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Feasibility of farm pond and recycling system to enhance productivity of *rabi* crops under semi-arid region

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ABSTRACT

A field experiment was conducted during *rabi* season 2010-2011 to 2011-2012 in Inceptisol soils to explore the possibilities of rainwater harvesting and recycling in different *rabi* crops for enhancing productivity and water productivity of crops under semi-arid conditions. Results showed that harvested rainwater was available in the farm pond for irrigation from the month of June to March during both the years. The available harvested rainwater may be used for supplemental irrigation to *kharif* crops and for pre-sowing irrigation and irrigation to *rabi* crops in the region. Statistical analysis of data revealed that coriander green leaves recorded significantly highest mustard seed equivalent yield among different crops. Coriander green leaves increased the net return by 6.11 times and Benefit Cost (B:C) ratio by 577% over marigold. The mustard was the second best crop which attained 112% higher mustard seed equivalent yield over marigold with 48.5% water saving. Among the different methods of irrigation for recycling of harvested rainwater in crops, surface irrigation method was recorded the maximum mustard seed equivalent yield of 285 kg ha^{-1} but it consumed maximum harvested rainwater of 3267.96 cum. FIRB (Raised Bed Furrow Irrigation) was found to be the best method of irrigation for recycling of precious harvested rainwater from the farm pond and it saved 48.7% water over surface method. Coriander green was recorded the highest mean water productivity of 2.02 kg cum^{-1}, which was 431.5% higher as compared to marigold (0.38 kg cum^{-1}) and saved about 8% of water over the same crop (2422.5 cum). Among different irrigation methods, FIRB irrigation method was recorded the highest water productivity of 1.74 kg m^{-3} but it recorded the mustard seed equivalent yield of 2615 kg ha^{-1}. The seepage and evaporation losses accounted as 68.7 and 31.3% of average storage losses in the agrifilm lined farm pond constructed in calcareous soils.

1. INTRODUCTION

The southern region of Rajasthan state comprising of 7 districts and partly Sirohi district of Rajasthan state with a geographical area of 5.08 M ha constitute about 14.82% of total geo graphical area of the state. The region has undulating topography, scanty and uneven distribution of rainfall scarce vegetation cover, lack of irrigation facilities and unfavorable edaphic conditions. About 70% area comes under rainfed agriculture with cropping intensity of 121%. The yield potential is low and agriculture is not economically viable with traditional management of land and water resources. This is caused by the occurrence of intermediate and terminal dry spell periods during the rainy season (Jat *et al*., 2003 and

2005). The average rainfall of Bhilwara district is 657.7 mm, out of which, 93.1% (614.5 mm) is received in monsoon season (June-September). The normal onset and withdrawal of monsoon is 2nd July and 1st October, respectively with 33 rainy days. Normal annual water balance of the district shows that the cumulative potential evapotranspirations (PET) is 1666.5 mm which indicate that the available rainfall is insufficient to meet water demand of crops. The mean maximum and minimum temperature is ranged from 24.7^{0}C (January) to 41^{0}C (May) and 7.5^{0}C (January) to 24.6^{0}C (June). Further, drought is the common climatic feature of the region which resulted in low and unstable production under dryland ecosystem. Inceptisol soils occupy more than 52% area on uplands in the region but the productivity of these soils is very low due to low fertility and moisture retentivity. The crops experience water stress even in short dry spells during rainy season and the short monsoon season further aggravates the situation. Consequently, unstable yield and failure of crops are very common in the region. Under such situation, farmers are unable to take even a single successful crop during the entire year because of a long duration of *kharif* crop or low water requiring *rabi* oilseed crop cannot be taken successfully without supplemental irrigation in the region.

