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Short communication

Evaluating Tomato productivity using hydrogels in a greenhouse environment in Zimbabwe

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Agriculture is central to Zimbabwe's economy, with most of the population dependent on farming (Ministry of Agriculture, Zimbabwe). However, productivity is hampered by water scarcity, soil degradation, and climate change (Nhemachena *et al.,* 2020). Greenhouse technology offers a controlled environment to mitigate these challenges (Mashonjowa *et al.,* 2013). Tomato cultivation is vital in Zimbabwe but faces drought, poor soil, and limited irrigation (Nhemachena *et al.,* 2020). Abror *et al.,* (2025) emphasised the importance of shade management in tomato cultivation in the tropics to optimise productivity and fruit quality. Sharma, & Changade (2025) reported that the crop water requirement (ETc) of tomato was consistently lower under protected cultivation due to microclimatic control, reducing irrigation requirements by up to 27% compared to open-field cultivation. Lee *et al.,* (2025) reported that the irrigation at 80% of ETc was recorded as the most appropriate for the crop growth rate (CGR), leaf area index (LAI), and yield of cherry tomato in Vietnam.

Hydrogels, polymers capable of water retention, are promising for improving soil moisture availability in greenhouses (Li *et al.,* 2020). Hydrogels are either synthetic or natural polymers that absorb and slowly release water, supporting plant growth. They can be incorporated into soil or used as a growing medium, providing consistent water and nutrients. Studies have shown that hydrogels can boost yields, reduce water use, and improve drought tolerance (Li *et al.,* 2020). Drought significantly reduces yields (Mupepi *et al.,* 2022), but hydrogels could address these issues by retaining moisture, reducing watering frequency, and improving soil structure. This study evaluates hydrogel effects on tomato productivity under controlled greenhouse conditions in Zimbabwe.

The experiment was conducted in a greenhouse at the University of Zimbabwe's Biological Sciences department from the 5th of February to the 10th of May 2024 during the summer and autumn season. Typical conditions inside the greenhouse included a temperature range of 25-35°C and relative humidity of 40-60%. Tomato seedlings (*Solanum lycopersicum*) were transplanted into plastic pots filled with a clay loam soil as the growing medium. The experiment was designed as a randomized complete block with three hydrogel treatments, namely no hydrogel (control), synthetic hydrogel, and organic hydrogel. The blocks were replicated into four blocks (B1 to B4), with two blocks assigned one of two water treatments of 100% (B1 and B3) and 60% (B2 and B4) of crop water requirements (CWR). Each block had 12 planting stations or pots, four each assigned to one of the three hydrogel treatments. This gave a total of 8 pots with the same water and hydrogel treatment combination, or 4 pots times 2 blocks. There is apparent repetition in Blocks 3 and 4, where the treatment assignments may seem similar, but the design allows for the assessment of the impact of water treatment on tomato productivity while accounting for potential block effects, enabling us to evaluate the consistency of treatment effects, ensuring the reliability of our results. The synthetic hydrogel used in this study was a super absorbent polymer (Polyacrylate-based) with a maximum absorbency capacity of 500 g g^{-1} and an organic hydrogel (Retenitis). The complete randomization of hydrogel treatments ensured that for each block, the plot numbers with each gel treatment varied from block to block (Table 1).

The experiment was set up with four replicates per treatment combination. Irrigation was done manually using a drip irrigation system and scheduled according to prevailing local microclimate. The cultivar used was Candela F1, an indeterminate tomato variety with good foliage cover. A single seedling was transplanted into each of 48 planting stations pre-watered to approximately field capacity on 5 February 2024.

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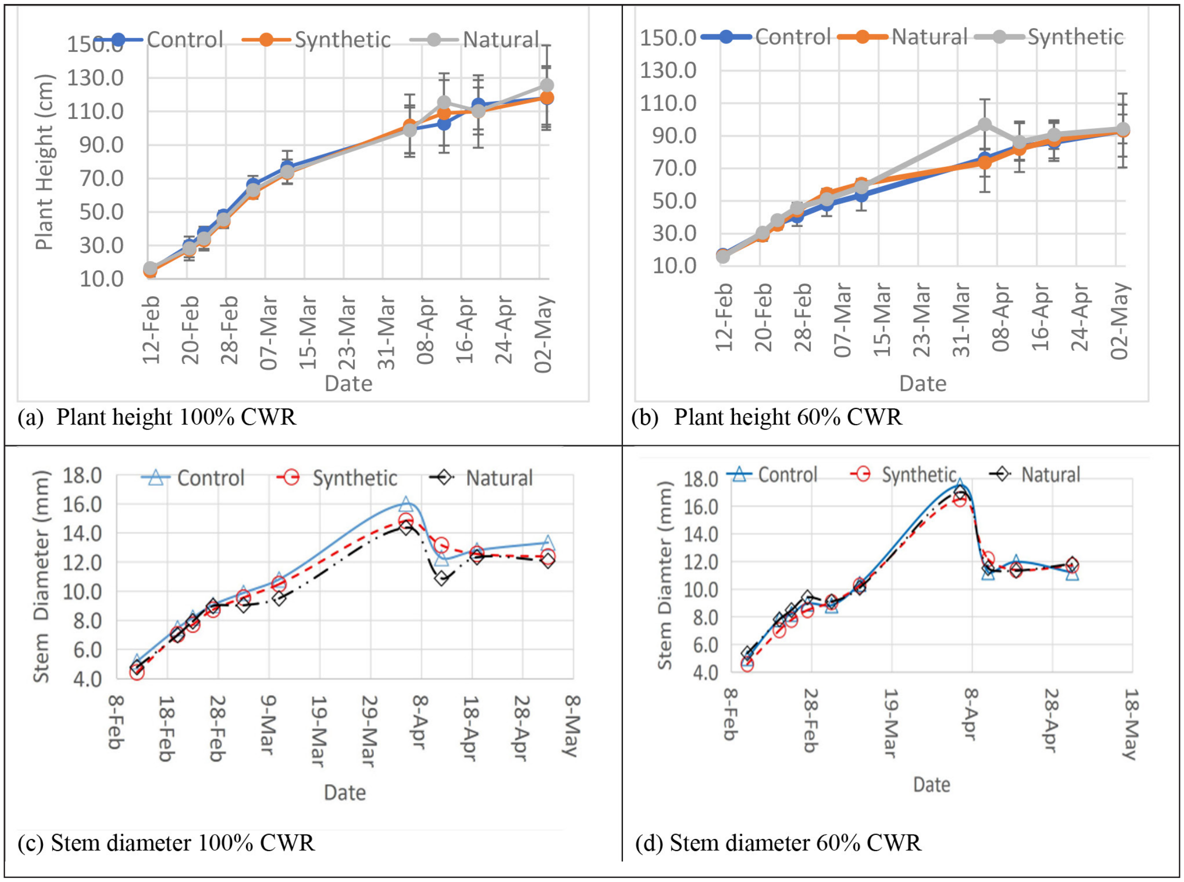

