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Research Paper

Effect of irrigation regime, Pusa hydrogel and vermicompost on growth, productivity and soil-nutrient status in late-sown wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2015–16 and 2016–17 at Crop Research Centre of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India to study the effect of Pusa hydrogel and vermicompost on crop productivity and soil nutrient status in late-sown wheat (*Triticum aestivum* L.). Three irrigation levels, viz., I_1 [at crown-root initiation (CRI) stage], I_2 (at CRI, booting and milking) and I_3 (at CRI, late tillering, late jointing, flowering and milking stage), and 4 moisture-conservation practices, viz. application of Pusa hydrogel @ 5 kg/ha, vermicompost @ 1 t/ha, Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha and no application, were tested in split-plot design, with 3 replications. Results revealed that, the growth parameters, viz. of plant height (106.6 and 103.8 cm), tillers/m, dry-matter accumulation (184.5 and 195.0 g/m), leaf-area index (3.15 and 3.23) and harvest index, of wheat were significantly higher under 5 irrigation levels than 3 and 1, being the lowest under 1 irrigation during 2015–16 and 2016–17, respectively. The wheat received 5 irrigations outyielded wheat received 3 and 1 irrigations during the first and second years by 7.6, 68.8% and 8.1 and 69.4% respectively. Similarly, wheat grown with 3 and 5 irrigations recorded 5.98 and 5.84 q/ha and 28.88 and 26.65 q/ha higher straw yield during 2015–16 and 2016–17 respectively. The highest available nitrogen (229.9 and 232.2 kg/ha) and potassium (177.2 and 179.1 kg/ha) were recorded with 5 irrigations, followed by 3 irrigations during the first and second years, respectively. The combined application of Pusa hydrogel @ 5 kg + vermicompost @ 1 t/ha over no application at harvesting resulted in 33.2 and 31.0% more dry-matter production/m and 34.6 and 38.4% higher grain yield/ha, besides 231.0 and 233.3 kg N, 14.6 and 15.1 kg P and 175.5 and 177.8 kg K/ha with 0.494 and 0.512% organic carbon after harvesting during 2015–16 and 2016–17, respectively.

Key words: Irrigation, Nutrient content, Pusa hydrogel, Vermicompost, Yield, Yield attributes

Wheat is one of the most important cereal crops in the world, grown across a wide range of environments and has the highest adaptation among all the crop species. Worldwide more land is devoted to the production of wheat than any other crop; it contributes about 60% of daily protein requirement and more calories to world human diet than any other food crops. Hydrogel (Super absorbent polymer) is a water-retaining, cross-linked hydrophilic, biodegradable amorphous polymer which can absorb and retain water at least 400 times of its original weight and make at least 95% of stored water available for crop absorption (Kalhapure *et al*., 2016). Applications of hydrogel in the soil forms an amorphous gelatinous mass on hydration and is capable of absorption and desorption over long period of time; hence it acts as a slow-release source of water in soil. However, hydrogel particles may be taken as '*miniature water reservoir'* in the soil and water will be removed from these reservoirs upon the root demand through osmotic pressure difference. Grain yield, nutrient uptake and water-use efficiency improved in winter wheat when hydrogel was applied @ 5 kg/ha in a sandy-loam soil. Various reports have suggested the beneficial impact of hydrogel in crop growth and soil properties (Roy *et al*., 2019).

Scheduling of irrigation based on phenological stages (crown root, tillering, booting, flowering, soft dough and hard dough stage) in wheat has been practical approach to the farmers. The impact of limited irrigation on crop yield and water-use efficiency (WUE) depends on the growth stage and the most sensitive stage may vary due to regional variability in environment and agronomic practices (Dar *et al*., 2019). Wheat responds to water stress from stem elon-

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gation to booting, followed by anthesis and grain-filling stages. Application of limited irrigation gets maximum yield and saves water compared to more irrigation schedules on wheat (Khokhar *et al.,* 2010). Vermicompost which is produced by the fragmentation of organic wastes by earthworms contains nutrients in forms that are readily available for plant uptake. There is good evidence that VC application promotes growth of plants and it has been found to have a positive effect on growth and productivity of cereals and legumes (Azarmi *et al*., 2008). There is an increasing interest in the potential use of VC as soil amendment, where the addition of VC improves the soil physical and chemical properties. Keeping all these points in view, the study was undertaken for enhancing the productivity in late-sown wheat.