Availability of underground water is also very limited due to depletion of ground water table by recurrent drought in the region but there is immense scope of rainwater harvesting and recycling on account of presence of numerous hillocks and undulating topography features of the area (Jat, 2007). Although the rainfall received during rainy season is scanty and erratic but high intensity storms result into a sizable runoff for storage and subsequent use for providing supplemental irrigation at critical stages of crop growth (Singh, 2000; Samra *et al*., 2002; Rajput *et al*., 2004; Anonymous, 2005; Gontia and Sikarwar, 2005; Narayan and Biswas, 2012). Generally, *kharif* crop experiences moisture stress at grain formation stage due to low moisture content caused by early recession of monsoon. Similarly, *rabi* crops can be successfully grown in tank or *nadi* bed condition on conserved moisture. Thus, due to depletion of soil moisture, low water retentively of soil and very meager rains received during the winter rising of *rabi* crops on conserved moisture is difficult without supplement irrigation. This will be possible only by adoption of proper dryland farming technology and the land can be brought under double cropping through proper utilization of residual soil moisture and by providing supplemental irrigation to the *kharif* crops and vegetables from harvested rainwater during dry spell periods (Wani *et al.,* 2003; Sahoo and Behera, 2017; Debarke and Abundrareb, 2004 and Kar *et al*.,2004). Panigrahi and Panda (2003) and Panigrahi *et al*. (2005) reported that farm pond is economically feasible for harvesting rainwater and its recycling to enhance crop productivity in rainfed areas. Similarly, Jat *et al*. (2015) reported the response of supplemental irrigation to *kharif* crops based on rainfall analyses from harvested rainwater in farm pond. Keeping these in view an investigation is planned to explore the possibility of raising *rabi* crops with harvested rainwater through farm ponds in the region.

2. MATERIALS AND METHODS

A field experiment was conducted during 2010-2011 to 2011-2012 in Inceptisol soils at Dryland Farming Research Station, Arjia, Bhilwara, (24^{0}20'N Latitude and 74^{0}40'E Longitude, and 432 m above mean sea level), Rajasthan. The soils of experimental field was sandy clay loam in texture having pH 8.15, organic carbon 0.4%, EC 0.43 dS m^{-1}, bulk density 1.5 gm cc^{-1}, the available N, P_20_5 and K_2O in soils were 245, 41 and 21.3 kg ha^{-1}, respectively. The field capacity and permanent wilting point moisture of surface soil layer were 21.3 and 9.1% on weight basis, respectively. There were four main treatments of crops such as T_1- Mustard, T_2- Gram, T_3- Coriander green and T_4- Marigold and three sub treatment of irrigation methods such as I_1- surface irrigation, I_2- Furrow irrigation raised bed (FIRB) and I_3- Alternate FIRB irrigation method (AFIRB). These treatments were imposed in randomized block design in three replications.

The crops were grown on conserved soil moisture during the month of October. The experimental site is located in Inceptisol soils area where only *kharif* season crops are grown under dryland eco system as there is no availability of ground water. An existing dug out farm pond (Dimension 17.9 x 13.8 m top width, 14.6 x 9.8 m middle, 12 x 8 m bottom width and 3 m depth) of 486 cum capacity was and having a 2.73 ha catchment area and rainwater from adjoining fields having slope 1.5 to 3% slope was diverted to the farm pond and stored water for providing pre sowing/