Fig. 1: Periodical plant height (a, b) and stem diameter (c, d) of tomato under irrigation and hydrogel treatments

The synthetic hydrogel was a superabsorbent polyacrylate with a capacity of 500 g g^{-1} The organic hydrogel was Retentis. Hydrogels were incorporated at recommended rates into the soil before transplantation. Irrigation was manual via drip system, scheduled based on meteorological data (temperature, humidity, solar radiation). Crop water requirement (CWR) was calculated using Stanghellini's (1987) equation, adjusted for greenhouse conditions. Data on plant height, stem diameter, fruit yield, and biomass were collected bi-weekly. Ripe fruits were weighed, and total biomass was recorded at harvest.

Growth and yield trends

This study evaluated the impact of hydrogel treatments on tomato growth and productivity in a greenhouse environment under two irrigation strategies: 100% and 60% of crop water requirements (CWR). The periodical plant height and stem diameter of tomato recorded under different irrigation and hydrogel treatments are presented in Fig. 1. Under 100% CWR, plants with hydrogels (both synthetic and organic) exhibited greater growth compared to controls. Under 60% CWR, growth was generally stunted, with minimal differences among treatments.

Table 1: Distribution of experimental treatments over the 48 pots

Block	Water treatment (CWR)	No gel pots	Synthetic gel pots	Organic gel pots
1	100%	1; 2; 11; 12	3; 4; 9; 10	5; 6; 7; 8
2	60%	5; 6; 7; 8	1; 2;11; 12	3; 4; 9;10
3	100%	1; 2; 11; 12	3; 4; 9; 10	5; 6; 7; 8
4	60%	3; 4; 9; 10	5; 6; 7; 8	1; 2; 11;12

At 100% CWR, natural hydrogel yielded an average of 564 g per plant which was higher than synthetic hydrogel (543.4 g) and control (474.0 g). Under 60% CWR, yields declined across all treatments, with no significant differences. Hydrogels improved yield under optimal water but were less effective during water stress (Table 2). The number of fruits and biomass followed similar patterns, emphasizing the importance of water availability. Hydrogels did not significantly augment these parameters under water stress. The results showed that water availability was the primary determinant of tomato crop productivity, with significant effects on total fruit yield, number of harvested fruits, and above-ground biomass. ANOVA results (Table 3) indicated that water treatment significantly affected total fruit yield (p- 0.0083), Hydrogel treatments did not produce statistically significant differences.

Table 2: Mean fruit yield of tomato (g per plant) as influenced by the treatments

Irrigation treatment	Control	Synthetic	Natural	Total
100% CWR	474.0	543.4	564.0	527.1
60% CWR	309.7	174.7	328.3	270.9

Table 3: ANOVA table for total fruit yield per plant (g)

Source of variation	SS	df	MS	F	P-value	F crit
Irrigation	393897	1	393897	8.776	0.008	4.414
Hydrogel	30959	2	15479	0.345	0.713	3.554
Interaction	43038	2	21519	0.479	0.627	3.554
Within	807872	18	44882			
Total	1275766	23				

Hydrogels (natural and synthetic) significantly enhanced yield only under optimal irrigation conditions (100% CWR), but their effectiveness diminished under water-stressed conditions (60% CWR). Water treatment had a significant effect on total fruit yield (P-value: 0.0083), total number of harvested fruits (P-value: 0.0026), and above-ground biomass (P-value: 6.89E-05). Hydrogel treatments failed to demonstrate statistical significance, suggesting that their impact may be negligible compared to the influence of water availability. Enhancing irrigation strategies is paramount for successful tomato cultivation in Zimbabwe's greenhouse settings.

Further research can focus on exploring hydrogel formulations that better retain moisture and integrating them with comprehensive water management practices. Investigating different formulations or concentrations of hydrogels and their long-term impacts can provide valuable insights for improving tomato productivity and water use efficiency and hence, by prioritizing effective water management and exploring innovative hydrogel formulations, farmers and researchers can work together to optimize tomato production in Zimbabwe's greenhouse settings

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