MATERIALS AND METHODS

The experiment was conducted at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh. The farm is geographically located at 29° 13’ 96" N, 77° 68’ 43" E, 218 m above the mean sea-level, Uttar Pradesh. The climate of this region is semi-arid and sub-tropical with extreme hot weather in summer and cold in winter season. There is gradual decrease in mean daily temperature in December reaching as low as 3.2°C, and a gradual increase is registered reaching as high as 45.0°C in May. Occasionally, frost does occur during the months of December and January. The total annual rainfall was 665 and 787 mm during the first and second years, respectively. Winter showers sometimes are accompanied by high wind velocity and hail storms. The soil of experimental site was sandy loam, low in available nitrogen and organic carbon, medium in available phosphorus, available potassium and alkaline in reaction.The treatments comprised 12 combinations of the 2 factors, i.e. irrigation levels (3) as main plot factor, viz. 1 irrigation at [crown-root initiation (CRI) stage], 3 irrigations (at CRI, booting and milking stage) and 5 irrigations (at CRI, late tillering, late jointing, flowering and milking stage), and moisture-conservation practices (4) as subplot factor (control, Pusa hydrogel @ 5 kg/ha, vermicompost @ 1 t/ha and Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha), were tested in split-plot design with 3 replications. Hydrogel is a synthetic polymer, insoluble, hydrophilic and can absorb large quantity of water. It has great potential in areas where opportunity for irrigation is limited and can increase the water availability during crop establishment. The capacity of the hydrogel to absorb and retain water is as much as 80-180 times its original volume and releases absorbed water slowly. The hydrogels can also modify various physical properties of soil like infiltration rates, density, soil structure and compaction, etc. Pusa hydrogel was mixed with soil (1 : 10 W/W) and applied at the time of sowing in bands of the seed line with respective treatments @ 5 kg/ha. The well-rotten vermicompost (2.3% N, 1.6% P_2O_5 and 1.5% K_2O on dry-weight basis) collected from the University Instructional Livestock Farm was applied as per the treatments. The vermicompost (1 t/ha) was mixed with soil and applied 10 days before sowing during both the years. The experimental crop was grown with standard recommended package of practices for wheat during both the years. Wheat var. ‘PBW 590’ was sown in rows, 20 cm apart at a depth of 5 cm using a seed rate of 125 kg/ha on 24 and 22 December during 2015 and 2016, respectively. Leaf-area index was measured by using leaf-area meter (LA-3100). The produce excluding root, of each net plot was allowed to sun-dry after harvesting and weighed to record the biological yield (grains + straw), plot-wise, and then converted into q/ha. After harvesting, threshing, cleaning and drying, the grain yield of wheat was estimated at 14% moisture content. The harvest index (HI) was computed as:

$$\text{Harvest index} = \frac{\text{Economic Yield (kg/ha)}}{\text{Biological Yield (kg/ha)}} \times 100$$

Soil-available nutrients and organic carbon content were estimated by using standard procedures as suggested by Prasad *et al.* (2006). The data were subjected to computer-based statistical tools using OPSTAT program for split-plot design.

RESULTS AND DISCUSSION

Growth parameters

Irrigation levels and moisture conservation practices exhibited significant effect on plant height, number of tillers and dry-matter production at harvesting of crop during both the years (Table 1). The irrigation applied at 5 times exhibited its superiority to 3 and 1 irrigations to record tallest plants and maximum number of tillers irrespective of the years. Moreover, crop received 5 irrigations obtained tallest plants, besides 22.9% and 22.4% higher number of tillers over 1 irrigation during 2015–16 and 2016–17 respectively. Wheat under 5 irrigations, being at par with 3 irrigations during 2016–17, accumulated highest mean dry-matter at harvesting (184.5 and 195.0 g/m row length) during first and second years, respectively. Sharma *et al.* (2020) also observed similar results. However, wheat receiving 1 irrigation only, accumulated the least mean dry-matter at harvesting (121.0 and 120.7 g/m) during first and second years respectively. Crop fertilized with Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha had significantly maximum plant height as compared rest of the treatments, irrespective of the years. However, application of vermicompost @ 1 t/ha, being at par with Pusa