supplemental irrigation. This pond was lined with 250 micron agrifilm for seepage reduction. This agrifilm was punctured while lying in the farm pond. However, seepage losses was less as the farm pond was dug out in the calcareous soils as compared to agriflim lined pond. A measured quantity of 5 ha cm water was applied to the field at each irrigation from the harvested rainwater in farm pond through surface irrigation method. Whereas in other irrigation methods for measurement of irrigation water, discharge of stream and application time was measured. It was Assuming that irrigation is applied at 60% irrigation efficiency. The rainfall received during the study period is shown in Fig. 1 and Fig. 2. A measuring scale was fixed in the farm pond for recording the depth of harvested rainwater and daily observation on depth of water was recorded for calculation of the available water and storage losses in the farm pond. The evaporation loss was determined as 0.7 x pan evaporation from water surface in the farm pond. Thereafter the seepage losses were determined as storage losses minus evaporation losses in the farm pond. The available harvested rainwater in farm pond during crop growing period during the study period has been depicted in Fig. 2. Mustard cv. 'laxmi', gram cv. 'Dahod yellow', coriander green *cv.* 'RC-1' and marigold *cv.* 'Local' were grown. The nursery was raised for transplanting of marigold before sowing of experiment. The crops were sown by single row bullock drawn seed cum fertilizer drill. The recommended packages of practices were followed to raise different crops. Irrigation was applied at 0.8 of cumulative pan evaporation (Anonymous, 1999). Effective rainfall and irrigation water applied during the crop growing period was measured. Water Productivity (WP) was calculated by dividing the seed yield with consumptive use (mm). Observations on yield and yield attributes of different crops were recorded at harvest. Mustard equivalent yield was calculated by converting the yield of other crops on the basis of existing market price of individual crop during 2010-2012. The mustard equivalent yield under different crops and irrigation method was analyzed as per statistical procedure of the randomized block design in three replications.

Cost-Benefit Analysis

For estimation of benefit generated from agrifilm lined farm soil lining, annual costs were worked out taking into consideration both fixed cost and variable costs. The investment costs on lining were amortized over a period of 20 years at 8% interest rate considering the life period of the farm pond as 20 years, using the following equation:

$$\text{Amortized cost (₹)} = \frac{r(I+r)^n x I}{(I+r)^n - I} \quad ...(1)$$

Where, r is the rate of interest, n is the number of years, and I is the Investment on the farm pond including agrifilm lining.

The opportunity cost of the land used for constructing the pond has been valued at @ ₹ 3000 ha^{-1} annum^{-1}, assuming that the net return from dryland @ ₹ 3000 ha^{-1} annum^{-1} in the study area. The annual maintenance cost of the farm pond was assumed to be 2% of the investment cost. Variable cost of irrigation has been worked out by considering actual diesel cost, hiring charges for pump set, labour cost incurred for pumping the water and for supplemental irrigations.

3. RESULTS AND DISCUSSION

Harvested Rainwater

The harvested rainwater was stored in the farm pond which is having capacity of 486 cum. This pond is lined with agrifilm of 250 micron thickness. The highest mean runoff of 540.7 cum was recorded in July month (Table 1). Though, highest mean rainfall (299 mm) was received during the month of August. This might be attributed due to occurrence of high intensity rainfall storm during the month of July which produced more runoff. Whereas least mean runoff of 32.645 cum was recorded during the month of September. The mean annual rainfall of 741.2 mm was produced mean runoff of 1498.067 cum. Thus, it

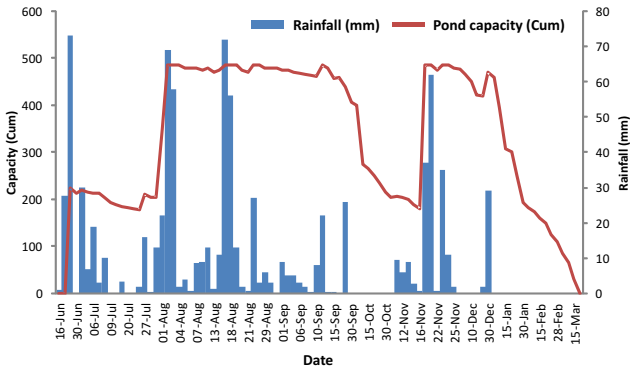

Fig. 1. Rainfall and water level in the farm pond during year 2010-11

clearly indicated that farm pond of 486 cum capacity was having more than 3 fillings in a rainy season. Table 1 also showed that the highest annual runoff was recorded during the year 2011 with rainfall of 722 mm. The mean annual rainfall received during the study period contributes about 87% to monsoon rains. This rainfall was produced about 87% of annual runoff from the catchment area.

