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Bhumika Painkra
Department of Agronomy, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Ashwani Kumar Thakur
Department of Agronomy, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Manish Kumar
Department of Agronomy, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Tejpal Chandraker
Department of Soil Science and Agriculture Chemistry, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Devendra Pratap Singh
Department of Agriculture Statistics and Social Science, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Corresponding Author:
Bhumika Painkra
Department of Agronomy, S G College of Agriculture and Research Station, Indira Gandhi Agriculture University, Jagdalpur, Chhattisgarh, India

Effect of mulching and hydrogel in relation to different growth characters, yield and economics of finger millet [*Eleusine coracana* (L.) Gaertn] under rainfed conditions

Bhumika Painkra, Ashwani Kumar Thakur, Manish Kumar, Tejpal Chandraker and Devendra Pratap Singh

Abstract
A study was conducted on finger millet to investigate the effect of finger millet [*Eleusine coracana* (L.) Gaertn.] on growth, yield, Water use efficiency and economics as affected by mulching and hydrogel application at New Upland Research cum Instructional (NURI) Farm, Lamker under S. G. College of Agriculture and Research Station, Jagdalpur, Chhattisgarh, India during *Kharif*, 2021. The experiment was carried out in randomized bock design with three replications. The study has been carried out with different treatment combinations of mulching and hydrogel. T_8, Sowing with crop residue mulch @ 5.0 t ha^{-1} + Hydrogel @ 7.5 kg ha^{-1} gave significantly higher grain yield, Straw yield and yield attributing character, growth character and water use efficiency as compared to other treatment. The treatment combination sowing with crop residue mulch @ 5.0 t ha^{-1} + Hydrogel @ 5.0 kg ha^{-1} were found at par with this treatment T_8. These results indicate that mulch along with hydrogel proved to be useful in achieving the higher yield and net returns.

Keywords: Mulching, hydrogel, water use efficiency

Introduction

Finger millet [*Eleusine coracana* (L.) Gaertn] is a staple food crop for millions of people in the semi-arid region of the world, particularly in Africa and India and especially those who survive on subsistence farming. It is a native African popular in South Asia (India and Nepal). This crop is grown across a large geographical area from Senegal and Nigeria to eastern and southern Africa, through the Middle East and into tropical Asia. Finger millet [*Eleusine coracana* (L.) Gaertn] is one of the most widely grown millets and belongs to the genus Elelusine in the Chloridoidae subfamily. This crop is adapted to a wide range of environments and can be grown in variety of soils with medium or poor water holding capacity but requires rainfall of at least 800 mm per annum (Thakur *et al.*, 2016) [31]. Finger millet was first domesticated at least 5,000 years ago in Ethiopia's highlands and Western Uganda and it was introduced to India, Sri Lanka and China around 3,000 years ago (Upadhyaya *et al.*, 2006) [32]. Finger millet is important small millet grown in India. It is a staple food in many of the country's hilly regions. It is used for both grain and forage. Grains are high in minerals and the best source of calcium and are used in a variety of dishes such as cakes, puddings and sweets. The green straw can be used to make silage. It is also beneficial for people suffering from diabetes (Anonymous, 2017) [3]. Finger millet or Ragi is one of the ancient millets in India and this review focuses on its antiquity, nutrient composition, usage, processing and health advantages. Finger millet has the more amount of calcium (344 mg) and potassium content (408 mg). It has more minerals, dietary fiber and sulfur-containing amino acids compared to white rice (Shobana *et al.*, 2013) [28]. Finger millet, also known as ragi or mandua in India is one of the small millet that originated in Ethiopia but widely cultivated in various regions of India and Africa. In India, Karnataka is the leading producer of finger millet accounting to 58% of its globle output. Finger millet ranks sixth in terms of production area in India behind wheat, rice, maize, sorghum and bajra. After sorghum, pearl millet, and foxtail millet, finger millet is the fourth most important millet in the world. Finger millet is widely cultivated Africa and South Asia under a varied of agro-climatic conditions and it is estimated that some 10% of the world's 30 million tonnes of millet produced (Chandra *et al.*, 2016) [7].

