Impact of irrigation and Pusa hydrogel on soil characteristics and physiological parameters of soil cultivated with Marigold (*Tagetes erecta* l.) *cv*. Culcutta orange.

Abstract

A study was conducted at College of Horticulture Bagalkot, University of Horticultural Sciences Bagalkot, to study the effect of different regimes of irrigation soil caharacteristics and physiological parameters of soil during the cultivation of Marigold (*Tagetes erecta* l.) *cv*. Culcutta orange. The results revealed significantly higher moisture content in marigold grown field soil irrigated with 100 per cent CPE (20.72, 17.50 and 12.24 per cent, respectively) at 30, 60 and 90 DAT. High pH (8.03) and bulk density (1.48 g/cm3) was observed at 80 (I_2) and 60 (I_3) per cent CPE respectively. The maximum water use efficiency (11.23 g plant $^{-1}$ lit^{-1}) was observed in plants irrigated with 60 (I_3) per cent CPE at 45-75 DAT. Relative water content was significantly highest in I_2: 80 per cent CPE (75.51 and 63.75 per cent, respectively) at 45 and 75 DAT. Maximum values of CGR (1.79 g m^{-2} day^{-1}), RGR (0.58 g g^{-1}day^{-1} × 102) and NAR (0.48 g m^{-2} day^{-1}) obtained in irrigation schedule at 80 per cent CPE. The maximum water use efficiency (12.12 g plant $^{-1}$ lit^{-1}) was observed in plant irrigated with 60 per cent CPE with 5.25 kg/ha hydrogel (I_3H_4) at 45-75 DAT. Relative water content of plant was significantly highest (82.07 and 71.47 per cent, respectively) in 80 per cent CPE with 5.25 kg/ha hydrogel (I_2H_4) at 45 and 75 DAT. Maximum value of CGR (2.20 g m^{-2} day^{-1}) obtained in irrigation schedule at 80 per cent CPE with 5.25 kg/ha hydrogel (I_2H_4). Relative growth rate (RGR) and net assimilation rate (NAR) were found to be non-significant with respect to treatment combination of different levels of irrigation and hydrogel.

Introduction

The issue of water management has assumed paramount importance and occupied the centre stage of politico-economic debates in world. India has already entered the shadow of the zone of physical and economic water scarcity (Singh et al., 1991). The area under dryland condition is 85 million ha (60 per cent of total cultivated area), which receives average annual rainfall less than 1150 mm. Also, more than 30 per cent of total geographical area of the country comes under low rainfall (less than 750 mm). Hence, there is an urgent need for efficient water resource management through enhanced water use efficiency. As water utilization is less in industrial (15 per cent) and domestic (5 per cent) sectors compared to agriculture (85 per cent) and there are no further chances to reduce quantity of water in these sectors, the focus should be on agriculture sector for water saving without compromising on crop production. Hydrogels are found to improve the physical properties of soils viz., porosity, bulk density, water holding capacity, soil permeability, infiltration rate etc. Increase in porosity results in improvement in seed germination and rate of seedling emergence, root growth and density, and reduced soil erosion due to reduction in soil compaction. It also increases biological/microbial activities in the soil, which increase oxygen/air availability in root zone of the plant. Pusa Hydrogel, a semi-synthetic super absorbent polymer, has been developed by the ICAR-Indian Agriculture Research Institute (IARI). Pusa hydrogel has been in use since 2012, and its benefits are now being reaped across the country. Pusa hydrogels are bio-degradable and they contain labile bonds either in the polymer backbone or in the cross-links used to prepare the hydrogels. The labile bonds can be broken under physiological conditions either enzymatically or chemically over a period of time. End products after degradation are CO_2, water and ammonia. Marigold is a versatile flowering plant belongs to the Asteraceae family with numerous uses in the floriculture industry which can be grown in the varied agroclimatic conditions hence used for the present student.

