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Effect of hydrogel on growth, fresh yield and essential oil content of ginger (*Zingiberofficinale* Rosc.)

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Abstract
The experiment was carried out during 2017 at Kademanuganahally, Hunsur, Mysore. The experiment was laid out in split plot design with two replications. Three different levels of irrigation (M1= 7 days, M2= 14 days and M3= 21 days interval) and eight levels of Pusa hydrogel (S1= Control, S2= 2.0 kg/ha, S3= 2.5 kg/ha, S4= 3.0 kg/ha, S5= 3.5 kg/ha, S6= 4.0 kg/ha, S7= 4.5 kg/ha and S8= 5.0 kg/ha of hydrogel) were allocated to main plots and sub plots, respectively. Results showed that hydrogel, irrigation levels and their interactions had a significant effect on growth, fresh yield and essential oil content of ginger. The highest plant height, number of leaves, number of tillers, fresh rhizome yield per plant, yield per hectare and essential oil percentage were recorded in treatment with 5.0 kg/ha Pusa hydrogel and irrigation at 14 days interval. The results indicated that hydrogel had a remarkable effect on enhancement of growth, yield and oil content of ginger.

Keywords: Ginger, Hydrogel, Irrigation, Rhizome yield.

Introduction
India is known as the land of spices from the time immemorial and has been the leading country in the world for production, consumption and export of spices. Ginger (*Zingiberofficinale* Rosc., Family: Zingiberaceae) is one of the oldest known spices valued for its aroma and pungency. Ginger is used both in fresh and dried form. It is utilised widely as spice, for pickles, candies and as a medicinal herb for the treatment of gastrointestinal diseases, including dyspepsia, nausea and diarrhea.
India occupies a unique position of being the largest producer and exporter of ginger in the world.In India, it is grown in an area of 1,32,620 ha with an annual production of 6,55,060 MT and productivity of 4.9 MT/ha (Anon, 2014) [1]. Water scarcity is one of the major limiting factor in cultivation of ginger.
Pusa Hydrogel is an indigenous product designed and developed by IARI, New Delhi to enhance the crop productivity per unit available water and nutrients, particularly in moisture stress agriculture. Synthetic polymers in the form of crystals or tiny beads available under several trade names such as Pusa Hydrogel, super absorbent polymers, root watering crystals and drought crystals are collectively known as hydrogels. Hydrogel is a water retaining, cross-linked hydrophilic, biodegradable polymer which can absorb and retain water at least 400 times of its original weight and make at least 95 per cent of stored water available for crop absorption (Johnson and Veltkamp, 1985) [2]. Hydrogel may prove as a practically convenient and economically feasible option to achieve the goal of agricultural productivity under conditions of water scarcity. The low application rate of Hydrogel is effective for almost all the crops in relation to soil type and climate of India. No research work has been done so far on effect of Hydrogel on the rhizomatic spice crops. Hence, the present investigation was carried out in 2017-18 at atKademanuganahally, Hunsur, Mysore

Materials and methods
The experiment was laid out in split plot design with irrigation (M) as main plot and Hydrogel (S) as a subplot with two replications. The experimental treatments comprised of three irrigation levels 7, 14, 21 days interval and eight hydrogel levels (Control with no hydrogel,

2.0 kg/ha, 2.5 kg/ha, 3.0 kg/ha, 3.5 kg/ha, 4.0 kg/ha, 4.5 kg/ha and 5.0 kg/ha). The variety Rio-de-Janeiro was used. Seed rhizomes having 3 to 4 buds weighing about 25-30g were treated with mancozeb (3g/l), Chlorpyrifos (4 ml/litre) and Streptomycin sulphate (1g/litre) solution for half an hour and dried in shade for twelve hours. Treated rhizomes were planted in the beds at 3.5 to 4.0 cm depth at a distance of 30 cm between rows and 30 cm between the plants.

Hydrogel was mixed with the sand in 1:10 ratio and applied to the beds before planting. All the inputs supplied and cultural operations carried out are same for crop raised in different irrigation levels.