Millets are important food grain in the diets of a large section of population in India. Millets are a significant source of nutrition for the tribal people in Bastar region of Chhattisgarh. The important small cereals among tribes of Bastar region are kodo millet (*Paspalum scrobiculatum* L.) and finger millet [*Eleusine coracana* (L.) Gaertn] little millet (*Panicum sumatrense*) after rice (Verma and Mishra, 2010) [33].

The term hydrogel refers to a three-dimensional cross linked polymeric network made of synthetic or natural polymers that can hold water in its porous structure. The inclusion of hydrophilic groups in the polymer chains such as amino, carboxyl and hydroxyl groups contributes to the hydrogels water holding ability. At physiological temperature and pH, these polymeric materials do not dissolve in water but they do swell considerably in an aqueous media. Hydrogels can be manufactured from almost any water soluble polymer and have a wide range of chemical and bulk physical properties. Further- more hydrogels can be made into slabs, micro-particles, nano-particles, coatings and films among other physical forms (Bharskar, 2020) [4].

The word mulch has been probably derived from the German word "molsch" means soft to decay, which apparently referred to the use of straw and leaves by gardeners as a spread over the ground as mulch. Mulches are used for various reasons in agriculture but water conservation and erosion control are the most important objectives particularly in arid and semi-arid regions. Mulching is the process or practice of covering the soil/ground to make more favourable conditions for plant growth, development and efficient crop production. While natural mulches such as leaf, straw, dead leaves and compost have been used for centuries, during the last 60 years the advent of synthetic materials has altered the methods and benefits of mulching (Sharma and Bhardwaj, 2017) [27]. Mulch is a general term for a protective ground cover that can include manure, wood chips, seaweed, leaves, straw, grasses, sands, stones (boulders), synthetic plastics and other natural products. While the term mulching may be defined as a practice of covering the surface of soil with these materials to reduce evaporation and also to moderate wide fluctuations in diurnal soil temperatures, especially in the root zone environment. It controls external evaporability and also reduces energy supply to the evaporating site by cutting off solar radiation falling on the ground. Its main function is limited to controlling first stage of drying which helps in improved moisture status, reduced soil temperature, besides checking seedling mortality and improving crop stand. (Loy and Wells, 1975) [15].

Material and Methods

Experimental site

A field experiment on finger millet was performed during *Kharif*, 2021 from first week of July to last week of October, 2021 at the New Upland Research cum Instructional (NURI) Farm, Lamker under S. G. College of Agriculture and Research Station, Jagdalpur, Chhattisgarh, India at the geographical co-ordinates latitudes of $19^0$13'28.21" N and $81^0$52'44.40" E longitude elevation 561 MSL. The area falls under India's Eastern plateau and hills region, which is classed as subtropical humid with hot summers and cold winters. The rain comes from the south-western monsoon. During the experimental season, the average rainfall during cropping season was 853 mm, with 50 rainy days and the maximum temperature was 32 °C and the minimum temperature was 21 °C, with relative humidity of 72-92 per cent, respectively received with an average of 3.07 hours of bright sunshine hours.

Soil sampling

A composite soil sample was collected from the experimental site from 0-15 cm soil profile depth for the pre-experimental soil chemical analysis, following the standard procedures. A fraction of this composite sample was also used for the mechanical analysis of soil by International pipette method (Table 1). Another part of the composite sample taken from the main field was air dried at room temperature, powdered to pass through 70 mesh (1.6 mm) sieve and was used for chemical analysis. The result obtained from the chemical analysis was compared with rating chart which have been presented in Table 2. The result showed that the soil of the experimental plot was low in pH, medium in electrical conductivity and organic carbon, available nitrogen was low and available P_2O_5 and available K_2O was medium.

