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Efficacy of Hydrogels under Sensor Based Irrigation on Growth and Productivity of Tree Mulberry

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Authors Contribution

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Abstract

A field experiment was carried out to study the efficacy of hydrogels under sensor-based irrigation on growth and productivity of tree mulberry during 2022-23. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatment combinations and three replications, observations were recorded at 30th, 45th and 60th Days After Pruning (DAP). Pooled data of five crops were analysed. The hydrogels were applied during beginning of first crop. Main plot include two different types of hydrogels *viz.,* Pusa hydrogel (T_1- Pusa hydrogel @ 1 kg/ac, T_2- Pusa hydrogel @ 2 kg/ac, T_3- Pusa hydrogel @ 3 kg/ac and T_4- Pusa hydrogel @ 4 kg/ac) and Zeba hydrogel (T_5- Zeba hydrogel @ 3 kg/ac, T_6- Zeba hydrogel @ 4 kg/ac, T_7- Zeba hydrogel @ 5 kg/ac, and T_8- Zeba hydrogel @ 6 kg/ac) and T_9-control without hydrogel. Among hydrogels, Zeba hydrogel @ 6 kg/ac (T_8) showed highest plant height (201.40, 243.17 and 270.74 cm, respectively), shoot length (131.89, 188.68 and 221.99 cm, respectively), number of shoots per plant (21.34, 23.41 and 28.83 no., respectively), number of leaves per shoot (23.07, 30.10 and 42.33 no., respectively), leaf area (92.72, 165.89 and 190.01 cm^2, respectively) and leaf yield (3.25 kg per plant, 6688.66 kg per ha and 33.44 tons per ha per year). Water productivity was found highest in mulberry plots laid out with Zeba hydrogel @ 6 kg/ac (T_8) found to be 590.29 kg per ha cm along with water used to produce per kg of leaf was recorded to be 169.40 L. Compared to without hydrogel plot 33.23 per cent of water can be effectively saved using Zeba hydrogel @ 6 kg/ac (T_8).

Keywords : V_1 tree mulberry, Sensor based irrigation, Hydrogels, Growth parameters

Mulberry is a perennial, deep rooted, fast growing and high biomass producing plant used for silkworm rearing and production of silk. The plant is known to respond extremely well to various inputs, particularly to the availability of optimum soil moisture and nutrients. Cultivation of mulberry for cocoon production is practiced predominantly under limited agronomic inputs. Insufficient water resources, erratic monsoon and long dry spell are some of the major limiting factors for the progress of mulberry sericulture. Further, mulberry is being raised by the resource starved farmers with marginal lands, low water holding capacity and organic matter with poor native fertility. Even though with sufficient cultivable land, sericulture farmers are facing tremendous challenges for expansion and maintenance of the existing mulberry area and its productivity. Water scarcity and its implications in agriculture as a whole and sericulture in particular has become very prominent under the era of climatic change as maximum amount of water is used by agricultural sector (85%) as compared to industry (10%) and domestic sector (5%). Under such situation, use of hydrogels to enhance water use efficiency for better productivity of mulberry can prove as suitable option for the sericulture farmers. Moisture content in mulberry leaves improves ingestion, digestion and also the conversion of nutrients in silkworm. Water content in mulberry leaves is considered as one of the criteria in estimating the leaf quality. The improvement of leaf quality and the productivity of leaves is immediately required for the sustainability of cocoon crops (Seenappa and Devakumar, 2015).

Among all the agronomic inputs, irrigation water has highest impact on mulberry leaf quantity and quality. In this sensor-based drip irrigation system, water is applied at frequent intervals over the soil to irrigate a limited area around the plant. Soil moisture sensors can be connected to an existing irrigation system controller. The sensor measures the soil moisture content in the root zone before a scheduled irrigation event and bypasses the cycle if the soil moisture is above a specific threshold. Hanson and Orloff (2002) examined that when the sensors are in the root zone at various points they aid in determining the acceptability of irrigation and actual depth of irrigation to be given.

Hydrogels are also called as hydrophilic gels or super absorbent polymers are categorised into different groups, such as naturally occurring, semi-synthetic or synthetic. Most of these polymers can retain 332-465 times water to its weight and release it slowly during drought under light soil (Dehkordi, 2016). Hydrogels are subjected to swelling due to its hydrophilic nature on coming in contact with water and release nearly 95 per cent of stored water available for crop absorption. The process of retaining water and releasing the same by super absorbent gels may last for two to five years depending on the soil environment and cultivation process. However, ultimately in due course of time, it breaks down into CO_2, water, ammonia and potassium ions without any residue, thus making it environment friendly (Trenkel, 1997). Hydrogels also act as soil ameliorant or conditioner by improving porosity, bulk density, soil permeability, compaction, infiltration rate, etc.