Material and Methods

Impact of irrigation and Pusa hydrogel on soil characteristics and physiological parameters of soil cultivated with Marigold (*Tagetes erecta* l.) *cv*. Culcutta orange was carried out during 2021 at College of Horticulture, Bagalkot. Bagalkot is located in Northern dry zone (zone-3) of Karnataka state at 160 46' North latitude and 740 59' East latitude at an altitude of 533.0 m above mean sea level. During the growth period of marigold crop, climate change influenced the growth, yield and quality of marigold. The factors like temperature, relative humidity and distribution of rainfall had impact on the crop growth and development. As per the meteorological data maximum temperature recorded was 38.61 ^{0}C and minimum 14.98 ^{0}C, maximum relative humidity 84.36 per cent and total rain fall of 15.63 mm was recorded during the whole experiment period. Soil sample was collected from 15 cm depth before transplanting of seedlings and developmental stage of crop. Soil colour in experiment plot was brown. For estimation of soil pH and EC randomly selected samples from the plots were analysed for soil pH and electrical conductivity (dsm-2).

Materials used

Pusa hydrogel: It is an indigenously developed product that boosts crop productivity per unit of available water and nutrients particularly in moisture-stressed conditions. It is made up of loosely interconnected three-dimensional network structures that absorb over 20 g of water per gram of xerogel (dry polymer). Since it is semi- synthetic, it has a lower monomer part load in the finished product. Pusa hydrogel has been reported to contain no traceable residual unreacted monomer, making it environmentally sound. Within a year, this form of gel degrades fully into carbon dioxide, water and ammonia.

Plant material: Healthy seedlings of marigold cultivar "Culcutta Orange" were used for the experiment collected from Kisan Nursery, Arabhavi. Plants had bushy and upright plant growth habit with serrated leaf margins. This crop is economically used for garland preparation and lutein extraction.

Treatment details
Main plot:
Irrigation interval
(I): Three I_1– 100 % CPE, I_2– 80 % CPE, I_3– 60% CPE (CPE-Cumulative pan evaporation)
Sub plot:
Hydrogel levels (H):
Five H1– Pusa Hydrogel 3.0 kg/ ha 26
H2– Pusa Hydrogel 3.75 kg/ha
H3– Pusa Hydrogel 4.50 kg/ha
H4– Pusa Hydrogel 5.25 kg/ha
H5– Control

Preparation of experimental site

The land was ploughed and harrowed two to three times upto a depth of 30 cm to bring it to a fine tilth by removing all the weeds, stubbles and stones. The beds were prepared as per plan and FYM (0.5 kg/ plot) was added as per the treatment details. Provision was made for paths (1m) for easy cultural operations. Irrigation was provided through drip irrigation. One month old, healthy, uniform seedlings of marigold were used for planting. Seedlings were planted at a spacing of 60 cm x 45 cm and for fast establishment of crop, light irrigation was given once in two days upto 15 days by using drip irrigation.

Irrigation Drippers were installed in the drip irrigation system, made up of a main line, sub lines and laterals that were drawn on an experimental plot. The 16 mm diameter laterals were spaced 60 cm apart with holes spaced 45 cm apart. The emitter had a 4 litre per hour discharge rate range. To handle irrigation according to treatment each drip line was fixed with a control valve. Irrigation was scheduled at weekly intervals based on cumulative pan evaporation.

Observations recorded:

Soil parameters

Bulk density (g cm^{-3}): Three soil samples from each treatment combination were taken and their bulk density was determined by the core sampler method (Blake, 1965) on dry weight basis and results were expressed in g cm^{-3}.

pH: pH of the soil was measured by taking three samples each in 1:2.5 soil water suspension using a digital pH meter with glass electrode as described by Piper, (1966).