Table 1: Analyzed results for initial chemical properties of the soil

Sl. no.	Particulars	Obtained observation	Range	Method adopted
1.	pH (1:2.5 Soil: water)	5.93	Low	Glass electrode pH meter (Piper, 1967) [20]
2.	EC (dS m^{-1})	0.10	Medium	Solubridge conductivity method, (Black,1965) [5]
3.	Organic Carbon (%)	0.58	Medium	Walkley and Black's rapid titration method (Black, 1965) [5]
4.	Available N (kg ha^{-1})	209.07	Low	Alkaline permanganate method (Subbiah and Asija, 1956) [30]
5.	Available P (kg ha^{-1})	19.81	Medium	Bray-kurtz P1 reagent (0.03 *N* NH_4F + 0.025 *N* HCL (Bray and Kurtz, 1945) [6]
6	Available K (kg ha^{-1})	169.63	Medium	Flame photometer method as described by (Muhr *et al.*, 1965) [18]

Table 2: Rating chart for evaluating the fertility status of soil

Sl. No.	Nutrient	Low	Medium	High
1.	Organic carbon (%)	0.25- 0.50	0.5-0.75	>0.75
2.	Available N kg ha^{-1}	<280	280-560	>560
3.	Available P kg ha^{-1}	<12.5	12.5-25	>25
4.	Available K kg ha^{-1}	<135	135-335	>335

Source: Muhr *et al.* (1963) [17] Soil Testing in India, U.S. Agency International Development Mission to India. New Delhi.

Experiment Design and Treatment

The experiment design used for the finger millet crop was randomized block design (RBD) with three replications. The experimental treatments were comprised of eight treatments *viz.*, T_1: Control, T_2: Sowing with crop residue mulch at 5.0 t ha^{-1}, T_3: Hydrogel at 2.5 kg ha^{-1}, T_4: Hydrogel at 5.0 kg ha^{-1}, T_5: Hydrogel at 7.5 kg ha^{-1}, T_6: T_2 + Hydrogel at 2.5 kg ha^{-1}, T_7: T_2 + Hydrogel at 5.0 kg ha^{-1} and T_8: T_2 + Hydrogel at 7.5 kg ha^{-1}.

Plant Material

The experimental plot was initially ploughed with a tractor driven disc plough and secondary tillage operations were done using disc harrow. The finger millet variety (Chhattisgarh Ragi-02) with potential quality and production was sown in first week of July, 2021 using the line sowing method (20 cm x 10 cm and depth 2.5 cm) and seed rate was 10 kg ha^{-1}. Total no. of plots were twenty four with a net plot size of 3.30 m × 4.10 m. The plots were fertilized as per the treatment details.

Sampling Method

In order to determine the effect of different treatments, a number of observations on growth and yield attributing characters were recorded at different stages of crop growth, and grain yield, straw yield by the crop at harvest were recorded. Days to flowering were recorded in each plot and days to maturity of the crop were recorded treatment wise and then analyzed. The plant population per square meter of each plot was investigated. For each plot of m^2, the plant population was counted using a 25 cm x 25 cm quadrate placed at random and cumulative sum was recorded as plant population (m^2). Plant height was determined at maturity as the height from the soil surface to the apex of the plant. Five plants were randomly selected from each plot. Each treatment mean value was recorded as plant height. The number of tillers $plant^{-1}$ was counted from each plot randomly and then averaged out. Five plants from each second row were randomly selected. For grain yield, plot wise weight of grains after threshing, cleaning and sun drying were taken. After harvesting of the ears, the remaining portion of the plant was harvested. The straw yield was calculated after complete removal of the moisture. Both the grain and straw yields were then converted into quintal per hectare. The weight of 1000 grain recorded as test weight in gram. Harvest index (HI) was determined as an indicator of photosynthetic efficiency and was expressed as the ratio of post harvest soil sampling and analyses were done to observe the effect of different treatments. Economic analysis was done for each treatment. Eventually water use efficiency of ragi crop has been expressed as the ratio of grain yield (ha^{-1}) to the water requirement (cm) of crop. The cost of inputs that were prevailing at the time of the harvesting period was considered for working out the economics of different treatment combinations. Total profit of the produce (grain + straw) was estimated and thus gross returns were calculated in Rs. ha^{-1}. Net returns were obtained by subtracting the cost of cultivation from the gross returns obtained. Benefit-cost ratios were calculated by dividing the net returns to total cost of cultivation.

