

Conservation measures for resource conservation and enhancing yield of sorghum (*Sorghum bicolor* L.) in red soils of Bundelkhand region in central India

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ABSTRACT

A study was conducted during rainy seasons (*kharif*) of 2005 to 2007 at CSWCRTI, Research Centre, Datia, Madhya Pradesh to evaluate the efficiency of conservation measures in reducing erosion losses and increasing sorghum yield on slopy agricultural lands in red soils. The treatments included farmer's practice (control), earthen contour bunds (CB) at 0.7 and 0.9 m VI, vegetative barriers (VB) of *Cenchrus ciliaris* and *Heteropogon contortus* at 0.7 m VI in runoff plots of 80x20m at 3% slope. Sorghum [*Sorghum bicolor* (L.) Monech.] was grown along contours except control under rainfed conditions in all the plots with recommended package of practices. Results indicated that different conservation measures were effective in conserving higher rainwater, reducing soil and nutrient losses and increasing yield of sorghum over control. Mean results of 3 years showed that highest runoff (31.6%), soil loss (939 kg ha⁻¹) and nutrient loss (organic carbon 10.39, N 2.36, P 0.63 and K 0.93 kg ha⁻¹) and lower grain yield (481 kg ha⁻¹) of sorghum were recorded under farmer's practice. However, lowest runoff (3.0%), soil loss (31 kg ha⁻¹) and nutrient loss (organic carbon 0.39, nitrogen 0.18, phosphorus 0.07 and potassium 0.18 kg ha⁻¹) and higher grain yield (531 kg ha⁻¹; 11% increase) of sorghum over farmer's practice were obtained under contour bund at 0.7 m VI. Study revealed that among different conservation measures, CB at 0.7 m VI found best for resource conservation and enhancing the yield of sorghum on sloping agricultural lands in red soils of Bundelkhand region in Central India.

1. INTRODUCTION

Soil erosion is a severe problem in most of the regions in the world. This situation exists in almost all parts of the India. It is estimated that out of 120.7 M ha degraded area in India, about 68% is affected by water erosion. The annual production loss in major rainfed crops (cereals, oilseeds and pulses) due to water erosion in India is estimated around 15.7% of total production and is equivalent to 162 billion with a minimum support price of 2008-09 (Anonymous, 2010). Conservation of top fertile soil and rainwater are a major concern for resource conservation and greater productivity of rainfed areas that constitute nearly 60% of the net cultivated area in India (Narayan and Biswas, 2012). Red soil group is one of the major three soil groups (red, black and submontane soil) found extensively in the rainfed

regions. Most red soils have low soil fertility and poor water retention capacity further these soils generally observed on higher elevation in topo-sequences that leads to higher rainfall as surface runoff (Narayan and Biswas, 2012). Under traditional cultivation practice, these soils suffer from rapid water erosion which reduces production capacity (Abrol and Sangar, 2006). Red soils have considerable agronomic potential which can be achieved through effective soil and water conservation practices. Bundelkhand region (7.04 M ha) consisting 6 districts of Madhya Pradesh and 7 districts of Uttar Pradesh with undulating topography in Central India has red soils in about 50% of its geographical area. Nearly 70% of the total area in the region is subjected to varying degree of erosion hazards (Tiwari and Narayan, 2010). About 70% area of the region

comes under rainfed agriculture. Conventional farming on sloping terrain in the region accelerates soil erosion reducing soil fertility and productivity. Contour bunds act as a barrier, check the velocity of flowing water, allow infiltration into the soil and help in soil and water conservation. Vegetative barriers slow down and disperse surface runoff causing deposition of eroded sediments while allowing some runoff to pass through (Dabney *et al.*, 1999). Vegetative barriers that involve intercropping of perennial leguminous trees or grass strips with annual crops reduce erosion (Angima *et al.*, 2003 and Owino *et al.*, 2006). Lack of scientific information on effect of mechanical and vegetative barriers on resource conservation and productivity of crops in Alfisols of semi-arid region of Bundelkhand in Central India resulted in situation of this study.

