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Efficacy of hydrogels under sensor based irrigation on nutrient status of tree mulberry leaves

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Abstract
A field experiment was carried out to study the efficacy of hydrogels under sensor-based irrigation on nutrient status of tree mulberry leaves 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 45th Days After Pruning (DAP). The hydrogels were applied during beginning of first crop and pooled data of five crops were analysed. 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. The major nutrients *viz.*, Nitrogen, Phosphorus and Potassium (3.25, 0.35 and 1.85%, respectively) and secondary nutrients *viz.*, Calcium, Magnesium and Sulphur (0.68, 0.47 and 0.32%, respectively) have recorded significantly on the application of Zeba hydrogel @ 6 kg/ac. The micronutrient content was significantly higher in mulberry leaves collected from T_8 which received Zeba hydrogel @ 6 kg/ac with Zn, Fe, Cu and Mn of 41.82, 242.62, 28.87 and 186.03 mg/kg, respectively.

Keywords: Tree mulberry, sensor based irrigation, hydrogels and leaf nutrients

Introduction
Mulberry foliage is the sole food for the silkworm (*Bombyx mori.* L). As mulberry belongs to genus *Morus* is a perennial crop can be maintained for many years, selection of land, recommended package of practices and water management are the primary factors for producing quality leaves. Among these, irrigation water plays a significant role as one of the key input in mulberry cultivation. The quality of mulberry leaves is critical to the performance and determines its economics for the 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) [21].
At present, about 95.0 percent of the mulberry region is under the irrigated condition, even though borewell water is a common source of irrigation in South India, its availability is getting scarce day by day due to quick groundwater depletion which often leads the farmers to fail to irrigate their mulberry gardens according to requirements. Water in the soil-plant system is a necessary medium for the distribution of nutrients through the plant, works as a solvent for biochemical reactions, represents as a medium of distribution for solutes, and helps in temperature regulation as well as a source of hydrogen in photosynthesis.
Among all the agronomic inputs, for the quantity and quality of mulberry leaf irrigation water possess highest impact. In sensor-based drip irrigation system, water is applied at frequent intervals over the soil to irrigate a limited area around the plant and the 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) [8] 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.

Mulberry requires about 1.5- 2.0 acre inches of water per irrigation at an interval of 6 - 12 days depending upon the type of soil and seasons. About eight number of irrigations are required per crop of 65-70 day duration to achieve the maximum leaf yield. Thus the annual requirement of irrigation water for five crops is about 75 acre inches of water equal to 1875 mm rainfall distributed equally @ 36 mm per week or 5-6 mm per day. However, 80 percent of average annual rainfall of 1,160 mm is received in 4-5 months in our country (Lal, 2001; Gupta and Deshpande, 2004) [12, 7].

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) [4]. Hydrogels are subjected to swelling due to its hydrophilic nature on coming in contact with water and release nearly 95 percent 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) [22]. Hydrogels also act as soil ameliorant or conditioner by improving porosity, bulk density, soil permeability, compaction, infiltration rate, *etc.* When the super absorbent hydrogel polymers are incorporated in moist soild, it becomes swollen after absorbing and storing a large quantity of water and nutrients within a short period and allows the absorbed water and nutrients within it slowly to the soil, mitigating the water and nutrient requirements of the plant especially during the drought stress condition. The peculiar water-nutrient reservoir and lending characteristics of the hydrogel polymers for the soil-plant system have been widely applied in the agricultural domain for substantial water and nutrient saving and ecological restoration (Li *et al.*, 2014) [13].

Materials and Methods

The experiment was conducted during 2022-23 in well-established V1 tree mulberry garden at L- Block, IFS Demonstration Unit, 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 treatments were planned in accordance with regular recommended dosage of Pusa hydrogel is 1-2.5 kg per acre and Zeba hydrogel is 5 kg per acre, in view that to access hydrogels at varied dosages. 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. Irrigation is applied at 50 percent DASM (Depletion of available soil moisture). All the other practices of mulberry cultivation followed as per standard package of practices (Dandin and Giridhar, 2014) [3]. Observations recorded at regular intervals till 60th day after pruning (DAP). The data on leaf parameters at 45th DAP of mulberry crop were recorded in each treatment on randomly selected five plants from each net plot 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) [18].