Soil moisture percentage (%): Soil samples were taken from three selected plots in each treatment. The soil moisture was determined gravimetrically after oven drying the samples at 105 °C for 24 hours to a constant weight. Soil moisture was calculated and expressed in percentage.

$$\textbf{Soil moisture (\%)} = \frac{\text{Fresh weight of soil} - \text{Oven dry weight of soil}}{\text{Oven dry weight of soil}}$$

Physiological parameters

Water use efficiency (WUE)

Water use efficiency was calculated as the ratio of biomass yield to the total amount of water applied and expressed as g plant-1 lit-1.

WUE = Biomass yield (g/plant) × Total water used (per lit.)

Relative water content (RWC) of plants (%)

During the stress period, 10 leaf discs of each replication from the third leaf from top of the primary branch were collected and relative water content was calculated by using the formula given by Bars and Weatherly (1962) and expressed in percentage.

$$\textbf{RWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Crop growth rate (CGR)

Crop growth rate (CGR)

During crop growth period, particularly at two time (45 and 75 days), uproot the entire plant and separate the leaves, stem and root. The fresh biomass was spread and dried in aerated oven drier and protected area from direct sunlight. In artificial drying optimum 34 temperature 50-60 oC was maintained. Using this dry weight, crop growth rate (CGR) was calculated by using the formula given by Watson (1952) and expressed in g. unit land $area^{-1}.time^{-1}$.

$$\textbf{CGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A}$$

W_1= Dry weight of the plant at time t_1, W_2= Dry weight of the plant at time t_2, A = Land area

Relative Growth Rate (RGR) (Williams, 1946)

During crop growth period particularly after (45 & 75 days) entire plant was uprooted then fresh biomass was spread and dried in aerated oven drier and kept in protected area away from direct sunlight. Using this dry weight, Relative Growth Rate (RGR) was calculated using the formula given by Blackman (1919) and expressed g. g^{-1} day^{-1}.

$$\textbf{RGR} = \frac{(\text{Loge W2}) - \text{Log W1})}{(t2 - t1)}$$

W_1= Dry weight of the plant at time t_1 W_2= Dry weight of the plant at time t_2

Net Assimilation Rate (NAR):

During crop growth period, uproot the entire plant then fresh biomass was dried in aerated oven drier Using this dry weight, Net Assimilation Rate (NAR) was calculated by using the formula given by Gregory (1926) and expressed in g. unit leaf $area^{-1}$. unit $time^{-1}$.

$$\textbf{NAR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\text{Loge } L_2) - \text{Log } L_1)}{(L_2 - L_1)}$$

Where

L_1 and W_1 = Leaf area (m^2) and dry weight of the plant (g) respectively at time t_1.

L_2 and W_2 = Leaf area (m^2) and dry weight of the plant (g) respectively at time t_2.

Results and discussion

The data with respect to soil moisture (%) as influenced by different irrigation intervals and hydrogel levels and their interactions is presented in **Table 1**. Soil moisture steadily decreased with the age of crop. Maximum soil moisture was reported in irrigation at 100 per cent of CPE (I_2) (20.72, 17.50 and 12.24 per cent, respectively) at 30, 60 and 90 Days after transplanting respectively. Whereas, least soil moisture was noticed in irrigation levels of 60 per cent CPE (I_3) (14.15, 12.28 and 9.31 per cent, respectively) at divergent growth stages. Soil moisture was remarkably enticed by application of various levels of Pusa hydrogel at all phases of growth (30, 60 and 90 DAT). Among all the concentrations, H_4 (5.25 kg/ ha) showed much higher soil moisture (23.11, 20.11 and 14.56 per cent, respectively) at all stages of crop 30, 60 and 90 DAT. The results of the present study were in accordance with the previous work done by Akhter et al. (2004), who opined that the hydrogel addition in soil was effective in improving soil moisture availability and thus increased the plant establishment. The treatment combination I_1H_4 (irrigation scheduled at 80 per cent CPE with 5.25 kg /ha of hydrogel) documented significantly greater soil moisture (27.00 per cent) and least was in I_3H_5 (11.10 per cent) at 30 DAT. Same patterns with respect to soil moisture was observed even at 60 and 90 DAT. I_1H_4 registered significantly greater soil moisture at 60 and 90 DAT (23.04 and 17.33 per cent, respectively) and lowest was catalogued in I_3H_5 (8.83 and 6.46 per cent, respectively). Similar findings were also documented by Anupama et al. (2007) and Kumar et al. (2016) in chrysanthemum, Singh et al. (2017) in mustard, Bala (2018) in Philodendron, and Kumar et al. (2018) in ginger.