Statically methods

All the observations recorded of pre and post-harvest during different intervals with respect to various growth, yield and laboratory studies were subjected to statistical analysis as per the procedure laid down by Gomez and Gomez (1984) [9]. The variance ratio (F-value) was used to test the significance of the treatment effect. Appropriate standard errors and critical difference at 5% probability level was used to test the statistical significance of the results.

Result and Discussion

Number of Plant Population (ha^{-1})

The data pertaining to plant population of finger millet at 30 DAS and at harvest are presented in Table 3. The data reveals that at 30 DAS and at harvest plant population was not significant but numerically treatment T_8 was found maximum plant population at 30 DAS and at harvest while lowest plant population was recorded in treatment T_1. Which in turn lead to better translocation of water, nutrients and photosynthates and finally better plant stand and yield.

Plant height (cm)

Effect of mulch and hydrogel on plant height are presented in Table 3. The data shows that treatment T_8 was recorded significantly taller plant at all the growth stages. Whereas, treatment T_1 recorded smaller plant height at all the growth stages. There are scientific evident that mulching has double actions; controlling weeds and providing soil cover, both of which reduce water loss through decreased evaporation and increased availability of soil moisture contents which increase plant height (Khurshid *et al.,* 2006 and Ahmed *et al.,* 2007) [13, 2]. The increase in the plant height may be due to supply of soil moisture around the root zone, which provided suitable micro environment for uptake and translocation of the nutrients which finally resulted in plant growth and development. (Saini *et al.,* 2018) [24]. An increase in plant height might be attributed to water availability and indirectly nutrients provided by hydrogel, which have been reported to increase the activity of cell division, cell expansion and cell elongation, ultimately leading to an increased plant. Similar results have been reported by Sivalapan (2001) [29].

No. of productive tillers $hill^{-1}$

Table 3. Reveals that number of productive tillers $plant^{-1}$ was affected by different mulching and hydrogel treatments. The data reveals that treatment T_8 produced significantly maximum number of productive tillers $hill^{-1}$ at all the growth stages. While, treatments T_1 was recorded minimum number of productive tillers at all the growth stages. Mulching might have reduced the fluctuation of soil temperature and increased the soil moisture and resulted in more rapid crop growth and produced more number of tillers and hydrogel retain moisture in the soil. These results are in line with those of Khurshid *et al.,* (2006) [13]; Ghalandarzadeh *et al.,* (2013) [8]; Ram *et al.,* (2013) [22]; Rajput *et al.,* (2014) [21].

Days to 50% Flowering and Days to Maturity

Effect of different mulch and hydrogel treatments on days to 50% flowering are presented in Table 3 and 4. Mulch and hydrogel had significant effect on days to 50% flowering. Early flowering was initiated in treatment T_1 among the all treatments, while late flowering was initiated in treatment T_8. Whereas, days to maturity was recorded non significant effect due to different hydrogel and mulch during one year experimentation but numerically early maturity was recorded in treatment T_1.

Table 3: Effect of mulch and hydrogel on plant population, plant height, number of productive tillers and days to 50% flowering of finger millet

Treatment	Plant population (ha^{-1})		Plant height (cm)	Number of Productive Tillers $hill^{-1}$	Days to 50% flowering
	At 30 DAS	At harvest			
T_1	472870	362563	67.13	2.80	72.67
T_2	474057	379246	75.13	3.00	73.67
T_3	474887	379909	83.67	3.13	74.00
T_4	475271	380217	90.47	3.47	74.33
T_5	477365	381892	96.60	3.60	75.00
T_6	477548	382038	102.87	3.73	75.33
T_7	477810	382248	108.27	3.73	75.67
T_8	478621	382897	114.73	3.80	76.33
S.Em±	1460.87	5660.58	3.21	0.14	0.66
CD at 5%	NS	NS	9.83	0.42	2.02
CV%	0.53	2.59	6.02	7.12	1.53

Length of panicle (cm)

The data pertaining to panicle length are presented in Table 4. The data reveals that treatment T_8 recorded significantly maximum panicle length but treatment T_7 and T_6 was found on par. Whereas, treatments T_1 recorded minimum panicle length. It might be due to mulch and hydrogel provide sufficient moisture up to the maturity stage which enhance the panicle length.

