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Performance of improved water management technology on rice grown in the Chambal command area of South-Eastern Rajasthan

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Abstract

On farm demonstrations were conducted during *kharif* seasons of 2011 to 2015 at farmer's field in Chambal command area of Rajasthan under Operational Research Programme of Agricultural Research Station, Kota to study the impact of improved water management technology on the water productivity and sustainability of rice. Treatments comprised irrigation of 5±2 cm standing water and refilling at 1-3 days after disappearance of ponded water which was compared with the farmers practice (FP) *i.e.* continuous submergence. Results revealed that improved water management technology gave higher and sustainable yield of rice over the years. The mean grain yield (4,506 kg/ha), production efficiency (34.7 kg/ha/day) and crop monetary efficiency (₹ 884/ha/day) recorded under IWMT being 7.5, 7.8 and 8.33 per cent higher as compared to the farmers practice, respectively. Mean sustainability yield index (0.932) and sustainability value index (0.913) were found 4.04 and 5.18 percent higher under IWMT in comparison to FP, respectively. Mean water expanse efficiency (89.0 kg/ha-cm), water use efficiency (36.7 kg/ha-cm), water profitability (9.45 ₹/M^3) and incremental cost benefit ratio (6.4) observed were also better in IWMP than farmers practice.

Key words: Rice, sustainability yield index, sustainability value index and water management technology.

Rice (*Oryza sativa* L.) is the staple food for nearly half of the world's population. Based on favourable monsoons, huge irrigation net work covering over 90 m ha has been developed since independence in the country that has made country self-sufficient in food grains production. However, the ever-growing competition over water, between farming and urban dwellers, and industrialists, is shrinking the available water resources for agriculture. The rapidly changing climate is also putting hurdles on the monsoon pattern and thus water supply to agriculture (Singh *et al.* 2013). It is in this context that efficient water use becomes more crucial in the coming years. There is also need to make food production less water dependant. Irrigated rice production system is the largest consumer of water in agriculture sector and its sustainability is threatened by increasing water shortage (Yang, 2012). Such water scarcity necessitates the development of alternate -irrigated rice system that requires less water than traditional-flooded rice (Naresh *et al.*, 2013). Keeping in view of these emerging challenges, efficient production technology need to be developed and adopted utilizing the available water resources in the right

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perspective without compromising on production and productivity of rice, field trials were conducted at farmer's field under operational research programme (ORP) with the aim to increase water productivity of rice.

Materials and Methods

A total of 12 on farm trials (6 each at left main and right main canal of Chambal command) were conducted each year at adopted villages namely Manasganv, Soli, Kotsuan Mandawari of Kota and Kotkhera, Khothiya and Lesarda of Bundi districts during *kharif* seasons for five consecutive years (2011 to 2015) in the selected farmers' field. For the selection of farmers to conduct the demonstrations, a farmer's group meeting was convened each year and receptive and innovative farmers were selected. Selected villages of Chambal command lies between 25º and 26º N latitude and 75º-30' and 76º-6' E longitude in the south-eastern part of Rajasthan. It comes under agro climatic zone V which is also known as humid south eastern plain of Rajasthan. The soils of the adopted villages for demonstrations belong to the order vertisols and inceptisols, mainly comprise of Chambal series (62%) and Kota variant (23%). The bulk density, pH and cation exchange capacity of these soils varies between 1.35-1.59 Mg / m^3, 7.7 - 8.4 and 30-40 C mol / kg, respectively. The soils have a very low water intake rate approximately 0.25 cm / hr on surface but are almost impermeable at 1.2 to 1.5 m depth. The potential moisture retention capacity is almost 120 mm of water in 1 m depth. The soils of the selected villages for demonstrations are poor in organic carbon (0.50±0.07) and available nitrogen (273±12 kg / ha) but are low to medium in available P_2O_5 (24.3± 0.8 kg / ha) and medium to high in available K_2O (295 ± 10 kg / ha).

Improved water management practices (IWMP) includes irrigation of 5±2 cm standing water and refilling at 1-3 days after disappearance of ponded water and compared with the farmer's practice (FP) *i.e.* continuous submergence (usually 10 cm in each irrigation). Beside this, demonstrated blocks as well as control blocks were followed the recommended package of practices *viz.*, high yielding varieties (Pusa Basmati-1121), seed treatment, nursery raising, recommended dose of fertilizer (120:60:60 NPK, kg / ha), crop geometry (20 cm × 20 cm) and seed rate (30 kg / ha). Each trial was laid out in an area of 0.1 ha. For assessing impact of improved water management technology (IWMT), transplanting of paddy in adjoining field with

Table 1. Weekly Rainfall and rainy day during *Kharif* 2011 to 2015.

