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Influence of Tillage Practices on Growth and Yields of Pearl Millet [*Pennisetum glaucum* (L.) R.Br.] Cultivars under Rainfed Conditions of Western Rajasthan

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Authors' contributions

This work was carried out in collaboration between all authors. Author JKV designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NKP managed the analyses of the study. Author BS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment comprising of four tillage practices in main and four cultivars of pearl millet in sub plots was laid out in split plot design with four replications and conducted during *kharif* 2014 at College of Agriculture, Bikaner. The results indicated that practice of conventional tillage + ridging and zero tillage + ridging was at par from each other in respect of growth and yield attributes (plant

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height, DMA at 45, 60 DAS and at harvest, effective tillers plant^{-1}). Conventional tillage + ridging and zero tillage + ridging significantly increased the grain yield by a magnitude of 11.17 and 10.06 per cent, respectively over zero tillage. The field water use efficiency (FWUE) was influenced significantly by various tillage treatments. The treatment zero tillage + ridging recorded the highest net return (₹ 25,546 ha^{-1}) and B:C ratio (3.69:1). Significantly higher effective tillers plant^{-1}, grain yield and harvest index were observed in pearl millet hybrids in comparison to composite cultivars and the hybrid cultivar MPMH-17 recorded the highest grain yield (1423 Kg ha^{-1}) and harvest index (30.4%). However, plant height (cm) and straw yield were higher in composites than hybrids. The hybrid cultivars recorded higher FWUE than composites. The hybrid cultivar MPMH-17 also fetched the highest net return (₹ 25,482 ha^{-1}), however, it was at par with Cv. RHB 177. The maximum B:C ratio (3.44:1) was also observed with Cv. MPMH 17.

Keywords: Tillage practices; cultivars; growth; yield attributes and yield.

1. INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.)R.Br] commonly known as bajra, is an important drought hardy coarse grain crop that provides staple food for the poor in a short period. It flourishes satisfactorily and can be cultivated under rainfall as low as 200 to 250 mm [1], which makes it one of the most reliable cereals in the rainfed regions of arid and semi-arid tropics. Occupying around 60% of the net sown area, the rainfed regions, are home to two third livestock and 40% of human population. About 90% of rainfed area is located in the north-west part, out of which 60% is located in Rajasthan. The productivity of pearl millet is greatly influenced by amount of rainfall and its distribution. Therefore, there is a need to focus our research efforts as to how the productivity potential can be best achieved by identifying suitable ameliorative measures to overcome the effect of moisture stress, which is mainly responsible for reduction in the productivity of rainfed pearl millet.

Techniques those ensure maximum storage of rainwater in the root zone and also prolong its availability to the crop, obviously, hold due promise in improving productivity of pearl millet in rainfed regions. Among several agronomic advantages that tillage operations offer to a crop, moisture conservation is of utmost importance. Beneficial effect of various tillage practices on moisture conservation and yields of *kharif* cereals have been reported by [2,3] by minimizing the risk of crop failure [4] under rainfed conditions. Minimizing the cost of production under rainfed conditions is of logical importance. On the basis of numerous reports, practice of zero/minimum tillage can understandably be incorporated owing to its positive effects [5] in sustaining the soil fertility by maintaining the crop residues on soil surface and improving water use efficiency and physical conditions of soils that is ultimately reflected in the enhanced crop productivity under rainfed conditions.

Choice of suitable variety is a prerequisite for successful crop production. In western Rajasthan, drought tolerant and early maturing varieties (to escape terminal drought) are always preferred due to weather abnormalities often experienced in this region. Yet, the use of particular cultivar depends on timing of onset of monsoon besides availability of seed (hybrid or composites) in the market. Timely and good rainfall of 30 mm received in the last week of June to the second week of July would promote cultivation of HYVs, while late arrival of effective rainfall generally encourage sowing of local cultivars. Since agronomic variations exist among pearl millet genotypes [6,7], evaluation of hybrids and composites was also considered as important aspect of present investigation. The present investigation carried out with the objectives (i) To find out the effect of tillage practices on growth and yield of pearl millet cultivars under rainfed condition, and (ii) To work out field water use efficiency and economics of pearl millet cultivars as influenced by tillage practices.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2014 comprising of four tillage practices in main plots and four cultivars of pearl millet in sub plots laid out in split plot design with four replications at the College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The pearl millet cultivars were sown at 45 cm x 10 cm spacing using seed rate of 4 kg ha^{-1} for each and applied dose of fertilizers was 40 kg N ha^{-1} and 32 kg P_2O_5 ha^{-1}. According to "Agro-ecological region map" brought out by the

National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Bikaner falls under Agro ecological region No. 2 (MgE1) under Arid ecosystem (Hot Arid Eco-region with desert and Saline soil), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity and hot & arid climate. Annual potential evapotranspiration (PET) in this region ranges between 1500-2000 mm. According to National Planning Commission, Bikaner falls under Agro-climatic zone XIV (Western Dry Region) of India. Benefit:Cost ratio was calculated to ascertain economic viability of the treatments.