Though India has the largest irrigation area, the irrigation efficiency has not been achieved more than 40 per cent. Per capita water availability in the country was dropped from 6008 m^3 in 1947 to 1486 m^3 in 2021 and is expected to dwindle down to 760 m^3 by 2060 (Johnson and Veltkamp, 1985). Among all the agronomical inputs, irrigation water has highest impact on mulberry leaf quantity and quality. Improvement in quality and quantity of crops may need to adopt new irrigation systems such as subsurface drip irrigation system which supplies water and nutrients directly to the crop root zone so crops can be efficiently utilize with water and nutrients. The need is to maximize the production per unit of water. Hence, in the current study, it is planned to evaluate the impact of hydrogels under sensor-based irrigation on growth and yield of mulberry.

Material and Methods

The experiment was conducted during 2022-23 in well-established V_1 tree mulberry garden at L- Block, AICRP- Agro-forestry, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru. The field is located at a latitude of 12°58' N, and longitude of 77°35' East and at an altitude of 930 m above mean sea level in the Eastern Dry Zone (Zone-5) of Karnataka. The recommended dosage of Pusa hydrogel is 1-2.5 kg per acre and Zeba hydrogel is 5 kg per acre. The experiment was established with nine treatment combinations *viz.,* Pusa hydrogel (T_1- Pusa hydrogel @ 1 kg/ac, T_2- Pusa hydrogel @ 2 kg/ac,T_3- Pusa hydrogel @ 3 kg/ac and T_4- Pusa hydrogel @ 4 kg/ac) and Zeba hydrogel (T_5- Zeba hydrogel @ 3 kg/ac, T_6-Zeba hydrogel @ 4 kg/ac, T_7- Zeba hydrogel @ 5 kg/ac and T_8- Zeba hydrogel @ 6 kg/ac)and T_9 - control without hydrogel, were laid out in RCBD design with three replications.

Hydrogels are applied at the root zone of the tree mulberry immediately after pruning along with the recommended dose of NPK during March, 2022. The hydrogels were applied only once in the five crops. Pooled data of five crops were given in the results. Irrigation is applied at 50 per cent DASM (Depletion of available soil moisture). All the other practices of mulberry cultivation followed as per standard package of practices (Dandin and Giridhar, 2014). Observations recorded at regular intervals at 30th, 45th and 60th day after pruning.

Plate 1: Structure of Pusa hydrogel

Plate 2: Structure of Zeba hydrogel

Soil moisture in the soil was measured by using soil moisture indicator, moisture probe meter and single point sensors. Sensors were placed in each treatment such way to avoid the error. Single point sensors were placed at 15 cm depth to ensure enough water for crop growth. These were connected to the IoT based field controller in turn to the gateway through wireless connection in order to store the data in clouds to monitor the water stored in the soil outside the area that can be recharged by drip irrigation (Li *et al.,* 2020).

Soil moisture indicator was developed by Sugarcane Breeding Institute, Coimbatore which works on principle of resistance but, the depiction will be in the form of colour (https://sugarcane.icar.gov.in/index.php/soil-moisture-indicator/).

The data on growth parameters at 30^{th}, 45^{th} and 60^{th} DAP of mulberry crop were recorded in each treatment on randomly selected five plants from each net plot out of 24 plants and mean value was worked out. The experimental data collected on growth components of plant were subjected to Fisher's method of Analysis of Variance (ANOVA) as outlined by Panse and Sukhatme (1967).

TABLE 1

Indicator readings and soil moisture status

Colour of LED	Soil moisture status	Inference
Blue	Ample moisture	No need of irrigation
Green	Sufficient moisture	Immediate irrigation not required
Yellow	Low moisture	Irrigation advisable
Red	Very low moisture	Immediate irrigation necessary

RESULTS AND DISCUSSION

The results and discussion on efficacy of hydrogels under sensor-based irrigation on growth and productivity of tree mulberry are revealed as following:

Plant Height (cm)

The data on plant height varied significantly due to different treatments at 30^{th}, 45^{th} and 60^{th} DAP (Table 2) and that too significant difference in plant height was observed among the hydrogels treated plots. Zeba hydrogel @ 6 kg/ac (T_8) has recorded increase in plant height (201.40, 243.17 and 270.74 cm, respectively) and the least plant height was recorded in Control (T_9 - 154.60, 198.34 and 209.85 cm after 30^{th}, 45^{th} and 60^{th} DAP, respectively). Hydrogels help in maintaining soil moisture levels, even during periods of drought or water scarcity. This reduction in water stress allows plants to allocate more resources towards above-ground growth, including stem elongation and leaf expansion, contributing to increased plant height. Meena (2009) reported that the increase in plant height of soybean was observed with an increase in concentration of super absorbent hydrogel in soil due to proper maintenance of water by hydrophilic polymer (HP) for longer duration.