Observations were recorded on various growth and yield parameters such as plant height, number of leaves per clump, number of tillers per clump, fresh yield per plant and yield per hectare. Growth parameters are recorded at 180 Days after planting. Essential oil content on fresh weight basis was obtained by hydro distillation of freshly harvested rhizomes using Clevenger apparatus. The data was subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The critical difference (CD) values are given at 5 per cent level of significance, wherever the 'F' test was significant.

Result and discussion

The data pertaining to plant height, number of leaves per clump and number of tillers per clump at 180 DAS as influenced by different irrigation levels, hydrogel levels and their interactions are represented in table 1. The maximum plant height was recorded in irrigation (M2) at 14 days interval (77.99 cm) which was followed by irrigation (M1) at 7 days interval (73.59 cm) whereas, the lowest was recorded in irrigation (M3) at 21 days interval (61.86 cm). With an increase in Pusa Hydrogel concentration there was an increase in plant height. The highest plant height (80.56cm) was recorded in S8 (5.0 kg/ha) followed by S7 (77.83cm) and lowest plant height (62.60cm) was observed in S1 (without Pusa Hydrogel). Among the interactions maximum plant height was recorded in 14 days irrigation interval with 5.0 kg/ha of hydrogel (M2S8) (92.17 cm) followed by 4.5 kg/ha of hydrogel (M2S7) (89.26 cm) and minimum plant height was recorded in 21 days irrigation interval with no hydrogel application (M3S1) (55.85 cm). An increase in plant height might be attributed to water availability and indirectly nutrients provided by superabsorbent polymer, which have been reported to increase the activity of cell division, cell expansion and cell elongation, ultimately leading to an increased plant height. Similar results have been reported by Al-Harbi *et al*. (1999) [3] in cucumber, Sendur Kumaran *et al.* (2001) [4] in tomato, Sivalapan (2001) [5] and Amiri *et al*. (2013) [6] in soybean. The positive effect of super absorbent on stem elongation is reported by Brar *et al*. (2001) [7] in maize and Anupama *et al*. (2007) [8] in chrysanthemum seedlings.

Table 1: Effect of different irrigation and hydrogel levels on Growth parameters of ginger

Treatments	Plant height (cm)				No. of leaves per clump				No. of tillers per clump			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S1 - control	68.10	63.84	55.85	62.60	187.02	174.74	162.84	174.86	14.69	13.45	12.79	13.64
S2 - 2.0 kg/ha	71.15	68.03	56.52	65.23	203.96	190.41	165.78	186.71	16.38	15.03	13.08	14.83
S3 - 2.5 kg/ha	71.91	71.13	57.21	66.75	205.21	217.72	168.80	197.24	16.50	17.79	13.38	15.89
S4 - 3.0 kg/ha	71.94	77.13	59.75	69.61	210.94	225.01	175.13	203.69	17.08	18.48	13.46	16.34
S5 - 3.5 kg/ha	72.52	78.87	64.00	71.80	211.85	243.44	176.19	210.49	17.16	20.33	13.61	17.03
S6 - 4.0 kg/ha	76.08	83.51	64.85	74.81	223.02	250.84	180.66	218.17	18.30	21.05	14.05	17.80
S7 - 4.5 kg/ha	76.10	89.26	68.13	77.83	229.74	258.48	191.05	226.42	18.96	22.20	15.09	18.75
S8 - 5.0 kg/ha	80.95	92.17	68.56	80.56	230.55	266.00	197.70	231.41	19.04	23.03	15.78	19.28
MEAN	73.59	77.99	61.86		212.78	228.33	177.27		17.26	18.92	13.90	
For comparing	**S. Em±**		**C.D. at 5%**		**S. Em±**		**C.D. at 5%**		**S. Em±**		**C.D. at 5%**	
M	1.69		7.28		0.35		1.51		0.12		0.50	
S	1.77		3.69		2.44		5.08		0.26		0.54	
S at same M	3.07		6.38		4.23		8.80		0.45		0.94	
M at same S	3.33		8.84		3.97		8.33		0.44		0.98	

Note: S-Hydrogel, M-Irrigation; M1- 7 Days interval, M2- 14 Days interval, M3- 21 Days interval.