Panicle Weight (g)

The data pertaining to panicle weight are presented in Table 4. The data shows that treatment T_8 recorded significantly higher panicle weight but treatment T_7, T_6, T_5 and T_4 was found significantly on par with treatment T_8. It was because mulch and hydrogel retain soil moisture up to the maturity stage which was able to fulfill the moisture to the crop.

No. of grains panicle^{-1}

The data presented in Table 4. Number of grains panicle^{-1} was recorded non significant effect in different mulch and hydrogel treatment but numerically more number of grains panicle^{-1} was recorded in treatment T_8 and minimum number of grains panicle^{-1} was recorded in treatment T_1.

Total no. of Grains Plant^{-1}

Total number of grains plant^{-1} was significantly affected by different treatment and it is presented in Table 4. Total number of grains plant^{-1} was recorded significantly maximum in treatment T_8 which was found similar in treatment T_7, T_6, T_5 and T_4. It might be due to the mulch and hydrogel provide sufficient moisture to the plant which might the more number of panicle plant^{-1} and had bear more seeds to the panicle.

Table 4: Effect of mulch and hydrogel on days to maturity, panicle length, panicle weight, number of seeds panicle^{-1} and total number of grains plant^{-1} of finger millet

Treatment	Days to maturity	Panicle length (cm)	Panicle weight (g)	No. of seeds panicle^{-1}	Total no. of grains plant^{-1}
T_1	104.67	7.60	8.66	1115.67	3204.73
T_2	106.53	7.73	9.42	1120.80	3437.33
T_3	107.50	8.10	9.69	1126.20	3605.84
T_4	108.33	8.13	9.98	1127.93	3986.29
T_5	109.47	8.20	9.99	1137.00	4166.95
T_6	110.17	8.37	10.17	1137.53	4248.45
T_7	110.67	8.60	10.21	1145.67	4352.84
T_8	111.57	9.10	10.30	1155.13	4471.31
S.Em±	1.76	0.29	0.29	15.39	172.50
CD at 5%	NS	0.87	0.87	NS	528.31
CV%	2.80	6.01	5.05	2.35	7.60

1000 seed weight (g)

Test weight of finger millet was affected by different treatments and the data are given in Table 5. Treatments T_8 produced significantly higher 1000 seed weight which was on par with T_7 and T_6 and lowest 1000 seed weight was recorded in treatment T_1. It was due to the mulch and hydrogel provide sufficient soil moisture which help the seed filling and bold grains among the panicles which in increase the test weight of the seed. Similar results reported by Sayyari and Ghanbari, (2012) [25] and Saini *et al.*, (2018) [24].

2.10 Grain and straw yield (kg ha^{-1})

Grain and straw yield ha^{-1} influenced significantly due to the different mulch and hydrogel are presented in Table 5. The data reveals that grain yield and straw yield had produced significantly highest in treatment T_8 which was at par with treatment T_7, T_6 and T_5 in grain yield and straw yield and lowest yield was recorded in treatment T_1. It might be due to maintained adequate available soil moisture in the root zone throughout the crop growth period. The present findings are similar with the findings of Mubeen *et al.*, (2012) [16]. Hydrogel had been reported to increase the growth attributes that lead to increased yield attributes and crop yield (Sendur *et al.*, 2001) [26]. Mulch is being a barrier to evaporation loss, maintained more moisture in the soil which supported more number of ear heads and enabled them to bear more grains and finally crop yields (Huang *et al.*, 2005) [11]. These results are coinciding with that obtained by Waly *et al.*, (2015) [35]. It may be attributed with super absorbing properties of the hydrogel which absorbs the water and releases it slowly to the growing plants as per the crop needs. The positive effect of superabsorbent polymers in increasing the yields was reported by Khadem *et al.*, (2010) [12], Gunes *et al.*, (2016) [10] and kumar *et al.*, (2017) [14] in maize crop.