TABLE 2

Influence of hydrogels under sensor-based irrigation on plant height and shoot length of tree mulberry

Treatments	Plant height (cm)			Shoot length (cm)		
	30th DAP	45th DAP	60th DAP	30th DAP	45th DAP	60th DAP
T_1	160.67	205.27	221.72	109.31	142.75	188.96
T_2	169.56	210.85	229.22	104.28	158.32	194.50
T_3	171.92	214.76	231.55	123.15	161.26	205.97
T_4	183.24	226.13	237.16	126.07	164.72	215.19
T_5	177.14	221.69	235.59	125.94	163.97	209.43
T_6	184.32	232.45	245.18	126.53	170.56	215.72
T_7	194.63	239.97	256.21	128.40	181.08	218.88
T_8	201.40	243.17	270.74	131.89	188.68	221.99
T_9	154.60	198.34	209.85	98.92	142.72	181.55
F- test	*	*	*	*	*	*
S.Em±	2.299	1.091	5.367	4.368	3.906	4.155
C.D.@5%	6.654	3.157	15.531	12.639	11.302	12.023
C.V (%)	2.897	1.102	5.054	8.180	5.332	4.514

DAP- Days after pruning, *- Significant

Similarly, Reyna *et al.* (2011) reported that the *Pinus gregii* seedlings with maximum plant height (21.8 cm) was recorded in the substrate with 80 per cent sawdust + 20 per cent bark with 4 g per litre of hydrogel and the lowest height (19.8 cm) was noticed with 60 per cent sawdust + 40 per cent bark without hydrogel. Nazarli *et al.* (2010) reported that the plant height of sunflower was significantly affected by water stress (irrigation frequency) and increasing the irrigation intervals had resulted in the decrease of plant height. The highest plant height (183.4 cm) was observed in six day irrigation interval along with 300 kg per ha of polymer, while the lowest value (98.2 cm) was noticed in 14 days irrigation interval with no hydrogel.

Shoot Length (cm)

The data on shoot length varied significantly due to different treatments at 30th, 45th and 60th DAP (Table 2) and significant difference in shoot length was observed among the hydrogels treated plots. Zeba hydrogel @ 6 kg/ac (T_8) has recorded highest shoot length (131.89, 188.69 and 221.99 cm, respectively) and the least shoot length was recorded in control (98.92 142.72 and 181.55 cm after 30th, 45th and 60th DAP, respectively). The significant difference in shoot length may be due to regulated supply of moisture by hydrogels at root zone have minimized the weed growth. Hydrogels can improve soil structure by preventing compaction and promoting aeration. Improved soil structure can facilitate root penetration and reduce soil resistance to root growth, indirectly supporting shoot development. Similarly, Akhter *et al.* (2004) reported that application of hydrogel in chickpea (*Cicer arietinum*) at 300 g per kg of seeds recorded highest shoot length (21.4 cm), shoot fresh weight (634 mg) and shoot dry weight (77 mg). Whereas, lowest attributes were recorded in no hydrogel application (17 cm, 394 mg and 46 mg, respectively). Kombali *et al.* (2016) reported that sub surface drip irrigation at 100 per cent pan evaporation recorded significantly higher cane length (226.6 cm) and cane girth (0.91 cm). Similar results were reported by Baasiri *et al.* (1986) that the hydrogel increased stem length of cucumber and the effect was more with the increasing concentration of aquastock hydrogel in soil. Esteban *et al.* (2011) conducted an experiment

TABLE 3
Influence of hydrogels under sensor-based irrigation on number of shoots and number of leaves of tree mulberry

