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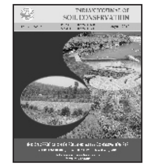

Efficacy of contour bunds and vegetative barriers in resource conservation on sloping agricultural land in Bundelkhand region

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ABSTRACT

A field experiment was conducted during rainy seasons of 2005 to 2007 at ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Datia, Madhya Pradesh to evaluate the efficacy of contour bunds and vegetative barriers in resource conservation on sloping agricultural land in Bundelkhand region. The treatments consisted farmer's practice (up and down cultivation without contour or vegetative barrier), earthen contour bund at 0.7 m vertical interval (VI), earthen contour bund at 0.9 m VI, vegetative barrier (VB) of *Cenchrus ciliaris* at 0.7 m VI, and VB of *Heteropogon contortus* at 0.7 m VI in runoff plots of 80 m x 20 m having 3% slope. Results of 3 years indicated that the time of starting of runoff was delayed most (ranging from 9 to 72 min) under contour bunds at 0.7 m VI followed by contour bunds at 0.9 m VI (ranging from 6 to 27 min) and followed by VB treatments (VB of *C. ciliaris*: from 1 to 31 min, and VB of *H. contortus*: from 2 to 39 min). Similarly, the time to peak by runoff was delayed highest under contour bunds at 0.7 m VI (from 5 to 474 min) followed by contour bunds at 0.9 m VI (from 4 to 384 min) and VB treatments (VB of *C. ciliaris*: from 1 to 19 min and VB of *H. contortus*: from 1 to 32 min) over farmer's practice. Among different treatments, contour bund at 0.7 m VI was found as a superior rainwater conservation measure for sloping agricultural lands in red soils of Bundelkhand region in Central India.

1. INTRODUCTION

In Central India, Bundelkhand region ($23^{0}10^{'}$–$26^{0}30^{'}$N and $78^{0}20^{'}$–$81^{0}40^{'}$E), with a total geographical area (TGA) of 7.04 M ha, has red soils in about 50% of its geographical area, and about 70% area comes under rainfed agriculture (Narayan and Biswas, 2012). Nearly 70% of the total area in the region is subjected to varying degrees of erosion hazards (Tiwari and Narayan, 2010). Conventional farming on sloping terrain in the region accelerates soil erosion, reducing soil fertility and productivity. Contour bunds act as a barrier for sediment and surface runoff and reduce the length and gradient of slopes, check the velocity of flowing water, allow infiltration into the soil, and help in soil and water conservation. Sediment and water are trapped and get accumulated behind these bunds, preventing the loss of soil particles, fertilizer and organic matter, and increasing infiltration of surface water (Vancampenhout *et al*., 2006). The effects of contour bunding on soil and water retention and improved crop establishment is immediately visible in the first year of its implementation, a situation that motivated farmers for wider adoption. Soil moisture is always higher in the contour bund field compared to the non-contour bund field during cropping season. Whereas runoff and erosion rates are observed higher in fields without contour bunds. Vegetative barriers of perennial leguminous trees or grass strips slow down runoff and reduce erosion, and with annual crops, offer a simple and effective alternative for erosion control on sloping croplands all over the world (Owino *et al*., 2006; Cullum *et al*., 2007; Lin *et al*. 2009). Many grasses, including vetiver grass, were demonstrated to be very effective in reducing soil and water losses (Dercon *et al*., 2006; Pansak *et al*., 2008). However, the efficiency of grass hedge is site specific and depends mostly on slope gradient, runoff volume, flow rate, size and density of sediment particles, grass species, density, interval and width of grass strips, and properties of the underlying soil mainly infiltration rate and rainfall characteristics (intensity and duration). Some studies have indicated that slope gradient and rainfall intensity are most important factors that significantly affect the effectiveness of grass hedge on a given site (Sun *et al*., 2008; Huang *et al*., 2010). As *C. ciliaris* and *H. contortus* are found in abundance in semi-arid region, they were selected to use as vegetative barrier in order to evaluate their effectiveness in controlling runoff as these are native perennials, tolerant to the climate extremes (droughts and high temperature during summers) and possess sufficient strength to remain erect against flowing water. Mechanical and vegetative soil and water conservation (SWC) measures are usually adopted practices all over the country for effective control and conservation of soil and water resources. However, the effectiveness of such native species and contour bunds for water loss on sloping cropland has yet to be determined, and should be well understood in order to correctly assess the effects on runoff characteristics of such grasses and mechanical measures in Bundelkhand region. Therefore, the present study was undertaken to evaluate the effectiveness of contour bunds and vegetative barriers in reducing runoff from sloping agricultural lands in red soils in Central India in order to find out a superior rainwater conservation measure.

