Indian Journal of Agronomy **70** (4): 430–438 (December 2025)
DOI: 10.59797/ija.v70.i4.5665

Research Paper

Integrated approach of tillage, mulch and nitrogen management enhanced the productivity and profitability of Pearl millet in Semi-Arid regions of India

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Received: July 2025; Revised accepted: December 2025

ABSTRACT

Intensive tillage and excessive nitrogen fertilization degrade soil health, reduce nutrient use efficiency and contribute to environmental issues such as erosion, nitrate leaching, eutrophication, and greenhouse gas emissions. To address this, a field study was conducted during the *kharif* seasons of 2023 and 2024 to assess the impact of tillage, mulch and nitrogen management. The study was conducted with four tillage practices namely conventional tillage (CT) + without mulch, conventional tillage (CT) + with mulch (Mustard stover 3 t/ha), minimum tillage (MT) + without mulch and minimum tillage (MT) + with mulch (Mustard stover 3 t/ha) in main plots and five nitrogen management strategies (control, 100% recommended dose of nitrogen (RDN) through chemical fertilizers, 75% RDN through chemical fertilizers and 25% RDN through FYM, 50% RDN through chemical fertilizers and 50% RDN through FYM and 100% RDN through FYM in sub plots. Conventional tillage with mustard stover mulch (3 t/ha) significantly improved growth and productivity depicted through maximum values of earhead length (28.59 cm), earhead diameter (27.75 mm), grain yield (2,533 kg/ha) and stover yield (5826 kg/ha). Among nitrogen management options, application of 75% RDN through chemical and 25% through FYM proved to be most effective N management option with maximum values of earhead length (29.56 cm), diameter (28.09 mm), grain yield (2,722 kg/ha) and stover yield (6,251 kg/ha). Notably, minimum tillage with mulch, coupled with 75% RDN through chemical and 25% through FYM, provided comparable yields and economic returns with ecological and climate-smart benefits. These findings highlight that adoption of either conventional tillage or minimum tillage with mulch with application of 75% RDN through chemical and 25% through FYM can improve productivity, profitability of pearl millet growers in semi-arid regions.

Key words: Economics, Farmyard manure, Mulch, Nitrogen, Pearl millet, Tillage, Yield

Pearl millet (*Pennisetum glaucum*), locally known as bajra, is a climate-resilient cereal crop grown extensively in arid and semi-arid regions of Africa and Asia. Its cultivation dates to prehistoric times, particularly in the Indian subcontinent where it has remained a staple for millions, especially in marginal environments. It thrives under harsh agro-climatic conditions and has superior tolerance to drought, heat, and low soil fertility compared to most other cereals. Often referred to as the "poor man's crop", pearl millet today is also recognized as a nutri-cereal due to its high nutritional value, making it a key crop for food and nutritional security in dryland areas. Its drought-resilient nature makes it indispensable for areas prone to climatic uncertainty. Globally, India and Africa together account for over 93% of pearl millet production. India leads the world in both area and production, with 7.38 million hectares under cultivation and an output of 10.72 million tonnes during 2023–24, averaging a productivity of 1453 kg/ha (DES, 2024). Rajasthan remains the largest contributor within India, cultivating the crop over 4.57 million hectares and producing 5.11 million tonnes with an average yield of 1117 kg/ha in 2023–24 (DES, 2024). Despite its adaptability, achieving high and stable yields of pearl millet remains a significant challenge, particularly in Rajasthan's sandy soils, which are low in organic matter, weak in structure, and poor in water retention capacity. The crop depends

Based on a part of Ph.D. Thesis of the first author submitted to the Department of Agronomy, Faculty of Agriculture, Jagan Nath University, Jaipur, Rajasthan in 2024 (unpublished)

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largely on southwest monsoon rains (June–September). However, erratic rainfall distribution, high evaporative losses, and soil degradation due to water and wind erosion lead to suboptimal productivity (Rana *et al*., 2012).

