

Rainwater conservation and yield of sorghum (*Sorghum bicolor*) as influenced by tillage and cover management practices in red soils

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ABSTRACT

A field experiment was conducted during *kharif* of 2002 to 2003 at 2% slope in red soils at Datia, Madhya Pradesh to evolve a suitable tillage and surface mulching practice for higher rainwater conservation for augmenting the crop growth and yield of sorghum [*Sorghum bicolor* (L.) Monech.] under rainfed conditions. Nine treatment combinations [T₁, zero tillage (no crop); T₂, T₁ + sorghum; T₃, T₂ + *in situ* surface mulching; T₄, traditional tillage (no crop); T₅, T₄ + sorghum; T₆, T₅ + *in situ* surface mulching; T₇, improved tillage (no crop); T₈, T₇ + sorghum and T₉, T₈ + *in situ* surface mulching] were evaluated under randomized block design with 3 replications. Maximum infiltration rate (5.6 cm/hr), pore space (47.9%), water holding capacity (37.1 cm of 0-30 cm soil layer) and water stable aggregates (48.11 and 49.92 of 0-15 and 15-30 cm soil layer, respectively) and lowest bulk density (1.38 Mg/m³) were recorded under improved tillage + sorghum + *in situ* surface mulching (T₉). Bulk density was maximum (1.54 Mg/m³) under zero tillage (T₁). Owing to higher rainwater conservation (78.9% mean of 2 years) growth, yield attributes and yield of sorghum increased significantly under increasing tillage depths and *in situ* surface mulching. Thus highest grain (3.31 t/ha) and stover (9.98 t/ha) yield and moisture use efficiency (7.84 kg/ha-mm) were recorded under T₉. The results indicated that improved tillage coupled with *in situ* surface mulching of sunnhemp was helpful for higher rain water conservation and increasing the yield of sorghum under rainfed conditions in red soils under semi - arid conditions of Madhya Pradesh.

Key words : Luvisols, Mulch, Rainwater, Runoff, Soil, Sorghum, Sunnhemp

An important avenue for achieving increased production goals is to enhance the productivity of vast areas under rainfed agriculture, which constitute nearly 60% of the net cultivated area of the country. Red soil group is one of the major groups among red, black and submontane soil which were found extensively in the rainfed regions. Most red soils have low water retention capacity. Under traditional cultivation practice these soils suffer from rapid water runoff and erosion reducing the productive capacity (Abrol and Sangar, 2006). Red soils have considerable agronomic potential but to achieve this potential there is need to popularize effective soil moisture conservation practices. The Bundelkhand region (23° 10' – 26° 30' N and 78° 20' – 81° 40' E) with a geographical area of 7.04 m ha in Central India has red soils in about 50% of its geographical area and rainfed agriculture is a common practice in view of limited ground water availability in the region. The red soils are found mostly on higher elevation in

topo sequences hence major part of rainfall is lost as surface runoff. Rainwater cannot enter in to deeper soil layer because of presence of hard and compact layer in sub-soil or due to crusting and hard setting behavior. As a result, crop growth is restricted and runoff, soil loss, nutrient loss and growth of weeds is increased resulting in poor yields. Under present situation, improved tillage has been viewed as a central management practice of loosening of impeded sub-soil layer and use of soil surface covers such as crop residue, grass mulch, green manure and legume crops have been advocated for improvement of soil environment and water conservation. Keeping these facts in view, present study was initiated to evolve a suitable tillage and surface mulching practice for higher rainwater conservation for augmenting the crop growth and yield of sorghum [*Sorghum bicolor* (L.) Monech.] in red soils under rainfed conditions.