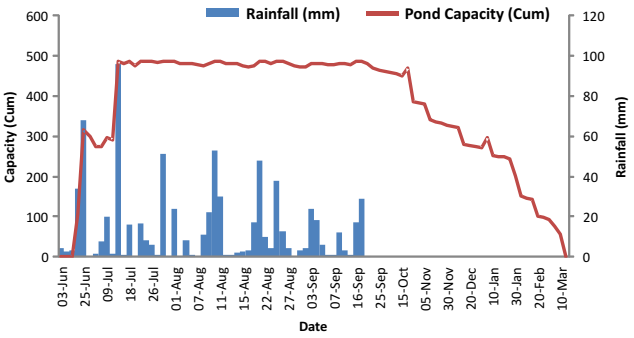

Fig. 2. Rainfall and water level in the farm pond during year 2011-12

Table: 1
Harvested rainwater in different months during the study period (2010-2012)

Months	Rainfall (mm)			Runoff (cum)		
	2010	2011	Mean	2010	2011	Mean
June	102.4	112	107.2	198.105	201.10	199.603
July	104.0	225	164.5	23.433	1057.92	540.7
August	332.0	266	299	689.185	333.76	511.473
September	54.6	119	86.8	0.00	65.25	32.625
November	167.4	0.00	83.7	427.327	0.00	213.664
Total	760.4	722	741.2	1338.05	1658.03	1498.067
Annual	792.8	722	757.4	1338.05	1658.03	1498.067

Yield

For analysis of yield data, mustard equivalent yield was worked out based on prevailing market price and are presented in Table 2. Statistical analysis of data revealed that coriander green was recorded significantly higher mustard seed equivalent yield as compared to rest of the crops. Coriander green was recorded the highest mean mustard seed equivalent yield (4037 kg ha^{-1}) with recycling of harvested rainwater in *rabi* crop. It was recorded 357% higher mustard seed equivalent yield as compared to marigold (884 kg ha^{-1}) with about 8% water saving. The mustard was the second best crop which attained 112% higher mustard seed equivalent over marigold with 48.5% water saving. The yield recorded in different methods of irrigation was not differed significantly. This may be attributed due to that the mustard seed equivalent yield does not increase in proportion to increase in water use. Thus, it indicates that FIRB irrigation method was recorded the mustard seed equivalent at par with surface irrigation method and saved the irrigation water by 48%. Similarly, AFIRB irrigation with FIRB method of irrigation in

Table: 2
Productivity and economics of different crops and irrigation methods with harvested rainwater (2010-2012)

S.No.	Treatments	Mustard equivalent yield (kg ha^{-1})						Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B:C ratio		
		Seed			Straw											
		2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
(a) Main plots (crops)																
1	T_1 - Mustard	1699	2043	1871	6786	5078	5932	46627	75184	60906	45327	64886	55107	3.75	7.4	5.58
2	T_2 - Gram	1118	865	992	3013	1241	2127	29273	19586	24430	1747	19586	10667	1.48	2.5	1.99
3	T_3 - Coriander	3239	4832	4036	-	-	-	76117	143290	109704	60367	143290	101829	3.80	10.3	7.05
4	T_4 - Marigold	468	1299	884	-	-	-	10998	25421	18210	7877	25421	16649	-0.42	2.5	1.04
	S.Em +	136	128													
	C.D. (P=0.05)	535	502													
(b) Sub plot (Irrigation methods)																
1	T1 - Surface irrigation method	2450	3251	2851	7350	2409	4850	64875	65976	65426	52775	65976	59376	4.36	4.8	4.58
2	T2 - FIRB irrigation method	2227	3003	2615	6125	2147	4136	58435	64486	61461	48635	64486	56561	4.96	6.2	5.58
3	T3 - Alternate FIRB irrigation	1847	2786	2317	5172	1763	3468	48505	59425	53965	39405	59425	49415	4.33	6.0	5.17
	S.Em +	213	225	219	2195	157										
	C.D. (P=0.05)	N.S.	N.S.		N.S.	N.S.										