Tillage and mulching are pivotal agronomic practices that significantly influence soil health, moisture dynamics, and overall crop performance, particularly in arid and semi-arid regions such as western Rajasthan. In such agro-ecologies, optimizing soil management practices is crucial for sustaining productivity and environmental health. However, continuous and intensive conventional tillage practices have been found to degrade soil structure, reduce soil organic matter, disrupt microbial populations, and cause soil compaction and erosion. To counter these issues, conservation tillage practices, including zero tillage and minimum tillage, have been increasingly advocated (Pingali *et al.*, 2004). These practices involve minimal disturbance of soil and promote residue retention on the surface, enhancing water infiltration, reducing evaporation, and improving soil structure over time. Mulching, when integrated with conservation tillage, significantly amplifies the benefits of soil moisture conservation and erosion control. In rainfed environments, where water is the most limiting factor, mulch acts as a protective barrier over the soil surface. Organic mulches improve biological activity and nutrient cycling, while synthetic mulches are more effective in reducing direct moisture loss and preventing salinity rise in the root zone (Dilip Kumar *et al*., 1990).

Nitrogen (N) is one of the most crucial nutrients for plant growth and productivity. It is a constituent of chlorophyll, amino acids, enzymes, nucleic acids, and vitamins. However, sandy soils in semi-arid regions are typically deficient in nitrogen due to low organic matter content and high leaching potential. Over-reliance on chemical nitrogen fertilizers often results in poor nitrogen use efficiency (only 40–60% recovery), higher production costs, and environmental concerns such as nitrate leaching, eutrophication, and greenhouse gas emissions (Malhi *et al.,* 2001). On the contrary, integrated nitrogen management, combining chemical fertilizers with organic amendments like farmyard manure (FYM), can improve nutrient availability, enhance microbial activity, and promote sustainable soil fertility (Paramesh *et al.,* 2023).

Given the intertwined challenges of moisture scarcity, low soil fertility, inefficient input use, and climate-induced variability, there is a compelling need to revisit and redefine the production strategies for pearl millet in semi-arid regions. While tillage and nitrogen management have been studied independently in the past, a system-based approach that integrates tillage intensity, mulch application, and site-specific nitrogen strategies remains underexplored in Rajasthan's rainfed farming systems.

MATERIALS AND METHODS

The field experiment was conducted at Agronomy Farm, Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Rajasthan), situated at 26° 85' N latitude and 75° 78' E longitude at an altitude of 431 meters above mean sea level. The region receives an average annual precipitation of 400 mm to 500 mm (CV 36%) and bulk of it (85 to 91%) is received from June to September (*Kharif* season) by the southwest monsoon. The maximum and minimum temperature ranged between 29.8°C to 36.5°C and 18.7°C to 26.1°C. The climate of experimental site is depicted in Figure 1 and 2. The soil of the experimental field was loamy sand in texture and slightly alkaline in reaction with *p*H of 8.2, poor in organic carbon (0.22%), low in available nitrogen (140.1 kg/ha) high in available phosphorus (26.3 kg/ha) and medium in potassium (128.5 kg/ha).

The experiment having 20 treatment combinations and three replications were laid out in split plot design. The treatment combinations comprised of four tillage and mulch practices, namely, conventional tillage (CT) + without mulch, conventional tillage (CT) + with mulch (mustard stover 3 t/ha), minimum tillage (MT) + without mulch and minimum tillage (MT) + with mulch (mustard stover 3 t/ha) in main plots and five nitrogen management strategies (control, 100% recommended dose of nitrogen (RDN) through chemical fertilizers, 75% RDN through chemical fertilizers and 25% RDN through FYM, 50% RDN through chemical fertilizers and 50% RDN through FYM and 100% RDN through FYM in sub plots.

