

Original Research Article

Enhancing small millet farming resilience through conservation agriculture in rainfed regions

Abstract

The Centre of Excellence in Millets, Athiyandal, conducted an extensive study from kharif 2020 to 2022, focusing on the impact of conservation agriculture practices on small millet crops in rainfed areas. The experiment comprised three main plot treatments: No tillage (S_1), Minimal tillage (S_2), and Mulching (S_3), with six sub-plot treatments including Finger Millet, Kodo Millet, Foxtail Millet, Little Millet, Barnyard Millet, and Proso Millet. Results revealed that a single ploughing significantly reduced weed populations, while mulching played a crucial role in curbing weed growth and conserving water. This led to notable increases in grain yield and straw yield, ranging from 24.3% to 36.1% over the control, alongside an improvement in relative water use efficiency (RWUE) from 5.16 to 7.03 kg/ha/mm. Kodo Millet exhibited similar positive trends, with significant enhancements in grain size, yield, and straw yield, resulting in yield increases ranging from 10.2% to 28.0% and improved RWUE from 4.08 to 5.22 kg/ha/mm. Foxtail Millet also demonstrated substantial gains in grain yield (1223 to 2914 kg/ha) and straw yield (2000 to 2914 kg/ha), with yield increases ranging from 54.9% to 63.7% and enhanced RWUE from 4.67 to 6.81 kg/ha/mm. These findings highlight the efficacy of conservation agriculture practices in weed management, water conservation, and yield improvement, offering sustainable alternatives to herbicide usage.

Key words : Zero tillage, Mulching, Rainwater use efficiency

1. INTRODUCTION

In contemporary agriculture, farmers face a complex landscape characterized by various challenges and opportunities. Climate change, soil degradation, water scarcity, and diminishing biodiversity pose significant threats to agricultural productivity and sustainability. Additionally, farmers grapple with fluctuating market prices, rising input costs, and the need to meet increasing food demands from a growing global population. In this context, conservation agriculture emerges as a compelling solution to address these multifaceted challenges at both the farm and societal levels.

Conservation agriculture marks a significant departure from conventional farming practices, emphasizing sustainable methodologies (FAO, 2022) (7) that not only bolster crop yields but also prioritize the long-term health of the land (Page *et al.*, 2020) (17). This holistic approach integrates three core principles: minimal soil disturbance, permanent soil cover, and diversified crop rotations. By adhering to these principles, farmers can mitigate the environmental impact of agriculture while fostering resilience and productivity (Somasundaram *et al.*, 2021) (19). Traditional farming often entails intensive tillage, disrupting the soil's natural structure and resulting in soil erosion, loss of organic matter, and increased vulnerability to pests and diseases. Conservation agriculture advocates for reduced or no-till farming, preserving the soil's integrity (Cameron *et al.*, 2015) (3). By minimizing disturbance, farmers can prevent

erosion, enhance water retention, and maintain a healthier soil ecosystem (Kassam *et al.*, 2019; Dalal *et al.*, 2011) (12). Another cornerstone of conservation agriculture is maintaining permanent soil cover, achieved through strategic use of cover crops or crop residues (Happset *et al.*, 2008; Abrol *et al.*, 2005) (8,1). Cover crops, sown during non-growing seasons, shield the soil from erosion and contribute organic matter. Leaving crop residues on the field post-harvest further shields the soil, suppressing weed growth, and enhancing fertility (Kaschuket *et al.*, 2010; Kirkegaard, 1995; Duan *et al.*, 2010) (11,13,6). This practice not only conserves soil but also promotes water retention and reduces the need for external inputs. Conservation agriculture acknowledges the significance of diversified crop rotations in fostering resilient and sustainable farming systems. Crop rotation disrupts pest and disease cycles, enhances soil health, and optimizes nutrient balance (Nhamo and Lungu, 2017) (16). This diversity not only benefits the environment but also diminishes reliance on chemical inputs (Silbanet *et al.*, 2020) (18), contributing to a more environmentally friendly and economically viable agricultural model.