different crops. Among the different methods of irrigation for recycling of harvested rainwater in crops, surface irrigation method was recorded the maximum mustard seed equivalent yield of 2850 kg ha^{-1} but it consumed maximum harvested rainwater of 3267.96 cum. However, FIRB irrigation method was recorded mustard seed equivalent of 2615 kg ha^{-1} with 48.7% water saving. Thus, it clearly indicated that if same quantity of irrigation water as given through surface irrigation method was given through FIRB irrigation method then 3870 kg total mustard seed equivalent yield was obtained (Table 4). Thus, it clearly indicated FIRB irrigation method was found to be the best method of water application among the different irrigation methods as it attained maximum total mustard seed equivalent yield. Similarly, the mustard straw equivalent yield followed the same trend as mustard seed equivalent yield in different crops and under irrigation methods.

Rainwater harvesting and recycling through a farm pond was found effective in increasing the yields in Chhatisgarh district of Madhya Pradesh under rainfed conditions (Anonymous, 2005). Kannan *et al.* (2006) also emphasized the need of rainwater harvesting and recycling through a farm pond for providing irrigation to *kharif* crops under dry spells and full filling the water requirement for *rabi* and summer crops.

Economics of Recycling of Harvested Rainwater

Economics analysis of application of irrigation in different crops through different methods and also cost of cultivation of crop was worked out and is presented in Table 3. Results revealed that maximum cost of cultivation (₹ 18164 ha^{-1}) was recorded in Marigold due to highest water used. However, it was recorded the least net return (₹ 43369 ha^{-1}) with B:C ratio of 1.04 while, coriander green was recorded the highest net return of ₹ 101828 ha^{-1} with highest B:C ratio of 7.05. Thus, coriander green increased the net return by 2214 times and B:C ratio by 632% over marigold. Similarly, among different methods of irrigation, surface irrigation method was recorded the maximum net return of ₹ 59376 ha^{-1} with B:C ratio of 4.58 whereas FIRB irrigation method was recorded the net return of ₹ 56561 ha^{-1} with highest B:C ratio of 5.56. Thus, if same water as given through surface irrigation method was given through the FIRB irrigation then it was recorded total net return of ₹ 83710 with increased B:C ratio by 27.6% (Table 4). If same water was given through alternate FIRB irrigation method to crop then it was recorded total net return of ₹ 81535. Thus, it clearly indicated that FIRB irrigation was found to be the best method of irrigation for recycling of precious harvested rainwater from the farm pond.

The cost of irrigating 1 ha of land was worked out and is presented in Table 5. The cost of creating one ha of irrigation potential through farm pond was estimated to be ₹ 6121 ha^{-1} (Table 5) against ₹ 8000 ha^{-1} for minor irrigation schemes (Singh *et al.*, 2008 and Ranade, 2014) and ₹ 27000 ha^{-1} for medium and major irrigation project in the VII plan (Samara *et al.*, 2002). Hence, in order to derive equitable benefits at

Table: 3
Productivity and benefit generated from water saving in different crops and irrigation methods with harvested rainwater (2010-2012)

Treatments	Water saving (%)	Additional area irrigated (ha)	Additional production from increased area (kg)	Total production with highest water used (kg)	Additional net return (₹)	Total net return (₹)
(a) Main plots (crops)						
T_1- Mustard	48.5	0.49	917	2788	27002	82109
T_2- Gram	48.4	0.48	476	1468	5120	11179
T_3- Coriander	8.0	0.08	323	4319	8146	109975
T_4- Marigold	-	-	-	884	-	16649
(b) Sub plot (irrigation methods)						
I_1- Surface irrigation	-	-	-	2851	-	59376
I_2- FIRB irrigation	48.1	0.48	1255	3870	27149	83710
I_3- Alternate FIRB irrigation	65.3	0.65	1506	5329	32120	81535

minimum cost and ensure proper water conservation, emphasis may be shift to construct a series of on farm reservoirs (farm pond or earthen embankment type pond) on watershed basis.