Earmarked blocks were one harrowing soon after receiving the pre-monsoon showers and these were later prepared for sowing by a harrowing followed by planking at the onset of rain. The pearl millet variety RHB 233 was sown using seed rate of 4 kg/ha. Sowing was done at 50 cm row and 15 cm plant intervals by "pora" method on 13th July 2023 and 15th July 2024. Sun dried mustard stover (3.0 t/ha) was spread in the ear marked plots over the soil surface uniformly in between rows after plant emergence (20 days after sowing). FYM was applied 10–15 days prior to sowing as per treatments. Half dose of Nitrogen was applied as basal and remaining half dose as top-dressing through urea at 30 DAS. The recommended dose of phosphorus (40 kg P_2O_5/ha) applied through Single Super Phosphate (SSP) during both the years of investigation at the time of sowing.

Total ear-bearing tillers of five tagged plants were counted at harvest from each plot and then computed average number of effective tillers/plant. Five earheads were randomly selected from tagged plants and the length was measured from the neck nodes to the tip of ear head and average length was recorded as earhead length. Diameter

of earhead was measured at top, middle and bottom of the ear head in millimeter by Vernier caliper and mean value was calculated. The total mature biomass harvested from each net plot 4.0 m × 3.0 m (12.0 m^2) area was sun dried, threshed and cleaned separately. The harvest index (H.I.) was calculated by dividing economical yield (grain yield) by the biological yield (grain and straw) and represented in percentage (Donald and Hamblin, 1976).

$$\text{Harvest Index}(\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

The benefit cost ratio of each treatment was calculated by dividing the gross returns with the mean cost of cultivation. The data from the split-plot design with 2 factors (tillage–conventional and minimum with and without mulch and integrated nitrogen management through chemicals and farmyard manure) were analyzed using two-way analysis of variance (ANOVA). Comparisons within each factor were conducted using the generated Critical Difference (CD) values at the 5% level of significance.

RESULTS AND DISCUSSION

Yield attributes

The highest number of effective tillers/plant at harvest was observed under conventional tillage with mulch, which was significantly superior to minimum tillage without mulch, but statistically at par with conventional tillage without mulch and minimum tillage with mulch across both years (Table 1). Significantly higher earhead length (28.01 and 29.17 cm) and earhead diameter (27.36 and 28.15 mm) were recorded under conventional tillage with mulch, which was significantly superior to minimum tillage without mulch, but remained statistically at par with conventional tillage without mulch and minimum tillage with mulch during both the years, respectively. Superior performance under conventional tillage with mulch can be attributed to enhanced soil aeration, better root development, and improved nutrient uptake facilitated by tillage, all of which contribute to increased plant vigour and tillering capacity (Basavarajappa *et al*., 2002 and Patel *et al*., 2020). Additionally, mulch helps preserve soil moisture, regulate soil temperature, and suppress weed growth, creating a more favorable environment for tiller emergence and survival (Chandna *et al*., 2020). The improved yield attributes in mulched plots may be attributed to enhanced soil moisture retention, moderated soil temperatures, and improved nutrient uptake, which collectively create optimal conditions for reproductive growth and assimilate allocation. These benefits promote better sink development. These findings agree with the studies by Chaudhary *et al*. (2016), Singh *et al*. (2017), and Patil *et al*. (2019).

Table 1. Effect of different tillage, mulch and N-management on yield attributes of pearl millet

Treatment	Number of effective tillers/plant at harvest		Earhead length (cm)		Earhead diameter (mm)	
	2023	2024	2023	2024	2023	2024
Tillage and Mulch						
CT without Mulch (T_1)	3.34	3.43	27.00	27.86	26.87	27.56
CT with Mulch (T_2)	3.45	3.55	28.01	29.17	27.36	28.15
MT without Mulch (T_3)	2.90	2.99	25.02	26.17	23.54	24.84
MT with Mulch (T_4)	3.29	3.35	26.42	27.48	25.90	26.81
SEm±	0.09	0.09	0.72	0.80	0.64	0.67
CD (P=0.05)	0.31	0.31	2.49	2.77	2.20	2.32
CV%	10.65	10.55	10.46	11.19	9.50	9.68
Nitrogen management						
Control (N_0)	2.89	2.94	23.61	23.66	22.68	24.38
100% RDN through Chemical (N_1)	3.41	3.54	27.66	29.07	27.21	27.83
75% RDN through Chemical and 25% RDN through FYM (N_2)	3.51	3.56	28.56	29.97	27.75	28.43
50% RDN through Chemical and 50% RDN through FYM (N_3)	3.28	3.38	26.94	28.03	26.12	27.00
100% RDN through FYM (N_4)	3.13	3.24	26.31	27.61	25.83	26.55
SEm±	0.07	0.08	0.57	0.54	0.48	0.54
CD (P=0.05)	0.20	0.24	1.65	1.56	1.38	1.55
CV%	7.47	8.69	7.46	6.78	6.40	6.92