Standard week	Period	Total rainfall (mm)					Rainy days				
	from - to	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
27	2.7.2009 - 8.7.2009	16.5	85.9	90.8	0.0	0.0	2	3	4	0	0
28	9.7.2009-15.7.2009	28.5	32.4	35.6	29.2	92.8	3	3	3	0	5
29	16.7.2009-22.7.2009	142.0	23.3	137.2	74	106.4	3	2	5	4	4
30	23.7.2009-29.7.2009	31.0	47.1	190.8	96.4	189.2	4	2	6	4	5
31	30.7.2009 -5.8.2009	129.0	5.8	112.8	39.0	9.4	3	1	5	2	3
32	6.8.2009-12.8.2009	35.5	240.7	142.9	333.6	44.4	2	6	6	4	2
33	13.8.2009-19.8.2009	14.0	50.2	32.0	15.4	121.8	2	4	2	1	4
34	20.8.2009-26.8.2009	36.0	28.9	75.1	0.0	0.0	5	3	4	0	0
35	27.8.2009-2.9.2009	183.0	32.6	0.00	13.4	0.0	6	2	0	1	0
36	3.9.2009-9.9.2009	78.0	97.8	0.00	114.8	5.8	3	3	0	3	1
37	10.9.2009-16.9.2009	48.5	59.5	4.6	18.8	0.0	2	2	0	1	0
38	17.9.2009-23.9.2009	34.50	29.4	22.2	0.00	0.00	1	1	1	0	1
39	24.9.2009-30.9.2009	0.00	0.00	43.8	0.00	0.00	0	0	1	0	0
40	1.10.2009-7.10.2009	0.00	0.00	7.4	0.00	0.00	0	0	1	0	0
41	8.10.2009- 14.10.2009	0.00	0.00	29.2	0.00	0.0	0	0	1	0	0
	Total	776.5	733.6	924.4	734.6	592.2	36	32	39	20	25

similar area was also done by the farmer which was considered as control plot. For the test plots, measurement of water was done by velocity-area method at field level. The demonstration plots were transplanted with improved water management practices during first fortnight of July and harvested in the mid of October every year. The rainfall received during growing period of rice were 776.5 mm, 733.6 mm, 924.4 mm, 734.6 mm and 592.2 mm with the total rainy days 36, 32, 39, 20 and 25 for the years of 2011, 2012, 2013, 2014 and 2015 respectively (table 1). Potential yield of rice crop in humid south eastern plain zone of Rajasthan was 6000 kg/ha. Production efficiency was calculated on the basis of average maturity days (130 days) of variety Pusha Basmati-1121. Water productivity was also analyzed using standard method (Singh and Kumar, 2011). For economic evaluation in term of gross and net returns and incremental benefit ratio, the prevailing market rates for input, labour and produce was utilized. Data were recorded from demonstration blocks and farmer's practice blocks. These recorded data were analyzed for different parameters, using following formulae, suggested by Prasad *et al.* (1993).

(A) Extension Gap=Demonstration yield(Di)- Farmers practice yield (Fi)

(B) Technology Gap= Potential yield(Pi)-Demonstration yield(Di)

(C) Technology Index=(Pi-Di)/Pi x 100

Statistical analysis of the data for standard deviation and coefficient of variation was done as described by Panse and Sukhatme, 1985. Sustainability indices (Sustainability yield index and sustainability value index) were work out using formula (Singh *et al.*, 1990).

$$SYI = \frac{\text{Estimated average yield (kg/ha)} - \text{Standard deviation}}{\text{Maximum yield (kg/ha)}}$$

$$SVI = \frac{\text{Estimated net return (Rs./ha)} - \text{Standard deviation}}{\text{Maximum net return (Rs./ha)}}$$

$$\text{Water use efficiency} = \frac{\text{Economic crop yield (kg/ha)}}{\text{Evapotranspiration (ha.cm)}}$$

$$\text{Water profitability} = \frac{\text{Net return (Rs./ha)}}{\text{Water applied (m}^3\text{)}}$$