3. RESULTS AND DISCUSSION

3.1 Effect of Different Treatments on Growth Parameters

3.1.1 Tillage practices

Results revealed that in comparison of zero tillage (T_2), the practice of conventional tillage + ridging (T_3) brought about significant improvement in plant height at harvest and in dry matter accumulation (DMA) at 45, 60 DAS and harvest (Table 2). The practice of conventional tillage (T_1) and zero tillage (T_2) did not differ significantly with each other in respect of all these growth characters, except DMA at 45 DAS. Despite the advantages of pre-sowing tillage operations that crop availed under conventional tillage + ridging treatment, the practice of ridging with zero tillage had brought about remarkable improvement in all the growth parameters and assigned this treatment (zero tillage + ridging) a status, equal to conventional tillage + ridging (T_3). Significant improvement in plant height and DMA at different stages due to conventional tillage + ridging over zero tillage was due to loosening of the soil more effectively than zero tillage practice and ridging at 30 DAS further added to it, which might have facilitated percolation and storage of water in the root zone as advocated by [8].

3.1.2 Cultivars

From the data pertaining to different growth attributes (Table 2), it is clear that plant height at harvest was the only character found to be influenced significantly by the different pearl millet cultivars. The variation in plant height of different pearl millet cultivars is obviously due to their genetic makeup as a result of breeding method adopted for their development. It can be confirmed from the fact that both the composites found superior than hybrids in respect of plant height at harvest but they did not differ significantly with each other. Similarly, both the hybrids also did not differ significantly with each other in this respect and recorded less height than composites. [6,9] also observed higher plant height in composites as compared to others.

Combined effect of tillage practices and cultivars on dry matter accumulation (DMA) at harvest (Table 1) was found significant among treatment combinations. Pusa Composite 443 with conventional tillage + ridging recorded maximum dry matter accumulation. Ridging, as stated earlier found beneficial both under conventional tillage and zero tillage but the cultivars, as usual, varied in their response.

Table 1. Combined effect of tillage practices and pearl millet cultivars on dry matter accumulation at harvest

Treatments mean	CT[1]	ZT[2]	CT+R[3]	ZT+R[4]
Pusa comp. 443	23.72	22.31	29.99	28.22
CZP 9802	25.37	26.57	27.03	23.39
MPMH 17	22.70	21.65	29.07	24.01
RHB 177	24.48	22.12	23.71	26.14
S.Em.± =1.37			C.D. (p=0.05)= 3.92	

3.2 Effect of Different Treatments on Yield Attributes and Yield

3.2.1 Tillage practices

A significant increase in yield and yield attributes *viz.,* effective tillers plant^{-1} (Table 2), grain yield, straw yield and biological yield (Table 3) was noticed under conventional tillage + ridging as compared to zero tillage. The zero tillage with the practice of ridging (T_4) also demonstrated similar effects on all these parameters. This increase in yield and yield attributes could be attributed to improvement in growth attributes (Tables 2 and 3) under the influence of different tillage treatments, as stated earlier, through increased availability of soil moisture and nutrients, which favourably influenced physiological processes of the plants and build up of food material. Positive effects of ridging on grain yield, straw yield and

[1] *Conventional tillage*
[2] *Zero tillage*
[3] *Conventional tillage + Ridging*
[4] *Zero tillage + Ridging.*

