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Red cabbage (*Brassica oleracea*) response to hydrogels under drip irrigation and fertigation regimes

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ABSTRACT

Water is the main constraint on agricultural output in arid- and semi-arid agroecologies, especially in winter. Hydrogels reduce percolation and evaporation losses in the soil root zone and provide a more continuous stream of moisture to the crop, enhancing water retention. Therefore, the impact of recently developed cross-linked hydrogels (SPG 1118 and Pusa Jal Nidhi) on the performance of red cabbage (*Brassica oleracea* L.) was studied during 2020–21 and 2021–22 using a spilt-plot design with three replications under drip fertigation. The study results revealed that application of full irrigation (100% ETc) exhibited significantly higher head yield of ~16% compared to limited irrigation (75% ETc). Content of NPK in leaf and head were significantly higher under full irrigation (1.31–1.38% of N in head and 2.49–2.62% of N in leaf) compared to limited irrigation. Among modified application of hydrogels, seedling root dipping with hydrogel SPG 1118 exhibited ~12% higher head yield over control plots. Application of SPG 1118 recorded ~4–5% and 9–14% of higher head yield over Pusa Jal Nidhi and control plots. Likewise, root-applied SPG 1118 hydrogel had higher plant height, number of leaves, and NPK uptake in head and leaf than soil-applied Pusa hydrogel and control. Due to vertical root development, control plots had longer roots (19.0–20.8 cm) and smaller root volumes (51.8–53.3 g) than hydrogel plots. Thus, root application of SPG 1118 with drip irrigation and fertigation increases hydrogel efficacy and reduces water and nutrient losses from evaporation and deep percolation.

Keywords: Drip fertigation, Evapotranspiration, Head yield, Red cabbage, SPG 1118 hydrogel

Red cabbage (*Brassica oleracea* L.) is highly nutritive exotic vegetable which possesses anti-cancerous property due to presence of Indole-3-carbinol (Tendaj *et al.* 2013). It is a cool-season crop that is vulnerable to drought. Red cabbage is shallow-rooted and grows in winter, when water is scarce, which might reduce output and head quality. Micro-irrigation methods improve water use efficiency by enhancing crop yields significantly (Rathore *et al.* 2020). However, drought-tolerant cultivars and precision water-saving irrigation must be addressed to maintain water balance in low-water conditions without reducing crop production (Rajanna *et al.* 2022a). Hydrogels reduce plant yield loss from water scarcity. These hydrogels boost rainfed agriculture crop and water output (Rajanna *et al.* 2022a). Therefore, hydrogels have been used frequently over the years to improve the water and nutrient availability in plants (Dehkordi and Seyyedboveir 2013). Furthermore, fertigation is achievable through the use of hydrogel, which is capable of absorbing fertilizer and releasing it with water (Satriani *et al.* 2018).

Hydrogels, cross-linked polymers having hydrophilic groups, may absorb huge amounts of water without disintegrating. Hydrogels when exposed to water can absorb more than their weight. In the water release phase of hydrogel, soil will gain free pore volume for root growth, air and water infiltration, and water storage (Guo *et al.* 2020). Water stays in the root zone, preventing deep percolation and nutrient leaching. Hydrogel effects on soils and plants vary depending on conditions in experiments including soil texture, crop used, hydrogel properties and origin, and irrigation water quality. Interestingly, modifying soil hydrogel application was effective and Rajanna *et al.* (2021) observed that seed treatment and slurry application of SPG 1118 provided significantly greater wheat crop yields than soil hydrogel application. There is interest in using hydrogel to improve water-use efficiency (WUE) and reduce water stress by increasing water availability, but there is little information about using newly developed hydrogel (SPG 1118) in vegetables and red cabbage. Therefore, the present study was formulated to assess the growth and development

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of red cabbage to different SPG 1118 and Pusa Hydrogels application techniques.