2. MATERIALS AND METHODS

A field experiment was conducted during 2005 to 2007 at CSWCRTI, Research Centre, Datia (25° 40' N, 78° 28' E and 342.42 m above MSL), Madhya Pradesh. The climate of Datia is semi-arid with an average annual rainfall of 830 mm (1968 to 2007). Nearly 90% of the total precipitation is received during monsoon period (from middle of June to September) with long dry spells causing frequent crop failure. The experimental soil is shallow, red, coarse gravely textured and sandy loam with pH 7.3, organic carbon 0.21%, EC 0.14 dS m⁻¹, bulk density 1.61 g cc⁻¹, and available N, P and K 251.0, 15.1 and 143.0 kg ha⁻¹, respectively. The experiment consisted of 5 treatments *viz.*, T₁ = control (farmer's practice i.e. up and down cultivation), T₂ = earthen contour bund at 0.7 m VI; T₃ = earthen contour bund at 0.9 m VI; T₄ = VB of *Cenchrus ciliaris* at 0.7 m VI and T₅ = VB of *Heteropogon contortus* at 0.7 m VI. Specifications of conservation measures adopted in field size runoff plots (80x20 m, slope 3%) have been given in Table 1. Sorghum ('CSH 14') was grown at 60x15 cm spacing under rainfed conditions in all the plots with recommended package of practices. Sowing was done along contours in all the plots except control. A fertilizer dose of 80 kg N and 40 kg P₂O₅ ha⁻¹ was applied as basal. Urea and di-ammonium phosphate

were used as the source of nitrogen and phosphorus, respectively. The crop was sown on July 11, 18 and 4 and harvested on November 5, 10 and October 27 in 2005, 2006 and 2007, respectively. Daily rainfall was recorded from the weather station at the research farm. Runoff from each treatment was measured with the help of an automatic water stage level recorder and eventwise representative runoff samples were collected for estimation of soil and nutrient loss. Event based runoff was summed to calculate the total seasonal runoff. Per cent seasonal runoff was calculated on the basis of seasonal runoff causing rainfall. Analysis of soil and nutrient loss in runoff water was done using standard chemical procedures (Jackson, 1973). In view of large plot size and non availability of large homogeneous area in red soils for accommodating more number of replications, treatments were time replicated. Data was analyzed as per statistical procedure of the randomized block design keeping years as replication (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

Rainfall

Total annual rainfall of 568.0, 547.2 and 547.8 mm was received during 2005, 2006 and 2007, respectively. During 2005, out of the total annual rainfall, a rainfall of 15.3, 7.1, 20.4 and 48.0 mm was obtained in the month of March, April, May and June, respectively, and 124.2 mm before sowing of sorghum in the month of July. However, during 2006 out of total annual rainfall, a rainfall of 35.0, 3.4, 39.7 and 38.9 mm was received in the months of March, April, May and June, respectively and 88.3 mm prior to sowing of sorghum in the month of July. During 2007, out of the total annual rainfall of 547.8 mm; a rainfall of 52.0, 36.0, 0.0, 2.4, 143.0 mm was received in the months of February, March, April, May and June, respectively and 2.8 mm prior to sowing of sorghum in the month of July. A rainfall of 353.0, 341.9 and 311.6 mm was received during crop growth period in respective year and the daily distribution of rainfall during crop growth season has been depicted in Fig. 1. The rainfall intensity varied from 0.70 to 5.00 mm hr⁻¹ in 2005, from 1.22 to 4.16 mm hr⁻¹ in 2006 and from 0.11 to 6.00 mm hr⁻¹ in 2007.

