



RESEARCH ARTICLE

Integrated sustainable weed management strategies for yield enhancement in organic finger millet

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Abstract

Effective weed management is crucial for improving yield in organic finger millet. To evaluate the effects of stale seedbed (SSB) and live mulching on weed control and crop performance, field experiments were conducted at model organic farm at College of Agriculture, Vellayani during the rabi and summer seasons of 2022–2023 under organic farming. The study followed a randomised block design with two factors: Three seedbed preparations-normal seedbed (NSB), SSB with light raking and SSB with flaming and four live mulch treatments: no mulch, cowpea, green gram and cluster bean. Live mulch crops were sown in the inter-row spaces of finger millet in 1:1 ratio. They were later uprooted at 50 % flowering of the live mulches to serve as *in situ* mulch. Stale seedbed with light raking combined with cowpea live mulch recorded the lowest total weed density (156.0 and 97.3 no. m⁻²). The lowest weed dry weight was recorded in the treatment involving SSB with light raking combined with green gram live mulch during the rabi season (13.5 g m⁻²). However, during the summer season, SSB with light raking combined with green gram and cowpea live mulch recorded the lowest weed dry weight (12.7 g m⁻²). These treatments also achieved the highest weed control efficiency (WCE) during the rabi and summer seasons, recording values of 89.6 and 88.8 %, respectively. Improved weed suppression translated into better yield attributes and higher grain yields of 938 kg ha⁻¹ in rabi and 832 kg ha⁻¹ in summer 2022–2023. Economic analysis showed that this combination produced the highest gross and net returns and the highest benefit-cost (B:C) ratio, indicating its profitability under organic conditions compared to other treatments. Overall, the study concludes that SSB with light raking followed by cowpea live mulching is an effective, sustainable and cost-efficient weed management strategy for enhancing the productivity of organic finger millet.

Keywords: cluster bean; cowpea; flaming; green gram; live mulch; stale seedbed; weed control

Introduction

Finger millet is an ancient rainfed crop predominantly cultivated in the peninsular region of India. Known for its climate-resilient nature and significant health benefits, it is valued as both a nutritious and adaptable food source. Its exceptionally high calcium content supports bone health and plays a vital role in preventing osteoporosis (1). Additionally, finger millet contains a wide range of bioactive compounds, including polyphenols, which exhibit strong antioxidant properties. These compounds help protect the body from oxidative stress and lower the risk of chronic diseases (2).

The crop's ability to thrive under harsh environmental conditions makes it a dependable option for food and nutritional security. India cultivates finger millet on 1.211 Mha, producing 1.696 Mt annually (3). With growing awareness of its nutritional value, farmers are increasingly adopting finger millet cultivation, leading to an expansion in the cultivated area. In Kerala, the crop is grown on 168 ha (2021–2022), with a total production of 279.1 tonnes (4).

Weeds pose a major challenge in finger millet cultivation, particularly during the early stages of crop growth. They cause substantial yield losses ranging from 35–62 % by competing with the crop for nutrients, water and light, as well as by serving as alternate hosts for pests and diseases (5). Maintaining a weed-free environment during the first five weeks after sowing is essential for improving input-use efficiency and crop productivity (6). Under the stale seedbed (SSB) technique, weed seeds present in the surface soil layer are stimulated to germinate and emerge prior to crop sowing. This initial flush of weeds is subsequently eliminated, thereby providing a weed-free environment that allows the crop to germinate and establish without early competition from weeds.

Effective weed control not only enhances yield but also reduces the incidence of pests and diseases, as many weeds act as hosts for these harmful organisms (7). Additionally, proper weed management helps mitigate allelopathic effects from certain weed species and conserves soil moisture, thereby improving crop resilience and enhancing the quality of the final produce (8).

Organic weed management is gaining increasing importance among farmers due to growing concerns regarding human health and environmental sustainability. However, its adoption is constrained by high labour requirements, limited availability of effective non-chemical weed control options, inconsistent weed suppression and intense crop-weed competition during the early growth stages. By reducing dependence on synthetic inputs, organic practices help minimise environmental degradation and promote a more sustainable agricultural ecosystem (9).

