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Effect of irrigation levels and moisture conserving polymers on growth, productivity and profitability of wheat

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ABSTRACT

The present field investigation was carried out during winter season of 2016-17 and 2017-18 at Rajasthan Agricultural Research Institute, Durgapura, Jaipur to evaluate the effect of different irrigation levels and moisture conserving polymers on performance of wheat. Results revealed that application of six irrigations resulted in significantly maximum plant height (at harvest) and dry matter at 60, 90 DAS and harvest. The application of six irrigations enhanced the CGR by the magnitude of 55.97, 23.36 and 27.55% (30-60 DAS), 42.87, 20.38 and 20.70% (60-90 DAS) and 71.09, 48.00 and 49.53% (90 DAS-at harvest) over control, three irrigations (at fixed interval) and three irrigations (at critical stages), respectively. The application of Pusa hydrogel resulted in significantly increased plant height, dry matter accumulation and CGR during all the growth stages.The maximum number of earheads (375.78/m^2), spike length (10.82 cm), number of grains/ear (30.84) and test weight (40.95 g) were registered with application of six irrigations. Pusa hydrogel improved the effective tillers by 3.61-7.31% and spike length by 8.20-15.70% over control and Herbal hydrogel. The mean maximum grain (4.74 t/ha), straw (5.73 t/ha) and biological yield (10.47 t/ha) were recorded with application of six irrigations. Pusa and Herbal hydrogel enhanced the mean grain, straw and biological yield of wheat by 6.65-13.69%, 6.90-14.41% and 6.79-14.09%, respectively. The application of six irrigations increased gross and net returns by magnitude of 64.14, 31.35 and 33.28% and 83.35, 42.25 and 44.98% over control, three irrigation (at fixed interval) and three irrigation (at critical stages), respectively. The highest gross returns (₹ 76924/ha) net returns (₹ 45548/ha) were recorded with application of Pusa hydrogel. Therefore, application of Pusa hydrogel provided additional net returns of ₹ 5689/ha to the farmers over control. The application of Pusa hydrogel and six irrigations to wheat using sprinkler system can be advocated as sustainable strategy for enhancing productivity and profitability of wheat cultivation in semi-arid condition.

Key words: Hydrogels, Irrigation, Moisture conserving polymers, Productivity and farm profitability, Wheat

Wheat is the most significant cereal in human nutrition and is thus cultivated worldwide over large areas i.e. 226 million ha (mha), constituting 32% of total cereal cultivated land (FAO 2016). It contributes about 20% of humans' daily dietary calorie and 21% of daily dietary protein intake. Wheat is the second most important food grain of India with an area of 30.5 mha, production of 98.4 million tonnes (mt), and an average productivity of 3216 kg/ha (Anonymous 2016). Rajasthan is one of the major wheat growing states in India with an area of 3.11 mha (10.3% area of country), 9.90 mt of production (10.6% production share at the national level), and productivity of 3175 kg/ha (Anonymous 2016).

Water is considered as one of the most crucial inputs for agricultural production. It facilitates a higher productive potential from the land, and significant response from applied agricultural inputs, viz. high-yielding varieties and fertilizer etc. (Kukal *et al.* 2014). Water scarcity is an emerging global concern in context of increasing population and competitive demands from agriculture, industry and urban inhabitants (Babel and Wahid 2008). Moreover, in the north-western states of country (major wheat growing belt) more than 80% of wheat area is irrigated using groundwater through deep-well pumping. In this zone, the annual groundwater draft is higher than the net annual groundwater availability (Amarasinghe *et al*. 2007). As a result, the groundwater table is lowering by approximately a meter annually, causing alarming situation in the region. Many agencies have already

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revealed faster depletion of groundwater stocks in the north and north-western parts of the country (CGWB 2014). At the current level in water consumption for wheat cultivation, the major wheat-producing belts may not possibly sustain their wheat production in future (Kang *et al*. 2002, Kukal *et al*. 2003). It has been estimated that by the year 2025, about two-thirds of the world will experience water scarcity. India has already entered the shadow of the zone of physical and economic scarcity. Poor use efficiency of water, nutrient and other agro-inputs is a serious bottleneck in realizing sustainable agricultural growth and food security for future (Halitligil *et al*. 2000). Therefore, there is an urgent need to reduce water requirement of the crop by improving use efficiency of irrigation water under changing climate situations.