Treatments	Number of shoots per plant			Number of leaves per shoot		
	30th DAP	45th DAP	60th DAP	30th DAP	45th DAP	60th DAP
T_1	15.09	15.22	18.24	17.53	23.22	34.00
T_2	15.36	17.00	19.66	19.15	24.32	36.32
T_3	16.07	18.10	20.27	18.87	24.65	38.16
T_4	17.42	19.50	21.43	20.84	28.70	39.3
T_5	17.29	18.65	20.35	20.66	26.20	38.19
T_6	18.13	20.47	20.57	21.45	28.32	39.83
T_7	20.98	22.22	25.61	22.45	28.96	40.5
T_8	21.34	23.41	28.83	23.07	30.10	42.33
T_9	13.41	15.86	16.5	15.81	18.70	32.2
F- test	*	*	*	*	*	*
S.Em±	1.148	0.893	1.182	1.018	1.204	0.988
C.D.@5%	3.323	2.585	3.422	2.947	3.483	2.860
C.V (%)	14.899	10.546	12.429	11.396	10.388	5.835

DAP - Days after pruning, * - Significant

on *Quercus suber* L. seedlings with four types of growing media and reported that mixing growing media with hydrogel at 0.7 per cent and 1.5 per cent favoured a highest shoot height in the seedlings compared to control.

Number of Shoots Per Plant

The significant difference in number of shoots per plant were observed among hydrogel treated plots at 30th, 45th and 60th DAP (Table 3). Zeba hydrogel @ 6 kg/ac (T_8) has recorded a greater number of shoots per plant (21.34, 23.41 and 28.83 no., respectively) and lowest number of shoots were recorded in control (13.41, 15.86 and 16.50 no. after 30th, 45th and 60th DAP, respectively). The significant difference in number of shoots may be due effective utilization of water stored in hydrogels by crop which is supplied directly to root zone. Hafiz *et al.* (2014) reported on potato (*Solanum tuberosum* L.) and concluded that the number of shoots per plant (3.42), tuber yield (42.54 tonnes per ha), protein content (3.468 µg) was recorded in the treatment with application of hydrogel (80 mg Hydrogel / treatment (two doses) + NPK (250:150:150 per ha) which was followed by the application of hydrogel (40 mg Hydrogel/treatment (one dose) + NPK (250:150:150 per ha) which recorded (3.27, 37.16 tonnes per ha, 3.40 µg, respectively) over the control which reported lesser attributes (2.66, 18.82 tonnes per ha, 3.06 µg, respectively) and these are in conformity with present findings. Zhang Zhang Jiang *et al.* (2005) observed the response of hydrophilic polymer under different water gradients on growth characteristics of an ornamental plant *Parthenocissus quinquefolis* and concluded that polymer significantly increased number of branches over control.

Number of Leaves Per Shoot

The results on number of leaves per plant were significantly influenced by hydrogels at 30th, 45th and 60th DAP (Table 3). Zeba hydrogel @ 6 kg/ac (T_8) has recorded highest number of leaves per shoot (23.07, 30.10 and 42.33, respectively) and lowest number of leaves per shoot (15.81, 18.70 and 32.20 after 30th, 45th and 60th DAP, respectively) was recorded in control (T_9). The significant difference in number of leaves may be due to hydrophilic association of hydrogels with rhizosphere zones of mulberry and making use of water efficiently. The results are in line with Atiyeh and Ebrahim (2013) reported that the application of 3 per cent hydrogel polymer after four days of irrigation has recorded highest number of leaves and surface area of the leaf in *Prunus cerasifera* and the lowest has been observed in treatments of irrigation after 12 days with no application of hydrogel polymer. Zhang-Zhang Jiang *et al.* (2005) observed the response of hydrophilic polymer under different water gradients on growth characteristics of an ornamental plant *Parthenocissus quinquefolis* and concluded that polymer significantly increased number of leaves over control.

Leaf Area (cm^2)

The findings on leaf area (cm^2) were significantly influenced by different treatments of hydrogels on tree mulberry at 30th, 45th and 60th DAP (Table 4). Zeba hydrogel @ 6 kg/ac (T_8) has recorded increased leaf area (92.72, 165.89 and 190.01 cm^2, respectively) and lowest leaf area was recorded in control (T_9 -76.01, 137.56 and 159.74 cm^2 after 30th, 45th and 60th DAP, respectively). Hydrogels can help regulate osmotic potential in plant cells. Adequate water availability due to hydrogel use reduces the risk of negative water potential gradients between soil and root cells. This minimizes the need for cells to expend energy to draw in water, allowing cells to expand and elongate more easily. Increased cell expansion contributes to larger leaf area. Improved water availability and nutrient uptake provided by hydrogels can contribute to optimal photosynthetic rates, ultimately leading to increased leaf area. Firouzeh *et al.* (2007) observed that the plants grown in soils with 225 kg per ha of hydrogel polymer had the greatest leaf area index (LAI) compared to control (without hydrogel polymer). Water deficit (8 and10 days irrigation intervals) reduced LAI while it was greatest at six days irrigation interval. These results were in conformity with the findings of Barakat *et al.* (2015) where application of 150g of super absorbent hydrogel per plant as soil amendment significantly increased leaf area, pseudo stem height and pseudo stem circumference in Grand Nain banana plant with 80 per cent irrigation water.

