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Effect of Tank Silt Application on Productivity and Economics of Maize-Based Production System in Southern Rajasthan

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ABSTRACT: Field experiments were carried out during 2008-09 to 2009-10 on farmers' field in the Operational Research Project area of Bhilwara district of Rajasthan to evaluate the effect of tank silt on productivity and economics of maize based cropping systems. The experiments were conducted at 10 farmers' field from five villages in one hectare with or without tank silt. Results revealed that application of tank silt with improved management practices recorded an increase of 36.6% in grain yield of maize over non-application of tank silt which was only 24.9% in case of farmers' practice. Application of tank silt benefited subsequent crop grown during rabi and produced a significant residual response in maize-wheat, maize-mustard and maize-taramira cropping systems. Application of tank silt brought out an increase of 18 to 32% in the productivity of different maize-based cropping systems under improved practice. Application of tank silt with improved and farmers' practice increased the WUE of maize by 24 and 21% over the non-application of tank silt, respectively.

Key words: Maize, tank silt, economics, grain yield, water use efficiency

Water tanks are an integral part of village settlements in southern Rajasthan. Runoff water carries along nutrients and fine organic matter particulates from agricultural lands. Often the sources and pathways of nutrients moved by sediments in the runoff are difficult to fully identify and assess the losses. In rainfed farming system, there is a need to capture significant amount of rainwater, which is generally lost as runoff and deep drainage. This stored water can be used for supplemental irrigation, increasing crop productivity and resource-use efficiency. However, deposition of sediments in tanks reduces its capacity and also hampers the additional water storage. Hence, removal of sediments from tanks is a relevant approach for rainfed farming systems. With the turn of the last century, there has been widespread recognition of field technologies which can enhance the water productivity in agriculture (Samra, 1997).

Several studies have identified the main constraints for increased productivity in the tropics as low rainwater use efficiency for crop production (35-45%), inherent low soil fertility, inappropriate soil, water and nutrient management practices, low adoption of stress-tolerant cultivars of crops, insufficient pest management options and poverty (Wani *et al*., 2002). Due to variations in seasonal rains during the monsoon season, crops experiences frequent dry spells. Use of tank silt has been reported in order to conserve rainwater, minimize land degradation, improve groundwater recharge, increase cropping intensity and crop productivity, (Kerr *et al*., 2000). The overall goal of the present study was to demonstrate the technology of tank silt application for enhancing the soil and water productivity of maize-based production systems.

Materials and Methods

The study was conducted at ten locations in five villages, *viz.*, Kochariya, Dariba, Mandpiya, Rooppura and Sunderpura of Bhilwara district situated between 25' and 27.5' North latitudes and 74.30' and 75.25' east longitude in the south-eastern part of Rajasthan. These villages predominantly have maize-based farming systems. Maize is grown on more than 50 per cent of gross cultivated area. Dominant soil types are sandy loam to clay loam (Table 1). At each site, experiment was laid out on 1.0 ha area. Tank silt was applied for 0.5 ha area and remaining 0.5 ha was used as control for comparison. Improved variety of maize (Var. Navjot) was compared with traditional variety of maize both under recommended package of practices and farmers' practice with and without application of tank silt. After maize, wheat (*Triticum aestivum*), mustard (*Brassica juncea*) and taramira (*Eruca sativa*) were grown during *rabi* season. The valuation of N and P in the sediment is based on the cost of unsubsidized fertilizers (Urea & DAP) at the existing rates. The benefit-cost ratio is calculated as the ratio of value of produce and cost of tank silt plus basic cost of cultivation.