Application of 75% RDN through chemical fertilizer and 25% RDN through FYM produced the highest number of effective tillers/plant (3.51 and 3.56), which was significantly superior to the control and 100% RDN through FYM (Table 1). Further, application of 75% RDN through chemical fertilizer and 25% RDN through FYM remained at par with 100% RDN through chemical fertilizer and resulted in significantly higher earhead length (28.56 and 29.97 cm) and earhead diameter (27.75 and 28.43 mm) of pearl millet over the control, 50% RDN through chemical + 50% RDN through FYM, and 100% RDN through FYM during both years. This improvement can be attributed to the complementary benefits of integrated nutrient management. Chemical nitrogen ensures a rapid supply of nutrients necessary for early vegetative and reproductive growth, while FYM improves soil structure, organic matter content, and microbial activity, enhancing nutrient use efficiency (Meena *et al*., 2017). The integration of fast-acting and slow-releasing nutrient sources thus supports sustained plant vigour and superior panicle development (Kumar *et al*., 2019). These findings are consistent with those of Sharma *et al*. (2020) and Gupta *et al*. (2021).

Number of effective tillers per plant in pearl millet was significantly influenced by the interaction of tillage, mulch and nitrogen management treatments during both the years (Table 2). The highest number of effective tillers/plant (3.86 and 3.95) was recorded under the combination of conventional tillage with mulch and the application of 75% recommended dose of nitrogen (RDN) through chemical fertilizers along with 25% RDN through farmyard manure (FYM) which was statistically at par with conventional tillage without mulch and minimum tillage with mulch under the same nutrient regime and also with 100% RDN applied through chemical fertilizers, while significantly outperforming the control in both years. The enhanced tiller production in this combination may be attributed to the complementary benefits of improved soil structure and moisture conservation from mulch, effective seedbed preparation and aeration from conventional tillage, and the dual nutrient availability provided by the integrated nutrient source. Conventional tillage supports robust root establishment, while mulch improves microclimatic conditions by regulating soil temperature, conserving moisture, and reducing weed pressure (Kumar *et al*., 2019). The integration of chemical fertilizers, which offer rapid nutrient availability, with FYM, which improves soil organic matter content, microbial activity, and nutrient buffering capacity, likely enhanced overall nutrient uptake and tiller formation (Yadav *et al*., 2020). These findings are consistent with those of Meena *et al*. (2018), who also reported enhanced tillering and crop performance in pearl millet when mulch and integrated nutrient management were combined.

Grain and stover yield

Grain and stover yield differed significantly between tillage and mulch treatments (Table 3). The highest grain yield (2,484 and 2,583 kg/ha) and stover yield (5,712 and 5,940 kg/ha) was recorded under conventional tillage combined with mulch, which was significantly superior to minimum tillage without mulch but remained statistically at par with conventional tillage without mulch and minimum tillage with mulch across both years. The percentage increase in grain and stover yield under conventional tillage with mulch over minimum tillage without mulch was 19.14% and 19.50% in 2023, and 19.69% and 19.69% in 2024. The increase in pearl millet yield can be attributed to

Table 2. Interaction effect of different tillage & mulch and N-management on number of effective tillers/plant

