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Effect of Mulching and Hydrogel on the Productivity of Finger Millet under Rainfed Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Rainfed farming, which is crucial for the nation's food security, is seriously impacted by moisture stress. The present study was conducted at the Agricultural Research Station, Vizianagaram, during rainy season to evaluate the effects of mulching and hydrogel applications on the moisture conservation, growth and yield of finger millet. The experiment was laid out in a randomised block design with eight treatments, comprising three doses of hydrogel (2.5 kg/ha, 5 kg/ha, and 7.5 kg/ha) applied alone and in combination with crop residue mulch (5.0 tons/ha). Results revealed that crop residue mulch @ 5.0 t/ha in combination with hydrogel application at 7.5 kg/ha (T_8), 5.0 kg/ha (T_7) and 2.5 kg/ha(T_6) produced 22.2%, 14.5%, 9.3% higher grain yields, respectively as compared to the control. Crop residue mulch @ 5.0 t/ha (T_2) alone showed 4.3% and 14.6% higher grain yield and straw yields as compared to the control. The net returns, benefit cost ratio, soil enzymes (urease, dehydrogenase, acid and alkaline phosphatase enzymes) and soil microbes (bacteria, fungi and actinomycetes) were also found to be higher in these treatments. Therefore, it is recommended to apply crop residue mulch @ 5.0 t/ha (T_2) alone or in combination with hydrogel @ 2.5 kg/ha in order to improve the soil moisture retention, crop yield, profitability and also to maintain soil health.

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Keywords: Rainfed farming; finger millet; crop yields; hydrogel application.

1. Introduction

Finger millet is an important crop among small millets and occupies a significant extent of area in India (12.48 L.ha) as well as in the world (45 L.ha). It is a major source of food grain for millions of people in Asia and Africa. Finger millet contains significant quantities of calcium, phosphorus, other micronutrients, essential amino acids, dietary fibre, antioxidants, etc. and hence it is known as a 'nutri-cereal'. By knowing its nutritional significance, a lot of demand has been created among consumers in recent times. Moreover, this crop is drought-tolerant, requires less water and can be grown on a wide range of soils and environmental conditions (Thakur *et al.*, 2016), however, tillering, flowering and grain filling stages are the most critical stages for moisture availability. In India, finger millet is the fourth largest millet crop grown after maize, sorghum and pearl millet. Karnataka is the leading producer, significantly contributing to the nation's output. Other major states are Uttarakhand, Maharashtra, Tamil Nadu, Andhra Pradesh, Odisha and Gujarat. Andhra Pradesh has nearly 23,000 ha of area under finger millet crop, giving 33,000 tonnes production with 1456 kg ha^{-1} productivity (Ministry of Agriculture and Farmers Welfare, GOI, 2025). Of the total area, nearly 60% of the area is located in the Eastern Ghats and Hills, grown mostly as rainfed crops under light-textured soils with poor moisture and nutrient holding capacities. Though these regions are characterised by heavy rainfall, irregular monsoon patterns and prolonged intermittent dry spells, which significantly affect the crop yields. Hence, moisture conservation practices like mulching, reduced tillage, rainwater harvesting, cover crops, hydrogel application, etc. must be adopted for profitable crop production in this area.

Mulching is widely recognised as a crucial practice for soil moisture conservation. It involves covering the soil surface surrounding plants with organic or synthetic materials in order to create favourable conditions for plant growth. This practice contributes to the conservation of soil water, reduction of evaporative losses, moderation of soil temperature, suppression of weed growth, minimisation of soil erosion, and improvement of overall soil health (Chakraborty *et al.*, 2008; Kader *et al.*, 2017).

Hydrogels are hygroscopic granules or beads, typically composed of potassium polyacrylate. Their hydrophilic polymeric structure swells upon contact with water, forming a transparent, non-toxic and biodegradable three-dimensional gel. This gel is capable of absorbing and retaining water up to several hundred times its dry weight and can subsequently release up to 95% of the stored moisture to plants under drought conditions. By maintaining elevated soil moisture levels, hydrogels can reduce evaporative losses by approximately 20–30%, thereby supporting optimal crop growth (Mushtaq *et al.*, 2022; Ashraf *et al.*, 2021).