Quantity of tank silt

How to decide the quantity of tank silt for a particular field is an important aspect not only for higher yield benefits but for economic viability too?, as pointed out during participatory rural appraisal. Farmers don't have any scientific base for deciding the number of tractor trolleys of tank silt to be applied in the field. The quantity of tank silt (Table 1) to be applied to the field was determined on the basis of available N content of tank silt by using user-friendly formula developed by Osman *et al*. (2009).

$$N = \frac{X}{25Y}$$

N = Number of tractor loads required for one hectare area
X = Nitrogen required by the crop (kg/ha)
Y = Available nitrogen content of tank silt (%)

Table 1 : Location of water tanks, distribution of soil types and details of desilted sediment

Site No.	Village	Name of tank	Texture		Amount of sediment recycled (t)
			Field soil	Tank sediment	
1	Sunderpura	Khakhra ki nadi	Sandy loam	Sandy clay loam	637.5
2	Kochariya	Kumawaton ki nadi	Sandy clay	Sandy clay	106.3
3	Kochariya	Kumawaton ki nadi	Sandy loam	Sandy clay	340.0
4	Rooppura	Rooppura talab	Clay loam	Sandy clay loam	106.3
5	Mandpiya	Mandpiya tank	Sandy loam	Clay loam	531.3
6	Dariba	Dariba talab	Sandy clay loam	Clay loam	425.0
7	Dariba	Dariba talab	Sandy clay loam	Clay loam	238.0
8	Mandpiya	Dariba tank	Sandy clay loam	Clay loam	340.0
9	Mandpiya	Mandpiya tank	Sandy loam	Clay loam	638.0
10	Dariba	Dariba talab	Sandy clay loam	Clay loam	170.0

Note: Each tractor trolley carries about 3.0 ± 0.5 t of tank silt

Results and Discussion

Response of maize to tank silt

A significant increase in yield of maize due to tank silt application was recorded in diverse soils. Table 2 summarizes the range and mean values of yield response of maize with and without tank silt application under field conditions. The mean yield increases were in range of 220 to 1070 kg/ha under improved practice and 220 to 660 kg/ha under farmers' practice. Maize grain yield differed significantly in various soil types. Similar trend was observed in stover yield (Table 3). Both under improved and farmers' conditions, the maximum increase in grain yield of maize was found in sandy loam soil followed by sandy clay loam and clay loam (Table 4). Use of tank silt in agriculture is an indigenous practice followed by Indian farmers who used it to improve soil structure and fertility. However, this practice is showing a declining trend with advent of fertilizers and reduced bullock power. Earlier research showed that application of sediments is an attractive option and demonstrated that they are potentially capable of supporting agronomic crops due to their higher fertility and water-holding capacity (Osman, *et al*., 2009; Mayalagu and Jawahar, 2000). As bulk of the sediments deposited in the water bodies is generally clay and fine silt, their application to the field soil makes good use of the deposited sediment containing clay and silt, nutrients and organic matter, and brings them back to the soil (Canet *et al*., 2003 and Olson & Jones, 1987).

Table 2 : Response of maize grain yield to application of tank silt under rainfed condition

Site No.	Name of tank	Grain yield (q/ha)			
		IP		FP	
		TS	TS_0	TS	TS_0
1	Sunderpura	43.50	32.80	27.10	20.80
2	Kochariya	38.10	32.60	22.80	20.20
3	Kochariya	38.60	33.40	28.40	24.40
4	Roop Pura	37.20	30.80	22.60	18.10
5	Mandpiya	32.60	23.60	24.40	20.60
6	Mandpiya	38.20	30.80	22.80	18.40
7	Mandpiya	34.20	32.00	28.40	26.20
8	Dariba	44.60	33.90	32.60	26.00
9	Dariba	32.20	26.30	25.40	19.20
10	Dariba	36.40	27.10	24.80	20.20
Mean		37.56	30.33	25.93	21.41
SEm±				1.18	
CD (P = 0.05)				3.41	

IP = Improved practice FP = Farmers' practice
TS = With tank silt TS_0 = Without tank silt

Table 3 : Response of maize stover yield to application of tank silt under rainfed condition

Site No.	Name of tank	Stover yield (q/ha)			
		IP		FP	
		TS	TS_0	TS	TS_0
1	Sunderpura	57.50	45.92	42.01	33.10
2	Kochariya	48.60	43.20	36.20	31.80
3	Kochariya	51.20	46.00	45.10	38.40
4	Roop Pura	52.08	43.50	35.50	31.40
5	Mandpiya	45.64	41.20	37.82	32.00
6	Mandpiya	53.48	46.10	35.34	30.50
7	Mandpiya	46.10	42.70	41.20	38.50
8	Dariba	57.40	49.50	44.50	41.70
9	Dariba	45.08	44.20	38.60	35.80
10	Dariba	52.20	46.70	38.00	35.50
Mean		50.93	44.90	39.43	34.87
SEm±			1.35		
CD (P=0.05)			3.91		