Nitrogen management	Tillage and mulch							
	2023				2024			
	CT without mulch	CT with mulch	MT without mulch	MT with mulch	CT without mulch	CT with mulch	MT without mulch	MT with mulch
Control	2.98	2.98	2.50	3.11	3.21	3.08	2.51	2.96
100% RDN through Chemical	3.59	3.59	3.10	3.36	3.72	3.73	3.15	3.57
75% RDN through Chemical and 25% RDN through FYM	3.60	3.86	3.32	3.26	3.58	3.95	3.41	3.31
50% RDN through Chemical and 50% RDN through FYM	3.38	3.41	2.95	3.40	3.43	3.47	3.07	3.54
100% RDN through FYM	3.14	3.41	2.65	3.31	3.23	3.50	2.83	3.39
			SEm±	CD (P=0.05)			SEm±	CD (P=0.05)
Tillage and mulch at same level of nitrogen			0.15	0.44			0.15	0.44
Nitrogen at same level of Tillage & mulch			0.14	0.40			0.17	0.48

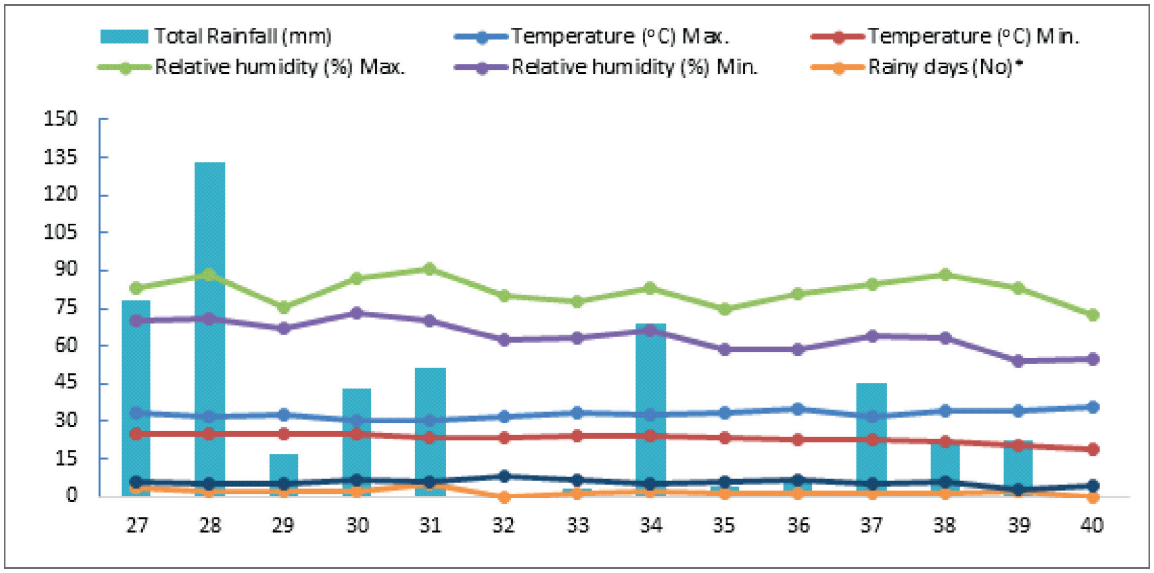

Fig. 1. Mean weekly weather parameters for crop season (*Kharif*, 2023)