Water Productivity and Water Use

Water productivity for different crops and different methods was worked out and are presented in Table 4. Results revealed that coriander green was recorded the highest mean water productivity of 2.02 kg cum^{-1}, which was 431.5% higher as compared to marigold (0.38 kg cum^{-1}) and saved about 8% of water over the same crop (2422.5 cum). The mustard was second best crop which increased water productivity by 326% over marigold and utilized total water as 1247.38 cum and also saved the precious harvested rainwater by 48.5%. Though, marigold utilized maximum harvested rainwater for irrigation (2422.5 cum) but it was recorded least mustard seed equivalent yield of 884 kg ha^{-1} which resulted in to least water productivity. This might be due to low yield and low market price of the marigold. The water used under different crops and methods of irrigation was differed significantly. This indicated that there is variation in water used but the mustard seed equivalent yield did not differ significantly under different methods of irrigation.

Among different irrigation methods, FIRB irrigation method was recorded the highest water productivity of 1.74 kg cum^{-1} but it recorded the mustard seed equivalent yield of 2615 kg ha^{-1}. Whereas surface irrigation method was recorded the least water productivity of 0.76 kg cum^{-1} with highest water used (3267.9 cum). Lower WP under surface irrigation might be due to proportionately more increase in evapo-transpiration than the increase in seed yield. These results were in conformity with the results obtained by Narayan *et al.* (1999) and Singh

Table: 4
Cost and benefit generated from harvested rainwater and recycling system through (2010-2012)

S.No.	Parameter	Cost of irrigation (₹ ha^{-1})
(a) Fixed Cost		
1	Amortized cost excavated farm pond over a period of 20 years and interest @ 8%	2445.0
2	Maintenance cost @ 2% of the investment cost (annual)	480.0
3	Opportunity cost of land (25 x 20 m) for farm pond excavated @ ₹ 3000 ha^{-1}	150.0
	Total fixed cost (₹)	3075.0
(b) Variable cost (₹)		
1	Hiring pump set for five days	500.0
2	Diesel cost (25 lit)	1250.0
3	Labour cost (11 man-days)	1485.0
	Total variable cost (₹)	3235.0
	Total cost annum^{-1} (₹)	6121.0

Table: 5
Effect of water recycling on mustard seed equivalent yield, water use and water productivity in different *rabi* crops and irrigation methods (2010-2012)

S.No.	Treatments	Mustard seed equivalent yield (kg ha^{-1})			Water use (cum ha^{-1})			Water productivity (kg cum^{-1})		
		2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
(a) Main plots (crops)										
1	T_1-Mustard	1699	2043	1871	1235.51	1260.25	1247.38 (48.5)	1.38	1.86	1.62
2	T_2-Gram	1118	865	992	1234.64	1265.83	1250.24 (48.4)	0.91	0.77	0.84
3	T_3-Coriander green	3239	4832	4036	1543.44	2961.25	2252.35 (8)	2.10	1.93	2.015
4	T_4- Marigold	468	1299	884	1882.51	2962.50	2422.51 (-)	0.25	0.50	0.375
	S.Em +	136	128		0.13	2.98				
	CD at 5%	535	502	0.5	0.43	11.70				
(b) Sub plot (irrigation methods)										
1	I_1- Surface irrigation	2450	3251	2851	3167.16	3368.75	3267.95 (-)	0.77	0.75	0.76
2	I_2- FIRB irrigation	2227	3003	2615	1642.01	1753.31	1697.71 (48.1)	1.36	1.32	1.34
3	I_3- Alternate FIRB irrigation	1847	2786	2317	1055.84	1215.31	1135.58 (65.3)	1.75	1.72	1.735
	S.Em +	213.0	225	219	54.93	174.49				
	CD at 5%	N.S	N.S							

Figure in parenthesis indicates the percent water saving

and Chandra (2004). Thus, more water used under surface irrigation than proportionately increase in mustard seed equivalent yield. The FIRB irrigation method saved the irrigation by 48.7% over surface irrigation method and increased the water productivity by 76%.