There was no significant difference among the irrigation intervals and different hydrogel concentration as well as the interaction between different levels of hydrogel and irrigation intervals with respect to pH of soil. This might be attributed to the fact that hydrogel has neutral pH and does not change the pH of the soil. Our results were in accordance with Trung et al. (2009) in Orthosiphon. However, among different irrigation intervals, the highest soil pH (8.03) was noted in I_2 (irrigation scheduling at 80 per cent CPE). While, the minimum pH was in irrigation at 60 per cent CPE (I_3) (7.97). Among different hydrogel levels, maximum pH (8.07) was catalogued with higher dose H_4 (5.25 kg/ha) of hydrogel application. Least pH was noted in control H_5 (7.94). The bulk density (BD) was also significantly influenced by irrigation intervals and is presented in Table 2. Significantly highest bulk density (1.48 g/cm^3) was inscribed in treatment I_3: Irrigation 60 per cent CPE which was on par with I_2 (1.46 g/cm^3). Notably least bulk density (1.43 g/cm^3) was noted in treatment I_1: Irrigation 100 per cent CPE at all growth phases. Significantly minimum bulk density of 1.39 gm/cm^3 was recorded in hydrogel (H_4) in which highest concentration of hydrogel 5.25 kg / ha was added which was on par with H_3 (1.42g/cm^3). Maximum bulk density 1.53g/cm^3 was observed in H_5 (without any hydrogel). The interaction between various concentrations of hydrogel and irrigation intervals with respect to bulk density was not significant. The soil particles are displaced and rearranged around the swollen particles of the hydrogel. So, the soil volume increases and hence the ratio of the dry mass of the soil to its volume decreases (El-Hady et al., 2006; Tayel and El-Hady, 1981).

Water use efficiency (WUE) (g /plant/lit) was significantly highest in irrigation I_3: Irrigation 60 per cent CPE (11.23 g plant^{-1} lit^{-1}) followed by I_2: 80 per cent CPE (9.64 g plant^{-1} lit^{-1})

documented at 45-75 DAT interval and lowest in irrigation 100 per cent CPE (9.11 g plant^{-1} lit-^{1}). The higher WUE with lower irrigation might be contribution towards less water loss due to evapotranspiration where water is critical for water supply. Similar findings were documented in Polisgowdar et al. (2013) in marigold and Kumar et al. (2016) in chrysanthemum.

Maximum WUE was noted in H_4 (5.25 kg /ha hydrogel) having 10.91 g plant^{-1} lit^{-1} which was followed by H_3 (10.46 g plant^{-1} lit^{-1}) documented in 45-75 DAT interval and minimum was observed in control (8.85 g plant-^{1} lit^{-1}). These records are in confirmation with those of Kumar et al. (2016) in chrysanthemum.

