The Pharma Innovation Journal 2024; 13(6): 19-22

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
TPI 2024; 13(6): 19-22

www.thepharmajournal.com
Received: 21-03-2024
Accepted: 26-04-2024

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Effect of irrigation regimes and hydrogel on yield attributes and yield of upland paddy

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Abstract

The irrigation management in upland paddy is a big challenge. To address this issue, a field experiment entitled "Effect of hydrogel and irrigation regimes on yield attributes and yield of upland paddy" was conducted on clay loam soils at Agricultural Research Station, Banswara during *kharif* season *2022.* The experiment consisted of 12 treatment combinations having three irrigation regimes (0.8, 1.0 and 1.2 IW/CPE) in main plots and four hydrogel levels (control, 10, 15 and 20 kg ha^{-1}) in sub plots evaluated under Split Plot Design (SPD) with three replications. The variety tested under this experiment was Mahi Sugandha. The impact of irrigation regimes and application of hydrogel on paddy yield was found significant. The maximum plant height, number of tillers per clump, paddy yield, straw yield and biological yield was found under irrigation regime I_3 (1.2 IW/CPE) followed by I_2 (1.0 IW/CPE). Further, the above yield attributes and yield parameters were found statistically at par under I_3 (1.2 IW/CPE) and I_2 (1.0 IW/CPE) irrigation regimes except plant height. The higher water use efficiency was recorded under lower levels of irrigation. Among the different hydrogel doses, H_{20} demonstrated the higher plant height, number of tillers per clump, paddy yield, straw yield and biological yield but these parameters remained statistically at par with H_{15} level of hydrogel except number of tillers. The soil parameters were remained non-significant with irrigations regimes but the hydrogel application reduced the soil pH and increased soil moisture and organic carbon content significantly.

Keywords: Irrigation regimes, hydrogel, yield, upland paddy

Introduction

Rice (*Oryza sativa* L.) is the second important extensively grown cereal crop which is a staple food for more than 50% of the population world-wide. Its grain contains 75-80% starch, 12% water, and 7% protein. Paddy production in India is mostly dependent on lowland rice but upland rice is also gaining importance and the production sustainability is difficult to maintain. In Rajasthan, paddy is grown mainly in Sriganganagar, Hanumangarh, Kota, Bundi, Baran, Jhalawar and Banswara districts, The farmers of Rajasthan facing the water scarcity problems. Therefore, water saving techniques are being invented by many innovators and scientists time to time. In past few decades the development of soil conditioners or hydrogels, particularly in regions with scarce water resources have been given more attention. The synthetic soil conditioners or hydrogels have very much potential in restoring and reclaiming soil moisture reserves where irrigation opportunities are less. Hydrogels are cross-linked polymers having a hydrophilic nature that are able to absorb large quantities of water without dissolving. Water absorption capacity is created by the hydrophilic functional groups found on the polymer and their resistance to dissolution arises from cross-links between the network chains. The application of hydrogel in arid and semi-arid regions increases the water holding capacity of the soil, soil water retention, irrigation efficiency, and crop water productivity. The sector that consumes the major amount of fresh water in India is agriculture (Singh *et al.* 2014 and Singh *et al.* 2018) [9, 10], and due to the limitation and scarcity of fresh water resources (Yadav *et al.* 2016 and Yadav *et al.* 2022) [16, 15]. Many approaches such as irrigation depth, interval, transpiration ratio, soil moisture status, climatological and plant indices have been tested on different crops and locations, showing beneficial impacts on water productivity and farm production. Recently, irrigation has been scheduled based on the climatological approach (IW/CPE), which integrates all weather parameters and applies a known amount of irrigation water when cumulative pan evaporation reaches a predetermined level (Sharma *et al.* 2021) [7]. Keeping in view the above facts, the present study was undertaken to find out the effect of hydrogel and irrigation regimes on yield attribute, yield and soil physio-chemical properties.

Materials and Methods

A field experiment was conducted during *kharif* season 2022 at Instructional Farm, Agricultural Research Station, (Maharana Pratap University of Agriculture and Technology) Banswara, (Rajasthan) to find out the effect of irrigation regimes and hydrogel on yield and yield attributes of upland paddy taking Mahi Sugandha as a test variety. The trial was conducted with three irrigation levels (0.8, 1.0 and 1.2 IW/CPE) in main plots and four hydrogel levels (control, 10, 15 and 20 kg ha^{-1}) in sub plots under Split Plot Design (SPD) replicated thrice. The treatment symbols used in the paper are I_1, I_2 and I_3 for 0.8 IW/CPE, 1.0 IW/CPE and 1.2 IW/CPE, respectively and H_0, H_{10}, H_{15} and H_{20} for control, 10 kg ha^{-1}, 15 kg ha^{-1} and 20 kg ha^{-1} hydrogel, respectively. Plant height was measured at harvest by randomly selected five plants from each plot with the help of one-meter wooden scale. The number of tillers were counted before harvesting from randomly selected five clumps in each plot and reported as average number of tillers per clump. Paddy was harvested as per schedule of harvesting and yield of each plot were recorded in kg per plot and converted in quintal per hectare. The water use efficiency (kg ha^{-1}cm) for a given treatments was calculated by dividing the paddy yield with the respective total water applied given by Dastane (1972) [2].