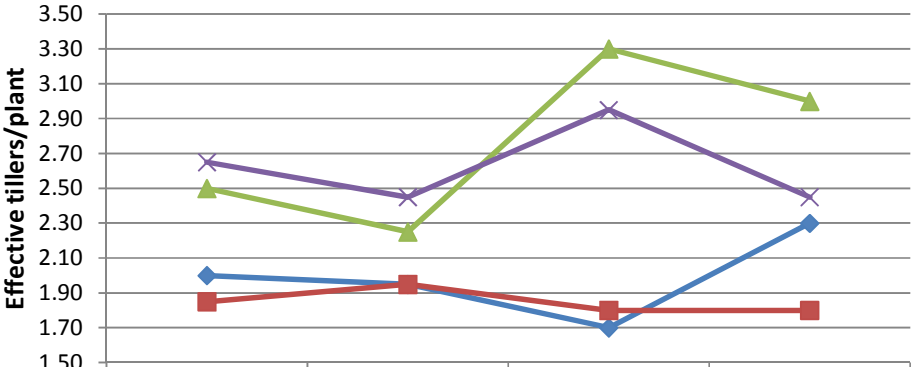
also on biological yield, either in conventional tillage (T_3) or in zero tillage plots (T_4), should also be viewed in the light of dry spell that crop experienced during its growth period. Our findings corroborate results of [10] who reported similar effects of riding in pearl millet. Beneficial effects of tillage practices on yield and yield attributes of different crops have been reported by several workers [11] (sorghum) and [12] (pearl millet) etc.). Significant improvement in grain and straw yield under conventional tillage + ridging treatment seems to be an outcome of increased dry matter accumulation (Table 2) right from early stages of crop growth till harvest due to favourable soil and plant environment so obtained under the influence of tillage practices, which led to increased photosynthetic efficiency under this treatment. Poorest crop growth and yield so obtained under zero tillage practice further explains these contentions. It can also be safely assumed that increased availability of nutrients to the crop in the presence of ample moisture might have helped in the increased synthesis of growth substances and naturally occurring phyto-hormones probably the auxin, which ultimately helped in increased effective tillers plant^{-1} (Table 2). Increased moisture availability due to the impact of ridging coincided with flower primordia initiation stage in our experiment, which might have helped in increased flowering, fertilization and grain formation resulting into higher yields.

3.2.2 Cultivars

The yield attributes and yield *viz.,* effective tillers plant^{-1}, grain yield, straw yield, biological yield and harvest index (Tables 2 and 3) differed significantly among cultivars of pearl millet which was tested in the present investigation. It was observed that number of effective tillers plant^{-1} (Table 2) was higher in hybrids (MPMH 17 and RHB 177) as compared to composites (Pusa composite 443 and CZP 9802). Hybrids also recorded significantly higher grain yield and higher harvest index as well, in comparison to composites (Table 3). The marked increase in grain yield so obtained with hybrids might be due to difference in their genetic potentials, which led to varied assimilation of photosynthates and its translocation to sink for grain yield formation. A point may be noted that all cultivars did not show significant variations in DMA at any of the stages but significant variations in harvest index were noted. This subscribes the view that hybrid (MPMH 17) had genetic ability to translocate dry matter more effectively to reproductive structures than that of composites. Moreover, grain yield formation is a complex process and governed by interaction between source and sink, hence the net photosynthesis and DMA primarily forms the basis of yield. Obviously, all the cultivars by virtue of their inheritance differ in such abilities and hybrids (MPMH 17) in our experiment took a lead in respect of yields (grain and straw). Significantly more number of effective tillers so observed in hybrids also contributed to grain yield because number of tillers per plant increases grain yield. [13] worked on the performance of hybrid and composite varieties of pearl millet and concluded that hybrids performed better than the composites. In terms of straw yield, however, composites namely, Pusa composite 443 and CZP 9802 registered excellence over hybrid. Significant increase in the plant height and slight increase in dry matter resulted in the increased straw yield of composites as compared to the hybrids. This opinion was supported by [14] who compared composites and hybrids in his study. Many reports {[15] and [7] etc.} have already indicated such variations in yields of hybrids and composite varieties.

Combined effect of treatments was found significant in terms of number of effective tillers plant^{-1}. It is obvious from the data (Fig. 1) that Cv. MPMH 17 recorded the highest number of effective tillers (3.30 plant^{-1}) under conventional tillage + ridging (T_3) treatment and found significantly superior to all other treatment combinations. Under zero tillage + ridging treatment (T_4) also, none other than MPMH 17 cultivar could establish its superiority, however, the other hybrid tested i.e. RHB 177 with 2.95 effective tillers plant^{-1} under treatment T_3 (Conventional tillage + ridging) found to be at par with this treatment combination (i.e. Cv. MPMH 17 under zero tillage + ridging).