Table 4 : Response to tank silt in rainfed maize yield under different soil types

Soil type	Additional yield (kg grain/ha)	
	IP	FP
Sandy loam	808	463
Sandy clay loam	703	490
Clay loam	595	355

Studies conducted on different soil types indicated that application of tank silt gave the maximum incremental response in sandy loam soil (2.4–2.83 kg grain/t soil) followed by sandy clay loam (1.46-2.85 kg grain/t soil) and clay loam soil (1.38-2.48 kg grain/t soil). This indicates that response is greater in light textured soil than heavy textured soil. Further, it was noted that response of maize to tank silt was found better when cultivated with improved package of practices in comparison to farmers' practice. On basis of mean value, it can be concluded that application of tank silt under improved management recorded an increase of 36.6% in grain yield of maize over non-application of tank silt which was only 24.9% in case of farmers' practice.

Residual effect

The studies on residual response of tank silt are limited. Application of tank silt benefits more than one crop grown in the system and produces a significant residual response, while direct responses are expected, residual responses are equally important. In maize-wheat system, the directly fertilized (with tank silt) maize crop contributed 77% under improved practice and 82% under farmers' practice to the rotational response in terms of total maize equivalent yield (MEY) and wheat raised on residual tank silt contributed 23 and 18% under improved and farmers' condition, respectively (Table 5).

Residual response of tank silt under maize-mustard system was more under irrigated mustard both under improved (8.54 q/ha MEY) and farmer's practice (4.14 q/ha MEY) in comparison to rainfed mustard under improved (6.21 q/ha MEY) and under farmer's practice (1.04 q/ha MEY). In maize-based cropping systems, increase in yield of taramira due to residual tank silt was minimum (4.20 and 0.50 q/ha MEY under improved and farmers' practice, respectively) as compared to wheat (12.58 & 8.26 q/ha MEY under IP and FP, respectively) and rainfed mustard (6.21 and 1.04 q/ha MEY under IP and FP, respectively) (Table 5). A good response is attributed to positive impact as several studies indicated that high clay content and organic matter in tank sediment improves soil physical condition, soil nutrient status, and soil biological properties (Tennakoon, 1988).

Desilting and recycling tank silt to fields is an important ITK in southern Rajasthan and contributes significantly to the food and economic security of farmers. During dry season (March to June), ten farmers took up desilting of village tanks and transported the sediment to their fields on their own (Anonymous, 2007 and Sharma *et al.*, 2008). There is enough information on effect of sediment application to crop land and improvement in soil properties in the States of Andhra Pradesh, Tamil Nadu and Karnataka (Padmaja *et al.*, 2003; Stegeny and Srivasamy, 2006 and Osman *et al.,* 2009).

Direct and residual effects of tank silt varied according to soil texture and availability of soil moisture and hence, the applied tank silt showed a differential response. In maize *irrigated* mustard cropping system, mustard contributed 47.63% to the total productivity of system with improved practice which was only 30.21% in case of rainfed mustard and 20.33% in case of rainfed taramira (Table 5). Results indicated that residual effect of tank silt was most pronounced in irrigated mustard followed by wheat, rainfed mustard and taramira. Residual response of *rabi* crops to tank silt also varied according to growing practices of kharif and *rabi* crops. Residual response of irrigated mustard, rainfed taramira and rainfed mustard crops to tank silt was significantly less under farmers' practice in comparison to improved practice. However, in case of wheat, residual effect of tank silt in both improved and farmers' practice was found at par.

System productivity

The productivity of maize- based cropping systems was studied from view point of maize equivalent yield (MEY).