MATERIALS AND METHODS

The present study was carried out at Precision Farming Development Centre, Water Technology Centre, ICAR-Indian Agricultural Research Institute (IARI), New Delhi (28° 38' N, 77° 10' E; 228.6 m amsl) during 2020–21 and 2021–22 to assess the growth and development of red cabbage to different SPG 1118 and Pusa Hydrogels application techniques under variable drip irrigation regimes. The experimental soils had a typical Yamuna alluvial profile with sandy loam texture. Experiment field topsoil (0–15 cm) has 1.02% soil organic carbon, 108.1 kg/ha available nitrogen (N), 25.3 kg/ha available phosphorus (P), and 166.3 kg/ha available potassium (K). Soil moisture content at field capacity and permanent wilting point was 27.8% and 10.2%, respectively with 40% porosity, and 1.15 cm/h hydraulic conductivity. The study site falls under semi-arid to subtropical weather and the warmest months are May and June, with maximum temperatures ranging from 40–48°C, while the coldest months are January and February, with minimum temperatures ranging from 3–6°C. During the months of June and January, the mean open pan evaporation reaches as high as 12.77 mm and as low as 0.5 mm per day, respectively.

The experiment on red cabbage (Pusa Red Cabbage Hybrid 1) consisted of two irrigation regimes M_1, full irrigation applied at 100% evapotranspiration (ETc), and; M_2, limited irrigation applied at 75% ETc assisted in main plots, with 5 methods of application, i.e. S_1, root dipping of Pusa Hydrogel (PHRD); S_2, soil application of Pusa Hydrogel (PHSA); S_3, root dipping of SPG 1118 (SPGRD); S_4, soil application of SPG 1118 (SPGSA) and; S_5, control (without application of hydrogel) assisted in sub-plots using split-plot design with three replications. The irrigation schedules were determined in the main plots using CROPWAT software (FAO 2009). The amount of irrigation was calculated in terms of gross irrigation requirements and pumping time per application, whereas irrigation time is dependent on crop evapotranspiration (ET_c) on daily basis.

Pusa hydrogel (Trade name: Pusa Jal Nidhi) is a cellulosic backbone cross linked with polyacrylate grafted (Anupama and Parmar 2010). SPG 1118 is a novel smart hydrogel recently developed by Division of Agricultural Chemicals, ICAR-IARI, New Delhi. The two test hydrogels (Pusa hydrogel and SPG 1118) were applied as root dipping and soil application @2.5 kg/ha. In root dipping, a 1:25 ratio of hydrogels slurry was prepared and roots of red cabbage 30 days old seedling were dipped for 6 h. In soil application, hydrogels were mixed with 2 mm sieved soil to make bulk and applied in planting furrows having 5–7 cm depth at the time of transplanting in each crop season. Field was well ploughed using disc arrow followed by cultivator. Field was levelled and divided into 20 plots to assign treatment randomly. Drip pipes were installed before sowing of the crop with flow rate of 2 litres/h. One month old seedlings were transplanted in first week of December in both the years at a spacing of 60 cm × 45 cm and harvested in first week of March with drip irrigation. Recommended dose of fertilizer (76:46:83 kg NPK/ha) was applied in the form of urea, di-ammonium phosphate and potassium sulphate. Urea was applied as two doses through fertigation. Standard agronomic practices were followed to control weeds and recording observations. Red cabbage growth and yield parameters were recorded from the net plot area of 7.56 m^2 (4.2 m × 1.8 m). Fully expanded leaves from the mid shoots or middle non-wrapper leaves and matured head were collected during harvest period from two experimental years. The nutrient concentrations in plant samples were determined from the oven dried samples at 54^0C for 72 h. After complete drying, dry weights were recorded and dried tissues were ground to determine the total N, P and K. Roots of randomly selected plants were sampled by taking soil core at 0–30 cm soil depth, later washed to remove soil debris. Then root samples were scanned through an image scanner and the length and weight of roots were determined.

Red cabbage growth and yield data recorded during the two years were analysed through the analysis of variance (ANOVA) test for a split-plot design as suggested by Gomez and Gomez (1954) and using SAS 9.3 software (SAS Institute, Cary, NC). The significance of the difference between the main plots (soil moisture levels), sub-plots (hydrogels), and interaction effect of soil moisture levels and hydrogels were compared with the help of LSD values at $P \leq 0.05$.