Rajasthan receives least precipitation in the whole country. It is also the poorest region of country in terms of surface-water resources. Wheat is cultivated in the region by meeting the required water need mainly through irrigation from groundwater resources (Hira 2009). Widespread use of groundwater resources for irrigating wheat in the region has resulted in excessive groundwater withdrawals and consequently caused an alarming receding of groundwater levels (couple of metres annually). Such a decline in groundwater levels also raised the energy costs of irrigation (Ali and Talukder 2008, Humphreys *et al*. 2010).Under this scenario, the productivity of wheat can only be sustained by using water saving technologies.

Several technologies and agronomic practices have been developed and recommended for improving water productivity of wheat. However, a holistic strategy to evolve integrated solutions for multiple problems has been elusive (Ladha *et al*. 2009). In this context 'Pusa Hydrogel', a novel semi-synthetic super absorbent polymer has shown potential to realize higher crop yield with limited water. A significant improvement in yield and water use efficiency in most of the test crops was reported by application of Pusa hydrogel (Anupama and Parmar 2012). Pusa hydrogel is an insoluble, cross-linked three-dimensional hydrogel which absorbs water more than 400 times of its weight and gradually releases it and also improves soil hydro-physical properties such as porosity, aggregate stability and hydraulic conductivity (Dabhi *et al*. 2013). It ha also been reported to improve seed germination, root growth and density, and help plants withstand extended moisture. Keeping this in view, the present field experiment was conducted to examine the effect of different irrigation levels and hydrogels on growth, productivity and profitability of wheat in semi-arid conditions of Rajasthan.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2016-17 and 2017-18 at the Research Farm of All India Coordinated Wheat and Barley Improvement Project of Rajasthan Agricultural Research Institute, Durgapura, Jaipur (26° 51´ N, 75° 47´ E, altitude 390 m above mean sea level) to examine the bio-efficacy of different hydrogels under variable irrigation levels. The experimental site falls in the Semi-Arid Eastern Plain Zone of Rajasthan (III-A) characterized by cold winters and hot summers. Occurrence of frost during December/January is quite common phenomenon of the region. The average annual rainfall of zone was 529 mm of which about 90% is received during later half of June to September with erratic distribution over time and space. The soil of the experimental field was sandy loam in texture with a pH of 8.0, low in organic carbon and nitrogen, medium in available phosphorus and potassium. The experiment was laid out in split plot with four irrigation treatments, viz. no irrigation; three irrigations at critical, stages, i.e. crown root initiation (CRI), late tillering (LT) and grain filling (GF); six irrigations at critical stages, i.e. CRI, tillering (TL), jointing (JT), boot Leaf (BL), flowering (FL), milkstage (ML); three irrigations at fixed intervals; of 40, 80 and 120 days after sowing in main plots; and four moisture conserving treatments, viz. Control, Pusa Hydrogel (2.5 kg/ha as soil application) and Herbal Hydrogel (*Gum Tragacantha, i.e.* goondkatira as seed treatment) were in sub plots with three replications.

Field preparation included one deep ploughing by mouldboard plough followed by two cross harrowing and planking. The wheat variety HD 2967 was sown during second week of November with a recommended seed rate of 100 kg/ha. The recommended dose of nitrogen, phosphorus and potash was 150-60-40 kg/ha, respectively, which was applied through urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O). During both the seasons 1/3rd quantity of total N and whole amount of P_2O_5 and K_2O were applied as basal at sowing, while remaining quantity of N was applied in two split of equal quantity at first and second irrigation. Pusa Hydrogel, at the rate of 2.5 kg/ha well mixed with sufficient quantity of soil was applied to allotted experimental plots in furrows just before the sowing of crops. Herbal hydrogel was applied in the form of seed treatment at the time of sowing of the crop. Crop was irrigated as per the treatment using sprinkler irrigation. Crop protection measures were followed as and when required. For total dry matter accumulation, plant samples were oven dried at 60°±2°C till constant weight was obtained. Dry weight was recorded and expressed in g/m^2.

The crop growth was calculated using following formula:

$$\text{Mean CGR} = \frac{W_2 - W_1}{T_2 - T_1}\ \text{g/m}^2\text{/day}$$

where, W_1 and W_2 are the dry weight values at time T_1 and T_2, respectively. T_1 and T_2 are time values in days.