While significantly higher water use efficiency 12.12 g plant^{-1} lit^{-1} was recorded in I_3 H_4: Irrigation 60 per cent CPE + 5.25 kg / ha hydrogel which was statistically on par with I_3H_3 (10.46 g plant-1 lit-1). Significantly lowest water use efficiency 7.62 g plant-1 lit-1was recorded in I_1H_5: Irrigation 100 per cent CPE + without application of hydrogel. Influence of irrigation intervals on relative water content is depicted in **Table 3**. It was recorded to be significantly highest in I_2: 80 per cent CPE (75.51 and 63.75 per cent, respectively) which was on par with irrigation at I_1 (74.67 and 62.78 per cent, respectively) at 45 and 75 DAT. Least relative water content (69.13 and 54.34 per cent, respectively) was noted in treatment I_3: Irrigation 60 per cent CPE at 45 and 75 DAT. Reduction of RWC of the leaf due to drought stress is related to the reduction of soil humidity. In these conditions, plants close their stomata to avoid more water wastage. The Abscisic acid that was synthesized in the root in drought stress conditions gets accumulated in stomata cells thereby promoting the closure of stomata (Chaves et al., 2002). The RWC of leaves was significantly influenced by Pusa hydrogel application also. Significantly maximum RWC (79.24 and 67.26 per cent, respectively) was revealed in treatment H_4 (5.25 kg / ha hydrogel) followed by H_3 (77.14 and 64.27 per cent, respectively) at 45 and 75 DAT. Notably, minimum of 65.38 and 52.26 per cent was noticed in H_5 having no hydrogel at 45 and 75 DAT respectively.

Interaction effects of irrigation interval and hydrogel levels on relative water content at different stages of plant growth revealed the combination I_2H_5 (Irrigation scheduled at 80 per cent CPE with 5.25 kg / ha of hydrogel) documented significantly higher relative water content (82.07 and 71.47 per cent, respectively) at 45 and 75 DAT. Notably, least was observed in I_3H_5: (65.17 and 50.00 per cent, respectively) at 45 and 75 DAT.

With respect to crop growth rate **Table 4** at 45 to 75 DAT significantly higher crop growth rate (1.79 g m^{-2} day^{-1}) was noticed in I_2: 80 per cent CPE which was on par with I_1: 100 per cent

CPE (1.67 g m^{-2} day^{-1}) whereas least was recorded with I_3: 60 per cent CPE (1.52 g m^{-2} day^{-1}). CGR differed significantly due to hydrogel levels. Hydrogel H_4 (5.25 kg / ha) treatment recorded significantly higher CGR (1.99 g m^{-2} day^{-1}) at 45 to 75 DAT and lowest was recorded in control (H_5) (1.34 g m^{-2} day^{-1}).

Among the interactions, higher crop growth rate of 2.20 g m^{-2} day^{-1} at 45 to 75 DAT was recorded in treatment combination of I_2H_4 (irrigation scheduled at 80 per CPE with 5.25 kg / ha of hydrogel) and lowest (1.08 g m^{-2} day^{-1}) was recorded in I_3H_5 (irrigation scheduled at 60 per cent CPE with no hydrogel application). At 45 to 75 DAT, among irrigation intervals, higher RGR (0.58 × 102 g g^{-1} day $^{-1}$) was observed in I_2: 80 per cent CPE which was on par with 100 per cent CPE (I_1) irrigation schedule (0.55 × 102 g g^{-1} day^{-1}) and lower RGR was obtained in 60 per cent CPE (I_3) irrigation schedule (0.46 × 102 g g^{-1} day^{-1}). Among different hydrogel levels, H_4 (5.25 kg / ha) recorded maximum RGR (0.61 × 102 g g^{-1} day^{-1}) at 45-75 DAT, which was followed by H_3 (0.55 × 102 g g^{-1} day^{-1}). Drought stress led to weak transfer of mineral nutrients from soil to plant (Hopkins, 2004) and causes significant reduction in biomass in comparison with control plants. Drought stress has a considerable influence on sorghum and alfalfa fresh and dry weight loss, according to Afsharmanesh (2009).

Whereas lowest RGR was recorded with no hydrogel (H_5) application (0.48 x 102 g g^{-1} day^{-1}). The interaction between various concentrations of hydrogel and irrigation intervals with respect to relative growth rate was not significant. These findings were in consistent with Yazdani et al. (2007) in soybean and Kumar et al. (2018) in ginger.