Small millets generally exhibit drought-tolerant traits, though certain conservation practices can augment yields during rainfed seasons. This study aims primarily to identify the most suitable conservation practices for cultivating small millets, acknowledging the necessity of optimizing conditions to achieve superior yields in rainfed environments.

2. MATERIALS AND METHODS

The field experiment took place at the Centre of Excellence in Millets, Athiyandal, covering the *Kharif* seasons from 2020 to 2022. Initial Soil analysis revealed low levels of available nitrogen (137.0 kg/ha), high levels of available phosphorus (32.1 kg/ha), and medium levels of potassium (141.0 kg/ha) (Table 1.). The study involved three treatments in main plots *viz.*, S₁ – No tillage; S₂ – Minimal tillage, and S₃ - Mulching and six treatments in the sub plot: Six small millet crops, namely C₁ - Finger Millet, C₂ - Kodo Millet, C₃ - Foxtail Millet, C₄ - Little Millet, C₅ - Barnyard Millet, and C₆ - Proso Millet, and. A split plot design was employed, with each treatment replicated three times. Crop planting maintained a spacing of 30 cm × 10 cm, utilizing the ATL 1 variety for all small millet crops (Foxtail millet, Finger millet, Little millet, Proso millet, and Kodo millet, except for Barnyard millet Co(KV)2). Fertilizer application followed allindiarecommended doses, with 40 kg/ha of urea, 20 kg/ha of superphosphate, and 20 kg/ha of muriate of potash applied as a basal dose, along with appropriate top dressing. Adherence to all recommended agricultural practices ensured the crop's specific requirements were met throughout the experiment. The average rainfall pattern of the cropping period is represented in Fig. 1. After completion, the collected data will undergo statistical analysis following Gomez and Gomez (1984) guidelines, aiming to understand the treatments' impact on the growth and yield attributes of small millets. Significant differences will be determined at a five percent (0.05) probability level for result interpretation.

Table 1. Initial soil parameters

Details	Value
I. Physical properties	
Texture	Sandy clay loam

II. Chemical properties	
1. pH	7.2
2. EC ds m ⁻¹	0.20
3. Organic carbon %	0.48
4. Available N kg/ ha ⁻¹	137.0
5. Available P kg/ ha ⁻¹	32.1
6. Available K kg/ ha ⁻¹	141.0

Treatments

Zero tillage / Minimum tillage: Millet fields may experience advantageous outcomes through the adoption of reduced or zero tillage techniques. Instead of employing extensive plowing methods, minimal tillage strategies focus on loosening the soil solely within the planting rows or utilizing specialized tools such as chisel plows or disc harrows. By implementing this approach, soil moisture conservation is promoted, erosion is mitigated, and soil structure is preserved, all while reducing the overall disruption to the soil ecosystem.

Mulching :Spreading crop residues, such as the straws from prior millet crops, within the field post-harvest can yield significant benefits. These mulching materials serve as a protective layer on the soil surface, diminishing evaporation, enhancing water infiltration, inhibiting weed proliferation, moderating soil temperature, and mitigating soil erosion. Additionally, these residues play a pivotal role in enriching organic matter content and facilitating nutrient recycling within the soil.

3. RESULT AND DISCUSSION

3.1. Plant height

Plant height is crucial for light absorption, impacting photosynthesis and overall growth. In agriculture, it directly correlates with crop yield and influences harvesting methods. Additionally, plant height plays a role in ecological interactions, affecting relationships with pollinators, herbivores, and the plant's adaptation to its environment. The plant heights of diverse millet crops, observed under distinct treatments, reveal unique growth trends. In the comparison across all three treatments, it is evident that Treatment S₃ - Mulching consistently yielded higher plant heights compared to other treatments. Specifically, the plant heights were recorded as 95.7 cm, 77.1 cm, 94.3 cm, 93.4 cm, 114.1 cm, and 114.2 cm for Finger Millet, Kodo Millet, Foxtail Millet, Little Millet, Barnyard Millet, and Proso Millet, respectively, under mulching treatment (Table 2.).