The yield attributes were estimated by selecting five plants form each experimental plot and average values were reported. The net plots, leaving the two border rows on the rows direction and half meter on opposite direction of the plots of wheat, were harvested manually with sickles. The produce was kept for sun drying in field for some days and after drying the biological yield was recorded and expressed in t/ha. After threshing the bundles from each plot, the grains were cleaned, dried and weighed. The grain yield was expressed in t/ha on dry weight basis at 12% moisture content. Straw yield, obtained by subtracting the grain yield from the weight of total biological yield for individual plots, was expressed in t/ha.

The net returns for each treatment were calculated by deducting the total cost of cultivation from gross returns of respective treatments, and the benefit:cost ratio was calculated by dividing the net returns with total cost of cultivation. All data recorded were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez 1984) for split plot. The least significant test was used to decipher the main and interaction effects of treatments at 5% level of significance ($P<0.05$).

RESULT AND DISCUSSION

Growth parameters

Irrigation levels had significant effect on plant height, periodic dry matter accumulation and CGR (Table 1). The maximum height at harvest (98.31 cm) was recorded with application of six irrigations while the minimum (70.27 cm) was under control. At early growth stage, i.e. 30 days after sowing (DAS), all the irrigation levels were statistically at par for dry matter accumulation and CGR. However, at later stages of the crop, application of six irrigations attainted maximum dry matter, i.e. 321.71, 787.57 and 1490.76 g/m^2 at 60, 90 DAS and at harvest, respectively. The application of six irrigations also enhanced the CGR by the magnitude of 55.97, 23.36 and 27.55% (30-60 DAS), 42.87, 20.38 and 20.70% (60-90 DAS) and 71.09, 48.00 and 49.53% (90 DAS-at harvest) over control three irrigations (at critical stages) and three irrigations (at fixed interval), respectively.Water is a fundamental constituent of plant protoplasm and its adequate supply is essential for cell division and cell elongation. Therefore, optimum availability of water with application of six irrigations to wheat might have improved the photosynthetic area of plants that cumulatively contributed to higher plant height, dry matter accumulation and CGR of crop. The results of this study are in close agreement those reported by Jalota *et al*. (2006) and Kharrou *et al*. (2011).

The application of Pusa Hydrogel resulted in significantly increased plant height (89.16 cm, at harvest) and dry matter accumulation (261.77, 671.30 and 1134.61g/m^2) at 60, 90 DAS and at harvest, respectively (Table 1). Similarly, the significantly maximum CGR was also recorded with application of Pusa hydrogel, which was enhanced by the magnitude of 7.34-15.19% (30-60 DAS), 8.30-20.33% (60-90 DAS) and 11.83-24.80% (90 DAS-at harvest) over control and herbal hydrogel (Table 2). Herbal hydrogel was found statistically at par with control for all the growth parameters (plant height, dry matter accumulation and CGR) at all the growth stages. However, significant variation in plant with the application of herbal hydrogel over control was observed at maturity stage of the crop. Plant growth depends on cell division and enlargement, which is highly

Table 1 Effect of different irrigation levels and moisture conserving practices on plant height, dry matter accumulation and CGR of wheat

Treatment	Plant height (cm)	Dry matter accumulation (g/m^2)				CGR (g/m^2/day)			
	At harvest	30 DAS	60 DAS	90 DAS	At harvest	0-30 DAS	30-60 DAS	60-90 DAS	90 DAS harvest
Irrigation levels									
No irrigation	70.27	32.33	159.41	426.08	629.31	1.08	4.23	9.01	6.67
Three irrigations (at CRI, LT and GF)	85.51	32.54	253.64	625.69	991.31	1.09	7.37	12.56	12.00
Six irrigations (at CRI, TL, JT, BL, FL and ML stages)	98.31	33.06	321.71	787.57	1490.76	1.11	9.62	15.78	23.33
Three irrigations (at 40, 80 and 120 DAS)	86.78	32.64	241.89	611.47	966.30	1.10	6.97	12.51	11.67
CD (P=0.05)	5.28	2.40	20.70	76.69	140.73	0.09	0.62	3.22	1.80
Hydrogels									
Control	78.84	32.38	226.19	552.73	901.12	1.08	6.46	10.98	11.66
Pusa Hydrogel @2.5 kg/ha	89.16	33.08	261.77	671.30	1134.61	1.11	7.62	13.78	15.36
Herbal Hydrogel @400 ml/100 kg seed	87.64	32.46	244.53	614.07	1022.52	1.09	7.06	12.64	13.23
CD (P=0.05)	3.61	2.33	25.43	82.17	167.24	0.08	0.83	1.97	2.53

dependent on plant-water relations. Augmentation in crop growth parameters with the application of Pusa hydrogel might be due to its property of retaining and releasing water to maintain proper soil moisture for longer period in the rhizosphere. Adequate moisture content in soil facilitates better root growth, proper translocation and uptake of nutrients in the soil by the plants, which support better plant growth. Pusa hydrogel also improves soil's physical conditions, that facilitate movements of water, dissolved nutrients and air into the soil (Jana *et al*. 2001, Singh *et al*. 2017).