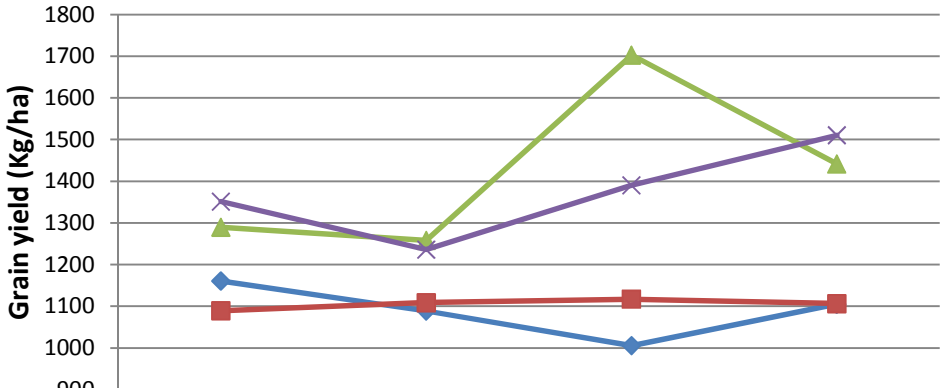
Data-table displayed along with Fig. 2 pertains to combined effect of different treatments on grain yield. It is obvious from the data that Cv. MPMH 17 recorded the highest grain yield of 1703 kg ha^{-1} under conventional tillage + ridging treatment (T_3) and significantly excelled all the other treatment combinations in this respect. Cv. MPMH 17 also gave grain yield of 1442 kg ha^{-1} with zero tillage + ridging treatment, which is statistically at par with the second best treatment combination i.e. RHB 177 under zero tillage + ridging (1511 kg ha^{-1}). It is further noticed that under conventional tillage (T_1) and zero tillage (T_2) treatments also, both the hybrids did not differ significantly from each other in respect of grain yield.



	Conventional tillage	Zero tillage	Conventional tillage + ridging	Zero tillage + ridging
Pusa Comp. 443	2.00	1.95	1.70	2.30
CPZ 9802	1.85	1.95	1.80	1.80
MPMH 17	2.50	2.25	3.30	3.00
RHB 177	2.65	2.45	2.95	2.45

S.Em.+ =0.10 C.D.(p=0.05)= 0.27

Fig. 1. Combined effect of tillage practices and cultivars on effective tillers per plant



	Conventional tillage	Zero tillage	Conventional tillage + ridging	Zero tillage + ridging
Pusa Comp. 443	1161	1089	1006	1105
CPZ 9802	1089	1109	1117	1106
MPMH 17	1290	1258	1703	1442
RHB 177	1351	1236	1391	1511