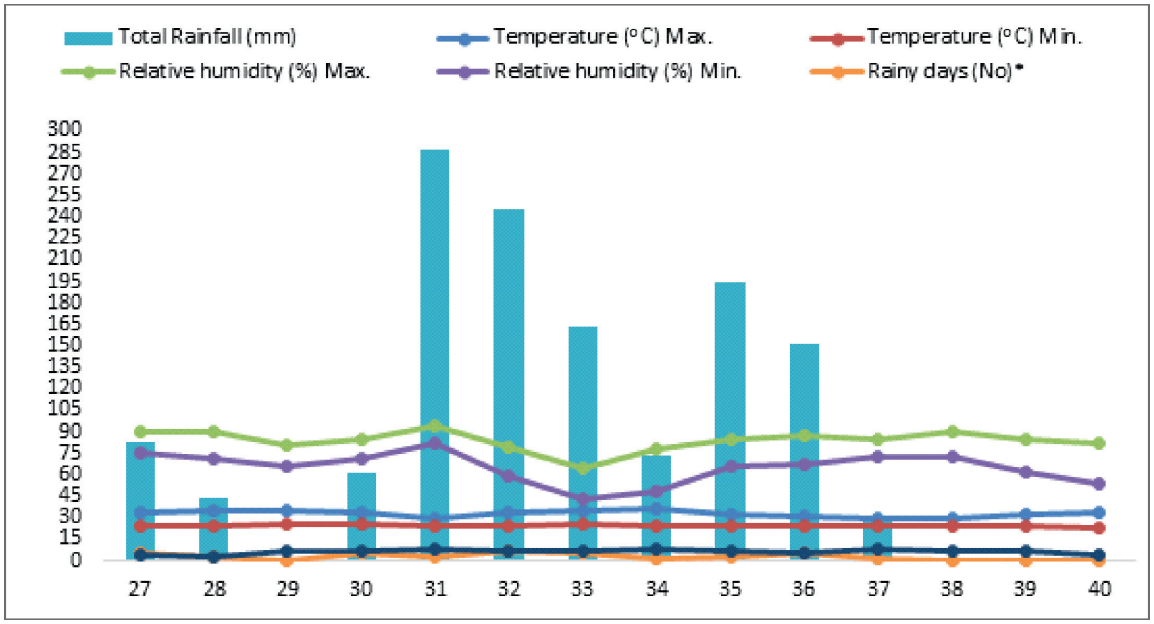

Fig. 2. Mean weekly weather parameters for crop season (*Kharif*, 2024)

the synergistic effects of tillage and mulching practices. Conventional tillage improves soil structure, promotes deeper root penetration, and enhances water and nutrient uptake (Jat *et al*., 2018). Mulching further supports yield improvement by preserving soil moisture, regulating soil temperature, and suppressing weed growth factors critical for optimizing crop growth in arid and semi-arid conditions (Patil *et al*., 2019). These findings are consistent with previous studies that have documented the positive impacts of tillage and mulching on pearl millet grain yield (Chandna *et al*., 2020; Reddy and Baisakh, 2021).

Nitrogen management had a significant impact on the grain and stover yield of pearl millet during both the years (Table 3). The highest grain yield (2,682 and 2,763 kg/ha) and stover yield (6,148 kg/ha and 6,355 kg/ha) was recorded with the application of 75% RDN through chemical fertilizers and 25% RDN through FYM. This treatment outperformed the control, 50% RDN through chemical + 50% FYM, and 100% RDN through FYM, while being statistically at par with 100% RDN through chemical fertilizers. The superior performance of the 75% chemical + 25% FYM treatment can be ascribed to the complementary effects of readily available nitrogen from chemical fertilizers and the soil-improving attributes of FYM. FYM en-

Table 3. Effect of different tillage, mulch and N-management on yield of pearl millet

Treatment	Yield (kg/ha)			
	Grain		Stover	
	2023	2024	2023	2024
Tillage and Mulch				
CT without Mulch (T_1)	2,355	2,460	5,443	5,657
CT with Mulch (T_2)	2,484	2,583	5,712	5,940
MT without Mulch (T_3)	2,085	2,158	4,780	4,963
MT with Mulch (T_4)	2,364	2,455	5,436	5,647
SEm±	70	67	134	163
CD (P=0.05)	243	232	465	565
CV%	11.7	10.7	9.7	11.4
Nitrogen management				
Control (N_0)	1,625	1,724	3,737	3,966
100% RDN through Chemical (N_1)	2,570	2,649	5,911	6,092
75% RDN through Chemical and 25% RDN through FYM (N_2)	2,682	2,763	6,148	6,355
50% RDN through Chemical and 50% RDN through FYM (N_3)	2,430	2,522	5,622	5,801
100% RDN through FYM (N_4)	2,302	2,411	5,295	5,545
SEm±	56	62	147	141
CD (P=0.05)	161	179	422	406
CV%	8.3	8.9	9.5	8.8

hances soil physical properties, microbial activity, and nutrient retention, while chemical fertilizers ensure quick nutrient availability, particularly during the early growth phases (Khambalkar *et al*., 2013; Verma *et al*., 2020). These findings align with the results of Meena *et al*. (2020) and Patel *et al*. (2017), who reported that integrated nutrient management enhances both soil fertility and grain yield in pearl millet.