Yield attributes

The analysis of variance of data indicated that irrigation levels had significant effect on yield attributes of wheat, viz. number of effective tillers, spike length, number of grains and test weight (Table 2). The maximum number of earheads (375.78/m^2), spike length (10.82 cm), number of grains/ear (30.84) and test weight (40.95 g) were registered application of six irrigations. Whereas, minimum number of effective tillers (253.39/m^2), spike length (6.44 cm), number of grains/ear (21.36) and test weight (30.33 g) were recorded under control (No irrigation). The application of six irrigations enhanced the number of effective tillers by 32.56, 17.32 and 19.91%, spike length by 40.45, 19.00 and 24.45%, number of grains by 30.74, 6.80 and 5.27% and test weight by 25.94, 12.09 and 14.10% over control, three irrigations (at critical stages) and three irrigations (at fixed interval), respectively.The application of six irrigation to wheat facilitates sufficient moisture for higher growth and development of the plants which enhanced photosynthetic efficiency by improving source-sink relationship of the plants leading higher growth and development reflected by higher yield attributes of plants.These findings were in accordance with those of Mubeen *et al*. (2013) and Ali *et al*. (2012).

The application of Pusa Hydrogel resulted in significantly effective tillers (321.92/m^2) and spike (9.29 cm) compared to control and herbal hydrogel (Table 2). The application of Pusa hydrogel improved effective tillers by 3.61-7.31% and spike length by 8.20-15.70% over control and herbal hydrogel. However, the number of grains and test weight under different moisture conserving treatments were found statistically at par, although highest values were recorded with the application of Pusa hydrogel. Use of Pusa hydrogel made available soil moisture to optimum level during growth period, which helped in better leaf area expansion and photosynthesis, ultimately greater plant growth and development, reflected from higher values of yield attributes. Similar results of higher yield attributes of wheat with the application of Pusa hydrogel were also reported by Narjary *et al*. (2012), and Anupama and Parmar (2012).

Crop productivity

Results revealed that irrigation levels had significant effect on wheat productivity (Table 2).The mean maximum grain (4.73 t/ha), straw (5.73 t/ha) and biological yield

Table 2 Effect of different irrigation levels and moisture conserving practices on yield attributes and yield of wheat

Treatment	Effective tillers (m^2)	Spike length (cm)	No. of grains/spike	Test wt (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biomass yield (t/ha)
Irrigation levels							
No irrigation	253.39	6.44	21.36	30.33	1.65	2.20	3.85
Three irrigations (at CRI, LT and GF)	310.67	8.76	28.74	36.00	3.22	4.04	7.26
Six irrigations (at CRI, TL, JT, BL, FL and ML stages)	375.78	10.82	30.84	40.95	4.73	5.73	10.46
Three irrigations (at 40, 80 and 120 DAS)	300.94	8.17	29.21	35.17	3.12	3.94	70.65
CD (P=0.05)	28.01	0.83	1.87	2.04	0.38	0.37	0.70
Hydrogels							
Control	298.38	7.83	27.12	34.45	2.94	3.66	6.60
Pusa Hydrogel @2.5 kg/ha	321.92	9.29	28.05	36.61	3.41	4.28	7.69
Herbal Hydrogel @400 ml/100 kg seed	310.29	8.52	27.44	35.78	3.18	3.98	7.16
CD (P=0.05)	18.98	1.03	2.05	1.93	0.18	0.44	0.75