2. MATERIALS AND METHODS

Study Area

A field experiment was conducted during 2005 to 2007 at ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Datia ($25^0$40'N, $78^0$28'E and 342.42 m above mean sea level), Madhya Pradesh. The climate of Datia is semi-arid with an average annual rainfall of 830 mm (1968 to 2007; Narayan *et al*., 2017). About 90% of the total precipitation is received during monsoon period *i.e.* from middle of June to September with long dry spells. 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 season are also common features. There is very little or no rain during winter season from November to February (Narayan *et al*., 2017). The maximum temperature touches 47^0C in the month of May-June while the minimum temperature goes as low as -1.5^0C in the month of December-January. Due to high wind velocity and high temperature, the evaporation rate remains very high. High annual evaporation rates (1400 mm to 1700 mm) leave a large water deficit.

The Experiment

The experiment consisted of 5 treatments *viz*., T_1 = control (farmer's practice - up and down cultivation without contour or vegetative barrier); T_2 = earthen contour bund at 0.7 m VI; T_3 = earthen contour bund at 0.9 m VI; T_4 = VB of *C. ciliaris* at 0.7 m VI and T_5 = VB of *H. contortus* at 0.7 m VI. The details of different conservation measures adopted in field size runoff plots of 80 m x 20 m on 3% slope have been given in Table 1. Test crop sorghum ('CSH 14') was grown at 60 cm x 15 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. Runoff from each treatment was measured with the help of an automatic water stage level recorder. The delay in starting of runoff and time to peak under different conservation measures over farmer's practice was calculated with the help of daily charts of automatic water stage level recorder. Event based runoff was summed to calculate the total seasonal runoff.

3. RESULTS AND DISCUSSION

Rainfall

During experimental period, a total annual rainfall of 568.0 mm, 547.2 mm and 547.8 mm was received during 2005, 2006 and 2007, respectively. However, a rainfall of 353.0 mm, 341.9 mm and 311.6 mm was recorded during crop growth period of sorghum during *kharif* season in respective year. The details about event-wise runoff causing rainfall, rainfall duration and rainfall intensity from 2005 to 2007 have been mentioned in Table 2. The rainfall intensity varied from 0.70 mm hr^{-1} to 5.00 mm hr^{-1} in 2005, from 1.22 mm hr^{-1} to 4.16 mm hr^{-1} in 2006, and from 0.11 mm hr^{-1} to 6.00 mm hr^{-1} in 2007. The rainfall duration of runoff causing events varied from 1:03 hr to 21:30 hr during 2005, from 0:30 hr to 14:15 hr in 2006, and from 0:55 hr to 8:00 hr during 2007. There were 7, 12 and 11 runoff events recorded during rainy season of 2005, 2006 and 2007, respectively.

Delay in Starting of Runoff

The starting of runoff was delayed higher under

Table: 1
Specifications of conservation measures in treatment plots

Treatment	Dimension / spacing					
	Length (m)	Top width (m)	Bottom width (m)	Height (m)	Side slopes	Vertical interval (m)
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 *C. ciliaris*	60	4 rows with 15 cm staggered plant spacing				0.70
Vegetative barrier of *H. contortus*	60	4 rows with 15 cm staggered plant spacing				0.70

Table: 2
Runoff causing rainfall, rainfall duration and rainfall intensity (I30) on various dates during 2005 to 2007