Table 1. Effect of irrigation levels and moisture-conservation practices on growth-parameters of wheat

Treatment	Plant height (cm) at harvesting		Tillers/m row length at harvesting		Dry-matter accumulation (g/m) at harvesting		Leaf-area index 90 DAS	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Irrigation levels								
1 Irrigation at CRI stage	85.5	81.3	74.9	70.7	121.0	120.7	2.72	2.58
3 Irrigations at CRI, booting and milking	99.5	98.5	86.8	79.6	163.1	161.0	2.98	2.92
5 Irrigations at CRI, late tillering, late jointing, flowering and milking stage	106.6	103.8	97.2	91.2	184.5	195.0	3.15	3.23
SEm±	0.7	0.8	0.6	0.3	6.2	4.9	0.07	0.01
CD (P=0.05)	2.6	2.8	2.5	1.4	24.3	19.3	0.26	0.04
Moisture-conservation practices								
Control	82.2	78.1	84.5	78.0	145.7	151.2	2.79	2.65
Pusa hydrogel @ 5 kg/ha	100.3	97.8	86.2	80.2	184.3	180.5	2.97	3.02
Vermicompost @ 1 t/ha	101.5	99.2	89.4	83.1	160.2	165.8	2.92	2.93
Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha	104.9	103.1	91.9	85.9	194.1	198.1	3.12	3.05
SEm±	1.2	1.1	0.4	0.4	3.7	1.7	0.01	0.01
CD (P=0.05)	3.4	3.4	1.1	1.2	11.2	5.2	0.04	0.02

CRI, Crown-root initiation

hydrogel @ 5 kg/ha, remained superior to the control at all the stages during both the years. Moreover, the increment in plant height under Pusa hydrogel @ 5 kg/ha along with vermicompost @ 1 t/ha at harvesting stage was 27.6% (2015–16) and 32.0% (2016–17) over the control. Joshi *et al.* (2013) also made similar observations in wheat.

Leaf-area index

The data revealed that, crop receiving 5 irrigations being at par with the crop receiving 3 irrigations in 2015–16 only, showed highest leaf-area index at 90 DAS (3.15 and 3.23 during 2015–16 and 2016–17 respectively). Although during the second year, each successive increase in level of irrigation from 1 to 5 in wheat significantly improved the LAI. Crop fertilized with Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha had significantly maximum leaf-area index as compared to all the other treatments, irrespective of the years. However, application of vermicompost @ 1 t/ha resulted in higher leaf-area index than the control, while lower as against Pusa hydrogel @ 5 kg/ha during both the years. Moreover, the leaf-area index under Pusa hydrogel gel @ 5 kg/ha along with vermicompost @ 1 t/ha was 3.12 (2015–16) and 3.05 (2016–17) at 90 DAS stage. Our results are in close conformity with those of Jahangir *et al.* (2008).

Yield

Wheat yields/ha (grain, straw and biological, Table 2) increased significantly with each successive increase in irrigation level and where the crop receiving 5 irrigations showed its superiority to record maximum grain yield as compared to 3 irrigations and 1 irrigation during both the years. The increment in grain yield/ha under 5 irrigations was to the tune of was 68.8% (2015–16) and 69.4% (2016–17) as against 1 irrigation. Though wheat that received 1 irrigation showed least grain yield compared to the others, irrespective of the years. The next in order was 3-time irrigation–at CRI, tillering and jointing which showed significantly more yield than 1 time irrigation. Although, in straw yield, wheat irrigated 5 times outyielded 3 times irrigation by 15.9 and 15.8 q/ha during first and second years, respectively. Dhaliwal *et al.* (2020) also observed similar results. Incorporation of Pusa hydrogel @ 5 kg/ha along with vermicompost @ 1 t/ha resulted in significantly highest grain yield over its individual component, irrespective of the years. The pace of increment over the control was 34.6% (2015–16) and 38.4% (2016–17). Though application of Pusa hydrogel @ 5 kg/ha resulted in significantly higher grain yield than the control, while lower as against vermicompost @ 1 t/ha during both the years. Tyagi *et al.* (2015) also reported similar results in wheat. Crop fertilized with Pusa hydrogel @ 5 kg/ha and vermicompost @ 1 t/ha gave 65.98 (2015–16) and 64.09 q/ha (2016–17) straw yield which was significantly higher over others, except vermicompost @ 1 t/ha during both the years. Although incorporation of Pusa hydrogel @ 5 kg/ha