The combined application of mulching and hydrogels may therefore represent an effective strategy for enhancing soil moisture conservation under rainfed conditions. Moreover, Choudhary *et al.* (2014) reported that the integrated use of mulch and hydrogel improved soil microbial activity and enhanced plant nutrient uptake. In this context, the present study aimed to assess the combined effects of mulching and hydrogel application on the growth, yield and economic profitability of finger millet.

2. Materials and Methods

A field experiment was carried out during the *kharif* season of 2021 at the Agricultural Research Station, Vizianagaram, located in the Coastal Agro-climatic Zone of Andhra Pradesh, India. The experimental site lies at 18°07′ N latitude and 83°25′ E longitude, at an altitude of 63 m above mean sea level. The soil of the experimental field was sandy loam in texture, neutral in reaction (pH 6.99) and non-saline, with an electrical conductivity of 0.21 dS m^{-1}. It was characterised by low organic carbon content (0.47%) and low available nitrogen (227 kg ha^{-1}), while available phosphorus (25.5 kg ha^{-1}) and potassium (315.0 kg ha^{-1}) were present at medium levels. During the crop growth period, the total rainfall received was 930 mm. The mean maximum and minimum temperatures recorded were 31.06°C and 29.02°C, respectively, while the relative humidity ranged from 61.23% to 87.26%.

The experiment was laid out in a randomised block design with three replications. The treatments comprised: T_1 – Control; T_2 – crop residue mulch @ 5.0 t ha^{-1}; T_3 – hydrogel @ 2.5 kg ha^{-1}; T_4 – hydrogel @ 5.0 kg ha^{-1}; T_5 – hydrogel @ 7.5 kg ha^{-1}; T_6 – T_2 + hydrogel @ 2.5 kg ha^{-1}; T_7 – T_2 + hydrogel @ 5.0 kg ha^{-1}; and T_8 – T_2 + hydrogel @ 7.5 kg ha^{-1}. Paddy straw was used as the mulching material. The hydrogel employed in the study was developed by the Indian Agricultural Research Institute (IARI) and consists of a semi- synthetic, cross-linked polymer derived from derivatised cellulose grafted with an anionic polyacrylate.

The finger millet variety 'Vegavathi', developed by the Agricultural Research Station, Vizianagaram, was used for the study. Seedlings were raised in nursery beds and transplanted into the main field at 25 days after sowing. Half of the recommended nitrogen dose (25 kg ha^{-1}), along with the full recommended doses of phosphorus (40 kg ha^{-1}) and potassium (25 kg ha^{-1}), were applied as basal fertilisers in the form of urea, single superphosphate, and muriate of potash, respectively. The remaining half of the nitrogen was applied as a top dressing at the tillering stage in the form of urea.

Observations on growth parameters, yield attributes, grain yield, straw yield, and economic returns were recorded. Post-harvest soil samples were also analysed for soil enzyme activities and microbial parameters. The collected data were subjected to statistical analysis using analysis of variance (ANOVA) following the procedure outlined.

3. Results and Discussion

3.1 Effect on the Growth and Yield of Finger Millet

Mulching and hydrogel application significantly influenced the growth and yield attributes of finger millet. The initial and final plant stand were not affected either by the hydrogel or mulching treatments. Plant height also did not vary significantly among the treatments (Table 1). However, the number of productive tillers recorded in T_8 (Crop residue mulch @ 5.0 t ha^{-1}+Hydrogel @ 7.5 kg ha^{-1}), T_7 (Crop residue mulch @ 5.0 t ha^{-1}+Hydrogel @ 5.0 kg ha^{-1}) and T_6 (Crop residue mulch @ 5.0 t ha^{-1} + Hydrogel @ 2.5 kg ha^{-1}) were significantly higher as compared to residue mulch alone or hydrogel application alone. Combined application of mulching and hydrogel effectively conserves soil moisture, particularly during critical stages of crop growth, which may favorably influence crop nutrient uptake and photosynthesis. Similar findings were reported by Aswinth *et al*. (2025), Ankit et al. (2022); Hirooka (2021), who observed that improved soil moisture through mulching and hydrogel application enhanced stomatal conductance, leading to improved CO_2 fixation and superior growth and yield attributes.