(10.46 t/ha) of wheat were recorded with application of six irrigations, which were 32.07-65.07%, 29.42-61.64% and 30.62-63.19% higher compared to control and three irrigations either at fixed DAS or critical stages (Table 2). Likewise, the crop supplied with three irrigations (either at fixed interval or at critical stages) increased the grain yield by 47.04 and 47.88%, straw yield by 44.21% and 45.94% and biological yield by 45.46% and 46.80%, respectively. The higher yield of wheat with six irrigations attributed can be to higher photosynthetic activity of plants due to optimum soil moisture for all the metabolic activities which leads to greater growth and development of the plants. Further, optimum moisture availability with six irrigations might improve the source sink relationship of the plants and facilitate higher translocation of photosynthetic substances from leaves to grain that leads to higher crop productivity. Whereas moisture stress in crops due to shortage of water may cause a decrease in translocation of carbohydrates and growth substances, disturb nitrogen metabolism, force loss of turgor and consequently cause a reduction in sink size and its growth. These results are in conformity with the findings of Yadav *et al.* (2010) and Rahim *et al*. (2010). The grain, straw and biomass yields of wheat different moisture conservation treatments were also found significant, and highest values of these were recorded with Pusa hydrogel (Table 2). However, application of herbal hydrogel produced statistically equal grain, straw and biological yield with Pusa hydrogel. Application of Pusa and Herbal hydrogel enhanced the mean grain, straw and biological yield of wheat the magnitude of 6.65-13.69%, 6.90-14.41% and 6.79-14.09%, respectively over control. This increment in crop productivity with application of Pusa hydrogel might be a result of higher plant growth, dry matter accumulation and yield attributes due to optimum availability of water compared to other treatments. Our results are in close agreement with the results of earlier researchers (Akhter *et al*. 2004, Rehman *et al*. 2011) who stated that application of hydrogels resulted in higher crop productivity.

Farm profitability

Among the irrigation regimes, the highest cost of cultivation (₹ 30803/ha), gross returns (₹ 105650/ha), net returns (₹ 74846/ha) and B:C ratio (2.62) were recorded with application six irrigations. Whereas, minimum values for cost of cultivation (₹ 25428/ha), gross returns (₹ 37884/ha) and net returns (₹ 12455/ha) and B:C ratio (0.57) were recorded under control (No irrigation) (Table 3). The application of six irrigation increased gross and net returns by 64.14, 31.35 and 33.28% and 83.35, 42.25 and 44.98% over control, three irrigations (at fixed interval) and three irrigations (at critical stages), respectively. Similarly, application of three irrigations (at fixed interval) and three irrigations (at critical stages) resulted in 4.62 and 4.73% higher gross, and 6.97 and 6.96% higher net returns compared to control, respectively. Among sub plot treatments, the highest cost of cultivation (₹ 31376/ha), gross returns (₹ 76924/ha) and net returns (₹ 45548/ha) were recorded with application of Pusa hydrogel (Table 3). Whereas minimum cost of cultivation (₹ 26376/ha), gross returns (₹ 66235/ha) and net returns (₹ 39858/ha) were recorded under control. However, the maximum B:C ratio (1.62) was observed with application of herbal hydrogel. The application of Pusa and herbal hydrogel increased the gross and net returns of wheat with magnitude of 13.89% and 12.49% over control. Thus, application of Pusa and Herbal hydrogels provided additional net returns of ₹ 5689/ha and ₹ 3514/ha to the farmers over no application. The higher crop productivity might be the principal reason for higher net returns with application of six irrigations and hydrogels compared to other treatments. Similar results of higher farm profitability were also reported by Parihar *et al*. (2003) for irrigation levels and Rehman *et al*. (2011) for hydrogels.

Conclusion

The results of this study demonstrate that cultivation of wheat with the application of six irrigations using sprinkler irrigation system resulted in significant improvement in the growth, productivity and profitability of wheat. Likewise, application of Pusa hydrogel and Herbal hydrogel resulted in higher productivity and profitability over control. Wheat growers can get additional income of ₹ 5689/ha by application of Pusa hydrogel. Pusa hydrogel and six irrigations to wheat using sprinkler system can be advocated

Table 3 Effect of different irrigation levels and moisture conserving practices on farm profitability

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Irrigation levels				
No irrigation	25428	37884	12455	0.57
Three irrigations (at CRI, LT and GF)	29303	72526	43222	1.61
Six irrigations (at CRI, TL, JT, BL, FL and ML stages)	30803	105650	74846	2.62
Three irrigations (at 40, 80 and 120 DAS)	29303	70483	41180	1.54
Hydrogels				
Control	26376	66235	39858	1.59
Pusa Hydrogel @ 2.5 kg/ha	31376	76924	45548	1.54
Herbal Hydrogel @ 400 ml/100 kg seed	28376	71749	43372	1.62

as sustainable strategy for enhancing productivity and profitability of wheat cultivation in semi-arid condition.

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