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Influence of hydrogel and graded levels of fertigation on growth and productivity of mulberry

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Abstract
A field experiment was carried out to study the influence of hydrogel and graded levels of fertigation on growth and productivity of mulberry during 2025. The experiment was laid out in Randomized Complete Block Design (RCBD) with eight treatment combinations and three replications, observations were recorded at 30, 45 and 60 days after pruning (DAP). Pooled data of two crops for the eight treatments were analyzed. Among all the treatments, T_6 - 100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1} showed maximum shoot length (116.44, 153.51 and 191.42 cm, respectively), number of shoots per plant (19.85, 20.73 and 22.73 no., respectively), number of leaves per shoot (21.43, 26.45 and 32.44 no., respectively) and leaf area (93.43, 148.87 and 190.04 cm^2, respectively). The leaf yield at 60 DAP recorded 40.58 t ha^{-1} yr^{-1} under the same treatment. Water productivity was found highest in mulberry plots laid out with 100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1} (T_6) found to be 611.61 kg per ha cm along with water used to produce per kg of leaf was recorded to be 163.5 L. When compared to control plot 21.43 per cent of water was effectively saved using 100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1} (T_6).

Keywords: Mulberry, hydrogel, fertigation, growth, productivity

Introduction
Mulberry is a robust, perennial deep-rooted foliage yielding plant, which produces high biomass and grows in tropics to temperate region throughout the year. The mulberry silkworm being monophagous insect, depends solely on mulberry for its growth and development. It has been documented that, approximately 70 per cent of silk proteins are derived directly from mulberry leaves. Silkworms must therefore be nourished with good quality mulberry leaves with sufficient quantity for obtaining sustained productivity of quality cocoons (Vijaya *et al.*, 2009) [22]. Therefore, cultivation of mulberry with proper nutrient management is a prerequisite for obtaining maximum profit in sericulture.

Mulberry is known to respond extremely well to various inputs, particularly to the soil moisture and nutrients. Insufficient water resources, erratic monsoon and long dry spell are some of the major limiting factors for the progress of mulberry sericulture. However, mulberry is being raised by the resource constrained farmers with marginal lands having shallow depth, low water holding capacity and organic matter with poor native fertility in most parts of sericulturally rich states of India. 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 sericulture have become very prominent under the era of climatic change. Under such a situation, use of hydrogels to enhance water use efficiency for better productivity of mulberry can prove as suitable option for the sericulture farmers.

Hydrogels are cross-linked water-absorbing polymers that absorb aqueous solutions through hydrogen bonding with water molecules. In agriculture, hydrogels - often referred as water retention granules, can swell significantly upon contact with water making them useful for improving soil water retention. Particularly in arid and semi-arid regions like much of India, these super absorbent polymers (SAPs) enhance water availability for plants by increasing the water-holding capacity of soils and substrates. The effectiveness of hydrogels varies based on their chemical properties, such as molecular weight, which affects their impact on soil properties (Neethu *et al.*, 2018) [16]. Harshitha Mala *et al.* (2023) [9] reported that the highest plant growth and yield parameters in mulberry were observed in the plots treated with Zeba hydrogel @ 6 kg per acre.

Apart from water, nutrient management in mulberry plays a major role in quality and productivity of foliage and the cocoons. Nutrients for plant growth and development may be provided either through soil applicants or liquid medium. Fertigation is one such technique of application of fertilizers along with irrigation water and it provides an excellent opportunity to save labour apart from maximizing the yield. Fertigation ensures adequate supply of water and nutrients with précised timing and uniform distribution to meet the crop nutrient demand. Yan *et al.* (2022) [23] reported that N and P fertilizer applied through fertigation increased wheat grain yield by 16 per cent over top dressed N. Fertigation allows up to 90 per cent absorption of the applied nutrients, while granular or dry fertilizer application typically result in absorption rates of 10 to 40 per cent thus saving 40-60 per cent of the applied fertilizer, which is mainly due to “better fertilizer use efficiency” and “reduction in leaching” (Kumar and Singh, 2002) [11].

Mulberry is one of the major commercial crops cultivated in eastern dry zone of Karnataka where availability of water is a major limitation. Hence, the study is planned to evaluate the combined effect of standardized dose of Zeba hydrogel @ 6 kg per acre along with varied fertigation levels on the growth and yield performance of mulberry.