TABLE 4

Influence of hydrogels under sensor-based irrigation on leaf area (cm^2) of tree mulberry

Treatments	30th DAP	45th DAP	60th DAP
T_1	77.98	138.42	161.43
T_2	81.13	143.99	162.95
T_3	83.07	145.74	163.36
T_4	86.26	149.35	170.98
T_5	84.24	148.35	166.39
T_6	88.29	154.49	175.67
T_7	90.66	162.38	181.46
T_8	92.72	165.89	190.01
T_9	76.01	137.56	159.74
F- test	*	*	*
S.Em±	1.986	4.848	2.224
C.D.@5%	5.747	14.028	6.435
C.V. (%)	5.256	7.247	2.921

DAP- Days after pruning, *- Significant

Leaf Yield (kg/plant)

The findings on leaf yield parameters were significantly influenced by hydrogels at 60th DAP and leaf yield was varied significantly among hydrogel treated plots of tree mulberry crop (Table 5). Zeba hydrogel @ 6 kg/ac (T_8) has recorded highest leaf yield *viz.,* 3.25kg per plant, 6688.66 kg per ha per crop and 33.44 tonnes per ha per year. The records were found on par with Zeba hydrogel @ 5 kg/ac (T_7) *viz.,* 3.09 kg per plant, 6356.39 kg per ha and 31.79 tons per ha per year. The minimal leaf yield was recorded in control T_9- 2.55 kg per plant, 5246.19 kg per ha and 26.23 tons per ha per year. The use of hydrogels in mulberry cultivation positively affects leaf yield by maintaining optimal water availability, enhancing nutrient uptake, reducing water stress, protecting against environmental challenges and supporting root development and hormone regulation. All these factors collectively contribute to improve cellular processes

TABLE 5

Influence of hydrogels under sensor-based irrigation on yield of tree mulberry

Treatments	Yield per plant (kg)	Yield (kg/ha)	Yield (tonnes/ ha/year)	Per cent increase over control
T_1	2.64	5433.29	27.15	3.52
T_2	2.75	5658.77	28.29	7.84
T_3	2.86	5896.22	29.42	12.15
T_4	2.92	6009.98	30.04	14.50
T_5	2.88	5926.88	29.63	12.94
T_6	2.96	6090.56	30.45	16.07
T_7	3.09	6356.39	31.79	21.17
T_8	3.25	6688.66	33.44	27.45
T_9	2.55	5246.19	26.23	-
F- test	*	*	*	-
S.Em±	0.042	27.509	0.834	-
C.D.@5%	0.121	79.604	2.413	-
C.V (%)	3.251	1.039	6.299	-

DAP- Days after pruning, *- Significant

and overall leaf growth, resulting in higher leaf yield. These results were in conformity with the findings of Miller *et al.* (2014) who evaluated and checked the performance of capacitance probes for automated drip irrigation of watermelons. They used multi-sensor capacitance probes (MCP) to automate high frequency drip irrigation in watermelons with the irrigation water treatments of 15 per cent available water depletion (AWD), 50 per cent AWD and no water application (fertigation only) were listed in sandy Coastal Plain soils in South Carolina. Significant yield increase of 44 and 18.4 per cent during 2008 in case of 15 per cent AWD irrigation water treatment and 45 and 40 per cent during 2010 was observed in comparison to no water application and 50 per cent AWD irrigation water treatments, respectively. Also, the results are in line with the findings of Yazdani *et al.* (2007) who reported significantly increased soybean seed yield (5495 kg per ha) by the application of super absorbent polymer (225 kg per ha) as compared to control plants (4172 kg per ha). Hameda *et al.* (2011) studied the effects of hydrogel polymer incorporated into sand (SS/HP) on development of maize (*Zea mays* L.) grown under saline conditions and reported that yields were increased in sand and hydrogel polymer (SS/HP) (v/v) than in pure sandy soil. Zhang-Zhang Jiang *et al.* (2005) observed the response of hydrophilic polymer under different water gradients on growth characteristics of an ornamental plant *Parthenocissus quinquefolis* and concluded that polymer significantly increased leaf biomass over control.