$$WUE = \frac{Yield\ of\ paddy\ (kg/ha)}{Total\ water\ applied\ (cm)}$$

Soil reaction (pH) was determined using pH meter in 1:2 soil water suspension as per method of USDA, Hand book No. 60 given by Richards (1954) [6]. Electrical Conductivity (dS m^{-1} at 25 °C) was measured with the help of conductivity meter of 1:2 soil water suspension as per method 4b, USDA, Hand book No. 60 given by Richards (1954) [6]. Organic carbon (%) was tested using rapid titration method given by Walkley and Black (1934). Bulk density (Mg m^{-3}) was determined using undisturbed core sampler method given by Singh (1980) [11]. The moisture content was determined by gravimetric method as prescribed by Reynolds (2017) [5].

Results and discussion

Plant Parameters

Plant height at harvest: The impact of irrigation regimes and hydrogel on plant height at harvest presented in Table 1. A significant increase was recorded in the plant height of paddy at harvest due to irrigation treatments. Maximum plant height at harvest (91.32 cm) was recorded under 1.2 IW/CPE (I_3) whereas minimum plant height (82.94 cm) at harvest was recorded under 0.8 IW/CPE (I_1). But, the plant height at harvest remained at par under I_2 and I_1 irrigation treatment. The soil application of hydrogel produced a significant result on plant height at harvest. The maximum plant height at harvest (89.02 cm) was found with the application of hydrogel at the rate of 20 kg ha^{-1} (H_{20}) and minimum (82.09 cm) was found under control (H_0). But the plant height with H_{10}, H_{15} and H_{20} hydrogel treatments remained statistically non-significant. The increase in plant height was due to water supplies with irrigation providing a congenial growth environment which improved the cell elongation, cell turgidity, opening of stomata and finally the partitioning of photosynthates efficiently to the sink.

No. of tillers per clump: The effect of irrigation regimes and soil applied hydrogel on number of tillers per clump at the time of harvest showed in Table 1. The significant increase in number of tillers per clump of paddy at harvest was observed with the irrigation treatments. Maximum number of tillers per clump (26.50) were recorded under 1.2 IW/CPE (I_3) whereas minimum number of tillers per clump (22.54) were recorded under 0.8 IW/CPE (I_1). Further, the number of tillers per clump at harvest remained at par under I_3 and I_2 irrigation regimes. The increasing levels of soil applied hydrogel increased the number of tillers per clump significantly. The maximum number of tillers per clump at harvest (32.00) were found with the application of hydrogel at the rate of 20 kg ha^{-1} (H_{20}) followed by H_{15} & H_{10} and minimum (16.66) were found under control (H_0).

Paddy yield: The impact of irrigation regimes and application of hydrogel on paddy yield is presented in Table 1. The maximum paddy yield (54.57 q ha^{-1}) was found under irrigation regime I_3 (1.2 IW/CPE) followed by I_2 (53.31 q ha^{-1}). The increase in paddy yield with the irrigation regime I_3 (1.2 IW/CPE) was 14.69% higher as compared to I_1 (0.8 IW/CPE). Further, the paddy yield was found statistically at par under I_3 (1.2 IW/CPE) and I_2 (1.0 IW/CPE). The paddy yield under I_2 was 12.04% higher as compared to I_1 (0.8 IW/CPE). Among the different hydrogel doses, H_{20} (57.54 q ha^{-1}) demonstrated the maximum paddy yield per hectare, whereas the minimum paddy yield (39.18 q ha^{-1}) was recorded under control (H_0). Further, the paddy yield under H_{20}, H_{15} and H_{10} found statistically at par. This might be due to the better moisture availability which favoured the development of yield attributes by the way of maintaining a better moisture regime. Similar results were also reported by Yadav *et al*. (2021) [17].