Materials and Methods

The experiment was conducted during 2025 in well-established V1 mulberry garden at 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 experiment was established with eight treatment combinations *viz.*, T_1 - 50% RDNK through fertigation, T_2 - 50% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}, T_3 - 75% RDNK through fertigation, T_4 - 75% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}, T_5 - 100% RDNK through fertigation, T_6 - 100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}, T_7 - control (RDNK as per Package of Practice) and T_8 - control (RDF as per Package of Practice). These treatments were laid out in RCBD design with three replications.

Zeba hydrogel application was carried out only once for first crop after the pruning. Fertigation (T_1 to T_6) application was carried out in three equal splits at weekly intervals (15th to 29th days after pruning) for both first and second crop (Mahesh *et al.*, 2022) [14], T_7 (without P for second crop) and T_8 (with P for both crops) were acted as control treatments. The fertilizers for T_7 and T_8 were applied at 20 days after pruning as per Dandin and Giridhar, (2014) [7]. FYM @ 20 t ha^{-1} yr^{-1} was applied after pruning of mulberry and irrigation was given based on soil moisture content for all the treatments. N (Urea) and K (Murate of potash) were applied through fertigation for both the crops. Phosphorus is immobile in soil, while is mainly responsible for root growth, so applied only once as basal dose for all the treatments except T_8 (Arunadevi and Selvaraj, 2013) [5].

Single point sensors were placed at 15 cm depth to ensure enough water for crop growth. 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, 45 and 60 DAP and yield parameters at 60 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 Sundararaj *et al.* (1972) [20].

Table 1: Indicator readings and soil moisture status

Colour of LED	Soil Moisture Percentage	Soil moisture status	Inference
Blue	75 - 100%	Ample moisture	No need of irrigation
Green	50 - 74%	Sufficient moisture	Immediate irrigation not required
Orange	25 - 49%	Low moisture	Irrigation advisable
Red	<25%	Very low moisture	Immediate irrigation necessary

Results and Discussion

The results and discussion on influence of hydrogel and graded levels of fertigation on growth and productivity of mulberry are revealed as following:

Table 2: Effect of Zeba hydrogel and graded levels of fertigation on shoot length and number of shoots per plant in mulberry

Treatments	Maximum shoot length (cm)			Number of shoots per shoot		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
T_1	103.65	140.54	179.28	14.87	15.91	17.69
T_2	106.88	142.71	182.28	16.60	17.66	19.53
T_3	106.35	142.24	181.76	16.27	17.33	19.22
T_4	109.87	148.00	187.02	18.89	19.95	22.15
T_5	109.73	147.50	186.47	18.46	19.50	21.70
T_6	116.44	153.51	191.42	19.85	20.73	22.73
T_7	98.53	130.88	166.97	12.88	14.00	15.85
T_8	100.48	134.26	169.27	13.98	15.40	16.99
F test	*	*	*	*	*	*
S.Em±	5.37	4.84	4.92	0.56	0.82	0.68
CD @ 5%	16.30	14.69	14.93	1.70	2.49	2.05
CV	5.21	4.60	4.72	5.07	7.18	6.01

DAP- Days after pruning; *Significant @ 0.05

Maximum shoot length (cm)

The shoot length of mulberry was significantly influenced by fertigation levels and hydrogel application at all stages of observation (30, 45 and 60 DAP). Among the treatments, T_6 (100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}) recorded the maximum shoot length (116.44, 153.51 and 191.42 cm at 30, 45 and 60 DAP, respectively), followed by T_4 (75% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}) and T_5 (100% RDNK through fertigation alone), which were significantly superior to their respective control treatments. The lowest shoot length was recorded in T_7 (control with RDNK) and T_8 (control with RDF). The superior performance of T_6 could be attributed to the synergistic effect of continuous nutrient supply through fertigation and improved soil moisture retention by hydrogel, which maintains an optimum moisture regime, at rhizosphere enhances nutrient uptake and promotes root proliferation and vegetative growth (Poorter and Nagel, 2000) [17]. The superiority of hydrogel-integrated treatments (T_2, T_4 and T_6) over the non-hydrogel treatments (T_1, T_3 and T_5) demonstrate that hydrogels improves the growth even under reduced fertilizer levels by enhancing water and nutrient use efficiency. Similar positive effects of hydrogels on shoot elongation were reported in other crops such as cucumber and chickpea (Baasiri *et al*., 1986; Akhter *et al*., 2004) [6;2], and in mulberry by Harshita Mala *et al*. (2023) [9]. Drip fertigation itself has shown the enhanced vegetative growth and shoot elongation compared to conventional methods, with 100 per cent or 75 per cent recommended dose under optimized fertigation conditions yielding superior results (Mahesh *et al*., 2022) [14]. The poor performance of control treatments (T_7 and T_8) underscores the inefficiency of traditional nutrient and water delivery methods, while the combined use of fertigation and hydrogel ensured precise nutrient availability, improved moisture conservation and consequently resulted in shoot elongation.