3.2. Number of tillers

Tillers is a key factor influencing crop yield, as they often develop into productive stems or ears. Efficient tillering is crucial for optimizing plant growth and achieving higher agricultural productivity. The tiller characteristics of various millet crops under different treatments exhibit distinct patterns. Upon comparing all three treatments, Treatment S₃ - Mulching consistently resulted in a higher number of tillers compared to Treatments S₁ and S₂. Specifically, the tiller counts were recorded as 4, 12, 4, 4, 4, and 5 for Finger Millet, Kodo Millet, Foxtail Millet, Little Millet, Barnyard Millet, and Proso Millet, respectively, under Treatment S₃(Table 2.).

3.3. 1000 grain weight

The 1000 grain weight, a crucial metric reflecting the average weight of a thousand grains, demonstrates distinctive trends among different millet crops under various treatments. Upon careful examination of all three treatments, it is apparent that Treatment S₃ - Mulching consistently yields higher 1000 grain weights compared to S₁- No tillage and S₂ – Minimal tillage. Specifically, the 1000 grain weights were recorded as 2.9, 3.9, 3.19, 3.69, 3.98, and 5.08 for Finger Millet, Kodo Millet, Foxtail Millet, Little Millet, Barnyard Millet, and Proso Millet, respectively, under S₃ - Mulching(Table 2.).

3.4. Grain yield

The grain yield, a pivotal measure indicating the amount of harvested grains per unit area, reveals distinctive patterns across various millet crops and treatments. Upon thorough examination of all three treatments, it is evident that Treatment S₃ - Mulching consistently results in higher grain yields compared to S₁- No tillage and S₂ – Minimal tillage. Specifically, the grain yields were recorded as 3010 kg/ha for Finger Millet, 2234 kg/ha for Kodo Millet, 2003 kg/ha for Foxtail Millet, 1015 kg/ha for Little Millet, 1004 kg/ha for Barnyard Millet, and 910 kg/ha for Proso Millet under S₃ - Mulching. This result confirmed with work of Mohammadi (2012) (15)(Table 3.).

3.5. Straw yield

The straw yield, representing the amount of above-ground plant material excluding grains, exhibits discernible trends across different millet crops and treatments. Specifically, the straw yields were recorded as 4602 kg/ha for Finger Millet, 3274 kg/ha for Kodo Millet, 2914 kg/ha for Foxtail Millet, 1514 kg/ha for Little Millet, 1497 kg/ha for Barnyard Millet, and 1186 kg/ha for Proso Millet under S₃ - Mulching. These variations underscore the substantial impact of different agricultural practices on the straw yield characteristics of each millet crop, emphasizing the importance of selecting appropriate treatments to optimize overall biomass production and contribute to sustainable farming practices(Table 3.).

3.6. Weed density

The Fig.2. reveals that the data showcases significant disparities in plant densities across different tillage treatments. The No tillage approach yields the highest sedge density at 62.6 No/m², suggesting that minimal soil disturbance favors sedge proliferation. The Minimal tillage treatment exhibits a reduced sedge density of 44.1 No/m², indicating that even minor soil disruption can hinder sedge growth and broadleaf plant densities respectively. Regarding grass densities are highest under No tillage

condition (55.4 No/m²), while Minimal tillage and Mulching treatments result in lower densities (22.5 No/m² and 10.5 No/m², respectively), indicating that tillage practices may suppress grass populations. The result confirmed by the Locke *et al.*, 2002 (14) and Swanton *et al.*, 2008 (20).

3.7. Rain water use efficiency

Rainwater Use Efficiency (RWUE), a crucial metric reflecting the effectiveness of utilizing rainwater for crop production, showcases distinct trends across different millet crops and treatments. In a thorough comparison of all three treatments, it becomes evident that Treatment S₃ - Mulching consistently results in higher RWUE values compared to No tillage and Minimal tillage. Specifically, RWUE values were recorded as 7.03 kg/ha/mm for Finger Millet, 5.22 kg/ha/mm for Kodo Millet, 6.81 kg/ha/mm for Foxtail Millet, 2.37 kg/ha/mm for Little Millet, 2.35 kg/ha/mm for Barnyard Millet, and 2.13 kg/ha/mm for Proso Millet under S₃- Mulching. These variations emphasize the considerable influence of diverse agricultural practices on rainwater utilization efficiency for each millet crop. The tillage practices influences conserving water and improving crop productivity confirmed by Jat *et al.*, 2009(10) (Table 3.).