Conventional tillage with mulch, combined with the application of 75% RDN through chemical fertilizer and 25% RDN through FYM produced the highest grain yield of 2,935 kg/ha and 3,075 kg/ha (Table 4) and stover yield of 6,750 kg/ha and 7,073 kg/ha (Table 5), which was statistically at par with conventional tillage without mulch and minimum tillage with mulch under the same nitrogen management regime (75% RDN through chemical + 25% RDN

Table 4. Interaction effect of different tillage, mulch and N-management on grain yield (kg/ha)

Nitrogen management	Tillage and Mulch							
	2023				2024			
	CT without mulch	CT with mulch	MT without mulch	MT with mulch	CT without mulch	CT with mulch	MT without mulch	MT with mulch
Control	1,607	1,746	1,449	1,697	1,691	1,796	1,631	1,779
100% RDN through Chemical	2,630	2,706	2,276	2,667	2,726	2,792	2,344	2,733
75% RDN through Chemical and 25% RDN through FYM	2,680	2,935	2,384	2,730	2,743	3,075	2,480	2,753
50% RDN through Chemical and 50% RDN through FYM	2,507	2,545	2,208	2,460	2,618	2,660	2,230	2,580
100% RDN through FYM	2,350	2,487	2,109	2,263	2,519	2,590	2,104	2,430
			SEm±	CD (P=0.05)			SEm±	CD (P=0.05)
Tillage and mulch at same level of nitrogen			122	352			122	352
Nitrogen at same level of Tillage and mulch			112	321			124	358

Table 5. Interaction effect of different tillage, mulch and N-management on stover yield (kg/ha)

Nitrogen management	Tillage and mulch							
	2023				2024			
	CT without mulch	CT with mulch	MT without mulch	MT with mulch	CT without mulch	CT with mulch	MT without mulch	MT with mulch
Control	3,697	4,017	3,333	3,903	3,889	4,131	3,751	4,092
100% RDN through Chemical	6,048	6,223	5,240	6,135	6,271	6,422	5,390	6,287
75% RDN through Chemical and 25% RDN through FYM	6,164	6,750	5,397	6,280	6,310	7,073	5,704	6,332
50% RDN through Chemical and 50% RDN through FYM	5,899	5,852	5,079	5,659	6,021	6,118	5,130	5,934
100% RDN through FYM	5,405	5,719	4,850	5,204	5,794	5,956	4,839	5,589
			SEm±	CD (P=0.05)			SEm±	CD (P=0.05)
Tillage and mulch at same level of nitrogen			295	849			295	849
Nitrogen at same level of Tillage and mulch			293	845			282	811

through FYM) and with 100% RDN through chemical fertilizers, while being significantly superior to the control in both years. The superior stover yield under this treatment combination can be attributed to the synergistic effects of tillage, mulching, and integrated nitrogen management (Meena and Gautam, 2005), which together improve soil structure, moisture retention, nutrient availability, and root development (Verma *et al*., 2020).

Economics

Conventional tillage with mulch was more remunerative as compared to other tillage and mulch practices (Table 6). Conventional tillage with mulch recorded appreciably higher gross returns (₹90,652 and ₹97,495/ha), followed by conventional tillage without mulch and minimum tillage with mulch during both years. The higher gross returns under conventional tillage with mulch can be attributed to

Table 6. Effect of different tillage, mulch and N-management on economics of pearl millet