Results and Discussions

Grain yield

Cumulative data over five year (Table 3) revealed that mean grain yield (4506 kg/ha), production efficiency (34.7 kg/ha/day) and crop profitability (₹ 884/ha/day) were found to be 7.5, 7.8 and 8.33 per cent higher under improved water management technology (IWMT) than mean grain yield (4193 kg/ha), production efficiency (14.30 kg/ha/day) and profitability (₹ 816/ha/day) obtained under farmers practices, respectively. However, maximum production efficiency (36.7 kg/ha/day) and crop profitability (₹ 1247 kg/ha) under IWMT were recorded during 2014 and 2012, respectively. The higher grain yield and efficiency indices in relation to production and profitability during particular year and mean basis under demonstrated blocks could be attributed to the adoption of improved water management technology and higher sale price of produce. Year wise variations in grain yield and ultimately in efficiency indices were due to variation in the environmental conditions prevailed during that particular year. Narolia *et al.* (2013) also reported that improved water management practices have showed positive effect on yield potentials of paddy crop. Mean water expanse efficiency (89.0 kg/ha-cm), water use efficiency (36.7kg/ha-cm) and water profitability (9.45 ₹/M^3) which were 57.0, 28.3 and 29.8 per cent higher in test blocks as compared to farmers practice, respectively resulted due to optimal depth of irrigation water applied and by virtue of that more yield obtained. Dhar *et al.*, 2011 reported similar results in rice crop at Jammu.

Yield Gap Analysis

Extension gap, Technology gap and Technological index were evaluated for all the five years. Extension gap is a parameter to know the yield difference between the demonstrated technology and farmer's practice; for study this ranged from 197 to 404 kg/ha with an average of 313 kg/ha. This indicated a wide gap between the demonstrated improved technology and its adoption by the farmers. (Table 4). Technology gap is a measure of difference between potential yield and yield obtained under improved water

Table 2. Effect of improved water management technology on sustainability yield and value index of paddy.

Particulars		2011		2012		2013		2014		2015		Mean	
		IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP
Grain yield (kg/ha) range	H	4450	4300	4890	4630	5050	4690	5000	4800	4150	4040	4708	4492
	T	4100	3750	4400	3945	4500	4020	4560	4070	3880	3630	4288	3883
Mean yield (kg/ha)		4306	4006	4628	4270	4775	4371	4797	4493	4022	3825	4506	4193
Standard deviation		112.4	191.7	158.5	241.7	167.1	181.4	146.6	184.0	89.1	103.1	120	166
CV (%)		2.61	4.79	3.42	5.66	3.50	4.15	3.06	4.10	2.21	2.70	2.66	3.96
Net return range (₹/ha)	H	133450	129200	172957	163619	111966	103174	104600	100636	84445	82832	121484	115892
	T	120748	109250	152720	135329	96395	84206	92579	80692	76804	71229	107849	96141
Mean Net return (₹/ha)		128226	118532	162150	148734	104192	94136	99049	92244	80818	76759	114887	106081
Standard deviation		4078	6954	6546	9980	4730	5134	4006	5026	2521	2919	3940	5520
CV (%)		3.18	5.87	4.04	6.71	4.54	5.45	4.04	5.45	3.12	3.80	3.43	5.20
SYI		0.942	0.887	0.914	0.870	0.913	0.893	0.930	0.898	0.948	0.921	0.932	0.896
SVI		0.930	0.864	0.900	0.848	0.888	0.863	0.909	0.867	0.927	0.891	0.913	0.868

H= Maximum yield at head reach of canal, T= Minimum yield at tail reach of canal IWMT=Improved water management technology FP=Farmers practice

Table 3. Effect of improved water management technology on grain yield, efficiency indices for water use and profitability of paddy.

Year	Yield (kg/ha)		% increase over FP	Water applied (cm)		WEE (kg/ha-cm)		WUE (kg/ha-cm)		WP (₹/M^3)		Production efficiency (kg/ha/day)		Monetary efficiency (₹/ha/day)	
	IWMT	FP		IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP	IWMT	FP
2011	4306	4006	7.5	108.6	133.6	95.7	57.2	39.7	30.0	11.81	8.87	33.1	30.8	986	912
2012	4628	4270	8.4	121.4	149.4	89.0	53.4	38.1	28.6	13.36	9.96	35.6	32.8	1247	1144
2013	4775	4371	9.2	130.6	152.6	125.7	72.9	36.6	28.6	7.98	6.17	36.7	33.6	801	724
2014	4797	4493	6.8	125.5	143.5	92.3	64.2	38.2	31.3	7.89	6.43	36.9	34.6	762	710
2015	4022	3825	5.2	130.7	154.7	60.9	42.5	30.8	24.7	6.18	4.96	30.9	29.4	622	590
Mean	4506	4193	7.5	123.3	146.7	89.0	56.7	36.7	28.6	9.45	7.28	34.7	32.2	884	816