Straw yield: Similar to the paddy yield, the straw yield also significantly affected by irrigation regimes and application of hydrogel doses (Table 1). The maximum straw yield (145.70 q ha^{-1}) was recorded under irrigation regime I_3 (1.0 IW/CPE) which was 14.70% higher as compared to straw yield (127.03 ha^{-1}) recorded under I_1 (0.8 IW/CPE). Furthermore, the straw yield of paddy was found statistically at par under I_3 (1.2 IW/CPE) and I_2 (1.0 IW/CPE) irrigation regimes. With the I_2 irrigation regime 12.06% more straw yield was achieved than the I_1 irrigation regime. When we compare the straw yield under different hydrogel treatments, the application of 20 kg hydrogel per hectare gave the maximum straw yield (152.83 q ha^{-1}) followed by 149.84 q ha^{-1} under H_{15} and 146.16 q ha^{-1} under H_{10} treatments of hydrogel. However, the straw yield of paddy was found statistically at par under H_{10}, H_{15} and H_{20} treatments of hydrogel. These results are in close conformity with the findings of Mankar and Beena (2018) [3] who has reported similar results with irrigation scheduling and hydrogel application in mustard. A proper supply of moisture with irrigation and hydrogel application letting an increased growth and development of the crop plants got evident in the form of higher straw yields. Similar results were also reported by Yadav *et al*. (2021) [17].

Biological yield: The data related to the biological yield of paddy as affected by irrigation regimes and application of hydrogel are also presented in Table 1. The highest biological yield (200.26 q ha^{-1}) was recorded under irrigation regime I_3 (1.2 IW/CPE) which was 14.69% higher as compared to I_1

(0.8 IW/CPE) irrigation regime. Further, the biological yield was remained statistically at par under I_3 (1.2 IW/CPE) and I_2 (1.0 IW/CPE) irrigation regimes. In respect to hydrogel treatments, H_{20} treatment gave the maximum biological yield (210.07 q ha^{-1}) followed by H_{15} and H_{10} treatments of hydrogel. Further, the biological yield of paddy was remained statistically at par under H_{10}, H_{15} and H_{20} treatments of hydrogel application. Higher biological yield was the subsequent effect of the increased seed and straw yields with irrigation and hydrogel application.

Water use efficiency

The effect of irrigation regimes and soil applied hydrogel on water use efficiency showed in Table 1. The significant decreased in water use efficiency of paddy was observed with the irrigation treatments. Minimum water use efficiency (83.18 kg ha^{-1}cm) was recorded under 1.2 IW/CPE (I_3) whereas maximum water use efficiency (108.78 kg ha^{-1}cm) was recorded under 0.8 IW/CPE (I_1). The increasing levels of soil applied hydrogel increased the water use efficiency. The highest water use efficiency (104.71 kg ha^{-1}cm) was found with the application of hydrogel at the rate of 20kg ha^{-1} (H_{20}) followed by H_{15} & H_{10} and lowest (71.66 kg ha^{-1}cm) was found under control (H_0). The water use efficiency with 10 & 15 kg ha^{-1} as well as 15 & 20 kg ha^{-1} hydrogel application remained statistically at par. Water-use efficiency depends on the seed yield and the consumptive use of water by the crop plants.

Table 1: Effect of hydrogel and irrigation regimes on Plant height and tillers per metre row length

Treatments	Plant Height (cm)	Number of tillers /clump	Paddy yield(q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Water Use Efficiency (kg ha^{-1}cm)
Irrigation regime						
0.8 IW/CPE (I_1)	82.94	22.54	47.58	127.03	174.60	108.78
1.0 IW/CPE (I_2)	84.94	25.50	53.31	142.35	195.66	97.52
1.2 IW/CPE (I_3)	91.32	26.50	54.57	145.70	200.26	83.18
SEm±	1.43	0.36	1.26	3.36	4.62	2.62
C.D. (p=0.05)	5.62	1.42	4.95	13.21	18.16	7.86
Dose of hydrogel						
Control (H_0)	82.09	16.66	39.18	104.60	143.78	71.66
10 kg/ha (H_{10})	86.54	20.70	54.74	146.16	200.90	100.13
15 kg/ha (H_{15})	87.95	30.00	56.12	149.84	205.96	102.66
20 kg/ha (H_{20})	89.02	32.00	57.24	152.83	210.07	104.71
SEm±	0.85	0.34	0.87	2.33	3.21	1.43
C.D. (p=0.05)	2.53	1.02	2.60	6.93	9.53	4.22

Soil Parameters

Soil pH: The data related to the effect of irrigation regimes and soil applied hydrogel on soil pH showed in Table 2. The irrigation regimes failed to show any significant effect on soil pH. The effect of soil applied hydrogel on soil pH was found significant. The lowest soil pH (8.036) was found with the application of hydrogel at the rate of 20kg ha^{-1} (H_{20}) followed by H_{15} & H_{10} and highest (8.28) was found under control (H_0). The applied hydrogel in the experiment is of organic nature which supply the organic carbon to the soil which ultimately affect the soil pH favourably (Chandar *et al*. 2012 and Singh *et al*. 2013) [1, 8].