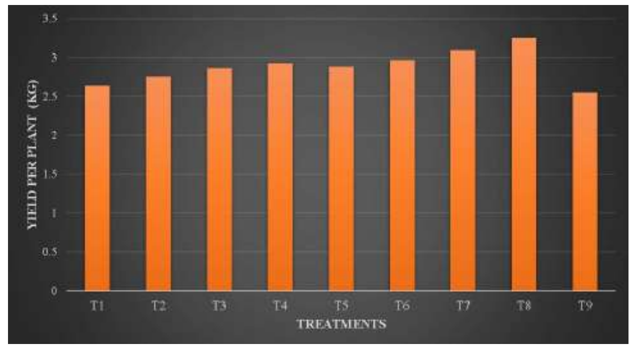

Fig. 1: Influence of hydrogels on leaf yield (kg per plant) of mulberry under sensor-based irrigation

Plate 3: A view of growth of mulberry in the plot with hydrogels

Water Productivity (kg per ha cm)

The results on water productivity were significantly influenced by hydrogels (Table 6). Total amount irrigation applied was recorded lowest in Zeba hydrogel @ 6 kg/ac (T_8- 11.33/ ha cm) and the highest was recorded in control (16.97/ ha cm). Water productivity was found highest in mulberry plots laid

TABLE 6

Quantity of water used and water saved as influenced by hydrogels under sensor based irrigation in tree mulberry

Treatments	Irrigation applied (ha cm)	Water productivity (kg/ha cm)	Water used to produce 1 kg of leaf (L)	Water saved (%)
T_1	15.75	344.95	289.89	7.25
T_2	15.16	373.21	267.93	10.68
T_3	14.91	395.43	252.88	12.14
T_4	14.27	421.09	237.47	15.91
T_5	14.65	404.50	247.21	13.68
T_6	13.74	517.12	225.61	20.88
T_7	12.11	524.85	190.52	23.76
T_8	11.33	590.29	169.40	33.23
T_9	16.97	309.13	323.48	-

out with Zeba hydrogel @ 6 kg/ac (T_8) found to be 590.29 kg per ha cm with water used to produce per kg of leaf was calculated to be 169.40 L. In the plots without hydrogel water productivity found to be lowest that 309.13 kg per ha cm with water used to produce per kg of leaf was recorded to be 323.48 L. 33.23 per cent of water can be effectively saved using Zeba hydrogel @ 6 kg/ac (T_8) compared to without hydrogel plot. The use of hydrogels in mulberry cultivation improves water productivity by creating a more stable and consistent water supply to plant cells. This leads to enhanced cellular activities, including nutrient uptake, photosynthesis and growth. By reducing water stress and maintaining favourable cellular conditions, hydrogels contribute to higher water use efficiency and improved overall productivity in mulberry crops. These results are in confirmation with findings of Alam *et al.* (2020) who reported that the maximum water productivity was found in alternate day irrigation with hydrogel (127.27 %) in turn increased leaf yield of 12.46 per cent and further it consumed 15 per cent of less water when compared to daily irrigation in mulberry. Similarly, Dukes *et al.* (2010) has summarized the reduction in irrigation water requirements for various type of crops in Florida region which showed that using tensiometers, the irrigation requirement of tomato crop was reduced by 40 to 50 per cent (73% reduction of water use at 0.15 bar pressure). Flannery and Busscher (1982) studied the use of synthetic polymer (Permasorb) in potting soils to improve water holding capacity in rye grass and reported that permasorb (6.4 g/l) significantly reduced the watering frequency by increasing water holding capacity of soil. The mean number of watering was significantly reduced (20.3) in soil treated with (6.4 g/l) Permasorb as compared to control (32.5). Agaba *et al.* (2011) reported the effect of hydrogel amended at 0.4 per cent, 0.2 per cent and a control (no hydrogel) on *Agrostis stolonifera* seeds. The 0.4 per cent hydrogel amendment in sand increased the water use efficiency of grass at eight-fold compared to the control. The effects of hydrophilic polymer on water use efficiency studied by Johnson and Leah (1990) concluded that the polymer reduced the water requirement of crop with increasing concentration. The polymer rate (5 g/ kg soil) achieved a significant reduction in water requirement (75 %) in lettuce. Abedi-Koupai and Kameni (2006) reported that hydrogel could reduce the required water to the level of 33 per cent less that of control in *Cupressus arizonica*. The results are in line with that of Johnson and Veltkamp (1985) and Bhat *et al.* (2006) who reported that increase in hydrogel concentration reduced the water requirement in *Conocarpus lancifolis*. Incorporation of two gram hydrogel and reducing amount of irrigation water by 15 per cent or three gram hydrogel with reducing irrigation by 30 per cent is profitable in cucumber under stress condition as compared to control plants (El-Hady and Wanas, 2006).