S.Em.± =39 C.D.(p=0.05)= 112

Fig. 2. Combined effect of tillage practices and cultivars on grain yield

3.3 Effect of Different Treatments on Field Water Use Efficiency

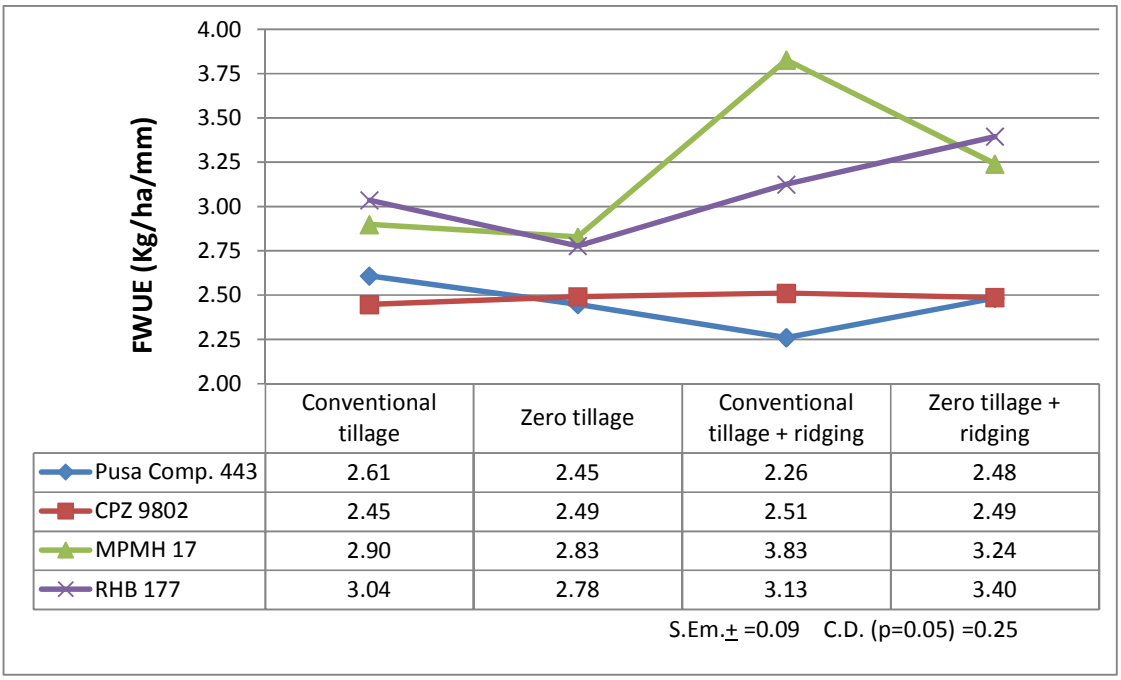
3.3.1 Tillage practices

The conventional tillage + ridging treatment (T_3) though exhibited the highest water use efficiency (2.93 kg ha^{-1} mm^{-1}) yet differences with zero tillage (T_2) were found significant only (Table 3). The practice of ridging significantly increased the field water use efficiency over zero tillage because better conservation of rain water and its prolonged availability, which resulted in higher grain yield. [16] reported higher irrigation water use efficiency under conventional tillage as compare to reduced tillage and zero tillage practices. [12] also states that WUE was highest with deep tillage as compare to reduced tillage. In zero tillage, lower soil moisture content might be due to the fact that increased resistance to water infiltration offered low retention of water in the soil.

3.3.2 Cultivars

Water use efficiency is calculated on the basis of grain yield obtained by the different pearl millet cultivars and water used by them in producing grain yield. It showed the ability of cultivars in utilizing the applied water. Field water use efficiency was significantly influenced by different pearl millet cultivars. Owing to higher grain yield and longer availability of applied irrigation water, hybrid MPMH 17 exhibited significantly higher field water use efficiency closely followed by other hybrid RHB 177. Both the composite cultivars namely, CZP 9802 and Pusa composite 443 were significantly inferior to hybrids in this respect (Table 3). [17] also found higher water use efficiency in sorghum hybrids (5.45-6.42 kg ha^{-1} mm^{-1}) than sorghum varieties (5.33-5.75 kg ha^{-1} mm^{-1}).

Data-table displayed along with Fig. 3 pertains to combined effect of tillage treatments and pearl millet cultivars on field water use efficiency. It is quite clear from the data that Cv. MPMH 17 in combination with conventional tillage + ridging treatment resulted in the highest field water use efficiency of 3.83 Kg ha^{-1} mm^{-1} and proved its significant superiority over rest of the other treatment combinations. Despite their statistical significance, other treatment combinations do not deserve any logical mention.



	Conventional tillage	Zero tillage	Conventional tillage + ridging	Zero tillage + ridging
Pusa Comp. 443	2.61	2.45	2.26	2.48
CPZ 9802	2.45	2.49	2.51	2.49
MPMH 17	2.90	2.83	3.83	3.24
RHB 177	3.04	2.78	3.13	3.40

S.Em.± =0.09 C.D. (p=0.05) =0.25

Fig. 3. Combined effect of tillage practices and cultivars on field water use efficiency

Table 2. Effect of tillage practices on growth and yield attributes of pearl millet cultivars

Treatments	Plant stand ('000 ha^{-1})		Plant height (cm)	Dry matter accumulation (g plant^{-1})			Effective tillers plant^{-1}	Test weight (g)
	45 DAS	At harvest	At harvest	45 DAS	60 DAS	At harvest		
Tillage practices								
Conventional tillage (T_1)	205.63	196.25	166.54	5.78	14.73	24.07	2.25	7.34
Zero tillage (T_2)	203.75	194.38	163.39	5.63	14.35	23.16	2.15	7.29
Conventional tillage + Ridging (T_3)	207.50	199.38	171.84	6.06	15.69	27.45	2.44	7.44
Zero tillage + Ridging (T_4)	206.25	197.50	168.40	5.91	15.22	25.44	2.39	7.40
S.Em.±	2.93	3.23	2.03	0.11	0.36	0.97	0.05	0.14
C.D. (p=0.05)	**NS**	**NS**	6.50	0.36	1.16	3.11	0.16	**NS**
Cultivars								
Pusa composite-443 (C_1)	206.25	196.88	172.20	6.07	15.55	26.06	1.99	7.24
CZP 9802 (C_2)	204.38	195.00	170.19	5.85	15.17	25.59	1.85	7.32
MPMH-17 (C_3)	206.88	198.13	163.48	5.76	14.72	24.36	2.76	7.49
RHB-177 (C_4)	205.63	197.50	164.30	5.70	14.54	24.11	2.63	7.42
S.Em.±	2.70	2.56	2.16	0.15	0.37	0.68	0.05	0.09
C.D. (p=0.05)	**NS**	**NS**	6.18	**NS**	**NS**	**NS**	0.14	**NS**