Analysis of elemental composition in mulberry leaves

Collection of plant samples

Plant samples were randomly collected from tagged plants in each treatment, cleaned with distilled water, air dried and then dried in hot-air oven for about 18 hours at 60 °C. The samples were then powdered and stored in polythene covers. These samples were analyzed for nutrient analysis of mulberry leaves. The different methods adopted for plant analysis is given in Table 1.

Table 1: Different standard methods adopted for plant analysis

Elements	Plant analysis Procedure	Procedure outlined by
Nitrogen (%)	Kjeldhal digestion distillation method	Piper (1966) [19]
Phosphorus (%)	Di-acid digestion and Vanadomolybdate method	Piper (1966) [19]
Potassium (%)	Di-acid digestion and Flame photometer Method	Jackson (1973) [9]
Calcium (%)	Di-acid digestion and Versanate titration	Jackson (1973) [9]
Magnesium (%)	Di-acid digestion and Versanate titration	Jackson (1973) [9]
Sulphur (%)	Di-acid digestion and Turbidometry	Jackson (1973) [9]
Fe, Zn, Cu and Mn (mg kg^{-1})	Digestion with di-acid and Atomic absorption spectrophotometry	Piper (1966) [19]

Estimation of Nitrogen

Nitrogen was determined by Kjeldahl digestion-distillation method. Plant sample (1 g) was digested in digestion flask using digestion mixture and sulphuric acid.

After complete digestion, the digested material was distilled in alkaline medium and the liberated ammonia was trapped in 2 percent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid (Piper, 1966) [19].

$$N\,(\%) = \frac{\text{TV X N. of acid X 0.014 X Vol. of digested sample}}{\text{Weight of the sample} \times \text{aliquot taken}} \times 100$$

Where, TV= titration value

Digestion of leaf samples for other elements (Except N)

Powdered leaf samples (1 g) were treated with 10 ml of concentrated HNO_3 and kept overnight for pre-digestion. Then the samples were digested with 10 ml of the di-acid mixture (9:4 ratio of HNO_3 and $HClO_4$) until the snow-white residue remained. The residue was cooled and diluted to 100 ml using double distilled water, filtered and used to analyze all the elements except nitrogen.

Estimation of Phosphorus

Phosphorus content in the di-acid digested extract was estimated by Vanadomolybdo- phosphoric yellow color method in nitric acid medium and the color intensity was measured at 420 nm wave length as described by Piper (1966) [19].

Estimation of Potassium
Potassium in the plant sample was determined by atomizing the diluted di-acid extract in a flame photometer as outlined by Piper (1966) [19].

Estimation of secondary nutrients
Calcium and magnesium were estimated by the EDTA titration or Versanate- titration method. Sulphur content in the di acid digested sample was estimated by turbid metric method as outlined by Jackson (1973) [9].

Estimation of micro-nutrients (Zinc, Iron, Copper and Manganese)
The di acid digested leaf extract was filtered using Whatman No. 1 filter paper. Then the extract was fed to atomic absorption spectrophotometer and zinc, iron, copper and manganese contents were recorded as outlined by Piper (1966) [19].

Results and Discussion
Primary nutrients (N, P, K) in mulberry leaves
Significantly higher nitrogen (3.25%) content was noticed at 45th day after hydrogel application, in the leaves harvested from mulberry tree which were grown by applying Zeba hydrogel @ 6 kg ac^{-1}. However, the observation was on par with that of T_7 (3.21% of N) and T_6 (3.16% of N) on 45th day after hydrogel application. The lowest N (2.83%) content was noticed in control plot on 45th day after hydrogel application, which was on par with T_1 (2.92% N) and T_2 (2.97%). Similarly, significant higher phosphorus (0.35%) content was recorded at 45th day after application with different levels of hydrogels, in the leaves harvested from plants which were grown by applying Zeba hydrogel @ 6 kg ac^{-1} and the observation was on par with T_7 (0.34% P) and T_6 (0.32% P). The least P (0.22%) content was recorded in control plot (T_9) on 45th day after treatment. Whereas, the observation was on par with T_1 (0.24% P) and T_2 (0.25% P). The maximum potassium (1.85%) content was observed in the leaves harvested from plants which were grown by applying Zeba hydrogel @ 6 kg ac^{-1} at 45th day after being applied with different levels of hydrogels. The potassium content in this treatment was on par with T_7 (1.82% K) and T_6 (1.78% K). The lowest potassium content was observed in control (T_9) (1.42%) on 45th day after treatment. However, the observation was on par with T_1 (1.50% K), and T_2 (1.58% K).