Table : 1
Specifications of conservation measures in runoff plots

Treatment	Dimension/spacing					
	Length (m)	Top width (m)	Bottom width (m)	Height (m)	Side slopes (m)	Vertical interval
Earthen contour bund	60	0.45	1.80	0.45	1:1.5	0.70
Earthen contour bund	40	0.45	2.25	0.60	1:1.5	0.90
Vegetative barrier of <i>Cenchrus ciliaris</i>	604 rows with 15 cm staggered plant spacing					0.70
Vegetative barrier of <i>Heteropogon contortus</i>	604 rows with 15 cm staggered plant spacing					0.70

Runoff

Runoff and peak runoff rates were influenced by vegetative as well as mechanical measures during all the three years. There were 8, 12 and 11 runoff events recorded during rainy season of 2005, 2006 and 2007, respectively.

The number of runoff causing events was higher under farmer's practice (8, 12 and 11 events), intermediate under VB of *H. contortus* (7, 12 and 10) and lower under contour bunds at 0.7 m VI (6, 5 and 6 events) during 2005, 2006 and 2007, respectively.

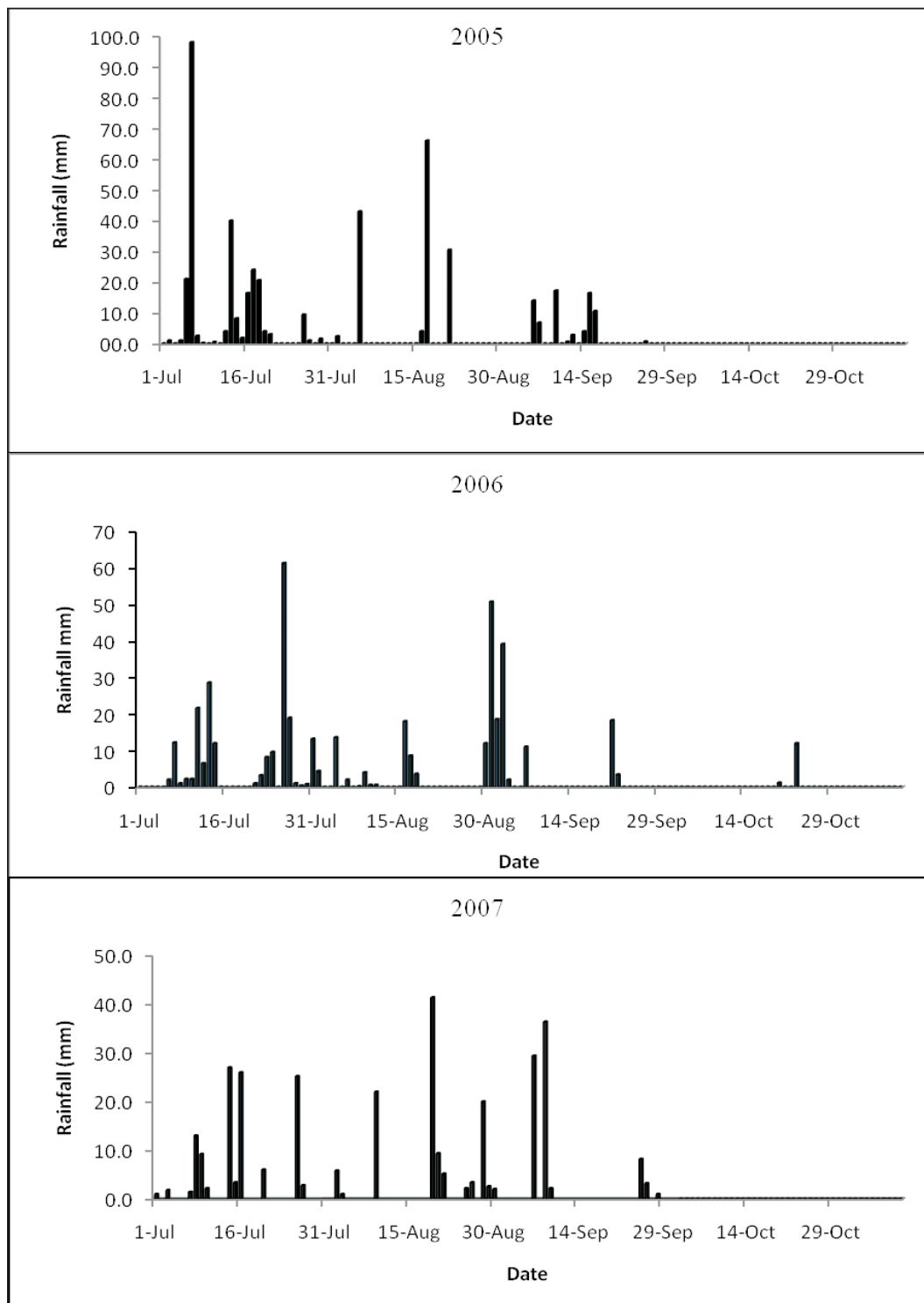


Fig. 1. Rainfall during crop growth period

Runoff depth decreased with the introduction of vegetative barriers and further with mechanical measures. The magnitude of runoff was higher under farmer's practice, intermediate under vegetative barrier treatments (T_4 and T_5) and lower under contour bunds at different vertical intervals (T_2 and T_3) during 2005, 2006 and 2007 (Fig 2). Mean results of three years indicated that runoff reduced considerably under different conservation measures and followed the following trend: contour bunds at 0.7 m VI > contour bund at 0.9 m VI > VB of *H. Contortus* at 0.7 m VI > VB of *C. ciliaris* at 0.7 m VI.