RESULTS AND DISCUSSION

Growth parameters: Performance of red cabbage to different SPG 1118 and Pusa hydrogel application techniques under variable drip irrigation regimes was studied and results on growth parameters are presented in the Table 1. Application of irrigation at full irrigation regime M_1 recorded significantly higher plant height (33.9–35.3 cm), number of leaves or non-wrapper leaves (15.7–17.0) and plant width (52.5–54.3) over limited irrigation regime M_2 (30.0–31.2 cm, 13.0–15.3 and 47.9–49.7 cm, respectively). Application of full irrigation regime M_1 enhances growth attributes due to frequent application of irrigation corresponds to crop water requirements throughout the development phases without causing water stress under full irrigation. Therefore, with optimum water availability enhanced the plant height, number of leaves, plant width and root weight by ~14%, ~21%, ~10% and ~12% respectively during the two study seasons. With respect to method of application of different hydrogels, S_3 recorded significantly higher plant height (35.1–36.3 cm), number of leaves (17.3–18.4) and plant width (54.1–56.0 cm) compared to S_5 and other hydrogel applied plots in red cabbage. In root dipping with hydrogel slurry, red cabbage could be able to extract soil moisture, retain and release the soil moisture as and when the crop needs. Thereby, enhancing the plant growth attributes in red cabbage. Rajanna *et al.* (2021) found that modifying the hydrogel application in terms of seed

Table 1 Effect of irrigation levels and application methods of different hydrogels on plant height, number of leaves and plant width during 2020–21 and 2021–22

Treatment	Plant height (cm) at harvest		Number of leaves at harvest leaves or non-wrapper leaves		Plant width (cm) at harvest	
	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22
Irrigation regime (ETc)						
M1	33.88	35.30	15.72	16.98	52.45	54.26
M2	29.70	31.20	12.99	15.58	47.88	49.71
SEm±	0.06	0.06	0.04	0.04	0.06	0.06
LSD (P=0.05)	0.23	0.22	0.15	0.15	0.25	0.25
Method of application of different hydrogel (MAH)						
S1	32.82	34.31	14.71	15.98	50.75	53.24
S2	30.63	31.86	13.53	14.40	49.09	50.27
S3	35.11	36.28	17.24	18.42	54.12	56.02
S4	32.76	34.17	15.07	16.23	51.18	53.10
S5	27.62	29.62	11.22	12.87	45.68	47.29
SEm±	0.03	0.02	0.02	0.02	0.03	0.03
LSD (P= 0.05)	0.07	0.07	0.06	0.05	0.08	0.09
I (ETc × MAH)	S	S	S	S	S	S

Treatment details are given under Materials and Methods.

treatment enhance wheat growth and yield attributes due to extended availability of water to plants during moisture stress. Among hydrogels, SPG 1118 application observed higher values of plant growth parameters compared to Pusa hydrogel. Interaction effect was also found to be significant with respect to irrigation regime and method of application of different hydrogel combinations. Therefore, S_3 under M_1 recorded significantly higher plant growth parameters over other combinations.

Red cabbage root length and weight: The total root length and root weight of red cabbage were recorded for different hydrogel application methods with different irrigation regimes at harvest during both years (Fig 1). Significantly higher root length (17.91–18.87 cm) was observed under M_2 as compared to M_1. However, appreciably higher weight was observed (58.85–60.65 g) under M_1 as compared to deficient irrigation regime. In adequate moisture condition, roots were concentrated in upper horizon with maximum horizontal development due to better moisture availability (Rajanna *et al.* 2022a). Hydrogels also showed a significant effect on root length and volume of red cabbage with control plots exhibited higher root length (19–20.75 cm) and lower root volume (51.78–53.32 g) of red cabbage as compared to both hydrogels. In case of hydrogels, SPG 1118 showed 2–4 g increase in root weight and 2–3 cm decrease in root length compared to Pusa hydrogel. In root dipped hydrogel plants, hydrogels were bound to plant roots thus enhancing the water availability in the soil, while in soil application; hydrogels were scattered in soil and sometimes not available to plant roots. Appreciably higher root weight and root length were observed in control plots as compared to hydrogels as due to profuse development of roots in upper horizon. Concurrently, Rajanna *et al.* (2022b) opined that, during water stress, roots