The Zeba hydrogel @ 6 kg/ac (T_8) can be particularly useful in arid and semi arid conditions where water conservation is essential. It has shown better results compared to other treatments because of the ability of the hydrogel to maintain its structural integrity and water holding capacity over time. The hydrogel is made up of natural polymer *i.e.,* starch and biodegradable in nature, which means it breaks down over time, leaving no harmful residues in soil.

Compared to cellulose, starch is relatively inexpensive and readily available making starch based hydrogels a cost-effective choice for agricultural use.

Irrigation is an important criterion in all agricultural inputs. However, method of irrigation plays an important role in determining the growth and yield of mulberry. Thus sensor based irrigation with hydrogels exhibited better results over conventional irrigation because hydrogels are placed near to rootzone of mulberry which helps in absorption of nutrients and reduction in evaporation loss directly from soil surface. Application of hydrogel increases maximum water holding capacity, prevent runoff and evaporation loss of water from the soil. Besides, loss of nutrient through leaching and volatilization can also be prevented which in turn benefited for the growth and development of tree mulberry production.

References

Agaba, H., Orikiriza, L. J. B., Obua, J., Kabasa, J. D., Worbes, M. and Huttermann, A., 2011, Hydrogel amendment to sandy soil reduces irrigation frequency and improves the biomass of *Agrostis stolonifera*. *Agric. Sci.,* **2** (4) : 544 - 550.

Akhter, J., Mahmood, K., Malik, K. A., Mardan, A., Ahmad, M. and Iqbal, M. M., 2004, Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. *Soil Environ.*, **50** (10) : 463 - 469.

Alam. K., Manjunatha, G., Mishra, S. K. and Siva Prasad, V., 2020, Impact of hydrogel with drip irrigation on mulberry production in Odisha. *Sericologia*, **60** (1) : 1 - 5.

Abedi-Koupai, J. and Kameni, A. J., 2006, Effects of hydrophilic polymer on the field performance of an ornamental plant (*Cupressus arizonica*) under reduced irrigation regimes. *Iran Polym. J.*, **15** (9) : 715 - 725.

Atiyeh, O. and Ebrahim, G. M., 2013, The effect of different levels of irrigation with super absorbent (S.A.P) treatment on growth and development of myrobalan (*Prunus cerasifera*) seedling. *African J. Agri. Res.*, **8** (17) : 1813 - 1816.

Baasiri, M., Ryan, J., Mucheik, M. and Harik, S. N., 1986, Soil application of a hydrophilic conditioner in relation to moisture, irrigation frequency and crop growth. *Commun. Soil Sci. Plant Anal.*, **17** : 573 - 589.

Barakat, M. R., El-kosary, S., Borhan, T. I. and Abd-alnafea, M. H., 2015, Effect of hydrogel soil addition under different irrigation levels on Grand nain banana plants. *J. Hortic. Sci. Ornam. Plants*, **7** (1) : 18 - 28.

Bhat, N. R., Al-messaie, H., Suleiman, H. K., Al-mulla, L., Christpher, A., Ferin, J. and Thomas, B., 2006, Polymer effectiveness at different temperature regimes under arid environmental conditions. *World J. Agric. Sci.*, **2** (4) : 429 - 434.

Dandin, S. B. and Giridhar, K., 2014, Handbook of Sericulture Technologies. Central Silk Board, Bangalore, pp. : 287.

Dehkordi, D. K., 2016, The effects of superabsorbent polymers on soils and plants. *Pertanika. J. Trop. Agric. Sci.*, **39** (3) : 267 - 298.

Dukes, D. M., Zotarelli, L. and Morgan, T. K., 2010, Use of irrigation technologies for vegetable crops in Florida. Workshop, *Hort technology*, **20** (1) : 12 - 19.

El-hady, O. A. and Wanas, S. A., 2006, Water and fertilizer use efficiency by cucumber grown under stress on sandy soil treated with acryamide hydrogels. *J. Appl. Sci. Res.*, **2** (12) : 1293 - 1297.

Esteban, C., Alberto, V. and Ramon, V. V., 2011, Using hydrogel and clay to improve the water status of seedlings for dryland restoration. *Plant and Soil*, **344** (1-2) : 99 - 110.

Firouzeh, Y., Iraj, A. and Gholam, A. A., 2007, Impact of superabsorbent polymer on yield and growth analysis of soybean (*Glycine max* L.) under drought stress condition. *Pak. J. Biol. Sci.*, **10** (23) : 4190 - 4196.