Peak runoff rates for all the runoff events recorded highest under farmer's practice and those were reduced considerably under vegetative barrier treatments (T_4 and T_5) and further under contour bunds during all the years (Fig. 2).

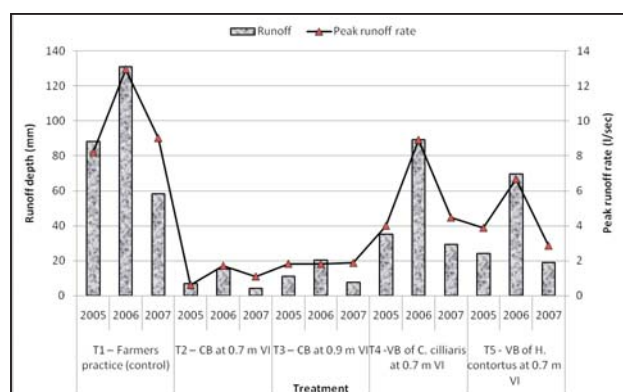


Fig. 2. Runoff depth and peak runoff rate as influenced by different treatments

During 2005 highest peak runoff rates (from 0.82 to 20.68 l sec⁻¹) were recorded under farmer's practice, intermediate under VB of *H. contortus* (from 0.07 to 8.19 l sec⁻¹) and lowest under contour bunds at 0.7 m VI (from 0.11 to 2.25 l sec⁻¹). Similar trend for peak runoff rates was also recorded during 2006 and 2007.

Higher runoff depth and peak runoff rates under farmer's practice were attributed to lower obstruction to flowing rainwater and low infiltration. Vegetative barriers

of *C. ciliaris* and *H. contortus* slow down and dispersed surface runoff hence intermediate runoff was recorded. However, contour bunds at 0.7 m VI checked the velocity of flowing water, created highest obstruction to flowing rainwater which resulted in delay in start time of runoff and time to peak and increased infiltration consequently lowest runoff was recorded. Effectiveness of different vegetative barriers in reducing runoff was also reported by several workers (Bharadwaj and Sindhwai 2007; Guto *et al.*, 2011; Mohapatra *et al.*, 2006 and Prasad *et al.*, 2005).