Date	Rainfall (mm)	Rainfall duration (hr min)	Rainfall intensity (mm hr^{-1})
2005			
Jun. 28	16.0	1:03	3.00
July 05	98.0	9:45	3.40
July 12	40.0	21:30	1.72
July 15	16.4	19:45	0.70
July 17	24.0	7:15	2.00
Aug. 04	43.0	15:35	0.22
Aug. 16	66.0	21:45	5.00
Aug. 21	30.5	18:05	3.80
2006			
July 10	21.6	0:45	4.16
July 12	28.6	13:35	2.30
July 25	61.4	7:05	4.00
July 26	19.0	4:30	1.12
July 30	13.2	1:10	2.20
July 31	4.4	7:45	3.00
Aug. 03	13.6	2:15	2.33
Aug. 15	18.0	1:00	2.68
Aug. 16	8.6	0:30	1.70
Aug. 30	50.8	6:55	2.50
Aug. 31	18.6	3:15	2.71
Sept. 01	39.2	14:15	1.06
2007			
June 26	16.8	1:30	0.21
June 27	24.4	3:50	1.80
July 07	13.0	3:00	0.11
July 08	9.2	8:00	1.90
July 15	22.0	6:15	2.00
July 15	5.0	0:35	3.20
Aug. 08	22.0	3:48	4.00
Aug. 20	41.4	6:15	0.15
Aug. 27	20.0	1:15	2.20
Sept.05	29.4	1:30	4.00
Sept. 07	36.4	2:55	6.00

mechanical measures and comparatively lower in vegetative measures over farmer's practice (control) during all the three years (Fig. 1). A critical look at the delay in starting of runoff over farmer's practice under different treatments indicated that during 2005, starting of runoff was delayed most under contour bunds at 0.7 m VI (ranging from 16 to 52 min) followed by contour bunds at 0.9 m VI (ranging from 10 to 44 min) and followed by VB treatments (VB of *C. ciliaris*: ranging from 2 to 31 min; VB of *H. contortus* : ranging from 3 min to 39 min). Similarly during 2006, starting of runoff was delayed from 9 min to 72 min under contour bunds at 0.7 m VI followed by 6 min to 25 min under contour bunds at 0.9 m VI followed by VB treatments (VB of *C. ciliaris*: from 2 to 9 min; VB of *H. contortus* : from 2 min to 12 min). Likewise in 2007, starting of runoff was delayed from 12 min to 30 min under contour bunds at 0.7 m VI followed by 8 min to 27 min under contour bunds at 0.9 m VI followed by VB treatments (VB of *C. ciliaris*: from 1 min to 11 min; VB of *H. contortus* : from 5 min to 23 min).

Delay in Time to Peaking of Runoff

The time to peaking of runoff was delayed higher under mechanical measures and lower in vegetative measures over farmer's practice (control) during all the three years (Fig. 2). During 2005, time to peak was delayed highest under contour bunds at 0.7 m VI (ranging from 12 min to 52 min) followed by contour bunds at 0.9 m VI (ranging from 6 min to 50 min) and followed by VB treatments (VB of *C. ciliaris*: ranging from 1 min to 19 min; VB of *H. contortus*: ranging from 2 min to 30 min) over farmer's practice during 2005. During 2006, it was delayed by 8 min to 474 min under contour bunds at 0.7 m VI, by 5 min to 384 min under contour bunds at 0.9 m VI and followed by VB treatments (VB of *C. ciliaris*: from 1 min to 6 min; VB of *H. contortus*: from 2 min to 12 min) over farmer's practice. Similarly in

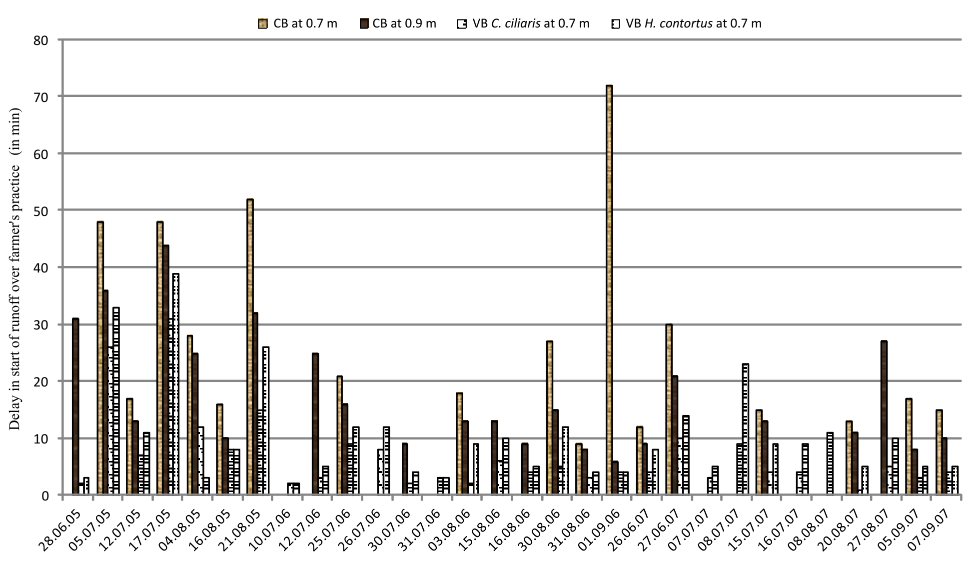

Fig. 1. Delay in starting of runoff over control as influenced by different treatments during 2005 to 2007