Table 2: Major nutrients content in tree mulberry leaves as influenced by hydrogels under sensor based irrigation

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	2.92	0.24	1.50
T_2	2.97	0.25	1.58
T_3	3.04	0.27	1.63
T_4	3.12	0.31	1.71
T_5	3.08	0.29	1.69
T_6	3.16	0.32	1.78
T_7	3.21	0.34	1.82
T_8	3.25	0.35	1.85
T_9	2.83	0.22	1.42
F- test	*	*	*
S. Em±	0.05	0.01	0.04
$CD_{0.05}$	0.16	0.03	0.12
CV	4.09	8.55	7.56

The increased moisture-supplying capacity of the soil, which promotes better root establishment, improved nutrient absorption and translocation, stronger plant growth, and higher yield, is responsible for the improved nutritional status in the hydrogel applied treatments. The flow of nutrients in soil solution and, ultimately, their absorption by developing plants are enhanced when there is sufficient moisture in the rhizosphere's root zone. Diffusion and mass flow of soil solution, fueled by plant root water uptake, are both necessary for the movement of mineral nutrients from the soil to the plant. The amount of water in the soil determines the diffusion rate. The greater difficulty of moving through the soil as it dries inhibits the transfer of nutrients to the root. (Lakso, 1984) [11].
Positive correlations were found between hydrogels and nitrogen, which is needed to form chlorophyll, phosphorus, which is needed to synthesis nucleic acid, and potassium, which is crucial for growth and elongation and may act as an osmotic regulator. Hydrogels also enhance the uptake of indole acetic acid, which is responsible for growth and development. According to Nova and Leomis (1981) [16], the plant's high rate of protoplasmic protein synthesis, which in turn led to protein synthesis and a rise in cell size, contributed to the vigor of its aerial organs and the plant's vertical development. Thus sufficient nutrition and water availability is essential for plant growth and development.
Application of hydrogel @ 7.5 kg ha^{-1} in furrows has resulted in better uptake of total nitrogen and phosphorous by sunflower crop (107.9 kg ha^{-1} and 23.78 kg ha^{-1}, respectively). This increased nutrient uptake by sunflower could be attributed to more moisture content in soil as a result of application of hydrogel. The results were in confirmity with Anter and De Boodt (1976) [1], El-Hady *et al.* (1981) [5], Rifat and Safdar (2004) [20] and Barihi *et al.* (2013) [2].

Secondary nutrients (Ca, Mg and S) in mulberry leaves
Significantly higher calcium (0.68%) content was noticed in mulberry leaves obtained from the treatment T_8 which received Zeba hydrogel @ 6 kg ac^{-1}. Lowest calcium (0.55%) content was noticed in control (T_9). The magnesium (0.47%) content was significantly higher in mulberry leaves obtained from the treatment T_8 which received Zeba hydrogel @ 6 kg ac^{-1} and lowest magnesium (0.32%) content was observed in control plot at 45th day after being applied with different levels of hydrogels to tree mulberry. There was significant difference among the treatments with respect to sulphur content at 45th day after treatment. Highest sulphur (0.32%) content was found in T_8 and lowest sulphur (0.24%) was found in control plot (T_1).

Table 3: Secondary nutrients content in tree mulberry leaves as influenced by hydrogels under sensor based irrigation

Treatments	Calcium (%)	Magnesium (%)	Sulphur (%)
T_1	0.56	0.34	0.25
T_2	0.58	0.36	0.26
T_3	0.61	0.38	0.26
T_4	0.63	0.42	0.28
T_5	0.61	0.40	0.27
T_6	0.64	0.44	0.29
T_7	0.67	0.45	0.30
T_8	0.68	0.47	0.32
T_9	0.55	0.32	0.24
F- test	*	*	*
S.Em±	0.02	0.02	0.01
C.D.	0.06	0.08	0.04
C.V (%)	8.67	5.12	11.84

Hydrogel usage decreased the leaching of fertilizers and herbicides and also reduced the irrigation requirement of the crops. Application of hydrogel promoted tillering and early flowering and delayed the permanent wilting point (Mohammad *et al*., 2008) [14].