4. CONCLUSION

Small millet crops, known for their inherent drought tolerance, exhibit superior performance in challenging climatic conditions. A recent study unveiled the benefits of adopting conservation agriculture practices for these crops. This approach not only results in a reduced cost of cultivation but also eliminates the need for tillage, mitigating issues such as poor establishment and high weed population. The study found that a single ploughing significantly lowers weed population, while the adoption of mulching proves instrumental in limiting both weed growth and water loss. As a result, grain yield, and straw yield, with positive yield increases over the control (ranging from 24.3% to 36.1%). The relative water use efficiency (RWUE) also improves from 5.16 to 7.03 kg/ha/mm. Kodomillet shows similar trends with notable increases in grain size, yield, and straw yield, resulting in positive yield increases (10.2% to 28.0%) and improved RWUE (4.08 to 5.22 kg/ha/mm). Foxtail millet demonstrates significant increases in grain yield (1223 to 2914 kg/ha) and straw yield (2000 to 2914 kg/ha), with positive yield increases (54.9% to 63.7%) and enhanced RWUE (4.67 to 6.81 kg/ha/mm). Conservation agriculture practices reduced weed growth and helps to avoid the usage of herbicides.

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UNDER PEER REVIEW

Table 2. Effect of Conservation agriculture on growth parameters of small millet

Crops	Plant height (cm)			No. of tillers (Nos.)			1000 grain weight		
	S ₁ -No tillage	S ₂ - Minimal tillage	S ₃ - Mulching	S ₁ -No tillage	S ₂ - Minimal tillage	S ₃ - Mulching	S ₁ -No tillage	S ₂ -Minimal tillage	S ₃ - Mulching
C₁ - Finger millet	78.3	89.8	95.7	2	3	4	2.70	2.80	2.90
C₂ - Kodomillet	51.7	68.2	77.1	5	9	12	2.80	3.20	3.90
C₃ - Foxtail millet	80.0	88.1	94.3	2	3	4	2.98	3.05	3.19
C₄ - Little millet	68.3	81.2	93.4	2	4	4	3.44	3.65	3.69
C₅ - Barnyard millet	81.2	92.6	114.1	2	3	4	3.67	3.90	3.98
C₆ - Proso millet	78.3	97.8	114.2	2	3	5	4.75	5.01	5.08

	SEd	CD (p=0.05)	CV (%)	SEd	CD (p=0.05)	CV (%)	SEd	CD (p=0.05)	CV (%)
S	1.65	4.57	5.79	0.15	0.42	10.53	0.06	0.17	5.41
C	2.69	5.49	6.67	0.16	0.32	7.82	0.11	0.23	6.65
S at C	4.56	NS	-	0.29	0.65	-	0.19	0.40	
C at S	4.66	9.52	-	0.27	0.56	-	0.19	0.39	

Table 3. Effect of Conservation agriculture on yield parameters of small millet

Treatments	Grain yield (kg/ha)			Straw yield (kg/ha)			Yield increase over control (%)			RWUE (kg/ha /mm)		
	S ₁ - No tillage	S ₂ - Minimal tillage	S ₃ - Mulching	S ₁ - No tillage	S ₂ - Minimal tillage	S ₃ - Mulching	S ₁ -No tillage	S ₂ - Minimal tillage	S ₃ - Mulching	S ₁ - No tillage	S ₂ - Minimal tillage	S ₃ - Mulching
C₁ - Finger millet	2210	2746	3010	3222	4098	4602	-	24.3	36.1	5.16	6.41	7.03
C₂ - Kodomillet	1745	1923	2234	2413	2730	3274	-	10.2	28.0	4.08	4.49	5.22
C₃ - Foxtail millet	1223	1895	2003	2000	2888	2914	-	54.9	63.7	4.67	6.75	6.81
C₄ - Little millet	570	814	1015	950	1278	1514	-	42.8	78.2	1.33	1.90	2.37
C₅ - Barnyard millet	648	812	1004	965	1226	1497	-	25.3	54.9	1.51	1.90	2.35
C₆ - Proso millet	611	724	910	887	1044	1186	-	18.5	48.9	1.43	1.69	2.13