Flannery, R. L. and Busscher, W. J., 1982, Use of a synthetic polymer in potting soils to improve water holding capacity. *Commun. Soil Sci. Plant Anal.*, **13** (2) : 103 - 111.

HAFIZ, N. F., MUHAMMAD, A. P., CHOUDHARY, M. A., MUHAMMAD, Y., MADIHA, B. AND MOHSIN, B., 2014, Effect of soil application of humic acid and hydrogel on morpho physiological and biochemical attributes of potato (*Solanum tuberosum* L.). *Pak. J. life Soc. Sci.*,**12** (2) : 92 - 96.

HANSON, B. AND ORLOFF, S., 2002, Monitoring soil moisture for maximum profit irrigation of alfaalfa. Proceedings, Western Alfalfa and Forage Conference.

HAMEDA, E. L., SAYED AHMED, E. L. AND SAYED, 2011, Influence of salinity stress on growth parameters, photosynthetic activity and cytological studies of *Zea mays* L. plant using hydrogel polymer. *Agricu. Biol. J. N. Am.*, **2** (6) : 907 - 920.

LI, W., AWAIS, M., RU, W., SHI, W., AJMAL, M., UDDIN, S. AND LIU, C., 2020, Review of sensor network-based irrigation systems using IoT and remote sensing. *Adv. Meteorol.*, **9** : 1 - 14.

JOHNSON, M. S. AND LEAH, R. T., 1990, Effects of hydro philic polyacryamide on efficiency of water use by crop seedlings. *J. Sci. Food Agric.*, **52** : 431 - 434.

JOHNSON, M. S. AND VELTKAMP, C. J., 1985, Structure and function of water storing agricultural polyacrylamides. *J. Sci. Food Agric.*, **36** : 789 - 793.

KOMBALI, G., SHESHADRI, T., NAGARAJU, THIMMEGOWDA, M. N., BASAVARAJA, P. K. AND MALLIKARJUNA, G. B., 2016, Performance of sugarcane under varied levels of irrigation and nutrients through subsurface drip fertigation. *Mysore. J. Agri. Sci.*, **50** (2) : 290 - 293.

MEENA, M. K., 2009, Influence of hydrophilic polymer on plant growth and physiology in Tomato (*Lycopersicon esculentum* L.). *M.Sc. (Ag). Thesis*, College of Agriculture, Dharwad. Univ. of Agric. Sci.

MILLER, G. A., FARAHANI, H. J., HASSELL, R. L., KULLAN ADELBERG, J. W. AND WELLS, C. E., 2014, Field evaluation and performance of capacitance probes for automated drip irrigation of watermelons. *Agril. Water Manage.*, **131** : 124 - 134.

NAZARLI, H., ZARDASHTI, M. R., DARVISHZADEH, R. AND NAJAFI, S., 2010. The effect of water stress and polymer on water use efficiency, yield and several morphological traits of sunflower under greenhouse condition. *Notulae Scientia Biologicae*, **2** (4) : 53 - 58.

PANSE, V. G. AND SUKHATME, P. V., 1967, Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi, pp. : 381.

REYNA, K., MALDONADO, B., ARNULFO, A., JAVIER, L. U., HUMBERTO, V. H. AND MANUEL, C. A., 2011, Nursery production of *Pinus greggii* in mixtures of substrate with hydrogel and irrigation levels. *Agrociencia*, **45** : 389 - 398.

SEENAPPA, C. AND DEVAKUMAR, N., 2015, Effect of different methods and levels of irrigation and mulching on growth and yield of mulberry in eastern dry zone of Karnataka. *Mysore. J. Agri. Sci.,* **49** (2) : 206 - 210.

TRENKEL, M. E.,1997, Controlled release and stabilized fertilizers in Agriculture. International Fertilizer Industry Association, Paris, France, pp. : 76.

YAZDANI, F., AKBARI, G. A. AND BEHBAHANI, S. M., 2007, Evaluation of the effect of different rates of superabsorbent polymer on soybean yield and yield component (*Glycine max* L.). Specialized training course and seminar on the application of superabsorbent hydrogel in agriculture, pp. : 20 - 32.

ZHANG-ZHANG JIANG, ZHANG-CHENGYI, S. AND ZHANG JIN ZHENG, 2005, Response of hydrophilic polymer under different water gradients on growth characteristics of *Parthenocissus quinquefolis*. *Bull. Bot. Res.*, **25** (1) : 74 - 79.