Soil Loss

There was considerable reduction in soil loss under vegetative barriers of grasses which was further increased under contour bunds at different vertical intervals over farmer's practice. Higher soil loss was recorded under farmer's practice (418, 1397 and 1002 kg ha⁻¹ during 2005, 2006 and 2007, respectively) during all the three years (Table 2). Soil loss was reduced by 78, 42 and 72% under *C. ciliaris*; 81, 58 and 81% under VB of *H. contortus*; 95, 94 and 94% under contour bund at 0.9 m VI and 98, 97 and 96% under contour bund at 0.7 m vertical interval during 2005, 2006 and 2007, respectively. Mean data of three years also indicated that soil loss was influenced significantly by different conservation measures. Soil loss due to VB of *C. ciliaris*, *H. contortus*, contour bunds at 0.9 and 0.7 m VI were reduced to 58, 69, 94 and 97%, respectively, over farmer's practice. Contour bunds checked the velocity of flowing water, increased the time of concentration and allowed higher infiltration into the soil consequently reduced the runoff and soil loss. Vegetative barriers achieved erosion control by slowing and filtering runoff and reducing the slope of the land which tends to reduce erosion rates. The findings of present study are in accordance with earlier findings of Bhanavase *et al.* (2007), Guto *et al.* (2011), Mohapatra *et al.* (2006) and Prasad *et al.* (2005) about reduction in soil loss with the introduction of vegetative barriers.

Nutrient Loss

The magnitude of loss of nutrients (organic carbon, nitrogen, phosphorus and potassium) in runoff recorded

Table : 2
Soil loss as influenced by different mechanical and vegetative measures during 2005 to 2007

Treatments	Soil loss (kg ha ⁻¹)			
	Years			
	2005	2006	2007	Mean
T ₁ - Farmers practice (control)	418	1397	1002	939
T ₂ - Contour bunds at 0.7 m VI	9	42	41	31
T ₃ - Contour bunds at 0.9 m VI	20	78	62	53
T ₄ - Vegetative barriers of <i>Cenchrus ciliaris</i> at 0.7 m VI	91	817	285	398
T ₅ - Vegetative barriers of <i>Heteropogon contortus</i> at 0.7 m VI	78	593	194	288
C D (P = 0.05)	-	-	-	409

Table: 3

Treatments	Nutrient loss (kg ha ⁻¹)																
	Organic carbon					N				P				K			
	2005	2006	2007	Mean		2005	2006	2007	Mean	2005	2006	2007	Mean	2005	2006	2007	Mean
T ₁ - Farmers practice (control)	3.28	15.9	12.0	10.39		1.08	3.30	2.70	2.36	0.37	0.82	0.70	0.63	0.70	0.40	1.70	0.93
T ₂ - Contour bunds at 0.7 m VI	0.08	0.60	0.50	0.39		0.08	0.30	0.15	0.18	0.03	0.12	0.05	0.07	0.09	0.36	0.10	0.18
T ₃ - Contour bunds at 0.9 m VI	0.23	1.40	0.70	0.78		0.16	0.50	0.20	0.29	0.06	0.16	0.10	0.11	0.15	0.37	0.20	0.24
T ₄ - Vegetative barriers of <i>C. ciliaris</i> at 0.7 m VI	0.91	8.90	3.00	4.27		0.40	2.40	1.10	1.30	0.14	0.77	0.30	0.40	0.29	1.49	0.60	0.79
T ₅ - Vegetative barriers of <i>H. contortus</i> at 0.7 m VI	0.66	8.40	2.20	3.75		0.39	1.70	0.60	0.90	0.13	0.53	0.20	0.29	0.32	1.72	0.40	0.81
C D (P = 0.05)	-	-	-	5.23		-	-	-	0.95	-	-	-	0.25	-	-	-	NS

higher under farmer's practice intermediate under VB treatments (*C. ciliaris* and *H. contortus*) and lower under contour bunds during all three years of study (Table 3). Mean results of three years also followed similar trend. Vegetative barriers of *C. ciliaris* and *H. contortus* recorded considerable reduction in nutrients loss. But among different treatments, contour bunds at 0.7 m VI recorded the highest reduction in organic carbon (96%), nitrogen (93%), phosphorus (89%) and potassium (80%) in runoff over farmer's practice.