Different irrigation interval had significant effect on number of leaves and number of tillers per plant (Table 1.). Highest number of leaves (228.33) and number of tillers (18.92) per clump were recorded in irrigation at 14 days interval (M2). With an increase Pusa Hydrogel concentration there was significant increase in number of leaves and tilers per plant at 180 DAS. Highest number of leaves and tillers per plant (231.41 and 19.28 respectively) were observed in S8 (5.0 kg/ha of hydrogel) and lowest leaves and tillers per plant (174.86 and 13.64 respectively) were observed in S1 (without Pusa Hydrogel). In interaction, irrigation at 14 days interval with hydrogel 5.0 kg/ha (M2S8) recorded maximum leaves and tillers per plant (266 and 23.03 respectively). Lowest leaves and tillers per plant (162.84 and 12.79 respectively) were recorded in 21 days irrigation interval with no hydrogel application (M3S1). Number of leaves and tillers per plant significantly increased with increased concentration of Pusa Hydrogel which may be due to significant amount of water in hydrogel structure and subsequently, putting the absorbed water into the soil around plant roots, thereby increasing soil's water holding capacity and providing a buffer against the product loss during the time between two irrigations, (Johnson and Woodhouse, 1990) [9] and because of the uninterrupted water availability, plants obtained continuous supply of water and nutrients and thereby resulted in leaf longevity on the plant compared to control. Pusa Hydrogel have been used as water-retaining materials in agricultural and horticultural crops because, when incorporated with soil, they can retain large quantities of water and nutrients, as reported by Yazdani *et al*., (2007) [10] in soybean. The stored water and nutrients are released slowly as required by the plant to improve growth under limited water supply in *Pinus halepensis*, (Huttermann *et al*., 1999) [11].

The data pertaining to yield per plant and yield per hectare as influenced by different irrigation levels, hydrogel levels and their interactions are represented in table 2. Highest yield per plant (308.93g) and yield per ha (30.89 t) were recorded in irrigation at 14 days interval (M2). Different hydrogel levels had significant effect on yield per plant and yield per ha. Highest yield per plant and yield per ha (312.99g and 31.30t respectively) were observed in S8 (5.0 kg/ha of hydrogel) and lowest yield per plant and yield per ha (230.40g and 23.04t respectively) were observed in S1 (without Pusa Hydrogel).

Table 2: Effect of different irrigation and hydrogel levels on Yield parameters of ginger

Treatments	Fresh yield per plant (g)				Fresh yield per ha (t)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S1 - control	255.37	240.10	195.73	230.40	25.54	24.01	19.57	23.04
S2 - 2.0 kg/ha	264.19	260.88	209.21	244.76	26.42	26.09	20.92	24.48
S3 - 2.5 kg/ha	275.58	286.62	227.29	263.16	27.56	28.66	22.73	26.32
S4 - 3.0 kg/ha	278.56	290.79	239.36	269.57	27.86	29.08	23.94	26.96
S5 - 3.5 kg/ha	284.82	325.64	248.03	286.16	28.48	32.56	24.80	28.62
S6 - 4.0 kg/ha	293.30	335.60	253.26	294.05	29.33	33.56	25.33	29.41
S7 - 4.5 kg/ha	298.68	363.20	260.46	307.45	29.87	36.32	26.05	30.74
S8 - 5.0 kg/ha	305.56	368.61	264.80	312.99	30.56	36.86	26.48	31.30
MEAN	282.01	308.93	237.27		28.20	30.89	23.73	
For comparing	S. Em±		C.D. at 5%		**S. Em±**		**C.D. at 5%**	
M	1.10		4.72		0.11		0.47	
S	2.89		6.00		0.29		0.60	
S at same M	5.00		10.40		0.50		1.04	
M at same S	4.80		10.55		0.48		1.05	

Note: S-Hydrogel, M-Irrigation; M1- 7 Days interval, M2- 14 Days interval, M3- 21 Days interval

In interaction, irrigation at 14 days interval with hydrogel 5.0 kg/ha (M2S8) recorded highest yield per plant and yield per ha (368.61g and 36.86t respectively). Lowest yield per plant and yield per ha (195.73g and 19.57t respectively) were recorded in 21 days irrigation interval with no hydrogel application (M3S1). Increase in yield with increase in polymer level can be a result of increased plants available water (Woodhouse and Jonhson, 1990) [9]; water is absorbed by the polymers that increase the water retention capacity of soils (El-Hady and Wanas, 2006; Bai *et al*., 2010; Han *et al*., 2013) [12, 13, 14]. Polymers gradually release water and nutrients to increase the efficiency of water and fertilizer consumption which in turn results in higher yield (Islam *et al*., 2011) [15]; this accords with El-Hady and Wanas (2006) [12] on cucumber and El-Badea*et al.* (2011) [16] on potato yield.