Harvest index (%)
Effect of different mulch and hydrogel on harvest index are presented in Table 5. The data shows that harvest index recorded non significant effect due to different mulching and hydrogel treatments, but numerically highest harvest index was observed in treatment T_6 and lowest harvest index was recorded in T_1. The obtained results are found to be in agreement also with those obtained by Ofosu-Anim and Leitch (2009) [19] and Abdel-Mageed *et al.*, (2016) [1].

Water use efficiency
Effect of different mulch and hydrogel on water use efficiency was significant Table 5. Maximum water use efficiency was recorded in T_8 which was on par with treatments T_7, T_6 and T5 and treatment T_1 shows minimum water use efficiency. WUE increased due to mulching because evapo-transpiration becomes less in inter rows. Whereas, application of hydrogel to the soil helped in retaining more moisture in the soil, increased water holding capacity of soil and decreased infiltration rate of soil (Vizaylaxmi *et al.*, 2012) [34]. It reduces the losses and provide water slowly to plant. Similar finding was also observed by Rostampour (2013) [23].

Table 5: Effect of mulch and hydrogel on test weight, grain yield, straw yield, harvest index and water use efficiency of finger millet

Treatment	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI (%)	WUE (kg ha^{-1} cm^{-1})
T_1	2.34	2585.51	4978.06	34.17	30.31
T_2	2.35	2890.23	5084.97	36.29	33.88
T_3	2.36	2916.34	5161.94	36.11	34.19
T_4	2.37	2992.21	5410.51	35.66	35.08
T_5	2.40	3055.27	5610.87	35.28	35.82
T_6	2.45	3232.88	5679.97	36.31	37.90
T_7	2.47	3275.25	6074.94	35.05	38.40
T_8	2.49	3326.24	6164.43	35.07	38.99
S.Em±	0.02	92.44	220.99	0.75	1.08
CD at 5%	0.05	280.38	670.31	NS	3.29
CV%	1.22	5.28	6.93	3.65	5.28

2.13 Gross income (Rs. ha^{-1}), Net income (Rs. ha^{-1}) and Benefit cost ratio
Effect of mulch and hydrogel on economics are presented in Table 6. The data shows that treatment T_8 produced maximum gross return among all the treatments and minimum gross return was recorded in treatment T_1. Effect of different mulch and hydrogel on net return was recorded maximum in treatment T_5 and lowest net return was found in treatment T_1. Treatment T_3 recorded significantly highest B:C ratio among the all treatments which was on par with treatment T_4, T_5 and T_1 whereas, lowest B:C ratio was found in treatment T_2.

Table 6: Effect of mulch and hydrogel on economics of finger millet

Treatment	Gross Return (Rs ha^{-1})	Net Return (Rs ha^{-1})	B:C Ratio
T_1	67126.90	46316.82	2.23
T_2	74798.21	46488.13	1.64
T_3	75489.48	53304.41	2.40
T_4	77510.53	53950.46	2.29
T_5	79187.25	54252.17	2.18
T_6	83661.95	53976.88	1.82
T_7	84918.67	53858.60	1.73
T_8	86238.19	53803.12	1.66
S.Em±			0.10
CD at 5%			0.30
CV%			8.60

Conclusion
- Number of tillers $hill^{-1}$, number of panicle $plant^{-1}$ which supports to produce more test weight, grain and straw yield which support to higher economics of finger millet.
- Sowing with crop residue and hydrogel produced highest plant height, number of productive tillers, LAI at all the growth stages. Number of seeds per panicle, total number of grain $plant^{-1}$ which produces more grain yield and straw yield.
- It increases the crop productivity per unit available water and nutrients, particularly in moisture stress condition. It improves physical properties of the soil, seedling emergence, root growth and seed germination that help plants to prolonged moisture stress.
- Mulching is proved to be useful in conserving of soil moisture and increasing productivity of finger millet. Straw mulch also provide benefit in terms of decreasing the temperature, improve availability of fertilizer, increasing infiltration rate and increase crop yield.

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