Number of shoots per shoot

The number of shoots per plant in mulberry was significantly influenced by fertigation levels and hydrogel application at 30, 45 and 60 days after pruning. Among the treatments, T_6 (100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}) recorded the maximum number of shoots per plant (19.85, 20.73 and 22.73 at 30, 45 and 60 DAP, respectively), followed by T_4 (75% RDNK + Zeba hydrogel @ 6 kg ac^{-1}) and T_5 (100% RDNK fertigation alone). The minimum number of shoots was observed in the controls T_7 (soil application of RDNK) and T_8 (soil application of RDF as per package of practice). The superior performance of T_6 can be attributed to the synergistic interaction between fertigation and hydrogel, ensuring continuous nutrient availability and optimal soil moisture that favour shoot initiation and multiplication. Continuous and balanced nutrient supply, especially nitrogen and potassium through fertigation, promotes axillary bud differentiation and sprouting, while the hydrogel maintains a favourable moisture regime, enhances cytokinin activity and reduces plant stress, collectively resulting in enhanced shoot formation (Kaplan *et al*., 2021) [10]. The combined fertigation and hydrogel effect, promotes root proliferation and efficient uptake of nutrients and growth hormones, leading to better photosynthetic activity and assimilate partitioning towards developing buds. These results align with the findings of Arunadevi and Selvaraj (2013) [5], who reported that fertigation ensures efficient use of water and fertilizers, thereby improving bud sprouting and shoot number in perennial crops. Similarly, Harshitha Mala *et al*. (2023) [9] reported that Zeba hydrogel @ 6 kg ac^{-1} significantly increased shoot numbers in mulberry, with treated plants producing an average of 20.4 shoots per plant against 14.6 in control, supporting the superior performance of T_6 in the present study.

Table 3: Effect of Zeba hydrogel and graded levels of fertigation on number of leaves per shoot and leaf area of mulberry

Treatments	Number of leaves per shoot			Leaf area (cm^2)		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
T_1	17.14	22.20	27.07	84.28	130.72	165.37
T_2	18.49	23.58	29.85	88.32	135.71	170.81
T_3	18.17	23.28	29.43	87.52	134.96	169.86
T_4	20.51	25.45	31.62	91.97	143.74	182.64
T_5	20.15	25.08	31.25	90.99	142.67	181.72
T_6	21.43	26.45	32.44	93.43	148.87	190.04
T_7	14.87	18.58	24.08	80.03	126.96	159.99
T_8	16.01	20.19	24.54	80.07	129.16	162.45
F test	*	*	*	*	*	*
S.Em±	1.62	1.68	1.52	5.79	5.82	5.52
CD @ 5%	4.91	5.09	6.42	17.57	17.66	16.69
CV	9.88	9.97	9.16	5.81	5.83	5.51

DAP- Days after pruning; *Significant @ 0.05

Number of leaves per shoot

The number of leaves per shoot in mulberry was significantly influenced by fertigation levels and hydrogel application at 30, 45 and 60 days after pruning. Among the treatments, T_6 (100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}) recorded the highest number of leaves per shoot (21.43, 26.45 and 32.44 at 30, 45 and 60 DAP, respectively), followed by T_4 (75% RDNK + Zeba hydrogel @ 6 kg ac^{-1}) and T_5 (100% RDNK fertigation alone). The lowest leaf numbers were observed in T_7 (RDNK control) and T_8 (RDF control), indicating the inefficiency of conventional fertilizer application compared to fertigation-based systems. The superior performance of T_6 can be attributed to the synergistic effects of continuous nutrient availability and improved soil moisture retention, which collectively enhanced leaf initiation and expansion. Fertigation ensures a steady nutrient supply, particularly nitrogen and potassium, promoting chlorophyll synthesis, protein formation and active cell division, while hydrogel maintains optimal soil moisture and turgor pressure, reducing plant stress and supporting vigorous vegetative growth. The improvement in leaf number per shoot under hydrogel-integrated fertigation treatments (T_2, T_4 and T_6) revealed the importance of combining water and nutrient management for enhanced canopy development. Efficient fertigation has been shown to promote leaf proliferation and overall vegetative growth in perennial crops (Arunadevi and Selvaraj, 2013) [5], while Suresh *et al*. (2021) [21] reported that drip fertigation with 100 per cent RDF significantly increased leaf production in mulberry compared to conventional methods. Similarly, Kumar *et al*. (2022) [12] observed that integrating fertigation with soil amendments like hydrogels or organic mulches improved leaf expansion and total leaf number. Harshitha Mala *et al*. (2023) [9] also demonstrated that hydrogel application had increased shoot and leaf numbers in mulberry, reinforcing that the combined fertigation and hydrogel approach creates favourable soil, water and nutrient conditions for maximum number of leaves.