At 45 to 75 DAT, among irrigation intervals, higher NAR (0.48 g.m^{-2} day^{-1}) was observed in I2: 80 per cent CPE which was on par with 100 per cent CPE (I_1) irrigation schedule (0.46 g.m-2 day^{-1}) and lower NAR was obtained in 60 per cent CPE (I3) irrigation schedule (0.43 g.m^{-2} day^{-1}). Among different hydrogel levels, H_4 (5.25 kg / ha) recorded maximum NAR (0.50 × g.m^{-2} day^{-1}) at 45-75 DAT which was on par with H_3 (0.47 g.m^{-2} day^{-1}). Whereas lower NAR was recorded with no hydrogel (H_5) application (0.41 g.m^{-2} day^{-1}). This result was similar to the reports of Munir et al. (2007) and Goksoy et al. (2004).

Summary & Conclusion

Significantly higher moisture content was recorded in soils irrigated with 100 per cent CPE (20.72, 17.50 and 12.24 per cent, respectively) at 30, 60 and 90 DAT but soils irrigated with the long gap by soils irrigated with 60 per cent CPE (I_3) recorded the lowest soil moisture content. Significantly higher moisture content (27.00, 23.04 and 17.33 per cent, respectively) was recorded in soils irrigated with 100 per cent CPE under 5.25 kg/ha hydrogel (I_1H_4) at 30, 60 and 90 DAT but soils irrigated with the long gap by soils irrigated with 60 per cent CPE and without any hydrogel (I_3H_5) application recorded the lowest soil moisture content. With respect high pH (8.03) and bulk density (1.48 g/cm^3) maximum was observed at 80 (I_2) and 60 (I_3) per cent CPE respectively. Remarkedly least pH and BD were observed in 60 (I_3) and 100 (I_1) per cent, respectively.

The maximum water use efficiency (11.23 g plant $^{-1}$ lit^{-1}) was observed in plant irrigated with 60 (I_3) per cent CPE at 45-75 DAT. Relative water content was recorded significantly highest in I2: 80 per cent CPE (75.51 and 63.75 per cent, respectively) at 45 and 75 DAT. Maximum values of CGR (1.79 g m^{-2} day^{-1}), RGR (0.58 g g^{-1}day^{-1} × 102) and NAR (0.48 g m^{-2} day^{-1}) obtained in irrigation schedule at 80 per cent CPE. The maximum water use efficiency (12.12 g plant $^{-1}$ lit^{-1}) was observed in plant irrigated with 60 per cent CPE with 5.25kg/ha hydrogel (I_3H_4) at 45-75 DAT. Least was recorded in plant treated with 100 per cent CPE without hydrogel (I_1H_4) application. Irrigation intervals and hydrogel combinedly influence of the relative water content of plant. It was recorded to be significantly highest (82.07 and 71.47 per cent, respectively) in 80 per cent CPE with 5.25 kg/ha hydrogel (I_2H_4) at 45 and 75 DAT. Least relative water content was noted in treatment combination of irrigation 60 per cent CPE without hydrogel (I_3H_5). Crop growth rate (CGR) was also significantly influenced by irrigation schedule and hydrogel level. Maximum value of CGR (2.20 g m^{-2} day^{-1}) obtained in irrigation schedule at 80 per cent CPE with 5.25 kg/ha hydrogel (I_2H_4). Least value was noted in treatment combination of irrigation 60 per cent CPE without hydrogel (I_3H_5). Relative growth rate (RGR) and net assimilation rate (NAR) were found to be non-significant with respect to treatment combination of different levels of irrigation and hydrogel.