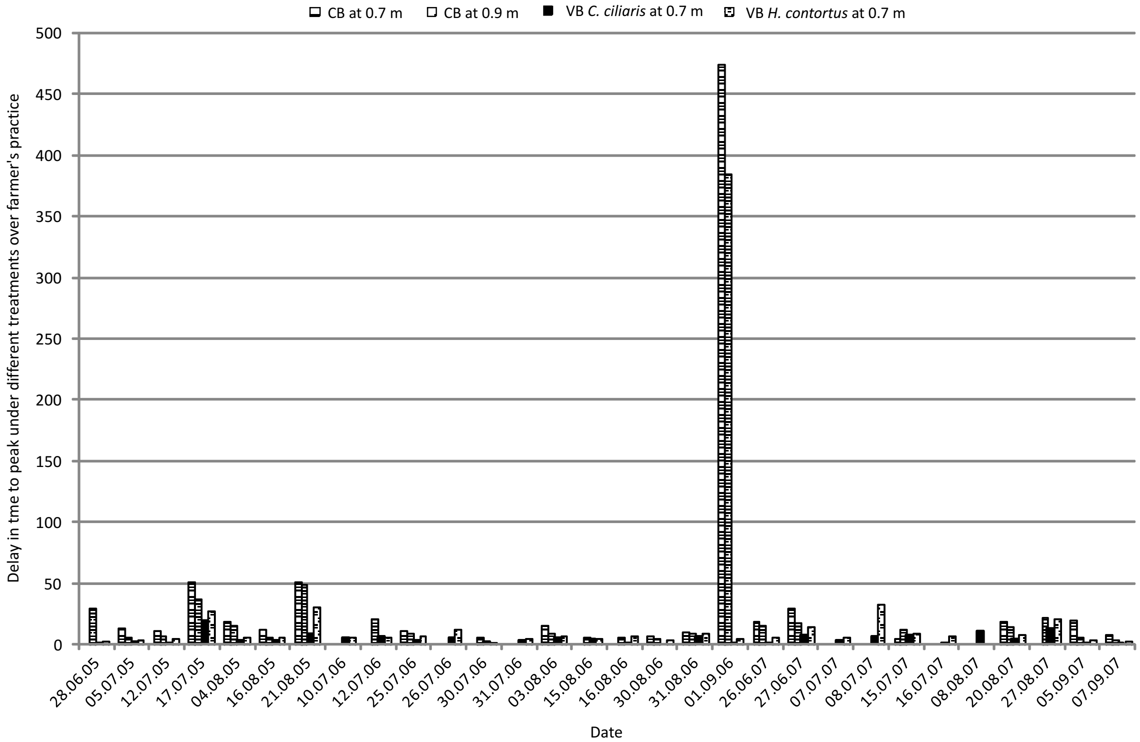

Fig. 2. Delay in time to peak over control as influenced by different treatments during 2005 to 2007

2007, highest delay in time to peak was observed under contour bunds at 0.7 m VI (5 min to 30 min) followed by contour bunds at 0.9 m VI (4 min to 23 min) and comparatively lower under VB treatments (VB of *C. ciliaris*: 1 min to 13 min; VB of *H. contortus*: from 2 min to 32 min) over farmer's practice.