The efficiency of vegetative barriers in soil conservation depends on vegetative development, natural undergrowth, soil surface management and performance of the associated crop (Spaan *et al.* 2005; Pansak *et al.* 2010). The magnitude of runoff (in terms of total depth, peak runoff rate and per cent of rainfall), soil loss and nutrient loss (in terms of organic carbon and nitrogen) was lower under vegetative barrier of *H. contortus* than *C. ciliaris*. This might be attributed to the quicker growth of vegetative barriers of *H. contortus* than *C. ciliaris*, that effectively intercepted higher soil sediment reducing higher runoff, soil and nutrient loss than vegetative barriers of *C. ciliaris*. Low runoff, soil loss and nutrient loss under contour bunds was attributed to decreased slope length, reduced runoff velocity and increased infiltration opportunity time. Between contour bunds at two vertical intervals (0.9 m and 0.7 m), contour bunds at 0.7 m VI were found more efficient in reducing runoff, soil loss and nutrient loss than contour bunds at 0.9 m VI. It was attributed to greater obstruction to rainwater with formation of three bunds in case of 0.7 m VI than 0.9 m VI with two bunds. Bhanavase *et al.* (2007), Mohapatra *et al.* (2006) and Tiwari and Kurothe (2006) have also reported reduction in nutrients loss under different vegetative barriers.

Grain Yield

Grain yields of sorghum with vegetative barriers and contour bunds were greater over farmer's practice. Mean grain yield of three years increased by 6, 9, 11 and 15% under vegetative barrier of *C. ciliaris*, *H. contortus*, contour bund at 0.7 m and 0.9 m VI, respectively (Fig. 3). Higher grain yields with vegetative barriers or contour bunds were probably attributed to reduced runoff, soil loss and greater conservation of rainwater and top fertile soil. Several workers have reported increase in yield under different vegetative barriers (Bhanavase *et al.*, 2007; Guto *et al.*, 2011 and Prasad *et al.*, 2005). Math and Patil (2013) have also reported higher *in-situ* rainwater conservation, reduced soil erosion and increased grain yield of winter sorghum under compartmental bunding over farmer's practice (no bunding) in deep black soils of south India.

4. CONCLUSIONS

This study was undertaken with the objective to evaluate the efficiency of different conservation measures in reducing erosion losses and augmenting the yield of sorghum on slopy agricultural lands in red soils. The study

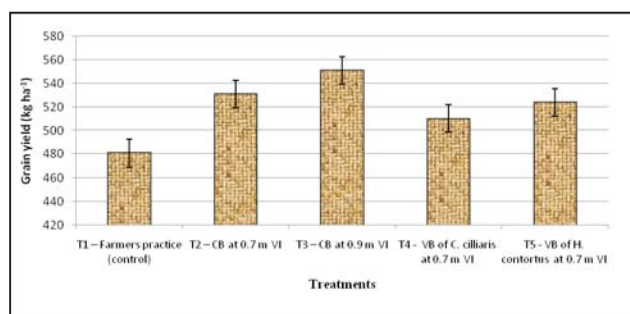


Fig.3. Grain yield of sorghum as influenced by different treatments

revealed that vegetative barriers and contour bunds at different vertical intervals reduced erosion losses and increased the grain yield of sorghum over farmer's practice (control). Among different conservation measures tried, contour bunds at 0.7 m VI conserved higher rainwater (42%), reduced higher top fertile soil loss (97%) and nutrients loss (organic carbon 96%, nitrogen 93%, phosphorus 89% and potassium 80%) and produced 11% higher grain yield of sorghum over farmer's practice. Therefore it is concluded that contour bunds at 0.7 m VI could be adopted for higher rainwater conservation, reduction in soil and nutrient loss and achieving higher yield of sorghum on sloping agricultural lands in red soils of Bundelkhand region in Central India.

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