MATERIALS AND METHODS

A field experiment was conducted during rainy season (*kharif*) of 2002 to 2003 in red soils at Datia Research

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Centre of Central Soil and Water Conservation Research and Training Institute (25° 40' N, 78° 28' E and 342.42 m above mean sea level). The climate of Datia is semi-arid with an average annual rainfall of 865 mm. Nearly 90% of the total precipitation is received in the monsoon extending from middle of June to September. The July and August months experience the heaviest rainfall, receiving on an average more than 250 to 300 mm during most of the years. Long dry spells during monsoon are also common features. The soils of experimental site come under red soils (alfisols) of Bundelkhand which have developed over granites and gneiss type parent material. These are coarse gravelly textured, shallow, neutral to slightly alkaline in reaction, low in organic carbon and available nutrients. The experimental soil was sandy loam in texture with pH 7.2, organic carbon 0.25%, EC 0.13 dS/m, bulk density 1.60 Mg/m³, and available N, P and K 255.0, 15.9 and 151.0 kg/ha, respectively. The experiment consisted of 9 treatment combinations viz., T₁, zero tillage (no crop); T₂, T₁ + sorghum; T₃, T₂ + *in situ* surface mulching; T₄, traditional tillage (no crop); T₅, T₄ + sorghum; T₆, T₅ + *in situ* surface mulching; T₇, improved tillage (no crop); T₈, T₇ + sorghum and T₉, T₈ + *in situ* surface mulching. These treatments were evaluated under randomized block design with 3 replications. In zero tillage, only furrows were opened for sowing. In traditional tillage, tillage depth was maintained up to 7 cm and in improved tillage treatment, soil was tilled up to a depth of 20 cm. Two manual weedings were carried out at 25 and 45 days after sowing (DAS). In zero tillage plots, weeds were cut from ground level with the help of a sickle at the weeding to avoid disturbance to soil, however, under traditional and improved tillage treatments, weeds were removed with the help of a 'kharpi'. Plot size was 15 m × 3.4 m and land slope was 2%. Sorghum 'CSH 14' was grown at 60 cm × 15 cm spacing on contours and recommended package of practices were followed. A fertilizer dose of 80 kg N and 17.6 kg P/ha was applied as basal through urea and di-ammonium phosphate respectively. A row of sunnhemp was grown in between 2 rows of sorghum and was cut from ground level and green biomass was spread uniformly on ground surface as mulch at 25 DAS as per treatment. The crop was sown on July 3 and harvested on November 2 in 2002, however, during 2003 the crop was sown on July 15 and harvested on November 11. During 2002, 36.0 mm rainfall was received before sowing, 41.7 mm during sowing to 25 days and 633.2 mm between 26 day to harvest. During 2003, 51 mm rainfall was received before sowing, 238.8 mm between sowing to 25 days and 835.0 mm during 26 day to harvest. The daily distribution of rainfall during crop season has been depicted for both the years in Fig. 1. Runoff was measured by diverting 1/25 part of the

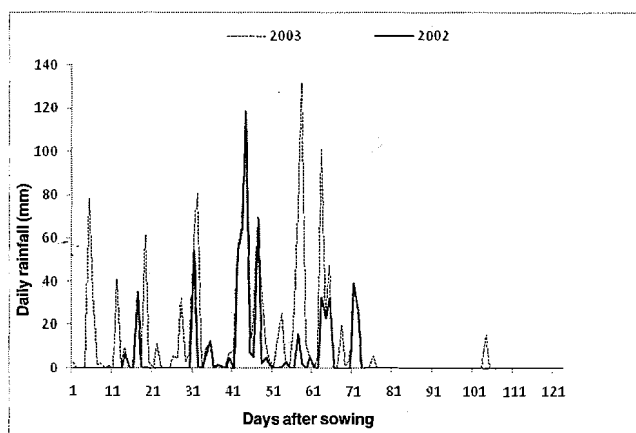


Fig. 1. Daily rainfall distribution (mm) during crop growth period (sowing to harvest) during 2002 and 2003

runoff to the collection tanks with the help of a Ramser's sampler. Event wise runoff was measured and summed to calculate the total seasonal runoff (Singh *et al.*, 1977). Rainwater conservation was worked out by subtracting the total runoff from received rainfall during crop growth period (sowing to harvest). Observations on growth, yield and yield attributes were recorded at harvest. Soil analysis was done using standard chemical procedures. Periodical soil moisture from 0-15, 15-30 and 30-45 cm soil layer was taken in to account for computing the moisture use. After experimentation, some soil physical properties were measured. Bulk density and total porosity were measured for two soil layers 0-15 and 15-30 cm by core sampler (Black, 1965). The infiltration rate was determined with double ring infiltrometre (Bertrand, 1965).