Among organic management practices, live mulching and SSB techniques have emerged as effective and eco-friendly approaches for weed management in finger millet. Live mulching suppresses weed emergence through rapid ground cover and shading effects, whereas the SSB technique reduces early weed competition by eliminating the initial flush of weeds prior to crop establishment, thereby favouring the growth of finger millet.

Live mulches are companion crops grown alongside the main crop and their rapid early growth suppresses weeds without adversely affecting the yield of the primary crop (10). They act as natural weed suppressors by competing for sunlight, water and nutrients, thereby reducing the germination and growth of unwanted weed species (11). This competitive interaction significantly limits weed proliferation, reducing labour and costs associated with manual weeding while reducing the need for herbicides, an approach well aligned with sustainable farming.

With this background, the present study was conducted to assess the effect of SSB techniques and live mulching on weed management and yield enhancement in finger millet.

Materials and Methods

To assess the impact of SSB and live mulching on weed management in organically grown finger millet, field experiments were conducted during the rabi and summer seasons of 2022–2023 at the model organic farm, College of Agriculture, Vellayani. The experimental site was located at 8.50° N latitude, 76.90° E longitude and 29 m above mean sea level. The experimental site experiences a warm and humid climate. The mean minimum and maximum temperatures during rabi were 20.4 and 31.4 °C respectively, while during summer the minimum and maximum temperatures were 24.5 and 37.6 °C respectively. The rainfall received during rabi was 151.8 mm over 21 days and 169.7 mm over 16 days during summer.

The field experiments were conducted during the rabi season (15 November 2022 to 10 February 2023) and the summer season (22 February 2023 to 22 May 2023). The soil of the experimental field was sandy loam, belonging to the Entisol order.

The soil was acidic (pH 5.76), low in available nitrogen (195.4 kg ha⁻¹) and organic carbon (0.35 %) and medium in available phosphorus and potassium (23.2 and 135.0 kg ha⁻¹ respectively).

Field experiments were laid out in RBD with two factors. The first factor consisted of three types of seedbed preparation: normal seedbed, SSB with light raking and SSB with flaming. The second factor consisted of four live mulch treatments: no mulch, cowpea, green gram and cluster bean. Each treatment combinations was replicated three times and the treatment combinations were listed in Table 1. Untreated finger millet seeds (variety PPR 2700 - Vakula) were sown at a seed rate of 5 kg ha⁻¹ with a spacing of 25 × 15 cm using a seed-cum-fertiliser drill. During ploughing, farmyard manure was applied at 15 t ha⁻¹. In addition, a basal application of bone meal equivalent to 20 kg P₂O₅ ha⁻¹ and potassium sulphate (K₂SO₄) equivalent to 20 kg K₂O ha⁻¹ was applied (12).

The experimental field was divided into 36 plots, each measuring 4.5 × 3.0 m. Earthen bunds, 30 cm wide and 30 cm height, were formed around every plot. According to the treatment plan, SSB was prepared in 24 treatment plots. For these SSB treatments, the plots were levelled and given a pre-sowing irrigation, then left undisturbed for 14 days to encourage weed seed germination. After this period, emerged weed seedlings were eliminated by shallow tillage in the SSB with light raking treatment and by using a flame torch in the SSB with flaming treatment.

Live mulch crops were sown in alternate inter-row spaces at a 1:1 ratio, maintaining a 15 cm plant-to-plant spacing. At 40 days after sowing (DAS) (coinciding with 50 % flowering of the live mulch), the live mulch was uprooted using a wheel-hoe weeder and left on the soil surface as *in situ* organic mulch.

Weed species present in the untreated (weedy) plots were identified and recorded to determine the dominant weed flora of the site. Absolute weed density was assessed by randomly placing a 0.25 × 0.25 m quadrat at two designated observation points. All weeds within each quadrat were uprooted and classified into grasses, broad-leaved weeds (BLW) and sedges. The absolute densities of grasses, sedges, BLW and total weeds at 60 DAS were then computed using formula and expressed as no. m² (13). The collected weed samples were shade-dried for two days, followed by oven-drying at 65 °C until a constant weight was achieved and the biomass was expressed in gram per square metre.