Among the cropping systems, the total system productivity was the highest in maize-wheat system and the lowest in the maize-taramira system. Application of tank silt brought out an increase of 18 to 32% in the productivity of different maize-based cropping systems under improved practice and 14 to 23% under farmers' practice (Table 6).

Table 5 : Direct and residual effect of tank silt on different crops

Site No.	Cropping system	Maize equivalent yield (q/ha)							
		IP				FP			
		TS		TS_0		TS		TS_0	
		K	R	K	R	K	R	K	R
1	Maize – wheat*	44.60	54.79 (40.50)	33.90	42.21 (31.20)	32.60	46.68 (34.50)	26.00	38.42 (28.4)
2	Maize – mustard*	38.20	17.08 (6.60)	30.80	10.87 (4.20)	22.80	9.32 (3.60)	18.40	8.28 (3.20)
3	Maize – mustard**	34.20	34.94 (13.50)	32.00	26.4 (10.20)	28.40	22.00 (8.50)	26.20	17.86 (6.90)
4	Maize – taramira*	38.20	10.38 (4.20)	30.80	6.18 (2.50)	22.80	5.19 (2.10)	18.40	4.69 (1.90)
5	Maize – fallow	36.94	-	29.51	-	25.07	-	20.50	-

*Rainfed ** Irrigated mustard K – *Kharif* ; R – *Rabi* ; TS – with tank silt ; TS_0 – without tank silt
Price : Maize – ₹ 850/q.; Wheat – ₹ 1150/q; Mustard – ₹ 2200/q; Taramira – ₹ 2100/q
Note : Data in parentheses indicate actual yield of rabi crops.

Table 6 : Effect of tank silt on the productivity of maize-based cropping systems

Site No.	Cropping system	Maize equivalent yield (q/ha)				Rotational response (q/ha)	
		IP		FP		IP	FP
		TS	TS_0	TS	TS_0		
1	Maize – wheat*	99.39	76.11	79.28	64.42	23.28	14.85
2	Maize- mustard*	55.28	41.67	32.12	26.68	13.60	5.44
3	Maize- mustard**	69.14	58.40	50.40	44.06	8.54	4.14
4	Maize- taramira*	48.58	36.98	27.99	23.09	4.89	6.71
5	Maize – fallow	36.94	29.51	25.07	20.50	7.43	4.57

*Rainfed ** Irrigated mustard K – *Kharif* ; R – *Rabi* ; TS – with tank silt ; TS_0 – without tank silt
Price : Maize – ₹ 850/q.; Wheat – ₹ 1150/q; Mustard – ₹ 2200/q; Taramira – ₹ 2100/q

Moisture retention capacity of soil

The results of laboratory study revealed that the moisture content of different soils was significantly influenced by the application of tank silt. Soil moisture values taken during early growth stage (35 DAS) after 8 days of no rains indicated that in case of tank silt applied fields, soil moisture content ranged from 9.45 to 18.40% with an average of 14.16% which was higher by 16.35% in comparison to no tank silt (12.17%). During dry spell of 15 days at grain formation stage of maize (67 DAS), soil moisture content values revealed that moisture content under tank silt soil samples was 12.11% which was higher by 5.40% over no tank silt soil samples (11.49%). Obviously, with tank silt treatment, moisture availability period was extended and the impact was greater with the higher dose of tank silt.

Water use efficiency

Water use efficiency was computed as the grain (WUE-GY) yield per mm of water used. There was a significant difference in WUE among the treatments (Table 7). There was a consistently higher WUE recorded with the application of tank silt at all sites irrespective of improved or farmers' practice. Maximum water use efficiency (8.47 kg/ha/mm) was recorded at site 8 followed by site 1 with treatment tank silt and improved practice (8.26 kg/ha/mm) while minimum water use efficiency was recorded at site 4 with treatment farmers' practice and no tank silt (3.44 kg/ha/mm).Data indicated that application of tank silt with improved and farmer's practice increased the WUE of maize by 24 and 21% over the non-application of tank silt, respectively.