RESULTS AND DISCUSSION

Runoff and *in situ* rain water conservation

There were 13 and 15 runoff events recorded during 2002 and 2003, respectively (Tables 1 and 2). The runoff of all events was influenced significantly by tillage, cropping and surface mulching during both the years. The event wise runoff decreased with the increasing tillage depth, introduction of sorghum and *in situ* surface mulching of sunnhemp. Total seasonal runoff also followed the similar trend during both the years. During 2002, maximum total seasonal runoff (372.6 mm) was recorded under zero tillage (T₁), it reduced to 295.4 mm with the introduction of sorghum (T₂) and it further reduced to 264.6 mm with *in situ* surface mulching of sunnhemp (T₃). The magnitude of total seasonal runoff gradually reduced under traditional and improved tillage following the similar trend with the introduction of sorghum and *in situ* surface mulching of sunnhemp. Minimum total seasonal runoff (168.3 mm) was recorded under improved tillage + sorghum + *in situ* surface mulching (T₉). During 2003, the

Table 1. Date-wise rain fall, runoff and rain water conservation (from sowing to 25 days and 26th day to harvest) as influenced by cropping, tillage and mulching during 2002

Treatment	Date and Rainfall (mm)														Total	Rain water conservation		
	Aug. 3	Aug. 7	Aug. 14	Aug. 15	Aug. 16	Aug. 17	Aug. 19	Aug. 29	Sep. 4	Sep. 5	Sep. 6	Sep. 12	Sep. 13	Sowing to 25 days (mm)		26 th days to harvest		
	54.5	12.5	54.2	65.0	118.7	7.4	69.0	15.8	32.7	23.0	32.5	39.2	26.3			mm	%	
	Runoff (mm)																	
T ₁	29.1	4.4	27.4	54.3	110.8	5.4	59.3	1.9	17.5	12.9	17.4	13.1	19.1	372.6	41.7	218.9	37.0	
T ₂	20.8	3.4	20.4	43.0	89.8	4.1	50.7	0.7	11.0	10.2	13.9	10.7	16.7	295.4	41.7	296.1	50.1	
T ₃	17.7	2.5	18.8	37.1	85.0	3.4	49.2	0.0	10.7	7.9	9.9	8.5	13.9	264.6	41.7	326.9	55.3	
T ₄	22.4	3.5	28.6	55.4	85.1	4.3	51.5	3.4	14.0	11.4	16.3	11.7	15.8	323.4	41.7	268.1	45.3	
T ₅	19.0	2.5	23.3	45.3	67.7	3.6	41.3	0.9	10.5	9.2	13.0	9.3	12.6	258.2	41.7	333.3	56.3	
T ₆	16.5	1.8	18.2	38.7	61.0	2.6	38.2	0.0	7.0	6.8	8.5	8.1	10.1	217.5	41.7	374.0	63.2	
T ₇	18.1	2.9	22.6	40.9	79.9	3.7	37.7	0.9	10.1	10.2	15.6	9.4	8.3	260.3	41.7	331.2	56.0	
T ₈	14.3	1.6	17.6	35.8	60.2	2.2	32.3	0.7	7.5	7.9	10.5	7.8	7.3	205.7	41.7	385.8	65.2	
T ₉	10.9	1.0	14.5	29.5	52.0	1.2	27.3	0.0	6.3	6.3	7.4	5.7	6.2	168.3	41.7	423.2	71.6	
SEm ±	1.4	0.2	1.1	3.2	4.0	0.5	2.5	0.6	0.6	0.6	0.8	1.0	0.8	11.8		9.0	1.5	
CD (P=0.05)	4.1	0.7	3.3	9.7	12.1	1.4	7.5	1.8	1.8	1.9	2.2	3.0	2.3	36.9		26.8	4.5	