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Table 1. Effect of Pusa hydrogel and levels of irrigatiom on soil characteristics under various irrigation intervals

Treatments	Soil moisture (%)														
	30 DAT					60 DAT					90 DAT				
	Irrigation														
Pusa hydrogel		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean
	H_1	17.84	17.19	13.67	**16.23**	H_1	15.89	15.17	11.88	**14.31**	H_1	10.13	10.00	7.81	**9.31**
	H_2	21.72	21.00	14.31	**19.01**	H_2	17.19	17.00	12.64	**15.61**	H_2	11.51	11.67	9.21	**10.80**
	H_3	24.03	23.67	15.33	**21.01**	H_3	20.00	19.12	13.24	**17.45**	H_3	13.71	13.33	11.02	**12.69**
	H_4	27.00	26.00	16.33	**23.11**	H_4	23.04	22.50	14.81	**20.11**	H_4	17.33	14.28	12.07	**14.56**
	H_5	13.00	12.33	11.10	**12.15**	H_5	11.36	11.61	8.83	**10.60**	H_5	8.52	7.02	6.46	**7.34**
	Mean	**20.72**	**20.04**	**14.15**		Mean	**17.50**	**17.08**	**12.28**		Mean	**12.24**	**11.26**	**9.31**	
		S.Em (±)		C.D @ 5%		S.Em (±)		C.D @ 5%			S.Em (±)		C.D @ 5%		
Irrigation (I)		0.42		1.73		0.35		1.37			0.29		1.16		
Pusa hydrogel (H)		0.31		0.92		0.36		1.04			0.30		0.88		
Interaction (I×H)		0.65		2.21		0.64		2.09			0.55		1.77		

Main plot treatments irrigation (I): I_1: 100 % CPE, I_2: 80 % CPE, I_3: 60 % CPE **CPE**: Cumulative Pan Evaporation
Sub plot treatments Hydrogel (H): H_1– 3.0 kg/ ha, H_2–3.75 kg/ha, H_3–4.50 kg/ha, H_4–5.25 kg/ha, H_5– Control **DAT**: Days after transplanting

Table 2. Effect of Pusa hydrogel on soil characteristics under various irrigation intervals

Treatments		Soil parameters								
		pH				Bulk density (g/cm^3)				
		Irrigation								
Pusa hydrogel		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean
	H_1	7.97	8.02	7.93	**7.97**	H_1	1.45	1.50	1.54	**1.50**
	H_2	8.02	8.04	7.93	**8.00**	H_2	1.43	1.47	1.44	**1.45**
	H_3	8.04	8.05	8.02	**8.04**	H_3	1.41	1.42	1.43	**1.42**
	H_4	8.06	8.11	8.05	**8.07**	H_4	1.38	1.39	1.40	**1.39**
	H_5	7.94	7.94	7.94	**7.94**	H_5	1.46	1.52	1.61	**1.53**
	Mean	**8.01**	**8.03**	**7.97**		**Mean**	**1.43**	**1.46**	**1.48**	
		S.Em (±)		**C.D @ 5%**		**S.Em (±)**		**C.D @ 5%**		
Irrigation (I)		**0.03**		**NS**		**0.01**		**0.04**		
Pusa hydrogel (H)		**0.11**		**NS**		**0.03**		**0.09**		
Interaction (I×H)		**0.18**		**NS**		**0.05**		**NS**		

Main plot treatments irrigation (I): I_1: 100 % CPE, I_2: 80 % CPE, I_3: 60 % CPE **CPE**: Cumulative Pan Evaporation
Sub plot treatments Hydrogel (H): H_1– 3.0 kg/ ha, H_2–3.75 kg/ha, H_3–4.50 kg/ha, H_4–5.25 kg/ha, H_5– Control **DAT**: Days after transplanting

Table 3. Physiological parameters at various growth stages of marigold as influenced by different levels of irrigation and Pusa hydrogel