Table 7 : WUE of maize with and without application of tank silt under IP and FP

Site No.	WUE of maize (kg/ha/mm)			
	IP		FP	
	TS	TS_0	TS	TS_0
1	8.26	6.23	5.15	3.95
2	7.24	6.19	4.33	3.84
3	7.33	6.34	5.39	4.63
4	7.07	5.85	4.29	3.44
5	6.19	4.48	4.63	3.91
6	7.26	5.85	4.33	3.49
7	6.50	6.08	5.39	4.98
8	8.47	6.44	6.19	4.94
9	6.12	5.00	4.82	3.65
10	6.91	5.15	4.71	3.84
Mean	7.14	5.76	4.92	4.07
SEm±			0.224	
CD (P=0.05)			0.647	

Economic evaluation

In order to check whether the task of sediment removal and their recommendations to apply to fields makes sense, the economic feasibility of such investment costs were estimated. The volume of sediment removed in different tanks ranged from as low as 97.0 cu m to 1066.0 cu m. The quantity of sediment removed from different tanks amounted to 3532.0 tons. The value of sediment was quantified in terms of fertilizer equivalent costs. The nutrient content in terms of N and P retrieved from the sediment was considered to be the profit (benefit) as against the expenditure (cost) incurred in removing the sediment from the tanks (Table 8). On this basis, benefit-cost ratio varied between 0.77 and 1.34 indicating that choice of tank in terms of nutrient content is also important for reducing the cost of tank silt application. Studies by agencies like ICRISAT show that it is economical to apply tank silt than fertilizers (Pamaja *et al*., 2003).

Table 8 : Economic valuation of tank silt in terms of plant nutrients returned to soil

Site No.	Name of tank	Amount of sediment (cum)	N in sediment (kg)	P in sediment (kg)	Total benefit in terms of N & P fertilizer equivalent (₹)	Labour required (person days)
1	Mandpiya tank	1063	826.0	18.0	15008	137.5
2	Khakara ki nadi	580	445.0	16.5	8342	75.0
3	Kumawaton ki nadi	406	377.0	4.9	6724	52.5
4	Rooppura tank	97	106.0	1.9	1908	12.5
5	Dariba ka talab	1066	1416.0	36.0	25902	138.0

The highest net return was obtained from maize- wheat cropping system followed by maize- mustard. Application of tank silt gave the maximum profit and B:C ratio under double cropping system in comparison to mono-cropping system. On mean basis, application of tank silt under double cropping system gave an additional return of ₹ 10705/ ha and ₹ 5985/ha over no tank silt application under improved and farmer's practices, respectively. While in case of maize-fallow, an additional return of ₹ 6463/ha and ₹ 4289/ha with the application of tank silt over no tank silt application under improved and farmer's practices, respectively.

The benefit-cost (B:C) ratio ranged between 1.90 and 3.29 and in the case of 90% of sites, the B:C ratio was greater than one with application of tank silt under improved practice. The benefit-cost ratio ranged between 1.64 under and 2.90 under farmers' practice for all the 10 sites under study (Table 9). Average benefit-cost ratio of 1.74 under improved practice and 1.26 under farmer's practice suggests that application of tank silt is not only economically viable but also have additional benefits in terms of increased water storage, improved soil quality and environmental protection. If indirect additional environmental benefits are also estimated in the benefit component, then there would be compounded benefit.

Conclusions

The application of tank silt based on available nitrogen content increased the yield of maize, moisture retention capacity, water use efficiency, net return and system productivity of maize based cropping system. Application of tank silt also reduces the chemical fertilizer cost and improves soil health.

Table 9 : Economics of tank silt application in maize-based production system

Site No.	Cropping system	Total cost (₹/ha)		Net return (₹/ha)		B:C ratio	
		IP	FP	IP	FP	IP	FP
1	Maize-wheat**	40775	39257	93229	74755	3.29	2.90
2	Maize-mustard*	37365	36156	50754	29738	2.36	2.82
3	Maize-mustard**	30085	29396	62721	46002	3.08	2.56
4	Maize-taramira*	43985	43074	39598	27584	1.90	1.64
5	Maize-fallow*	22083	21397	35083	23760	2.59	2.11

*Rainfed ** Irrigated

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