Peak Runoff Rate

Peak runoff rates for all the runoff events were recorded highest under farmer's practice, which were reduced considerably under vegetative barriers treatments and further under contour bunds during all the years (Fig. 3). During 2005 highest peak runoff rates (from 0.82 1 sec^{-1} and 20.68 l sec^{-1}) were recorded under farmer's practice, intermediate under VB treatments (VB of *C. ciliaris*: ranging from 0.0 1 sec^{-1} to 13.59 l sec^{-1}; VB of *H. contortus*: 0.0 1 sec^{-1} to 11.04 l sec^{-1}) and lowest under contour bunds at 0.7 m VI (from 0.0 1 sec^{-1} to 2.25 l sec^{-1}). Similarly, during 2006 highest peak runoff rates (from 2.16 1 sec^{-1} to 31.34 1 sec^{-1}) were recorded under farmer's practice, intermediate under VB treatments (VB of *C. ciliaris*: ranging from 2.07 1 sec^{-1} to 17.07 l sec^{-1}; VB of *H. contortus*: 1.04 1 sec^{-1} to 20.34 l sec^{-1}) and lowest under contour bunds at 0.7 m VI (from 0.0 l sec^{-1} to 3.18 l sec^{-1}). In 2007, highest peak runoff rates (from 1.10 1 sec^{-1} to 38.42 l sec^{-1}) were recorded under farmer's practice, intermediate under VB treatments (VB of *C. ciliaris*: ranging from 0.5 1 sec^{-1} to 22.10 l sec^{-1}; VB of *H. contortus*: 0.0 1 sec^{-1} to 11.04 l sec^{-1}) and lowest under contour bunds at 0.7 m VI (from 0.0 1 sec^{-1} to 3.79 l sec^{-1}).

Runoff Depth

Runoff depth of all the runoff events were recorded higher under farmer's practice, intermediate under vegetative barriers treatments, and lower under contour bunds during all the years (Table 3). During 2005, runoff depths ranged from 1.2 mm to 23.05 mm under farmer's practice, 0.0 mm to 9.32 mm under VB of *C. Ciliaris,* 0.0 mm to 7.21 mm in VB of *H. Contortus,* and lowest in contour bunds at 0.7 m VI (0.0 mm to 4.9 mm). Similarly during 2006, highest runoff depth (from 1.1 mm to 37.65 mm) were recorded under farmer's practice, intermediate under VB treatments (VB of *C. ciliaris*: ranging from 0.65 mm to 26.84 mm; VB of *H. contortus*: 0.61 mm to 20.52 mm) and lowest under contour bunds at 0.7 m VI (from 0.0 mm to 7.14 mm). In 2007, highest runoff depth (from 0.41 mm to 17.2 mm) were recorded under farmer's practice, intermediate under VB treatments (VB of *C. ciliaris*: ranging from 0.18 mm to 6.96 mm; VB of *H. contortus*: 0.0 mm to 7.02 mm) and lowest under contour bunds at 0.7 m VI (from 0.0 mm to 2.02 mm).

Early start of runoff and early time to peak, higher peak runoff rates and higher runoff depth under farmer's practice were attributed to lower obstruction to flowing rainwater and low infiltration. Vegetative barriers of *C. ciliaris* and *H. contortus* slowed down the runoff velocity, resulting into increased rainwater infiltration and dispersed surface runoff, hence caused intermediate delay in starting of runoff, delay in time to peak, peak runoff rate and runoff depth. Vegetative barriers not only slow down the move-