Table 2. Date-wise rainfall, runoff and rainwater conservation (from sowing to 25 days and 26th day to harvest) as influenced by cropping, tillage and mulching during 2003

Treatment	Date and Rainfall (mm)														Total	Rain water conservation				
	Jul. 20	Jul. 21	Jul. 27	Aug. 3	Aug. 12	Aug. 16	Sep. 1	Sep. 6	Sep. 9	Sep. 10	Sep. 11	Sep. 12	Sep. 16	Sep. 18		Sep. 21	Sowing to 25 days		26 th day to harvest	
	78.3	34.0	40.6	61.5	32.5	80.0	35.5	24.5	19.0	56.5	129.0	11.0	68.5	14.8		19.2	mm	%	mm	%
	Runoff (mm)																			
T ₁	41.3	30.0	30.7	45.6	24.9	46.1	19.1	13.3	10.6	31.9	82.5	8.1	52.0	7.9	13.1	457.1	91.2	38.2	286.6	48.1
T ₂	29.9	24.1	20.4	30.7	20.0	29.5	13.4	7.2	8.5	24.4	52.0	5.3	40.9	4.6	8.1	319.0	133.7	56.0	382.2	64.1
T ₃	29.9	22.0	19.8	22.1	12.5	21.8	12.4	5.8	5.9	16.8	42.1	1.6	36.6	2.6	5.8	257.7	145.1	60.8	432.1	72.5
T ₄	35.5	29.0	25.0	29.8	21.5	38.3	16.4	11.3	11.0	28.0	46.2	7.0	49.6	6.4	11.4	366.4	119.5	50.0	349.0	58.5
T ₅	29.4	27.2	15.7	21.6	13.6	18.5	11.7	4.8	5.6	21.6	40.7	3.0	35.6	2.8	6.9	258.7	144.9	60.7	431.3	72.4
T ₆	26.0	24.3	16.2	15.8	11.6	14.0	8.4	1.2	4.2	13.5	36.6	0.9	30.5	0.6	4.8	208.6	156.5	65.6	469.8	78.8
T ₇	30.9	26.5	17.1	23.0	16.3	21.8	12.8	6.5	8.8	19.4	47.1	3.7	33.7	2.3	7.5	277.4	141.3	59.2	416.2	69.8
T ₈	21.5	23.4	14.2	15.7	11.0	18.0	8.3	2.7	4.1	12.1	34.6	1.7	30.0	0.6	4.5	202.4	164.1	68.7	468.4	78.6
T ₉	19.4	19.5	9.4	12.2	7.0	14.0	5.4	0.0	0.6	7.9	29.4	0.0	19.0	0.0	2.1	145.9	178.4	74.7	510.6	85.7
SEm ±	1.4	1.2	2.1	2.9	1.4	3.3	1.0	1.2	0.9	2.1	3.2	1.2	2.5	0.9	1.4	18.1	5.4	2.3	13.7	2.3
CD (P=0.05)	4.2	3.7	6.3	8.6	4.2	10.0	3.1	3.7	2.7	6.3	9.5	3.6	7.6	2.7	4.1	54.2	16.2	6.8	41.0	6.9

(MUE) of sunnhemp

The quantum of dry biomass yield significantly increased under increasing tillage depth during both the years (Table 3). There was 110 and 294% higher dry biomass yield recorded under traditional and improved tillage during 2002 and 49 and 125% during 2003 over zero tillage. Highest dry biomass yield (169.4 and 202.2 kg/ha during 2002 and 2003, respectively) was recorded under improved tillage + sorghum + sunnhemp (T_9) during both the years, whereas lowest dry biomass yield (43.0 and 90.0 kg/ha during 2002 and 2003, respectively) was recorded under zero tillage + sorghum + sunnhemp (T_3).

