kg/ha, nutrient application can be reduced by 25% without decreasing the yield of crop.

Table 1: Periodic plant height of wheat as affected irrigation, nutrient and hydrogel levels

Treatment	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Irrigation levels					
I_0	3.9	9.0	35.4	73.2	88.4
I_2	4.3	10.1	41.4	81.8	94.3
I_3	4.3	11.7	46.3	86.4	96.7
I_4	4.3	12.0	47.7	87.7	99.5
CD (p=0.05)	0.1	1.4	1.6	1.6	2.3
Nutrient and hydrogel levels					
$RDF_{100}H_0$	4.3	10.5	42.5	83.6	95.1
$RDF_{100}H_{2.5}$	4.3	11.1	43.3	84.2	97.9
$RDF_{100}H_5$	4.3	11.3	43.7	84.9	98.1
$RDF_{75}H_0$	3.8	9.3	39.6	72.8	86.3
$RDF_{75}H_{2.5}$	4.3	10.5	42.5	82.8	92.7
$RDF_{75}H_5$	4.4	11.3	43.8	85.4	98.3
CD (p=0.05)	0.2	0.6	0.7	1.4	2.1
Interaction	NS	NS	NS	NS	NS

Table 2: Effect of irrigation, nutrients and hydrogel levels on periodic tiller count of wheat crop

Treatment	Tiller count m^{-2}			
	30 DAS	60 DAS	90 DAS	120 DAS
Irrigation levels				
I_0	189	298	303	303
I_2	189	345	394	388
I_3	190	373	422	425
I_4	190	370	426	428
CD (p=0.05)	NS	4	5.2	5
Nutrient and hydrogel levels				
$RDF_{100}H_0$	188	335	377	377
$RDF_{100}H_{2.5}$	189	353	397	399
$RDF_{100}H_5$	190	355	402	400
$RDF_{75}H_0$	187	332	351	350
$RDF_{75}H_{2.5}$	188	350	388	389
$RDF_{75}H_5$	189	356	403	402
CD (p=0.05)	NS	4	6	5
Interaction	NS	NS	NS	NS

Table 3: Periodic dry matter accumulation of wheat crop under different irrigation regimes, nutrients and hydrogel levels

Treatment	Dry matter accumulation (q ha^{-1})			
	30 DAS	60 DAS	90 DAS	120 DAS
Irrigation levels				
I_0	2.4	14.7	42.9	91.3
I_2	2.8	21.1	60.1	122.1
I_3	2.8	25.2	65.0	129.0
I_4	2.8	25.6	67.1	134.1
CD (p=0.05)	0.1	1.7	3.3	3.2
Nutrient and hydrogel levels				
$RDF_{100}H_0$	2.8	20.5	57.6	118.1
$RDF_{100}H_{2.5}$	2.8	22.8	60.6	121.0
$RDF_{100}H_5$	2.9	23.3	62.7	123.2
$RDF_{75}H_0$	2.3	18.4	49.7	110.2
$RDF_{75}H_{2.5}$	2.7	21.2	59.5	119.0
$RDF_{75}H_5$	2.9	23.6	62.6	123.1
CD (p=0.05)	0.2	1.8	2.9	2.8
Interaction	NS	NS	NS	NS

Table 4: Effect of irrigation, nutrients and hydrogel levels on periodic leaf area index of wheat crop

Treatment	Leaf area index (LAI)			
	30 DAS	60 DAS	90 DAS	120 DAS
Irrigation levels				
I_0	0.69	2.79	3.75	3.25
I_2	0.86	3.25	4.83	4.05
I_3	0.87	3.66	5.16	4.28
I_4	0.87	3.67	5.40	4.62
CD (p=0.05)	0.05	0.16	0.21	0.22
Nutrient and hydrogel levels				
$RDF_{100}H_0$	0.84	3.20	4.68	3.94
$RDF_{100}H_{2.5}$	0.85	3.43	5.02	4.30
$RDF_{100}H_5$	0.86	3.52	5.15	4.40
$RDF_{75}H_0$	0.70	2.87	3.75	3.02
$RDF_{75}H_{2.5}$	0.84	3.25	4.84	4.10
$RDF_{75}H_5$	0.86	3.53	5.17	4.42
CD (p=0.05)	0.06	0.25	0.26	0.27
Interaction	NS	NS	NS	NS

Table 5: Yield attributes and yield as influenced by irrigation, nutrient and hydrogel levels

Treatment	Total tillers (No. m^{-2})	Effective tillers (No. m^{-2})	1000-grain weight (g)	Grains ear^{-1}	Grain yield (q ha^{-1})	Biological yield (q ha^{-1})
Irrigation levels						
I_0	310	250	41.8	51.1	41.59	107.38
I_2	393	322	41.9	51.2	51.09	138.44
I_3	424	352	40.9	51.7	58.00	151.29
I_4	435	356	41.7	51.8	58.27	156.00
CD (p=0.05)	12	14	NS	NS	2.33	4.19
Nutrient and hydrogel levels						
$RDF_{100}H_0$	382	315	41.3	51.4	51.03	132.40
$RDF_{100}H_{2.5}$	397	332	40.8	51.8	54.07	142.10
$RDF_{100}H_5$	407	339	42.9	51.8	55.79	146.79
$RDF_{75}H_0$	366	271	41.8	51.2	44.45	120.47
$RDF_{75}H_{2.5}$	389	325	40.9	51.3	52.45	141.19
$RDF_{75}H_5$	401	338	41.6	51.4	55.62	146.32
CD (p=0.05)	10	12	NS	NS	1.76	4.79
Interaction	NS	NS	NS	NS	NS	NS

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