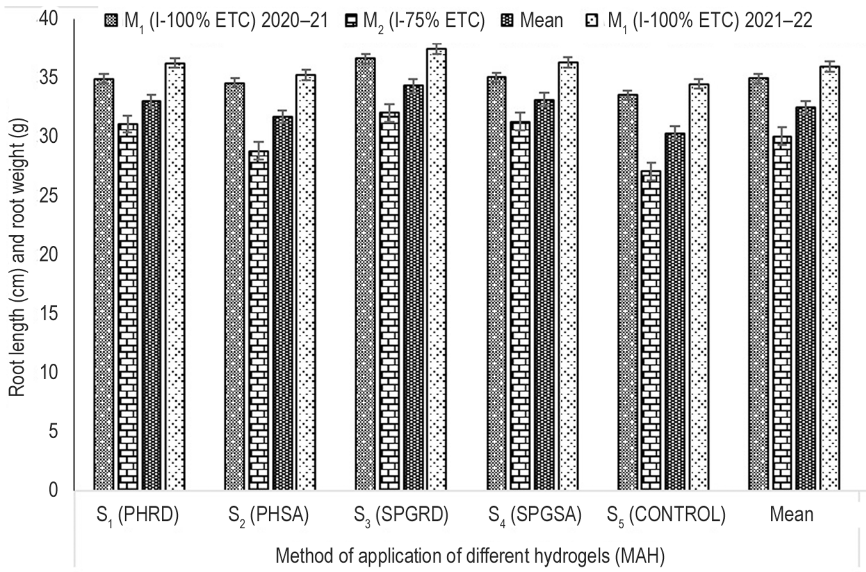

Fig 1 Effect of irrigation levels and application methods of different hydrogels on root length and width during 2020–21 and 2021–22.
Treatment details are given under Materials and Methods.

in control plots and lower moisture regimes reached lower horizons and exhibited a vertical distribution.

Red cabbage yield: A significant effect of different hydrogel on yield was observed during 2020–21 and 2021–22 (Table 2). Red cabbage head yields in M_1 were significantly higher (35.0–36.0 t/ha) as compared to M_2. Application of irrigation at 100% ETc for the full crop growing season improved soil moisture availability, which improved nutrient availability and led to stronger vegetative development (Singh *et al.* 2014). Therefore, fully irrigated red cabbage produced ~16% significant higher head yields over deficient irrigation. In adequate irrigation applied plots, the soil surface remained wet for a longer period that favouring higher water and nutrient uptake and finally enhanced yield parameters and yield compared to deficient irrigation (Rathore *et al.* 2020). The modified hydrogel application methods were found to be significant on head yield of red cabbage. Among two methods of application, root dipping showed higher yield in both hydrogels, the extent of increase being was 3–6% over soil application of hydrogels. Hydrogels are treated as miniature water bodies in the soil that hold water and made it available to crop in uniform manner which enhances water-use efficiency (Fidelis *et al.* 2018). It might also due to extended availability of water to plants during period of water stress under hydrogel applied plots. Among the two tested hydrogels, SPG 1118 hydrogel produced significantly higher cabbage head yield (33.16–35.21 t/ha) over Pusa hydrogel. Root dipped SPG 1118 hydrogel shows (3–4 t/ha) increased yield over to control. Head yield of soil applied SPG 1118 hydrogel (33.16–34.14 t/ha) shows on par with yield of root dipped Pusa hydrogel (33.02–34.1 t/ha). S_3 produced significantly higher growth and yield attributes of red cabbage thereby enhancing the head yield significantly. However, when soil is treated with hydrogel, its water volumetric content increases dramatically, and when the soil dries, the stored water is gently released back into the soil.

However, hydrogel efficiency could be further enhanced through modification of hydrogels as well as method of hydrogel application. Therefore, S_3 exhibited 3–4 t/ha of increased yield over to S_5 (control) due to adequate moisture available from head initiation to head maturity stage of crop which eventually result in higher yield attributes and yield. Irrigation regimes and hydrogel interaction effects were also significant. Among the interaction effects, combined application of S_3 under M_1 regime exhibited significantly higher head yield (36.7–37.5 t/ha) in red cabbage as compared to other treatment combinations in both study years (Fig 2).

Nutrient uptake: The data on NPK uptake by red cabbage leaf and head influenced by different hydrogel application methods was estimated. During both study years, the content of NPK in leaf and head was significantly higher under full irrigation (1.31–1.38% of N in head and 2.49–2.62% of N in leaf) compared to limited irrigation. Higher water availability in root zone increased the nutrient solubility which helped roots to absorb it and translocate to the plants (Ghani *et al.* 2000). The modified method of application shows significant effect of NPK levels in head and leaf with root application of hydrogel observed higher NPK levels compared soil application of both hydrogels. The results indicated that slight increase of head P (0.24–0.25%) and K (1.3–1.33%) in SPG 1118 compared to Pusa hydrogel. Therefore, adequate moisture in the rhizosphere improved nutrient mobility in soil solution and ultimately, nutrient absorption by developing plants. Hydrogel have been used