The moisture use by sunnhemp before mulching was significantly influenced by different tillage depths during 2003 (Table 3). Lowest moisture use (192.8 mm) was recorded under zero tillage + sorghum + sunnhemp (T_2) which increased to 211.9 mm under traditional tillage + sorghum + sunnhemp (T_6) and highest (228.4 mm) was recorded in improved tillage + sorghum + sunnhemp (T_9). The MUE of sunnhemp increased under increasing tillage depths during both the years, however, the increase in 2003 was non-significant. There was 107 and 296% increase in MUE in 2002 and 34 and 89% increase in 2003 was recorded under traditional (T_6) and improved tillage (T_9) over zero tillage in respective year. The favorable soil environment and higher rainwater conservation under improved tillage resulted in higher dry biomass yield and MUE of sunnhemp.

Growth, yield attributes, yield and MUE of sorghum

Plant height and yield attributes of sorghum increased significantly with increase in tillage depth (Table 3). *In situ* surface mulching was also found helpful in increasing the plant height as well as yield attributes. Maximum plant

height, cob length, grain weight per cob and 1,000 grain weight were recorded under improved tillage + sorghum + *in-situ* surface mulching (T_9) whereas, minimum values were recorded under zero tillage + sorghum (T_2) during 2002 and 2003.

Tillage depth significantly influenced the grain and stover yield of sorghum (Table 3). Under improved tillage (T_8) grain yield increased by 226 and 47% during 2002 and 157 and 25% during 2003 over zero (T_2) and traditional tillage (T_5), respectively. *In situ* surface mulching was also found helpful in increasing the grain and stover yield under all tillage depths. Highest grain yield of 2.76 and 3.86 t/ha was recorded under T_9 (improved tillage + *in situ* surface mulching during 2002 and 2003, respectively). There was 79, 22 and 10% increase in grain yield under T_3 , T_6 and T_9 because of *in situ* surface mulching of sunnhemp during 2002 and 62, 9 and 11% during 2003 over no surface mulching treatment (T_2 , T_5 and T_8) under zero, traditional and improved tillage, respectively. The stover yield also increased significantly under increasing tillage depth and *in situ* surface mulching. It recorded 3.90, 6.48 and 7.80 t/ha in 2002 and 4.12, 8.24 and 10.78 t/ha in 2003 under zero (T_2), shallow (T_3) and improved tillage (T_8) which increased to 4.16, 7.32 and 8.67 t/ha in 2002 and 6.23, 9.03 and 11.29 t/ha in 2003 with *in situ* surface mulching of sunnhemp in T_3 , T_6 and T_9 , respectively.

MUE increased significantly under increasing tillage depth and surface mulching of sunnhemp in both the years (Table 3). During 2002 and 2003, lowest MUE (2.26 and 2.26 kg/ha-mm) was recorded under zero tillage (T_2), which increased under traditional tillage (4.48 and 4.81 kg/ha-mm) and it further increased considerably under

Table 4. Soil properties as influenced by cropping, tillage and mulching (after experimentation)

Treatment	Pore space (%) 0-30 cm	Water holding capacity (cm) 0-30 cm	Water stable aggregates		Bulk density (Mg/m ³) 0-15 cm	Infiltration rate (cm/hr)
			0-15 cm	15-30 cm		
T_1	41.5	32.1	33.80	34.68	1.54	0.28
T_2	44.0	32.7	35.46	36.02	1.50	1.56
T_3	45.9	34.1	39.74	48.12	1.46	1.98
T_4	43.8	30.9	37.97	39.89	1.52	2.21
T_5	45.5	32.4	41.73	38.24	1.51	3.04
T_6	47.2	35.1	42.26	47.89	1.44	3.62
T_7	45.2	34.1	37.56	40.90	1.50	4.24
T_8	47.2	35.1	42.56	41.27	1.47	5.11
T_9	47.9	37.1	48.11	49.92	1.38	5.60
SEm±	18.2	2.5	2.34	3.94	0.20	0.11
CD (P=0.05)	NS	NS	7.03	NS	0.05	0.33

improved tillage (5.85 and 5.44 kg/ha-mm) in T_5 and T_8 , respectively. The MUE increased by 119, 45 and 26% in 2002 and 154, 52 and 52% in 2003 with surface mulching of sunnhemp in T_3 , T_6 and T_9 , respectively. Highest MUE of 7.39 and 8.28 kg/ha-mm was recorded under improved tillage with surface mulching of sunnhemp (T_9) in 2002 and 2003, respectively. The increase in grain and stover yield and MUE due to rainwater conservation under increasing tillage depth and *in situ* surface mulching was attributed to higher crop growth which in turn reflected on crop growth and yield attributes. The findings are in accordance with those of Pandey *et al.* (2005).