Leaf area (cm^2)

Leaf area of mulberry was significantly influenced by the interaction of fertigation levels and hydrogel application at 30, 45 and 60 DAP. The T_6 treatment (100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}) recorded the highest leaf area (93.43, 148.87 and 190.04 cm² at 30, 45 and 60 DAP, respectively), followed by T_4 (75% RDNK + Zeba hydrogel @ 6 kg ac⁻¹) and T_5 (100% RDNK fertigation alone), which were significantly superior over the fertigated treatments without hydrogel. The lowest leaf area was observed in T_7 (RDNK control) and T_8 (RDF control), reflecting the limited efficiency of conventional fertilizer application without precise nutrient and moisture management. The superior performance of T_6 can be attributed to the synergistic effects of continuous nutrient supply and improved soil moisture retention that collectively enhanced cell expansion, chlorophyll synthesis and overall leaf development. Fertigation ensures steady nitrogen and potassium availability, promoting photosynthetic activity and cell division, while hydrogel maintains turgor pressure, reduces water stress and supports sustained leaf expansion. The improvement in leaf area under hydrogel-integrated fertigation treatments (T_2, T_4 and T_6) highlights the positive interaction between water and nutrient management in promoting vegetative growth. Similar results were reported by Ajwa and Trout (2006) [1], who found that improved water availability and nutrient uptake through hydrogels enhanced photosynthesis and leaf area. Arunadevi and Selvaraj (2007) [4], who observed significantly higher leaf area in mulberry under drip fertigation compared to conventional fertilization. Firouzeh *et al.* (2007) [8] also demonstrated that soybean plants treated with 225 kg ha⁻¹ of hydrogel polymer recorded the highest leaf area index Likewise, Singh *et al.* (2018) [19] observed a significant increase in LAI in sugarcane when hydrogel was applied at 2.5 kg ha⁻¹ at planting. Zhang *et al.* (2012) [25] reported that fertigation improved maize leaf area through enhanced nutrient uptake. Collectively, these studies emphasises that integrating the fertigation with hydrogel application creates favourable soil, water and nutrient conditions, promoting leaf expansion and overall vegetative development.

Table 4: Effect of Zeba hydrogel and graded levels of fertigation on leaf yield of mulberry

Treatments	Leaf yield (kg plant^{-1})	Leaf yield (kg ha^{-1})	Leaf yield (tonnes ha^{-1} yr^{-1})	Per cent increase over control (%)
T_1	2.91	6332	31.66	12.43
T_2	3.22	6992	34.96	24.15
T_3	3.15	6854	34.27	21.69
T_4	3.62	7862	39.31	39.59
T_5	3.56	7750	38.75	37.61
T_6	3.73	8116	40.58	44.11
T_7	2.59	5633	28.16	__
T_8	2.78	6039	30.19	__
F test	*	*	*	-
S.Em±	0.12	255	1.34	-
CD @ 5%	0.36	774.05	4.07	-
CV	6.39	6.36	6.70	-

*Significant @ 0.05

Leaf yield

Leaf yield of mulberry was significantly influenced by fertigation levels and hydrogel application at 60 DAP. The maximum leaf yield was recorded in T_6 (100% RDNK through fertigation + Zeba hydrogel @ 6 kg ac⁻¹), averaging 3.73 kg plant⁻¹, 8116 kg ha⁻¹, and 40.58 t ha⁻¹ yr⁻¹, representing a 44.11% increase over control. Treatments T_4 (75% RDNK + Zeba hydrogel @ 6 kg ac⁻¹) and T_5 (100% RDNK fertigation alone) also produced significantly higher yields compared to their respective controls. The minimum yields were obtained in T_7 (RDNK control) and T_8 (RDF control), indicating the limited efficiency of conventional fertilizer application without fertigation or hydrogel. Overall, the combination of fertigation and hydrogel (T_2, T_4 and T_6) consistently enhanced leaf yield, with T_6 showing the maximum advantage. The improvement in leaf yield may be attributed to the synergistic effects of efficient nutrient delivery and improved soil moisture retention. Continuous nutrient supply through fertigation promotes steady vegetative growth and higher biomass accumulation, while hydrogel maintains soil moisture and reduces water stress, sustaining leaf turgidity and also improves photosynthetic efficiency. Similar observations were reported by Lee *et al.* (1992) [13], who recorded a 22 per cent yield increase with additional fertilizer and Naveen *et al.* (2019) [15] highlighted that continuous nutrient availability improves nutrient use efficiency and reduces its losses. Additionally, Arunadevi and Selvaraj (2007) [4], Seenappa *et al.* (2015), Suresh *et al.* (2021) and Mahesh *et al.* (2022) [18,21&14] noted higher mulberry yields under optimized fertigation, while Singh *et al.* (2018) [19] and Kumar *et al.* (2022) [12] observed further improvements with hydrogel application. Collectively, these studies confirm that integrating fertigation with hydrogel creates favourable conditions for maximising the leaf yield in mulberry.