Influence of different levels of irrigation and hydrogel on essential oil content of the ginger are represented in figure 1. The maximum essential oil content was recorded in irrigation (M2) at 14 days interval (1.90 %). The highest essential oil content was recorded in S8 (5.0 kg/ha) (1.98 %). The interaction effect of irrigation and hydrogel levels on essential oil content of ginger was found to be non-significant. The maximum essential oil content was recorded in M2S8 (2.05 %) and lowest was in M3S1 (1.49 %). Increase in the ginger essential oil is a result increase in hydrogel level and due to increase in rhizome yield. Our results agreed with Singh *et al*. (1987) [17] findings on dill and Saeid-Al Ahl *et al.* (2009) [18] on anise, indicating that water deficiency has reduced the essential oil yield of these plants.

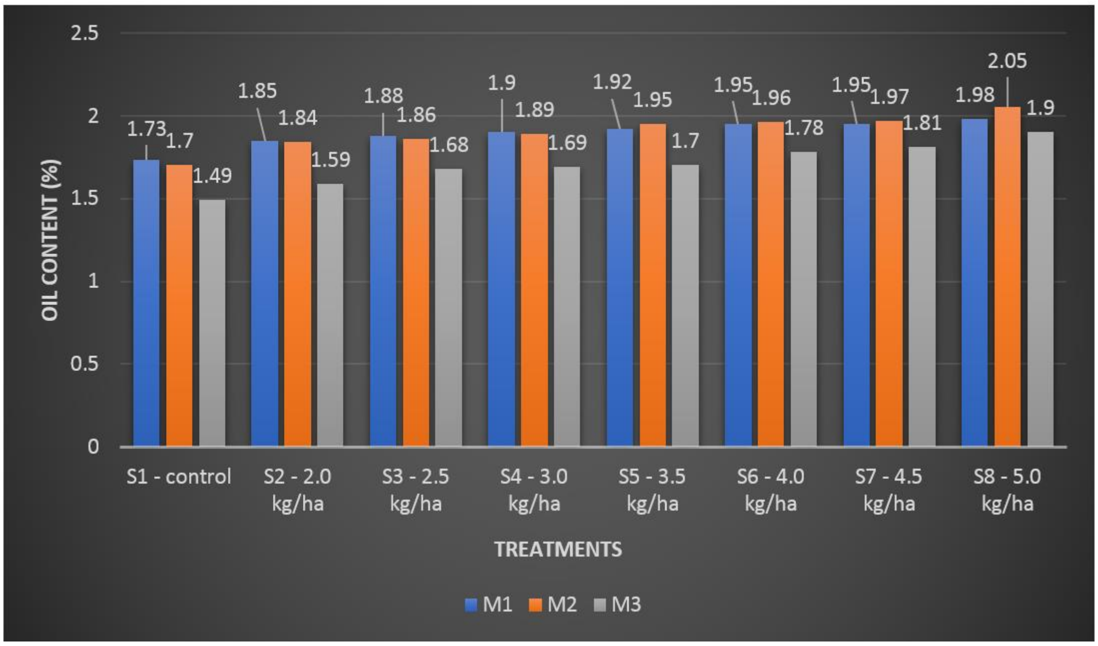

Fig 1: Effect of different treatments on essential oil content of ginger.

Conclusion

Pusa Hydrogel plays an important role in enhancement of absorption capacity and retention of water in soil, fighting against water shortage and decreasing harmful effects of drought stress. Based on the results of this experiment and durability of hydrogel in soil it can be concluded that application 5.0 kg/ha of hydrogel under 14 days irrigation interval regime increases growth and yield of ginger.

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