Productive tillers were counted by placing a 0.25 × 0.25 m quadrat at two points within each plot. All tillers bearing ear heads inside the quadrat were recorded and expressed as number per square metre. Ear head weight from the tagged productive tillers was measured, averaged and expressed in gram. For each treatment, the net plot area was harvested separately and the grains were threshed, winnowed and sun-dried to a constant

Table 1. Treatment combinations

Treatment combinations	Treatment abbreviation
Normal seedbed without live mulch	l_1m_1
Normal seedbed followed by cowpea live mulch	l_1m_2
Normal seedbed followed by green gram live mulch	l_1m_3
Normal seedbed followed by cluster bean live mulch	l_1m_4
Stale seedbed with light raking without live mulch	l_2m_1
Stale seedbed with light raking followed by cowpea live mulch	l_2m_2
Stale seedbed with light raking followed by green gram live mulch	l_2m_3
Stale seedbed with light raking followed by cluster bean live mulch	l_2m_4
Stale seedbed with flaming without live mulch	l_3m_1
Stale seedbed with flaming followed by cowpea live mulch	l_3m_2
Stale seedbed with flaming followed by green gram live mulch	l_3m_3
Stale seedbed with flaming followed by cluster bean live mulch	l_3m_4

weight. Grain yield was then calculated and expressed in kilogram per hectare.

Weed index and weed control efficiency (WCE) was calculated using the standard formula (14, 15). Gross return, net return and B:C ratio were calculated using the current market prices of inputs and price of grain (₹ per 100 kg). Statistical analysis was performed using the Kerala Agricultural University (KAU) grapes statistical package (16). As the interaction between land preparation and live mulching showed a significant influence on the parameters examined in this study, the corresponding interaction effect results are presented below.

Results and Discussion

Weed flora

The major weed species present in the experimental field during both the seasons were *Phyllanthus niruri* L., *Ageratum conyzoides* L., *Synedrella nodiflora* (L.) Gaertn., *Commelina benghalensis* L., *Oldenlandia umbellata* L., *Boerhavia diffusa* L., *Cleome viscosa* L., *Alternanthera sessilis* (L.) R.Br. ex DC. and *Physalis minima* L. among the broad leaf weeds, *Panicum maximum* Jacq., *Setaria barbata* (Lam.) Kunth and *Eleusine indica* (L.) Gaertn. among the grasses and *Kyllinga monocephala* Rottb. was the only sedge present in the experimental field. The diversity was more in the case of broad leaf weeds than grasses.

Effect on absolute density of grasses, sedges and broad leaf weeds

Results on absolute weed density at 60 DAS for both seasons showed that broad-leaved weeds (BLW) were the dominant weed group in the experimental field, with sedges being the next most prevalent (Table 2). The absolute density of grasses was significant only during the rabi season. Among the treatments, l_2m_2 resulted in the lowest grass density (13.3 no. m^{-2}), followed by l_2m_3 (22.7 no. m^{-2}). With respect to sedge density, l_1m_3 recorded the lowest value (18.7 no. m^{-2}), which was on par with l_2m_2 (26.7 no. m^{-2}) during rabi 2022–2023. In summer 2022–2023, the treatment l_2m_4 registered the lowest sedge density (9.3 no. m^{-2}), which was statistically comparable to l_1m_3 and l_1m_4 . For BLW, l_3m_2 recorded the lowest

density (102.7 no. m^{-2}) and was on par with l_2m_2 during rabi 2022–2023. However, during summer 2022–23, l_3m_4 recorded the lowest BLW density (60.0 no. m^{-2}), which was on par with l_2m_2 , l_3m_3 , l_1m_3 and l_1m_2 .

Overall, the results indicated that SSB with light raking and flaming followed by live mulching significantly reduced the density of grasses, sedges and BLW. This reduction can be attributed to the favourable influence of SSB and live mulches in suppressing weed emergence. Earlier studies indicated that SSB by itself can reduce weed density by about 15.9 % when compared with an unweeded control (17). Another study showed that both flaming and cultivation, whether applied individually or together, were highly effective for controlling weeds in organic maize systems (18). Adopting a SSB at least 30 days before sowing was reported to significantly reduce the density of grasses, sedges and broad-leaved weeds in sesame compared to a conventional seedbed (19). Similarly, significant reductions in BLW, particularly *Melochia corchorifolia* L. and *C. viscosa*, were reported under SSB in sesame (20).