Table 2. Effect of irrigation levels and moisture-conservation practices on grain, straw and biological yields and harvest index of wheat

Treatment	Yield (q/ha)						Harvest index (%)	
	Grain		Straw		Biological			
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Irrigation levels								
1 Irrigation at CRI stage	27.25	26.58	51.74	50.37	78.99	76.95	38.46	38.48
3 Irrigations at CRI, booting and milking	42.75	41.63	57.72	56.21	100.48	97.84	42.54	42.55
5 Irrigations at CRI, late tillering, late jointing, flowering and milking stage	46.01	45.02	73.62	72.02	119.62	117.03	44.43	44.44
SEm±	0.30	0.47	0.59	0.68	0.87	1.12	0.12	0.18
CD (P=0.05)	1.28	1.82	2.32	2.67	3.62	4.58	0.45	0.71
Moisture-conservation practices								
Control	30.71	28.12	56.11	55.01	86.82	83.13	41.50	41.43
Pusa hydrogel @ 5 kg/ha	42.30	41.42	59.53	58.35	101.83	99.77	41.54	41.51
Vermicompost @ 1 t/ha	44.46	43.17	62.47	60.68	106.93	103.85	41.57	41.56
Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha	46.97	45.62	65.98	64.09	112.95	109.71	41.58	41.57
SEm±	0.88	0.68	1.47	1.52	2.48	2.52	0.27	0.08
CD (P=0.05)	2.97	3.00	4.38	4.50	7.46	7.60	NS	NS

CRI, Crown-root initiation

was at par with vermicompost @ 1 t/ha, while significantly superior to the control in recording the maximum straw yields. Moreover, the control was inferior from rest of its counterparts during both the years. Our results confirm the findings of Singh *et al.* (2017) in wheat.

However, considerable improvement was noted in biological yield/ha with the increasing irrigation frequency. Though application of 5-time irrigation in wheat resulted in significantly maximum biological yield (119.62 and 117.03 q/ha), while the lowest biological yield (78.99 and 76.95 q/ha) was found under the crop received only 1 irrigation as compared to the other irrigation levels during 2015–16 and 2016–17, respectively. Combined application of Pusa hydrogel @ 5 kg/ha and vermicompost @ 1 t/ha, being at par with vermicompost @ 1 t/ha, resulted in the highest biological yield as compared to the control and Pusa hydrogel @ 5 kg/ha. Although incorporation of vermicompost @ 1 t/ha alone remained at par with Pusa hydrogel @ 5 kg/ha, it recorded significantly higher grain yield over the control during both the years. Harvest index also increased significantly owing to supplementing the irrigation from 1 to 3 in wheat during both the years. The beneficial effect of organic manures on grain, straw, biological yields and yield-attributing characters might be the fact that after proper decomposition and mineralization, these manures supplied available plant nutrients directly to the plants and also had solubilizing effect on fixed forms of nutrients in soil. The better performance of these treatments in terms of yield could be attributed to better expression of their yield attributes because of reduction in competition or increase in moisture conservation. This could be attributed to the selectivity of these manures to crop and their effect on moisture conservation, as has already been reported by Ramasamy and Suresh (2011). Kalhapure *et al*. (2016) opined that, 2 irrigations in wheat can be saved by application of hydrogel without compromising the grain yield. Although, moisture conservation practices failed to bring any significant change in harvest index during both the years, but the maximum and minimum, being under combined application of Pusa hydrogel @ 5 kg/ha along with vermicompost @ 1 t/ha and control, respectively, during both the years.