Table 5: Quantity of water used and water saved as influenced by Zeba hydrogel and graded levels of fertigation in mulberry

Treatment	Irrigation applied (ha-cm)	Water productivity (kg ha cm^{-1})	Water used per 1 kg leaf (L)	Water saved (%)
T_1	14.81	427.55	233.5	12.31
T_2	13.97	500.50	199.3	17.28
T_3	14.23	481.66	207.8	15.74
T_4	13.58	578.94	172.1	19.59
T_5	14.19	546.16	183.3	15.98
T_6	13.27	611.61	163.5	21.43
T_7	16.89	333.51	299.8	-
T_8	16.89	357.55	279.7	-
F test	*	*	*	-
S.Em±	0.74	20.93	12.96	-
CD @ 5%	2.24	63.50	39.31	-
CV	8.72	8.97	8.82	-

*Significant @ 0.05

Water Productivity (kg per ha cm)

The quantity of water applied, water productivity and water use efficiency in mulberry were significantly influenced by fertigation levels along with the hydrogel application. The highest water productivity (611.61 kg ha cm^{-1}) and lowest water requirement per kg of leaf (163.5 L kg^{-1}) were recorded in T_6 (100 % RDNK through fertigation + Zeba hydrogel @ 6 kg ac^{-1}), along with the maximum water savings (21.43%) compared to conventional irrigation. Treatments T_4 (75 % RDNK + Zeba hydrogel @ 6 kg ac^{-1}) and T_5 (100 % RDNK fertigation alone) also showed improved water productivity (578.94 and 546.16 kg ha cm^{-1}, respectively) and considerable water savings (19.59%). In contrast, T_7 and T_8 (conventional RDNK/RDF) required the highest water application (16.89 ha-cm), exhibited the lowest water productivity (333.51-357.55 kg ha cm^{-1}) and resulted in no water savings. Overall, the combination of hydrogel and fertigation (T_2, T_4 and T_6) effectively reduces water consumption while increasing yield per unit of water. The enhanced water productivity and savings observed under hydrogel-integrated fertigation treatments can be attributed to improved soil moisture retention by hydrogels, which maintain optimal moisture, reduce evapotranspiration losses and allow longer irrigation intervals without compromising crop growth. Fertigation ensures timely and precise nutrient delivery to the root zone, supporting sustained vegetative growth and efficient leaf production. The combined effect promotes deeper root growth and better synchronization of water and nutrient uptake, leading to reduced irrigation frequency and higher water productivity. These results are in confirmation with findings of Alam *et al*. (2020) [3] who reported that the maximum water productivity was found in alternate day irrigation with hydrogel (127.27%) which in turn has increased the leaf yield by 12.46 per cent and further it consumed 15 per cent of less water when compared to daily irrigation in mulberry. Similar results have been reported by Zhang *et al*. (2017) [24] in maize, Mahesh *et al*. (2022) [14] in mulberry and Harshitha Mala *et al*. (2023) [9] confirming that integrating hydrogel application with fertigation enhances water use efficiency, maximizes vegetative growth and leaf yield, and provides a sustainable strategy for mulberry cultivation under limited water conditions.

It is concluded that the integration of Zeba hydrogel with fertigation significantly improved mulberry growth, and yield attributes. Growth traits such as shoot length, number of shoots, number of leaves and leaf area were maximum under 100 per cent RDNK + Zeba hydrogel @ 6 kg ac^{-1}, closely followed by 75 per cent RDNK + Zeba hydrogel @ 6 kg ac^{-1}. Leaf yield and water productivity was also highest in hydrogel-treated plots, demonstrating the synergistic role of moisture conservation and efficient nutrient availability.

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