Effect on total density of weeds

Land preparation and live mulching practices had a significant effect on total weed density of weeds (Fig. 1). The stale seedbed with shallow tillage followed by live mulching with cowpea (l_2m_2) recorded the lowest total weed density (156.0 no. m^{-2} during rabi and 97.3 no. m^{-2} during summer). In the rabi season, this treatment outperformed all others significantly, whereas in the summer season, it was statistically comparable to l_2m_4 , l_2m_3 and l_1m_4 . The percentage reduction in total weed density in l_2m_2 over the control (l_1m_1) was 72 % during rabi 2022–2023 and 68 % during summer 2022–2023.

The superior reduction in total weed density under l_2m_2 can be attributed to the substantial suppression of weeds brought about by the SSB, which reduced early-season weed pressure and allowed the crop to grow with minimal competition. Additionally, cowpea established rapidly and provided complete ground cover, thereby smothering weeds by intercepting photosynthetically active radiation. Live mulches suppress weeds mainly through shading, competition for both above- and below-ground resources and allelopathic effects (21). A study in cotton reported that SSB combined with live mulches significantly reduced total weed count and weed

Table 2. Effect of stale seedbed and live mulching on absolute density of weeds during rabi 2022–2023 and summer 2022–2023

Treatments	Absolute density of grasses (no. m^{-2})		Absolute density of sedges (no. m^{-2})		Absolute density of BLW (no. m^{-2})	
	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023
l_1m_1	8.47 (70.7)	5.94(34.7)	9.64 (92.0)	6.80 (45.3)	19.66(385.3)	15.07(226.7)
l_1m_2	6.50 (41.3)	4.86(22.7)	5.92 (34.7)	4.40 (18.7)	13.43(180.0)	9.35 (86.7)
l_1m_3	5.84 (33.3)	4.78(22.7)	4.43 (18.7)	3.40 (10.7)	12.13(146.7)	9.81 (96.0)
l_1m_4	6.47 (41.3)	3.90(14.7)	5.72 (32.0)	3.78 (13.3)	15.99(254.7)	11.29(126.7)
l_2m_1	7.97 (62.7)	4.83(24.0)	8.38 (69.3)	6.18 (37.3)	17.95(321.3)	14.27(202.7)
l_2m_2	3.75 (13.3)	3.00 (8.0)	5.23 (26.7)	5.36 (28.0)	10.81(116.0)	7.89 (61.3)
l_2m_3	4.82 (22.7)	3.15 (9.3)	5.80 (33.3)	4.78 (22.7)	11.87(140.0)	11.09(122.7)
l_2m_4	5.36 (28.0)	3.58(12.0)	5.84 (33.3)	3.12 (9.3)	12.92(166.7)	9.57 (92.0)
l_3m_1	7.55 (56.0)	3.75(13.3)	8.53 (72.0)	9.54 (90.7)	17.79(316.0)	11.09(122.7)
l_3m_2	4.91 (24.0)	3.37(10.7)	5.61 (30.7)	5.25(26.7)	10.17(102.7)	8.68 (74.7)
l_3m_3	5.20 (26.7)	3.00 (8.0)	5.97 (30.7)	4.70 (21.3)	11.98(142.7)	8.56 (73.3)
l_3m_4	5.72 (32.0)	3.78(13.3)	6.08 (36.0)	5.96 (34.7)	13.29(176.0)	7.72 (60.0)
SEm ($\pm$)	0.24	0.42	0.35	0.40	0.39	0.59
CD ($p = 0.05$)	0.694	NS	1.017	1.172	1.159	1.743

NS: not-significant; BLW: broad leaf weeds; Values in parentheses are original values; Values are subjected to square root transformation $\sqrt{x+1}$.