Khalid and Elhindi (2012) [10] reported that subsurface drip irrigation was more efficient than surface drip irrigation for enhancing growth parameters and nutrient concentrations in plants and fertility in soil. The results were similar with Genaidy *et al.* (2016) [6] who reported that the highest calcium content (3.48%) in leaves of Valencia orange trees in subsurface drip irrigation than surface drip irrigation (2.37%), which means the more the availability of water, more the nutrient uptake could be. Combination of organic and inorganic nutrient sources along with hydrogels or soil conditioners result in synergistic and improved conservation and synchronization of nutrient release and crop demand, leading to increased fertilizer efficiency and higher yields (Otitoloju, 2014) [17].

Micronutrients (Zn, Fe, Cu and Mn) in mulberry leaves

Among all the treatments, zinc content was significantly higher in leaves obtained from T_8 plot which received Zeba hydrogel @ 6 kg ac^{-1} (41.82 mg kg^{-1}) and lowest Zinc (38.84 mg kg^{-1}) content was witnessed in control plot (T_9) on 45^{th} day after application of different levels of hydrogels. Significantly higher content of iron (242.62 mg kg^{-1}) was observed in leaves obtained from T_8 which received Zeba hydrogel @ 6 kg ac^{-1}. Whereas, least Fe content (238.15 mg kg^{-1}) was recorded in control plot (T_9) at 45^{th} day after application of different levels of hydrogels to tree mulberry. The higher copper content (28.87 mg kg^{-1}) was from leaves obtained T_8 which received Zeba hydrogel @ 6 kg ac^{-1}, among all the treatments and that was on par with T_7 (28.12 mg kg^{-1}) and T_6 (27.95 mg kg^{-1}) at 45^{th} day after application of different levels of hydrogels. However, lower Copper (25.62 mg kg^{-1}) content was observed in control plot (T_9). Maximum manganese content (186.03 mg kg^{-1}) was found in the leaves collected from T_8 applied with Zeba hydrogel @ 6 kg ac^{-1}. The result was on par with T_7, T_6, T_4 and T_5 (185.47, 184.53, 184.00 and 183.79 mg kg^{-1} respectively). Whereas, the lowest Mn content was found in control plot (T_9) (182.61 mg kg^{-1}).

Table 4: Micronutrients content in tree mulberry leaves as influenced by hydrogels under sensor based irrigation

Treatments	Zinc (mg/kg)	Iron (mg/kg)	Copper (mg/kg)	Manganese (mg/kg)
T_1	39.19	238.47	25.72	182.90
T_2	39.35	238.75	25.9	183.08
T_3	39.42	239.33	26.23	183.53
T_4	40.47	240.47	27.42	184.00
T_5	40.26	239.89	26.55	183.79
T_6	40.80	240.86	27.95	184.53
T_7	41.26	242.27	28.12	185.47
T_8	41.82	242.62	28.87	186.03
T_9	38.84	238.15	25.62	182.61
F- test	*	*	*	*
S. Em±	0.28	0.62	0.17	0.38
$CD_{0.05}$	0.81	1.79	0.49	1.10
CV	3.95	6.329	3.41	5.46

The favourable effect is in improving the nutrient availability in soil might be an increased activities of nitrogen fixing bacteria and rate of humification which in the FYM added in turn enhances the availability of both native and added macro and micronutrients in the soil thus stimulating the plant growth (Narendra and Bhanwer, 2011) [15].

Application of hydrogel @ 7.5 kg ha^{-1} in furrows has resulted in better uptake of sulphur, zinc and boron by sunflower crop. (16.48 kg ha^{-1}, 509.7 g ha^{-1} and 228.4 g ha^{-1}, respectively). The results were in confirmatory with Anter and De Boodt (1976) [1], Rifat and Safdar (2004) [20] and El-Hady *et al*. (1981) [5].

Conclusion

At present, the distribution of rainfall has been impacted by climate change, especially in dry land areas where plants are more vulnerable to the lack of moisture and nutrients during vital phases of growth. Cultivating crops using appropriate alternative farming approaches is therefore necessary. It has been demonstrated that applying hydrogel boosts the soil's ability to store water while reducing runoff and evaporation loss. Additionally, it is possible to stop nutrient loss through volatilization and leaching, which benefits plants' growth and development. In the same way, the findings of the current investigation can also be attributed. T_8 (Zeba hydrogel @ 6 kg ac-1) performed better for all the nutrients in the present study and can also be investigated on a wider scale.

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