	SEd	CD (p=0.05)	CV (%)	SEd	CD (p=0.05)	CV (%)
S	35.11	97.47	7.27	52.73	146.40	7.33
C	54.91	112.14	8.04	81.17	165.77	8.02
S at C	93.65	200.92		138.75	298.00	
C at S	95.10	194.23		140.59	287.12	

Fig.1. Rainfall received during the cropping period

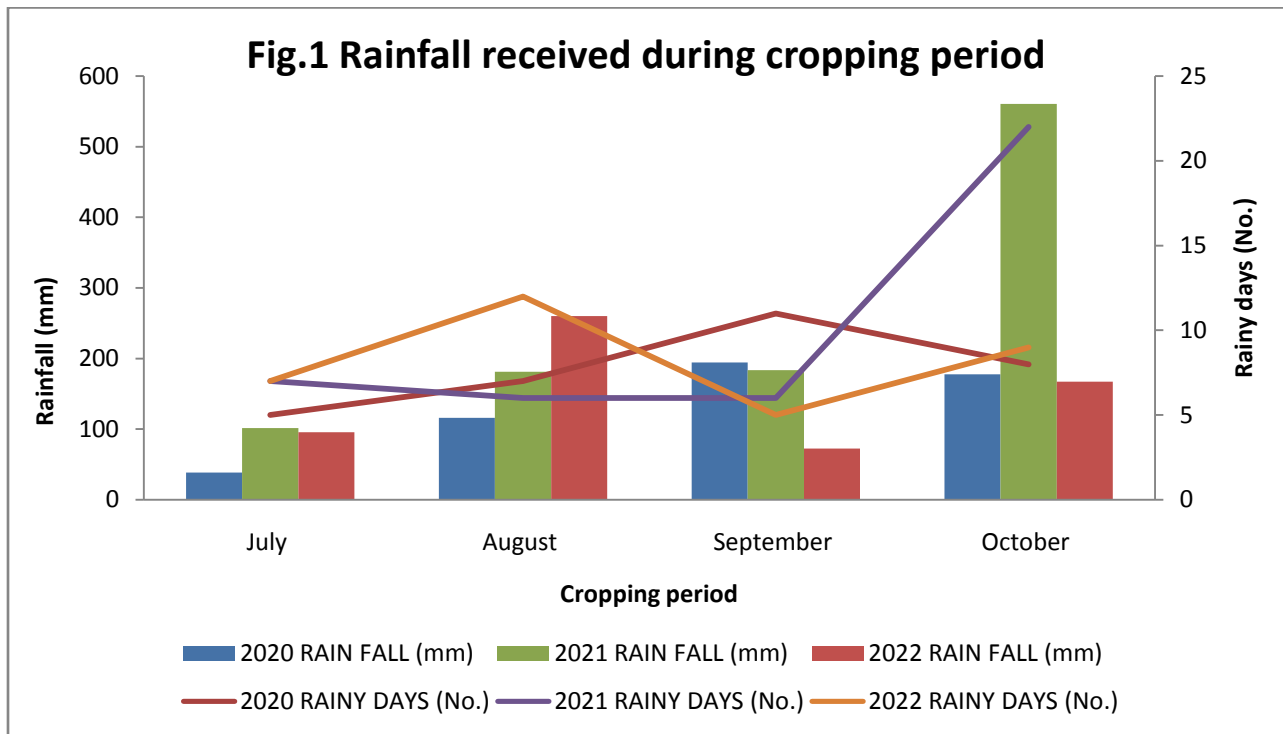


Fig. 2. The effect of conservation practices on total weed dry weight (g m^{-2}) at harvest of small millets