Table 2 Effect of irrigation levels and application methods of different hydrogels on head weight, head yield and head NPK of red cabbage during 2020–21 and 2021–22

Treatment	Head weight (kg)		Head yield (t/ha)		Head nitrogen (%)		Head phosphorous (%)		Head potassium (%)	
	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22	2020–21	2021–22
Irrigation regime (ETc)										
M_1	0.89	0.93	34.5	35.96	1.31	1.38	0.23	0.24	1.29	1.32
M_2	0.67	0.70	30.7	30.85	1.18	1.19	0.21	0.21	1.18	1.16
SEm±	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
LSD (P=0.05)	0.01	0.01	0.27	0.28	0.01	0.01	0.00	0.00	0.01	0.01
Method of application of different hydrogel (MAH)										
S_1	0.88	0.89	33.2	34.12	1.31	1.33	0.23	0.23	1.37	1.27
S_2	0.63	0.67	31.1	32.16	1.22	1.22	0.21	0.21	1.17	1.19
S_3	1.02	1.09	34.5	35.21	1.37	1.42	0.24	0.25	1.30	1.33
S_4	0.85	0.89	33.6	34.14	1.29	1.34	0.23	0.23	1.25	1.27
S_5	0.51	0.54	30.1	31.39	1.03	1.09	0.19	0.19	1.07	1.14
SEm±	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
LSD (P= 0.05)	0.01	0.01	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
I (ETc×MAH)	S	S	S	S	S	S	S	S	S	S

Treatment details are given under Materials and Methods.

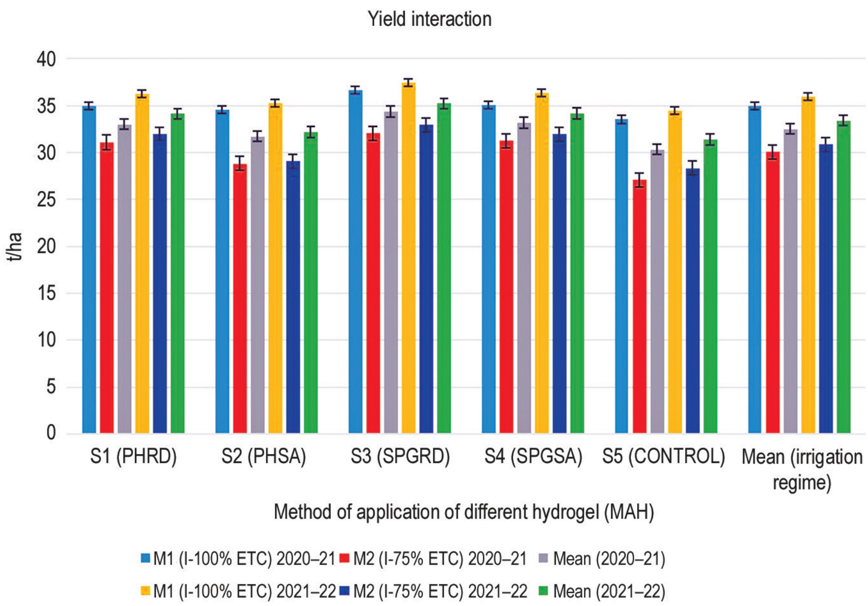

Fig 2 Effect of irrigation levels and application methods of different hydrogels on head yield interaction during 2020–21 and 2021–22.
Treatment details are given under Materials and Methods.

as water retaining polymers that reduces water and plant nutrient losses due to deep percolation and hence, nutrient leaching could be minimized (Tyagi *et al.* 2015).

The study showed that, application of hydrogels along with modified methods of application proved to enhance red cabbage growth and yield parameters and NPK content in head both under water stressed and well-watered conditions. Likewise, S_3 (root dipping with SPG 1118 hydrogel application) led to better growth parameters that finally contributed to higher yield attributes, curd yield, better root proliferation and higher nutrient uptake in red cabbage. Therefore, change in method of application of hydrogel increases efficiency of hydrogel and combination of SPG1118, drip irrigation and fertigation reduces evaporation and deep percolation losses of water and nutrient, and can be proved advantageous to obtain higher yield of red cabbage under drip fertigation.

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