**NS: Non Significant*

Table 3. Effect of tillage practices on yields, harvest index, FWUE and economics of pearl millet cultivars

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest index (%)	Field water use efficiency (Kg ha^{-1}mm^{-1})	Net return (₹ ha^{-1})	B:C ratio
Conventional tillage (T_1)	1223	3304	4526	27.2	2.75	21645	2.87
Zero tillage (T_2)	1173	3237	4410	26.8	2.64	23326	3.64
Conventional tillage + Ridging (T_3)	1304	3607	4911	26.4	2.93	23570	2.93
Zero tillage + Ridging (T_4)	1291	3484	4775	27.7	2.90	25546	3.69
S.Em.±	26	65	65	0.6	0.06	444	-
C.D. (p=0.05)	84	207	208	**NS**	0.19	1420	-
Cultivars							
Pusa composite-443 (C_1)	1090	3649	4739	23.4	2.45	22244	3.18
CZP 9802 (C_2)	1105	3513	4618	24.0	2.48	21859	3.13
MPMH-17 (C_3)	1423	3258	4681	30.4	3.20	25482	3.44
RHB-177 (C_4)	1372	3211	4583	30.2	3.08	24502	3.38
S.Em.±	19	59	59	0.5	0.04	363	-
C.D. (p=0.05)	56	170	**NS**	1.6	0.13	1040	-

**NS: Non Significant*

3.4 Effect of Different Treatments on Economics

3.4.1 Tillage practices

The cost of cultivation and net return were affected due to different tillage practices on account of cost involved. The treatment zero tillage + ridging accrued more net return (₹ 25546 ha^{-1}) and B:C ratio (3.69:1) as compared to conventional tillage + ridging (Table 3) because there was no cost of field preparation was involved in case of zero tillage practice but in conventional tillage system, higher cost of tillage operations is involved in field preparation. These findings are in confirmation with that reported by [11,16].

3.4.2 Cultivars

Data (Table 3) indicated that the highest net return (₹ 25482 ha^{-1}) and B: C ratio (3.44:1) was realized with hybrid MPMH 17. In terms of net reruns, however, this cultivar (MPMH 17) did not differ significantly from other hybrid RHB177. Composite cultivars namely, Pusa composite 443

and CZP 9802 were inferior to both the hybrids. This is obviously due to high returns to investment of MPMH 17. Hybrid cultivars recorded larger B:C ratio than composite cultivars. However, data on combined effect of treatments, gave clearer picture of treatment suitability in terms of net returns ha^{-1}. The Composite variety Pusa Composite 443 under zero tillage + ridging treatment recorded the net return of (₹ 27742 ha^{-1}), which is statistically at par with that recorded by RHB 177 under zero tillage + ridging treatment (₹ 27156 ha^{-1}) and MPMH 17 under conventional tillage + riding (₹ 28932 ha^{-1}).

Table 4. Combined effect of tillage practices and pearl millet cultivars on net return (₹ ha^{-1})

Treatments mean	CT[5]	ZT[6]	CT+R[7]	ZT+R[8]
Pusa comp. 443	19374	22549	19311	27742
CZP 9802	21180	23936	21382	20937
MPMH 17	24074	21766	28932	27156
RHB 177	21951	25055	24654	26347
S.Em.± =725			C.D. (p=0.05)= 2080	

It is clear from the data in Table 4 cultivar MPMH 17 gave the highest net return of ₹ 28932 under conventional tillage + ridging treatment. This combination of treatments (i.e. cultivar MPMH 17 under conventional tillage + ridging) proved significantly superior to other treatment combinations except, where Cv. Pusa composite 443 or MPMH 17 was grown under zero tillage + ridging.

4. CONCLUSION

On the basis of one year experimentation, it may be concluded that higher gain yield and net return of pearl millet can be obtained by growing MPMH 17 in combination with zero tillage + ridging or conventional tillage + ridging in rainfed areas of western Rajasthan.

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[5] *Conventional tillage*
[6] *Zero tillage*
[7] *Conventional tillage + Ridging*
[8] *Zero tillage + Ridging.*

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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