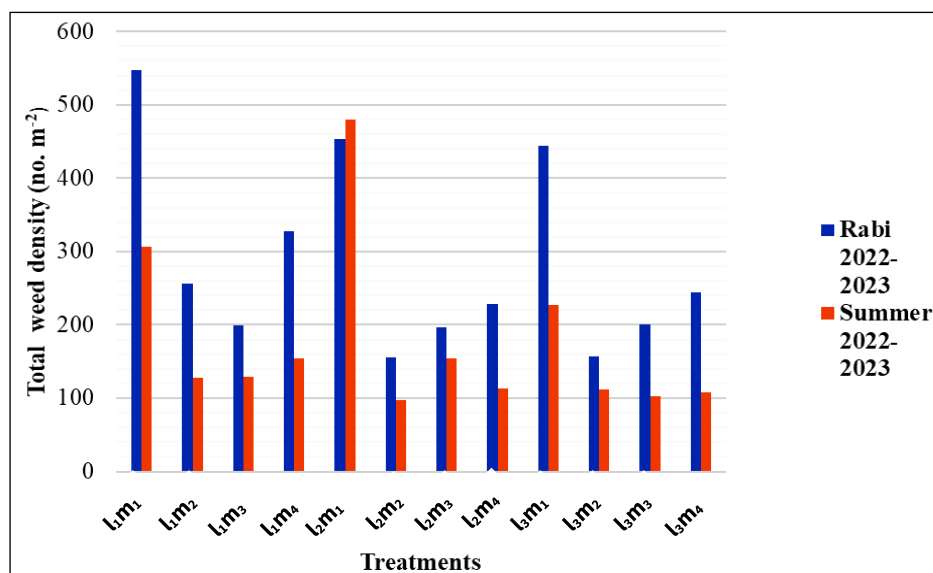


Fig. 1. Total weed density as influenced by land preparation and live mulches (rabi 2022–2023 and summer 2022–2023).

biomass compared to pre-emergence herbicide application followed by two hand weeding (22). Another study showed that cowpea intercropped at a population of 30 plants m² simultaneously with maize reduced weed biomass by 36.9 % and increased maize yield by 4.2 % compared to maize monocropping (23).

Effect on weed dry weight and weed control efficiency

At 60 DAS, the lowest weed dry weight was recorded in l₂m₃ (13.5 g m²), followed by l₂m₂ during the rabi season (Table 3). In the summer season, both l₂m₂ and l₂m₃ recorded the lowest weed dry weight (12.7 g m²). Correspondingly, the WCE was highest in l₂m₃ (89.6 %), followed by l₂m₂ (87.6 %) during rabi, whereas in summer, both l₂m₃ and l₂m₂ exhibited higher WCE values of 88.8 %.

The lower weed dry weight and higher WCE observed in l₂m₂ and l₂m₃ can be attributed to the substantial reduction in total weed density (Table 2), resulting from the combined effects of the SSB and live mulching, which effectively weakened weed emergence and growth. Stale seedbed with light raking has been reported to significantly reduce total weed count and biomass and enhance WCE compared to a non-stale seedbed in sesame (20). The increased weed population in the control plot (l₁m₁) can be linked to the exposed inter-row spaces in finger millet, which provided a favourable environment for uninterrupted weed growth. Intercropping systems possess inherent potential to suppress weeds through allelopathic effects (24).

It was reported that a SSB followed by mechanical weeding markedly reduced the weed population in lettuce also (25). Stale seedbed combined with live mulches significantly reduced total weed count and biomass compared to pre-emergence herbicide application followed by two hand weeding (22).

Effect on yield attributes

The combined effect of land preparation and live mulches significantly influenced the number of productive tillers per square metre, ear head weight and thousand-grain weight (Table 4). Among the treatments, the SSB with light raking followed by live mulching with cowpea (l₂m₂) recorded the highest number of productive tillers per square metre (58.0 and 53.3 no. m²) and was statistically comparable with l₁m₂ (57.3 and 52.0 no. m²) during both rabi and summer seasons. Similarly, ear head weight (17.33 and 20.50 g) and 1000-grain weight (1.54 and 1.79 g) were also significantly higher in l₂m₂.

The SSB effectively eliminated the first flush of weeds emerging from the soil surface, providing a competition-free environment for finger millet during the early growth stages. Subsequently emerging weeds were suppressed by the rapid ground-covering growth of cowpea used as live mulch. Reduced weed pressure in the initial stages, coupled with the incorporation of live mulch at 50 % flowering, enhanced nutrient availability for

Table 3. Effect of land preparation and live mulches on weed dry weight and weed control efficiency at 60 DAS during rabi 2022–2023 and summer 2022–2023