Mulch or hydrogel application (T_2, T_3, T_4 and T_5) significantly enhanced the finger millet grain and straw yields as compared to the control, where no mulch or hydrogel was applied (Table 2). However, the combined application of mulching and hydrogel (T_6, T_7, T_8) resulted in significantly higher grain and straw yields than all other treatments. Crop residue mulch @ 5.0 t/ha showed 4.3% and 14.6% higher grain yield and straw yields as compared to control. Crop residue mulch @ 5.0 t/ha in combination with hydrogel application produced 22.2%, 14.5%, 9.3% higher grain yields at 7.5 kg ha^{-1}, 5.0 kg ha^{-1} and 2.5 kg ha^{-1}, respectively, as compared to control (1962 kg/ha). By creating a favorable soil moisture regime, mulching and hydrogel application facilitated uninterrupted water and nutrient uptake, which ultimately contributed to enhanced photosynthetic activity. These results align with the research findings of Aswinth *et al*. (2025); Vikramarjun *et al*. (2025) in pearl millet. Mi *et al.* (2017) also reported similar results. Compared to the control, all the treatments exhibited higher water use efficiency. Notably, crop residue mulch in combination with hydrogel at different dosages has shown higher WUE than their respective sole applications (Table 2). Hydrogels reduce the water loss from evaporation and runoff and enhance soil structure and water infiltration, which ultimately contributes to increased water use efficiency (Zhang & Guan, 2022; Kebede *et al*., 2022). Furthermore, hydrogel helps in maintaining the soil moisture for an extended period of time, thereby mitigating drought stress in crop plants (Albalasmeh *et al*., 2022). In addition to regulating soil temperature, controlling weeds control and reducing evaporation, mulches also improve soil structure and nutrient cycling through enhanced earthworm activity in the soil (Qin *et al*., 2015).

Table 1. Effect of mulching and hydrogel on growth and yield attributing characters of finger millet

Treatments	Initial plant stand/m^2	Final plant stand/m^2	Plant height (cm)	Productive tillers/hill	Test weight (g)
T_1: Control	31.7	29.0	112.7	4.2	3.35
T_2:Crop residue mulch @ 5.0 t/ha	32.7	29.7	115.6	4.4	3.38
T_3:Hydrogel @ 2.5 kg/ha	32.3	30.3	113.9	3.9	3.13
T_4:Hydrogel @ 5.0 kg/ha	32.7	31.3	116.6	4.3	3.26
T_5:Hydrogel @ 7.5 kg/ha	32.7	30.3	117.1	4.4	3.33

Treatments	Initial plant stand/m^2	Final plant stand/m^2	Plant height (cm)	Productive tillers/hill	Test weight (g)
T_6:T_2 + Hydrogel @ 2.5 kg/ha	32.0	30.3	117.3	5.0	3.21
T_7:T_2 + Hydrogel @ 5.0 kg/ha	33.0	31.0	118.3	5.1	3.32
T_8:T_2 + Hydrogel @ 7.5 kg/ha	32.7	31.3	119.1	5.3	3.29
SEm±	0.47	0.88	4.16	0.18	0.06
CD (0.05)	NS	NS	NS	0.55	0.19
CV (%)	2.53	5.00	6.20	6.88	3.34

Table 2. Effect of mulching and hydrogel on yield, economics and water use efficiency of finger millet

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	BCR	WUE (kg/ha-cm)
T1: Control	1962	4246	68396	42059	2.60	2.02
T_2:Crop residue mulch @ 5.0 t/ha	2047	4866	71549	47712	3.00	2.11
T_3:Hydrogel @ 2.5 kg/ha	1989	4448	69391	40804	2.43	2.05
T_4:Hydrogel @ 5.0 kg/ha	2008	4590	70111	39275	2.27	2.07
T_5:Hydrogel @ 7.5 kg/ha	2018	4752	70517	37431	2.13	2.08
T_6:T_2 + Hydrogel @ 2.5 kg/ha	2145	4915	74903	48816	2.87	2.21
T_7:T_2 + Hydrogel @ 5.0 kg/ha	2246	5071	78392	50055	2.77	2.31
T_8:T_2 + Hydrogel @ 7.5 kg/ha	2398	5323	83641	53054	2.73	2.47
SEm±	90.72	178.88	3069.6	3069.6	0.11	-
CD (0.05)	275.11	542.49	9309.2	9309.2	0.33	-
CV (%)	7.48	6.49	7.25	11.84	7.20	-