WEE= Water expanse efficiency, WUE=Water use efficiency, WP= Water profitability.

management technology demonstration, this is of greater significance than other parameters as it indicates the constraints in implementation and drawbacks in our package of practices, these could be environmental or varietal. This also reflects the poor extension activities, which resulted in lesser adoption of improved water management technology and package of practices by the farmers. Technology gap can be lowered down by strengthening the extension activities and further research to improve the package of practices. It is dependent on technology gap and is a function expressed in percent. For the five years of study it varied from 20.1 percent to 33.0 percent, with an average of 24.9 per cent. The very low technology index (20.1) during the year 2014 could be due to adoption of improved water management practices, favorable climatic conditions, free from insect pest and disease incidence. High technology index (33%) observed in the year 2015 shows a poor performance of package of practices and demonstrated technology. This was mainly due to early withdrawal of monsoon and unfavorable climatic conditions with incidence of pest and diseases. Such higher technology indices have been also reported in rice crop by Narolia *et al.* (2013).

Economic analysis

Mean data (Table 4) of five years revealed that 8.3 per cent higher net return was found in improved water management technology (₹ 1,14,887 / ha) as compared to farmers practices. Grain yield, cost of inputs and sale price of produce determine the economic returns and these vary from year to year as the cost of input, labor and sale price of produce changes from time to time. The year wise additional returns from improved water management technology over farmer's practice varied from ₹ 4,059 to ₹ 13,416. The mean additional cost of input of all the demonstrations for five years was 1,400 (Table 4). This additional investment along with non-monitory management factors gave an additional mean return of ₹ 8,806. The higher sale price of produce, in spite of low production and higher additional cost of input during 2012 gave highest additional returns under improved technological demonstrations over farmer's practice. The incremental benefit cost ratio (IBCR) on overall average basis was 6.4. The highest IBCR during five years was observed in 2012 (9.6) this is due to comparatively higher grain yield, less cost of input and a good sale price. The results are in agreement with the findings of Singh *et al.* 2012.

Sustainability

The improved water management technology *i.e.* irrigation of 5±2 cm standing water and refilling at 1-3 days after disappearance of ponding water, gave higher grain yield, sustainability yield index and value index compared to the farmers practice. Higher standard deviation and ultimately coefficient of variation in yield observed under farmer's practices during all the experimental years was due to more variations in the yield from farmer to farmer and were lesser in improved water management technology. However, the

Table 4. Economic analysis of improved water management technology on paddy at farmer's field.

Year	Cost of inputs (₹ × 1000 / ha)		Additional cost in IWMT (₹ / ha)	Sale price (₹ / q)	Total return (₹ / ha)		Additional return in IWMT (₹ / ha)	Effective gain (₹ / ha)	IBCR	EG (kg / ha)	TG (kg / ha)	TI (%)
	IWMT	FP			IWMT	FP						
2011	28.0	26.8	1200	3500	128226	118532	9694	8494	8.1	300	1694	28.2
2012	29.0	27.6	1400	4000	162150	148734	13416	12016	9.6	358	1372	22.9
2013	31.0	29.6	1400	2700	104192	94136	10056	8656	7.2	404	1225	20.4
2014	32.0	30.5	1500	2600	99049	92244	6805	5305	4.5	304	1203	20.1
2015	33.0	31.5	1500	2700	80818	76759	4059	2559	2.7	197	1978	33.0
Mean	30.6	29.2	1400	3100	114887	106081	8806	7406	6.4	313	1494	24.9

IWMT= Improved water management technology, FP= Farmers practices, EG= Extension gap, TG=Technology gap, TI= Technology Index sustainability yield index (SYI) and sustainability value index (SVI) were more under improved technology than farmer's practices (Table 1). The mean SYI under improved water management technology varied from 0.913 - 0.942 and SVI of 0.888 - 0.930, whereas value of SYI under farmers practice ranged from 0.870 - 0.921 and 0.848 - 0.891 of SVI. Mean data further revealed that SYI (0.932) and SVI (0.913) increased to the tune of 4.01 and 5.2 per cent over farmers practice. This showed that the improved water management technology is more sustainable as well as economical also as compared to farmer's practice. Chery *et al.* (2014) also observed similar trends in cotton based intercropping system under semi-arid vertisols.

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