Treatments	Weed dry weight (g m ²)		Weed control efficiency (%)	
	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023
l ₁ m ₁	11.43 (129.7)	10.66 (113.3)	0.0	0.0
l ₁ m ₂	4.02 (15.2)	4.06 (15.5)	88.3	86.3
l ₁ m ₃	4.15 (16.2)	4.16 (16.3)	87.5	85.6
l ₁ m ₄	5.15 (25.5)	5.07 (24.7)	80.3	78.2
l ₂ m ₁	4.45 (18.9)	4.16 (16.3)	85.4	85.6
l ₂ m ₂	4.14 (16.1)	3.70 (12.7)	87.6	88.8
l ₂ m ₃	3.81 (13.5)	3.70 (12.7)	89.6	88.8
l ₂ m ₄	4.49 (19.2)	4.04 (15.3)	85.2	86.5
l ₃ m ₁	5.06 (24.6)	4.54 (19.6)	81.3	82.7
l ₃ m ₂	4.39 (18.3)	3.90 (14.3)	85.9	87.4
l ₃ m ₃	4.21 (16.7)	4.09 (15.7)	87.1	86.1
l ₃ m ₄	4.37 (18.1)	4.64 (20.7)	86.0	81.7
SEm (±)	0.096	0.20	-	-
CD (p = 0.05)	0.284	0.582	-	-

Values in parentheses are original values; Values are subjected to square root transformation $\sqrt{x+1}$.

Table 4. Yield and yield attributes as influenced by land preparation and live mulches during rabi 2022–2023 and summer 2022–2023

Treatments	Productive tillers (m ⁻²)		Ear head weight (g per plant)		1000 grain weight (g)	
	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023
l ₁ m ₁	37.3	29.3	9.77	10.10	1.16	1.22
l ₁ m ₂	57.3	52.0	15.37	16.53	1.40	1.53
l ₁ m ₃	44.3	40.0	15.2	16.67	1.34	1.36
l ₁ m ₄	42.0	37.3	10.2	11.93	1.21	1.25
l ₂ m ₁	42.7	40.0	10.33	10.90	1.18	1.23
l ₂ m ₂	58.0	53.3	17.33	20.50	1.54	1.79
l ₂ m ₃	51.0	46.7	15.93	15.87	1.43	1.48
l ₂ m ₄	45.3	41.3	15.03	15.78	1.41	1.51
l ₃ m ₁	41.7	37.3	11.8	12.37	1.25	1.23
l ₃ m ₂	49.7	45.3	16.17	18.83	1.53	1.56
l ₃ m ₃	48.3	44.0	15.20	16.02	1.41	1.36
l ₃ m ₄	46.3	41.3	14.23	14.19	1.27	1.27
SEm (±)	1.7	1.9	0.20	0.28	0.02	0.02
CD (p = 0.05)	4.87	5.67	0.599	0.837	0.052	0.066

crop uptake. Live mulching also improved soil health and moisture retention through the addition of organic matter.

Similar results have been documented in upland rice, where the SSB practice resulted in better expression of yield attributes compared to normal seedbed (NSB) (26). In okra SSB followed by banana leaf mulching and mechanical weeding with a wheel-hoe weeder markedly lowered weed density and biomass, which in turn enhanced the yield attributes (27). Likewise, yield components of maize were found to be higher under cowpea live mulching compared to no-mulch conditions (28).

Effect on yield

The combined effect of land preparation and live mulches significantly affected yield and weed index in finger millet (Table 5). The SSB with light raking followed by cowpea live mulching (l₂m₂) recorded the highest grain yield (938 and 832 kg ha⁻¹ during rabi and summer 2022–2023 respectively) and the lowest weed index across both seasons. In contrast, continuous crop-weed competition throughout the season resulted in the highest weed index (46.3 and 56.9%) in the control (l₁m₁) during rabi and summer respectively.

The combined effect of SSB and live mulching contributed to a substantial reduction in total weed count and biomass, thereby providing a favourable, competition-free environment for crop growth. Increased nutrient availability resulting from reduced weed density and minimised nutrient removal by weeds enhanced nutrient uptake by the crop, resulting in better expression of yield attributes and ultimately higher yield (Table 4).