Treatment	Cost of cultivation (₹/ha)		Gross returns (₹/ha)		Net returns (₹/ha)		Benefit: cost ratio	
	2023	2024	2023	2024	2023	2024	2023	2024
Tillage and Mulch								
CT without Mulch (T_1)	39,360	40,560	86,080	92,848	46,720	52,288	2.21	2.31
CT with Mulch (T_2)	43,860	45,060	90,652	97,495	46,792	52,434	2.09	2.18
MT without Mulch (T_3)	36,360	37,560	76,035	81,455	39,675	43,894	2.12	2.21
MT with Mulch (T_4)	40,860	42,060	86,269	92,679	45,409	50,619	2.14	2.23
SEm±	-	-	2,379	2,568	2,379	2,568	0.06	0.06
CD (P=0.05)	-	-	8,234	8,887	8,234	8,887	0.20	0.22
Nitrogen management								
Control (N_0)	31,350	32,550	59,310	65,093	27,960	32,543	1.89	2.01
100% RDN through Chemical (N_1)	35,517	36,717	93,799	99,996	58,282	63,279	2.64	2.73
75% RDN through Chemical and 25% RDN through FYM (N_2)	39,650	40,850	97,799	104,300	58,149	63,450	2.47	2.55
50% RDN through Chemical and 50% RDN through FYM (N_3)	43,484	44,684	88,864	95,204	45,380	50,521	2.05	2.13
100% RDN through FYM (N_4)	50,550	51,750	84,024	91,003	33,474	39253	1.66	1.76
SEm±	-	-	2,085	2,325	2,085	2,325	0.05	0.06
CD (P=0.05)	-	-	6,007	6,697	6,007	6,697	0.14	0.16

multiple factors. Conventional tillage is known to enhance soil aeration, improve seedbed preparation, and increase nutrient availability, leading to better crop establishment and productivity (Baker *et al*., 2018). Additionally, the incorporation of mulch aids in soil moisture conservation, weed suppression, and improved soil health, which collectively enhance yield and profitability (Zhang *et al*., 2019). Conventional tillage with mulch recorded higher net returns (₹46,792 and ₹52,434/ha), followed closely by conventional tillage without mulch (₹46,720 and ₹52,288/ha) and conventional tillage without mulch gave the highest benefit cost: ratio of 2.21 and 2.31 during both years, respectively. The higher net returns under conventional tillage with mulch can be attributed to improved seedbed preparation and better soil aeration, which are common benefits of conventional tillage (Bezboruah *et al*., 2024).

Application of 75% RDN through chemical fertilizer and 25% RDN through FYM fetched gross returns of ₹97,799 and ₹1,04,300/ha with net returns of ₹58,149 and ₹63,450/ha, which was at par with 100% RDN through chemical fertilizer, yielded gross returns of ₹93,799 and ₹99,996/ha with net returns of ₹58282 and ₹63279/ha respectively, across both years (Table 6). The application of 100% RDN through chemical fertilizer resulted in the highest benefit cost ratio (2.64 and 2.73), which was significantly superior to the control, 75% RDN through chemical + 25% RDN through FYM, 50% RDN through chemical + 50% RDN through FYM, and 100% RDN through FYM during both years. The increase in gross returns can be attributed to the immediate and concentrated supply of nutrients through chemical fertilizers, essential for rapid crop growth, FYM improves soil organic matter, structure, water retention, and microbial activity, ensuring a gradual and sustained nutrient release (Tandon, 2020). These findings are in agreement with the research of Singh *et al*. (2021), Ali *et al*. (2022) and Patel *et al*. (2014).

A study of two year revealed that combination of conventional tillage with mulch significantly enhanced growth, yield and yield-attributing characteristics of pearl millet. Similarly, the application of 75% recommended dose of nitrogen (RDN) through chemical fertilizer along with 25% RDN through farmyard manure (FYM) resulted in significantly higher growth, yield and net returns when compared to the control, 50% RDN through chemical and 50% through FYM, and 100% RDN through FYM. Overall, findings highlight that adoption of either conventional tillage or minimum tillage with mulch with application of 75% RDN through chemical and 25% through FYM can improve productivity, profitability of pearl millet growers in semi-arid regions.

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