Soil-nutrient status

Available nitrogen was increased with broadening irrigation level where crop receiving 5 times irrigation did showed its superiority to record maximum available nitrogen as compared to 3 irrigations and 1 irrigation (Table 3). The under 5 irrigations was to the tune of was 7.3% (2015–16) and 7.7% (2016–17) as against 1 irrigation. Though 1 irrigation was inferior from the over other treatments in recording least grain yield, irrespective of the years. Application of 1 irrigation resulted in 8.8 and 6.8% lower available phosphorus as against crop received 5 irrigation during 2015–16 and 2016–17 respectively. The next in order was 3-time irrigation which resulted in significantly higher 1-time irrigation and minimum compared to 5-time irrigation, irrespective of the years. Though 5-time irrigation resulted in significantly maximum available potassium (177.2 and 179.1 kg/ha), the lowest available potassium

Table 3. Influence of irrigation levels and moisture-conservation practices on available N, P, K and organic carbon content of the soil at wheat harvesting

Treatment	Available nutrients in soil (kg/ha)						Organic carbon (%)	
	N		P		K			
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
Irrigation Levels								
1 Irrigation at CRI stage	213.4	215.6	12.8	13.1	165.8	167.1	0.462	0.480
3 Irrigations at CRI, booting and milking	222.3	224.5	13.0	13.9	171.3	174.3	0.471	0.491
5 Irrigations at CRI, late tillering, late jointing, flowering and milking stage	229.9	232.2	14.0	14.1	177.2	179.1	0.485	0.502
SEm±	0.3	0.2	0.2	0.1	0.2	0.2	0.003	0.003
CD (P=0.05)	0.9	1.0	0.8	0.3	0.6	0.6	0.008	0.007
Moisture conservation practices								
Control	212.2	214.3	11.9	12.3	167.3	168.9	0.461	0.462
Pusa hydrogel @ 5 kg/ha	219.4	221.6	12.9	13.4	170.2	172.6	0.473	0.474
Vermicompost @ 1 t/ha	225.0	227.2	13.6	14.0	172.7	174.8	0.480	0.483
Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha	231.0	233.3	14.6	15.1	175.5	177.8	0.494	0.512
SEm±	0.5	0.5	0.2	0.1	0.2	0.2	0.003	0.003
CD (P=0.05)	1.5	1.4	0.4	0.4	0.7	0.6	0.008	0.008

CRI, Crown-root initiation

(165.8 and 167.1 kg/ha) was found under the crop received 1 irrigation as compared to the other irrigation levels during 2015–16 and 2016–17 respectively.

Crop grown without fertilization obtained lowest available nitrogen of 213.4 kg/ha (2015–16) and 215.6 kg/ha (2016–17) as compared to all the other treatments. Although incorporation of Pusa hydrogel @ 5 kg/ha along with vermicompost @ 1 t/ha recorded significantly highest available nitrogen over its individual component, irrespective of the years. Though application of Pusa hydrogel @ 5 kg/ha resulted in significantly higher available nitrogen over the control while lower as against vermicompost @ 1 t/ha during both the years. Crop fertilized with Pusa hydrogel @ 5 kg/ha and vermicompost @ 1 t/ha obtained 14.6 kg/ha (2015–16) and 15.1 kg/ha (2016–17) available phosphorous, being significantly higher over the other treatments. Incorporation of Pusa hydrogel @ 5 kg/ha showed superiority over the control but was inferior to vermicompost @ 10 q/ha in respect of available phosphorous. The control remained inferior to rest of its counterparts during both the years. Crop grown without Pusa hydrogel and vermicompost (control) exhibited significantly less lower available potassium than all other treatments. The combined application of Pusa hydrogel @ 5 kg/ha and vermicompost @ 1 t/ha had recorded significantly highest available potassium as compared to the control, Pusa hydrogel @ 5 kg/ha and vermi compost @ 1 t/ha irrespective of the years. Organic carbon also showed the similar trend as in case of available nitrogen in soil during both the years. The lowest organic carbon was noted under wheat received only 1 irrigation, irrespective of the years. Crop receiving Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha and vermicompost @ 1 t/ha also had significantly higher organic carbon as against Pusa hydrogel @ 5 kg/ha and the control during both the years. Our results are closely related to the findings of Ghanshyam *et al.* (2010).

Thus, application of 3–5 irrigations along with Pusa hydrogel @ 5 kg/ha + vermicompost @ 1 t/ha seems to be the best option for obtaining higher values of growth parameters and yields in wheat crop, besides improving soil-nutrient status.