Treatments	Water use efficiency (WUE) (45-75 DAT) (g plant^{-1} lit^{-1})					Relative water content (RWC) (%)									
						45 DAT					75 DAT				
	Irrigation														
Pusa hydrogel		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean
	H_1	8.71	9.55	10.77	**9.77**	H_1	72.29	73.41	66.11	**70.60**	H_1	60.00	61.05	50.23	**57.09**
	H_2	8.88	9.79	11.17	**9.99**	H_2	75.30	76.12	68.04	**73.15**	H_2	63.27	64.23	54.18	**60.56**
	H_3	9.02	10.00	11.60	**10.46**	H_3	79.46	80.30	71.67	**77.14**	H_3	67.42	68.28	57.12	**64.27**
	H_4	9.48	10.62	12.12	**10.91**	H_4	81.00	82.07	74.67	**79.24**	H_4	70.15	71.47	60.17	**67.26**
	H_5	7.62	8.22	10.51	**8.85**	H_5	65.32	65.67	65.17	**65.38**	H_5	53.08	53.72	50.00	**52.26**
	Mean	**9.11**	**9.64**	**11.23**		**Mean**	**74.67**	**75.51**	**69.13**		**Mean**	**62.78**	**63.75**	**54.34**	
		S.Em (±)		C.D @ 5%		S.Em (±)		C.D @ 5%			S.Em (±)		C.D @ 5%		
Irrigation (I)		**0.14**		**0.55**		**0.62**		**2.52**			**0.45**		**1.81**		
Pusa hydrogel (H)		**0.09**		**0.26**		**0.69**		**2.03**			**0.63**		**1.85**		
Interaction (I×H)		**0.19**		**0.67**		**1.24**		**3.98**			**1.08**		**3.37**		

Main plot treatments irrigation (I): I_1: 100 % CPE, I_2: 80 % CPE, I_3: 60 % CPE **CPE**: Cumulative Pan Evaporation

Sub plot treatments Hydrogel (H): H_1– 3.0 kg/ ha, H_2–3.75 kg/ha, H_3–4.50 kg/ha, H_4–5.25 kg/ha, H_5– Control **DAT**: Days after transplanting

Table 4. Physiological parameters at various growth stages of marigold as influenced by different levels of irrigation and Pusa hydrogel

Physiological parameters (45-75 DAT)															
Treatments	Crop Growth Rate (CGR) ($g\ m^{-2}\ day^{-1}$)				Relative Growth Rate (RGR) ($g.g^{-1}day^{-1} \times 10^2$)					Net Assimilation Rate (NAR) ($g.m^{-2}\ day^{-1}$)					
	Irrigation														
Pusa hydrogel		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean		I_1	I_2	I_3	Mean
	H_1	1.63	1.67	1.55	**1.62**	H_1	0.52	0.55	0.44	**0.50**	H_1	0.45	0.47	0.42	**0.45**
	H_2	1.63	1.71	1.57	**1.64**	H_2	0.53	0.58	0.46	**0.52**	H_2	0.45	0.48	0.43	**0.45**
	H_3	1.66	1.82	1.63	**1.70**	H_3	0.58	0.59	0.49	**0.55**	H_3	0.47	0.49	0.44	**0.47**
	H_4	1.98	2.20	1.78	**1.99**	H_4	0.64	0.66	0.52	**0.61**	H_4	0.50	0.52	0.47	**0.50**
	H_5	1.43	1.53	1.08	**1.34**	H_5	0.49	0.52	0.42	**0.48**	H_5	0.41	0.44	0.39	**0.41**
	Mean	**1.67**	**1.79**	**1.52**		Mean	**0.55**	**0.58**	**0.46**		Mean	**0.46**	**0.48**	**0.43**	
		S.Em (±)		C.D @ 5%		S.Em (±)		C.D @ 5%			S.Em (±)		C.D @ 5%		
Irrigation (I)		0.04		0.17		0.01		0.03			0.01		0.03		
Pusa hydrogel (H)		0.03		0.08		0.01		0.02			0.01		0.04		
Interaction (I×H)		0.06		0.21		0.02		NS			0.03		NS		

Main plot treatments irrigation (I): I_1: 100 % CPE, I_2: 80 % CPE, I_3: 60 % CPE **CPE**: Cumulative Pan Evaporation

Sub plot treatments Hydrogel (H): H_1– 3.0 kg/ ha, H_2–3.75 kg/ha, H_3–4.50 kg/ha, H_4–5.25 kg/ha, H_5– Control **DAT**: Days after transplanting