Electrical Conductivity: The data pertaining to the effect of irrigation regimes and soil applied hydrogel on electrical conductivity showed in Table 2. Both the irrigation regimes as well as soil applied hydrogel failed to show any significant effect on electrical conductivity of soil.

Bulk Density: The effect of irrigation regimes and soil applied hydrogel on bulk density of soil was also found non-significant (Table 2).

Particle Density: The data pertaining to the effect of irrigation regimes and soil applied hydrogel on particle density of soil presented in Table 2. The data revealed that the irrigation regimes and soil applied hydrogel didn't show any significant effect on soil particle density.

Porosity: The results pertaining to porosity as affected by different irrigation regimes and hydrogel doses are given in Table 2. The data showed that irrigation regimes didn't bring any significant change in the soil porosity. Also, soil applied hydrogel showed a non-significant influence on the soil porosity.

Soil moisture content after irrigation: The data on the effect of irrigation regimes and soil applied hydrogel on soil moisture content showed in Table 2. The irrigation regimes failed to show any significant effect on moisture content of soil. But the soil applied hydrogel increased the moisture content of soil significantly. The maximum moisture content (21.42%) was found with the application of hydrogel at the rate of 20 kg ha^{-1} (H_{20}) followed by H_{15} & H_{10} and minimum (20.39%) was found under control (H_0). The soil moisture under H_{20} & H_{15} and H_{15} & H_{10} hydrogel treatments remained statistically at par.

Organic Carbon

The results pertaining to organic carbon in soil are also given in Table 2. The data showed that the different irrigation regimes were unable to have any significant impact on the soil organic carbon. Further, the data showed that the application of hydrogel increased the soil organic carbon significantly. The maximum soil organic carbon was found under application of hydrogel at the rate of 20 kg per hectare (H_{20}) followed by H_{15} and H_{10} levels of hydrogel application. The soil organic carbon was found 13.05% higher under H_{20} level as compared to control (H_0). The soil organic matter can be calculated by multiplying organic carbon with the factor 1.724. Addition of any organic material adds organic carbon to the soil (Yadav *et al*. 2005; Yadav and Chhipa 2007) [13, 14]. Further, hydrogels release water into the soil, they contribute to maintaining consistent and higher soil moisture levels. This not only benefits the plants but also increases the field capacity of the soil as it can hold more water against gravity. These results are in close conformity with the findings of Neethu *et al*. (2018) [4].

Table 2: Effect of hydrogel and irrigation regimes on soil properties

Treatment	pH	Electrical Conductivity (dSm^{-1})	Bulk Density (Mg m^{-3})	Particle Density (Mg m^{-3})	Porosity (%)	Moisture content after irrigation (%)	Organic carbon (%)
Irrigation Regime							
0.4 IW/CPE	8.180	0.643	1.475	2.620	43.70	20.985	0.481
0.6 IW/CPE	8.180	0.656	1.485	2.627	43.48	20.951	0.483
0.8 IW/CPE	8.182	0.651	1.490	2.635	43.45	21.124	0.487
SEm±	0.011	0.005	0.0011	0.003	4.021	0.142	0.0001
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS
Dose of hydrogel							
Control	8.280	0.654	1.480	2.623	43.58	20.39	0.452
10 kg/ha	8.246	0.653	1.480	2.626	43.65	21.03	0.483
15 kg/ha	8.160	0.638	1.486	2.630	43.47	21.24	0.488
20 kg/ha	8.036	0.653	1.486	2.630	43.47	21.42	0.511
SEm±	0.024	0.012	0.002	0.005	0.764	0.206	0.0001
C.D. (p=0.05)	0.152	NS	NS	NS	NS	0.617	0.0111

Conclusion

On the basis of one year experiment, it is concluded that irrigation at 1.2 IW-CPE ratio gave the maximum production of paddy. Similarly, the application of 20 kg hydrogel per hectare proved highest paddy yield, straw yield and biological yield. Higher doses of hydrogel remained statistically non-significant for paddy yield. Maximum water use efficiency was obtained under 0.8 IW-CPE irrigation regime and 20 kg hydrogel per hectare. Hence, irrigation can be delayed by applying higher doses of hydrogel. No significant change was observed due to different irrigation regimes on soil properties except moisture content. But the application of hydrogel decreased the soil pH and increased soil organic carbon significantly.

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