REFERENCES

Atiyeh, R.M., Lee, S., Edwards, C.A., Arancon, N.Q. and Metzger, J.D. 2010. The influence of humic acids derived from earthworms processed organic wastes on plant growth. *Bioresources Technology* **84**: 7–14.

Azarmi, A., Khvndly, A. and Behnia, A. 2008. Effect of previous subsidence of soil and sediment run-off from the rain Shbysazy. *Iranian Journal of Range and Desert Research* **16**(4): 445–455.

Dar, Eajaz Ahmad, Singh Brar, Ajmer, Poonia, Todarmal and Amin Bhat, Mohammad. 2019. Influence of sowing dates and irrigation schedules on growth and yield of drip-irrigated wheat (*Triticum aestivum*) under semi-arid conditions of Punjab. *Indian Journal of Agronomy* **64**(2): 218–225.

Dhaliwal, L.K., Buttar, G.S., Kingra, P.K. and Kaur, Sukhjeet. 2020. Effect of sowing time, planting methods and irrigation scheduling on yield response, water and radiation-use efficiencies of wheat (*Triticum aestivum*) in Punjab. *Indian Journal of Agronomy* **65**(1): 53–60.

Ghanshyam, Kumar, Rakesh and Jat, R.K. 2010. Productivity and soil fertility as affected by organic manures and inorganic fertilizers in greengram (*Vigna radiata*)–wheat (*Triticum aestivum*) system. *Indian of Journal of Agronomy* **55**(1): 16–21.

Jahangir, Abedi-Koupai, Sohrab, Farahnaz and Gareth, Swarbrick. 2008. Evaluation of hydrogel application on soil water retention characteristics. *Journal of Plant Nutrition* **31**(2): 317–331.

Joshi, R., Vig, A.P. and Singh, J. 2013. Vermicompost as soil supplement to enhance growth, yield and quality of (*Triticum aestivum* L.) a field study. *International Journal of Recycling of Organic Waste in Agriculture* **2**(16): 2–7.

Kalhapure, A., Kumar, R., Singh, V.P. and Pandey, D.S. 2016. Hydrogels: A boon for increasing agricultural productivity in water stressed environment. *Current Science* **111**(11): 1,773–1,779.

Khokhar, B., Hussain, I. and Khokhar, Z. 2010. Effect of different irrigation frequencies on growth and yield of different wheat genotypes in Sindh. *Pakistan Journal of Agriculture Research* **23**: 108–113.

Prasad, R., Shivay, Y.S., Kumar, D. and Sharma, S.N. 2006. *Learning by doing exercises in soil fertility* (*A Practical Manual for Soil Fertility*), Division of Agronomy, Indian Agricultural Research Institute, New Delhi, pp. 68.

Ramasamy, P.K. and Suresh, S.N. 2011. Effect of vermicompost on root numbers and length of sunflower plant (*Helianthus annuus* L.). *Journal of Pure and Applied Microbiology* **4**(1): 297–302.

Roy, Trisha, Kumar, Suresh, Chand, Lekh, Kadam, D.M., Bihari, Bankey, Shrimali, S.S., Bishnoi, Rajesh, Maurya, U.K., Singh, Madan, Muruganandam, M., Singh, Lakhan, Sharma, S.K. Kumar, Rakesh and Mallik, Anil. 2019. Impact of Pusa hydrogel application on yield and productivity of rainfed wheat in North West Himalayan region. *Current Science* **116**(7): 1,246–1,251.

Sharma, Vijay, Dhyani, V.C., Chaturvedi, Sumit and Singh, Gurvinder. 2020. Growth, yield and economics in late-sown wheat (*Triticum aestivum*) as affected by irrigation levels and moisture-conservation practices. *Indian Journal of Agronomy* **65**(3): 364–367.

Singh, S.P., Singh, R.K. and Kumar, S. 2017. Effect of irrigation schedule, mulching and hydrogel on wheat (*Triticum aestivum* L.). *Journal of Pharmacognosy and Phytochemistry* **6**(5): 2,659–2,973.

Tyagi, V., Singh, R.K. and Nagargade, M. 2015. Effect of hydrogel, NPK and irrigation levels on yield, nutrient uptake and water use efficiency of wheat (*Triticum aestivum* L.). *Research on Crops* **16**(4): 653–656.