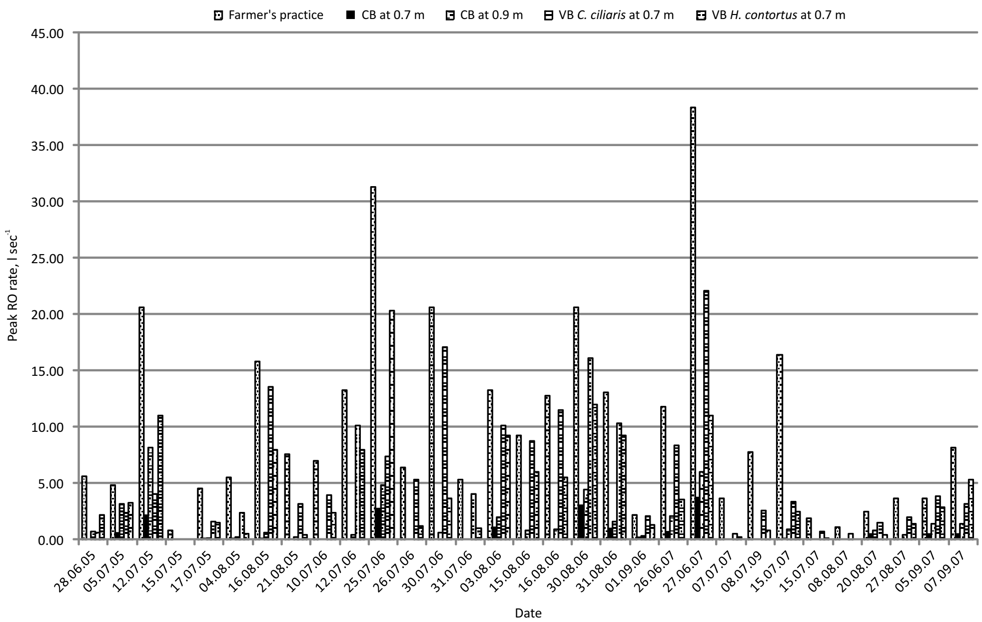

Fig. 3. Peak runoff rate (l/s) as influenced by different treatments during 2005 to 2007

Table: 3
Runoff depth (mm) as influenced by different treatments during 2005 to 2007

Date	Treatment				
	Farmer's practice	Contour bund at 0.7 m VI	Contour bund at 0.9 m VI	VB of *C. ciliaris* at 0.7 m VI	VB of *H. contortus* at 0.7 m VI
28.06.05	2.63	-	0.08	0.24	1.39
05.07.05	23.05	4.90	5.80	9.32	7.21
12.07.05	19.10	1.39	3.46	6.49	5.55
15.07.05	1.20	-	-	-	-
17.07.05	4.75	0.37	0.42	1.55	0.96
04.08.05	6.16	0.08	0.31	3.73	2.29
16.08.05	18.83	0.05	0.56	7.41	5.82
21.08.05	12.51	0.06	0.44	6.55	1.03
10.07.06	5.22	-	-	1.44	0.82
12.07.06	13.12	-	0.21	5.71	4.69
25.07.06	27.09	3.86	4.77	22.91	20.52
26.07.06	3.88	-	-	3.63	0.86
30.07.06	1.10	-	0.35	0.65	0.61
31.07.06	1.63	-	-	1.21	0.73
03.08.06	9.51	0.72	0.85	8.76	6.57
15.08.06	3.86	-	0.61	2.81	2.61
16.08.06	6.70	-	0.40	3.88	3.56
30.08.06	37.65	7.14	9.28	26.84	19.21
31.08.06	7.70	1.73	1.98	5.97	5.59
01.09.06	13.40	1.63	1.80	5.30	3.88
26.06.07	8.01	0.33	1.11	6.26	2.26
27.06.07	17.21	2.02	3.10	6.96	7.02
07.07.07	1.85	-	-	0.25	0.09
08.07.07	2.42	-	-	0.98	0.55
15.07.07	6.55	0.24	0.54	1.92	2.02
15.07.07	1.96	-	-	0.18	0.04
08.08.07	0.41	-	-	0.34	-
20.08.07	4.08	0.41	0.68	2.37	0.56
27.08.07	4.99	-	0.37	2.41	1.09
05.09.07	4.40	0.59	0.98	3.75	2.83
07.09.07	6.45	0.63	0.71	3.84	2.41

ment of water thus giving more time for infiltration of water, but also their roots have soil binding properties which reduces erosion (Dass *et al*., 2010). Contour bunds at 0.7 m VI created highest obstruction to flowing rainwater and checked the velocity of flowing water, which resulted in most delay in starting time of runoff and time to peak, peak runoff rates and runoff depth. Effectiveness of different vegetative barriers and contour bunds in reducing runoff was also reported by several workers (Mohapatra *et al*., 2006; Bharadwaj and Sindhwal 2007; Guto *et al*., 2011).

4. CONCLUSIONS

The study revealed that the starting of runoff was delayed most under contour bunds at 0.7 m VI (from 9 min to 72 min) followed by contour bunds at 0.9 m VI (from 6 to 27 min) and VB treatments (VB of *C. ciliaris*: from 1 min to 31 min; VB of *H. contortus* : from 2 min to 39 min). Further, the delay in time to peak of runoff also followed the similar trend. Peak runoff rates for all the runoff events and runoff depth were recorded highest under farmer's practice, which were reduced considerably under vegetative barriers treatments and further under contour bunds during all the years. Among different treatments, contour bund at 0.7 m VI was found to be superior rainwater conservation measure for sloping agricultural lands in red soils of Bundelkhand region in Central India.

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