3.2 Effect on Economics

Gross income did not differ significantly among T_8 (T_2 + Hydrogel @ 7.5 kg/ha), T_7 (T_2 + Hydrogel @ 5.0 kg/ha) and T_6 (T_2 + Hydrogel @ 2.5 kg/ha); however, these treatments were superior to the remaining treatments, while the control recorded the lowest gross income. This clearly indicates a synergistic effect between mulching and hydrogel application, which significantly enhanced the yield attributing characters and grain yield compared to their individual applications. Painkra *et al.* (2022) also reported similar results in finger millet. Similarly, the net income was also higher with T_8: T_2 + Hydrogel @ 7.5 kg/ha as compared to other treatments, however it remained on par with T_7: T_2 + Hydrogel @ 5.0 kg/ha, T_6: T_2 + Hydrogel @ 2.5 kg/ha and T_2: Crop residue mulch @ 5.0 t/ha. The benefit-cost ratio also did not vary significantly among these four treatments (T_2, T_8, T_7 and T_6). From this, sole application of crop residue mulch @ 5.0 t/ha was found to be a cost-effective alternative and proved superior to the sole application of hydrogel at various dosages.

3.3 Effect on Enzymes and Microbial Population in Soil

Soil enzymes like urease, dehydrogenase, acid and alkaline phosphatase enzymes were significantly higher in the combined application of mulching and hydrogel applied together (T_8, T_7 & T_6) as compared to their sole applications and the control. Acid and alkaline phosphatase enzymes recorded with crop residue mulch @ 5.0 t/ha were statistically on par with those observed under the combined application of mulching and hydrogel. The lowest level of enzymes was noticed in the control treatments (Table 3).

Soil microbial population, including bacteria, fungi and actinomycetes were significantly higher in T_8: T_2 + Hydrogel @ 7.5 kg/ha, T_7: T_2 + Hydrogel @ 5.0 kg/ha, T_6: T_2 + Hydrogel @ 2.5 kg/ha and T_2: Crop residue mulch @ 5.0 t/ha as compared to all other treatments. Crop residue mulch @ 5.0 t/ha was effective in enhancing the soil microbial population both when applied alone or in combination with hydrogel. The lowest microbial population were observed in the control, where no mulch or hydrogel was applied. The enhanced soil enzymes and microbial populations may be attributed to increased organic carbon content associated with residue mulching, which serves as a major energy source for microorganisms. Additionally, hydrogels contribute to improved soil health, promoting beneficial microbial communities and enzyme functions by stabilizing moisture and nutrients. Analogous results were reported by Tiquia *et al*. (2002) and Bhagat *et al*. (2016).

Table 3. Effect of mulching and hydrogel application on soil enzymatic activity and soil microbial population

Treatments	Urease (mg/g/hr)	Dehydrogenase (µg TPF/g/hr)	Acid phosphatase (µg PNP/g/hr)	Alkaline phosphatase(µg PNP/g/hr)	Bacteria (10^{-7} cfu/g soil)	Fungi (10^{-3} cfu/g soil)	Actinomycetes (10^{-5} cfu/g soil)
T1: Control	2.33	182.37	3.27	3.63	4.33	1.53	4.67
T_2:Crop residue mulch @ 5.0 t/ha	2.78	210.80	3.67	4.09	8.67	2.90	10.00
T_3:Hydrogel @ 2.5 kg/ha	2.64	193.77	3.46	3.78	4.67	1.70	5.33
T_4:Hydrogel @ 5.0 kg/ha	2.70	212.86	3.56	3.84	5.00	2.03	5.67
T_5:Hydrogel @ 7.5 kg/ha	2.72	217.67	3.60	3.94	5.67	2.10	6.33
T_6:T_2 + Hydrogel @ 2.5 kg/ha	3.15	239.87	3.87	4.11	9.00	3.10	9.33
T_7:T_2 + Hydrogel @ 5.0 kg/ha	3.27	246.33	3.95	4.26	9.67	3.17	10.33
T_8:T_2 + Hydrogel @ 7.5 kg/ha	3.16	251.0	3.92	4.38	10.33	3.33	9.67
SEm±	0.10	9.55	0.10	0.15	0.64	0.17	0.79
CD (0.05)	0.32	28.95	0.32	0.46	1.95	0.52	2.40
CV (%)	6.37	7.54	4.94	6.51	15.56	12.00	17.89

4. Conclusion

From this experiment, it can be concluded that the application of crop residue mulch @ 5.0 t/ha, either alone or in combination with hydrogel at 2.5 kg/ha was found to be the most effective in enhancing finger millet yield and profitability apart from enhancing the soil health.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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