Availability of Harvested Rainwater

In general, the volume of harvested rainwater in the pond followed the trend of received rainfall. It increased with the increasing rainfall and decreased with the recession of monsoon (Fig. 2). It is evident from Fig. 2 that the harvested rainwater was available in the farm pond up to the month of March during both the years. In light texture soils and semiarid-conditions harvested rainwater may not be available for a longer duration because of higher storage losses including seepage and evaporation losses that in heavy textured soils and humid conditions. In view of preciousness of water, it is advisable to make use of available in the farm pond as early as possible judiciously for supplemental irrigation owing to further loss to stored water.

During the drought or deficient monsoon years, the harvested water may not be available for a longer duration, under such situation; it may be used for providing supplemental irrigation at critical growth stages to a *kharif* crop. This may be caused by heavy average storage losses which include evaporation as well as seepage losses. Results further reveled that maximum evaporation and seepage was recorded during the month of June, September and February, (Table 6). However, during normal or excessive monsoon years the harvested water may remain available for a longer duration and it could be utilized for providing supplemental irrigation to *kharif* crops during dry spells, if needed, and also for providing pre-sowing or supplemental irrigation to *rabi* oilseed crops. Diwivedi (2004) found rainwater harvesting and recycling technique successful in enhancing crop production and increasing irrigation potential in rainfed areas of Sidharth Nagar district of Uttar Pradesh where 97.25% area is rainfed.

The highest water availability of 486 cum was available during the month of August followed by July and November. This may be attributed due to occurrence of high rainfall in July and winter rains in November (2010). The mean seepage and evaporation of losses accounted as 68.7 and 31.3% of average storage losses in the agrifilm lined farm pond constructed in calcareous soils (Table 6). The harvested rainwater was available in the farm pond for raising crops upto the month of Feb-March.

Table: 6
Average storage losses and water availability in different months in agrifilm lined farm pond during the study period (2010-2011)

Months	Storage losses (cm)			Water availability (m^3)
	Evaporation	Seepage	Average storages losses	
June	24.14	25.86	50	181.92
July	13.83	23.17	37	486.0
August	10.04	23.96	34	435.3
September	9.31	40.69	50	354.07
October	13.66	15.34	29	243.78
November	11.14	15.86	27	193.94
December	8.88	31.12	39	152.76
January	8.3	34.7	43	89.26
February	9.48	38.52	48	48.06
March	5.4	1.35	8	13.15
Total	114.18	250.57	365	-
	(31.3 %)	(68.7)		

In light textured soils, through a farm pond, rainwater, could be harvested and recycled for irrigation and the ill effect of drought could be mitigated and at least one successful crop/year under drought year and two crop year in normal monsoon year could be taken up by utilizing the harvested rainwater.

Sharda and Ojasvi (2005) also found potentiality of rainwater harvesting and recycling in increasing the yield of crops significantly in various parts of the country.

4. CONCLUSIONS

Results of the present study suggested that rainwater harvesting and recycling through a farm pond can successfully be practiced on Inceptisol soils for providing pre-sowing irrigation/irrigation in *rabi* crops. The harvested rainwater is available in the farm pond for irrigation to crop up to the month of February-March. Further, available water in the farm pond can also be judiciously utilized for pre-sowing/supplemental irrigation to monsoon/*rabi* season low water requiring crops/varieties such as coriander green and mustard crop with FIRB irrigation method for increasing the growth, yield,

net returns and water productivity in order to enhance the productivity of large dryland areas in semi-arid regions of the country.

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