Soil properties

The soil physical properties after experimentation were significantly influenced by tillage and surface cover management practices (Table 4). The bulk density reduced significantly with the increasing tillage depth and was recorded minimum (1.38 Mg/m³) under improved tillage + sorghum + *in situ* surface mulching (T_9) whereas maximum (1.54 Mg/m³) was recorded under zero tillage (T_1). Pore space and water holding capacity of 0-30 cm soil layer also increased with increasing tillage depth and surface mulching though the increase was non-significant. Maximum pore space (47.9%) and water holding capacity (37.1 cm) were recorded under improved tillage + sorghum + *in situ* surface mulching (T_9) and minimum (41.5% and 32.1 cm) in zero tillage (T_1). The water stable aggregates were also increased with increasing tillage depth and *in situ* surface mulching. Maximum water stable aggregates (48.11 and 49.92) were recorded in improved tillage + sorghum + *in situ* surface mulching (T_9) whereas minimum (33.80 and 34.68) were recorded under in zero tillage (T_1) in 0-15 and 15-30 cm soil layer, respectively. The infiltration rate increased under increasing tillage depth and *in situ* surface mulching and was maximum (5.60 cm/hr) under improved tillage + sorghum + *in situ* surface mulching (T_9) and minimum (0.28 cm/hr) under

zero tillage (T_1). The increase in infiltration rate under improved tillage was attributed to improved porosity, reduced runoff and bulk density and favorable tilled conditions. This is in agreement with the findings of and Pandey *et al.* (2005) and Gurumurthy and Rao (2006a).

Thus it is concluded that in red soils, improved tillage (20 cm) coupled with *in situ* surface mulching of sunnhemp is helpful for enhancing rain water conservation as well as its retention and utilization for achieving higher yield of sorghum under rainfed conditions in semi-arid conditions of Madhya Pradesh.

REFERENCES

- Abrol, I.P. and Sangar, S. 2006. Sustaining Indian agriculture – conservation agriculture the way forward. *Current Science* **91**(8): 1020–1025.
- Bhardwaj, S.P. and Sindhwali, N.S. 1998. Zero tillage and weed mulch for erosion control on sloping farm land in Doon Valley. *Indian Journal of Soil Conservation* **26**: 81–85.
- Bertrand, A.R. 1965. Rate of water intake in field. In: *Methods of Soil Analysis, Part- I*. (Black, C. A. Ed.) pp. 374–390. American Society of Agronomy, Madison, Wisconsin.
- Black, C.A. 1965. *Methods of Soil Analysis*, Part II. American Society of Agronomy, Madison, Wisconsin, USA.
- Gurumurthy, P. and Rao, M.S. 2006. Effect of tillage and irrigation regimes on soil physical properties and performance of sunflower in rice fallow 1. Soil physical properties and crop establishment. *Journal of the Indian Society of Soil Science* **54**(1): 12–17.
- Gurumurthy, P. and Rao, M.S. 2006a. Effect of tillage and irrigation regimes on soil physical properties and performance of sunflower in rice fallows. II. Water use and crop yield. *Journal of the Indian Society of Soil Science* **54**(1): 18–23.
- Pandey, I.B., Sharma, S.L., Tiwari, S. and Misra, S.S. 2005. Economics of tillage and weed management system for wheat (*Triticum aestivum*) after lowland rice (*Oryza sativa*). *Indian Journal of Agronomy* **50**(1): 44–47.
- Singh, R., Prasad, S. N., Singh, K. D. and Samra, J. S. 1977. Run-off, Soil and Nutrient losses in Vertisols of South Eastern Rajasthan. Bulletin No. T-34/K-4, Central Soil and Water Conservation Research and Training Institute, Research Centre, Kota, Rajasthan.