Similar findings have been reported in earlier studies. In okra, SSB followed by banana leaf mulching and mechanical weeding with a wheel-hoe weeder significantly reduced weed

density and biomass, leading to higher yields (27). Likewise, SSB followed by green gram live mulching plus one manual hoeing significantly enhanced dry matter production and yield in wheat (29). In sesame, SSB combined with shallow tillage resulted in a 48 % yield increase over conventional methods (30). Management of the first or second flush of weeds through SSB techniques has also been associated with higher yields in soybean (31). Furthermore, brown manuring with sesbania and cowpea effectively reduced weed populations and enhanced yield in direct-seeded rice (32).

Effect on economics

Evaluating weed management practices under field conditions is critically important. The treatment involving SSB with light raking followed by cowpea live mulch (l₂m₂) recorded the highest gross returns during both seasons (₹93800 and ₹83200 ha⁻¹ respectively), as well as the highest net returns (₹40058 and ₹29458 ha⁻¹ respectively) and benefit-cost (B:C) ratios (1.75 and 1.55 respectively) (Table 6). The superior grain yield obtained under l₂m₂ primarily contributed to these higher economic returns. The SSB followed by cowpea live mulching and its later incorporation markedly lowered both weed density and weed biomass. Comparable results were observed in another study where a 14-day SSB, along with the simultaneous establishment of cowpea live mulch and its incorporation by shallow hoeing, led to increased rice grain yield. Additionally, the SSB achieved a higher B:C ratio than the conventional seedbed (33).

Conclusion

Overall, the findings demonstrated that adopting the stale seedbed (SSB) technique with light raking, followed by live mulching with cowpea sown in a 1:1 ratio and incorporated at 50 % flowering using a

Table 5. Effect of stale seedbed and live mulching on yield and weed index in finger millet during rabi 2022–2023 and summer 2022–2023

Treatments	Grain yield (kg ha ⁻¹)		Weed index (%)	
	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023
l ₁ m ₁	503	359	46.3	56.9
l ₁ m ₂	699	641	25.4	22.9
l ₁ m ₃	641	600	31.7	25.4
l ₁ m ₄	607	587	35.3	29.6
l ₂ m ₁	630	543	32.9	34.6
l ₂ m ₂	938	832	0.0	0.0
l ₂ m ₃	757	667	19.3	19.8
l ₂ m ₄	696	603	25.8	27.5
l ₃ m ₁	639	541	31.8	34.9
l ₃ m ₂	830	677	11.6	18.6
l ₃ m ₃	709	612	24.5	25.2
l ₃ m ₄	699	571	25.5	31.4
SEm (±)	11.57	14	-	-
CD (p = 0.05)	34.14	43.96	-	-

Table 6. Gross return, net return and B: C ratio as influenced by land preparation and live mulches during rabi 2022–2023 and summer 2022–2023

Treatments	Gross return (₹ ha ⁻¹)		Net return (₹ ha ⁻¹)		B:C ratio	
	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023	Rabi 2022–2023	Summer 2022–2023
l ₁ m ₁	50333	35900	12091	-2342	1.32	0.94
l ₁ m ₂	69933	64100	21191	15358	1.43	1.32
l ₁ m ₃	64067	60000	15575	11508	1.32	1.24
l ₁ m ₄	60667	58700	10925	8958	1.22	1.18
l ₂ m ₁	62967	54300	19725	11058	1.46	1.26
l ₂ m ₂	93800	83200	40058	29458	1.75	1.55
l ₂ m ₃	75667	66700	22175	13208	1.41	1.25
l ₂ m ₄	69567	60300	14825	5558	1.27	1.10
l ₃ m ₁	63933	54130	9691	-112	1.18	1.00
l ₃ m ₂	82967	67700	18225	2958	1.28	1.05
l ₃ m ₃	70867	61200	6375	-3292	1.10	0.95
l ₃ m ₄	69900	57100	4158	-8642	1.06	0.87

wheel-hoe weeder, is an effective, cost-efficient and ecologically sustainable weed management strategy for organically cultivated finger millet. This practice effectively suppresses weeds, reduces labour and weed management costs, improves soil health and significantly enhances grain yield and can therefore be recommended as a sustainable and cost-effective weed management practice for finger millet.

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Authors' contributions

SKR conceptualised and designed the research. VDVS drafted the manuscript. SKR, JD, SPP and AB provided guidance throughout the study. ARD, MRP and VVK were responsible for literature collection and reference formatting. All authors read and approved the final manuscript.

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