Enhancing Crop Productivity and Water Use Efficiency in Chambal Command Area of Rajasthan : Prospectus and Perspectives

PRATAP SINGH, R.S.NAROLIA, I.N. MATHUR, N.N.SHARMA,S.S.TOMAR & P.K.GUPTA

All India Coordinated Research Project on Water Management, Agricultural Research Station (MPUAT, Udaipur) Kota 324001, Rajasthan, India
psd427@rediffmail.com

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ABSTRACT

Improving the efficiency of water use through proper improvement of water management techniques and other production factors is essential to boost on-farm productivity. An important aspects is to link on-farm issues to the scheme level and to apply an integrated management of water management at regional level. Valuing water as an economic and marketable goods may be insufficient since water acts not only for production but is also supporting other natural resources. The water use efficiency (WUE) indicators defined by those ratios is useful to identify the best irrigation scheduling strategies for rainfed and irrigated agriculture and to analyze the water saving performance of irrigation systems and respective management and to compare different irrigation systems including deficit irrigation . The water use indicators are yet far from common usage but they have the potential to be very useful for water resource planning and management at the farm and scheme levels. For farm irrigation, indicators for the uniformity of water distribution are still of great usefulness. Therefore, it is necessary to perform a rigorous analysis of on-farm water management practices and their possible improvements in order to develop sustainable irrigated agriculture, that tend to preserve the environment through a more rational use of the scarce water resources. Most of the irrigation projects throughout the world functioning on the principle on the gravity flow operates with 25-40 percent efficiency. Thus, perhaps on third of the water that is released into canal systems at their head-works is actually beneficially used by crops for evapotranspiration. Irrespective of the method of irrigation, no method or system of irrigation is hundred percent efficient and not all the water that is applied during any irrigation enters the soil and is held in root zone of crops. Very often, reasons for poor efficiency are beyond control of irrigator as well as project authorities, as some unavoidable losses due occur due to seepage and leakage in conveyance system, non uniform distribution of water in the field, percolation below root zone and wastage due to surface runoff at the end of the field. Very often, reasons for losses in surface irrigation systems are beyond control of its user and project authorities. High efficiency is not possible by surface irrigation unless lands are perfectly leveled and prepared for efficient water application for irrigation besides strict control on water releases. In many areas, specifically in water deficit state of Rajasthan, increase efficiency would result in increased irrigated acreage as well as decreased problems of salinity and drainage. Increased average irrigation efficiency always results in increase in crop yield. The sustainability of water resources in agriculture is one of the major concerns in both quantitative and qualitative points of view. Increasing demand for agriculture water and decreasing per capita availability warrant farmers and agriculture managers. Agriculture is the largest user of water in the country (up to 80% of the total available water, Singh and Kumar,2010. Therefore, water security can be warranted by a large increase in agricultural water use efficiency. This can be achieved only when a sustainable water management policy is applied at both network and farm levels. Such policy is largely based on the adoption of modern irrigation techniques such as drip and sprinkler, known to have higher water application efficiency than traditional surface irrigation and to allow in the same time water conservation in limited-water resources environments. All that is needed is to increase the efficiency and productivity of the water already being used through better management and technologies. Water productivity can be increased by obtaining more production with the same amount of water. Excessive irrigation in agriculture is a major source of pressure on surface and ground water, this is in part the result of intensive farming methods requiring large input of water. Farmers for reasons of poverty, lack of basic security and lack of training and agricultural know-how rely basically on inefficient flooding irrigation methods. There is little investment in much more efficient irrigation systems, notably pressurized irrigation used elsewhere in the region. The gross Chambal command area in Rajasthan is 4,85,000 ha out of which 2,29,000 ha is under irrigation.

Chambal Command Area : The Chambal command, lies between 25º and 26ºNorth latitude and 75º-30' and 76º-6' East longitude, in the south eastern part of Rajasthan. Its elevation ranges from 170 to 260 m above mean sea level. The command area comprises part of Kota, Bundi & Baran districts and comes under agro climatic zone V of Rajasthan which is also known as humid south eastern plain of Rajasthan. Chambal is the major river in the area, which is joined by several tributaries such as the Kalisindh, Parwan, Parwati, Mej and Banas rivers as it flows north ward out of the command area.

Canal System : Kota Barrage, situated in Kota city serves the main canal system, from here the two main canals – right and left take off. It has a storage capacity of 0.08 MAF with a free reservoir level (FRL) of 854 ft. It has 19 sluice gates of size 40 ft x 40 ft. The left main canal has a design capacity of 42 m^3/s and right main canal has a design capacity of 188 m^3/s. The left main canal is approximately 2.74 km in length with 966 km of branches, distributaries and minors. The right main canal within the state of Rajasthan is 124 km in length with 1367 km of branches, distributaries and minors. The Chambal irrigation project, is one of the large irrigation and power projects built in India and completed during the period 1953-1971.Soybean/rice-wheat (65%) is the major dominating cropping system. Generally water losses in canal irrigation system are 15-20 % in main canal,6-8% in minors,20-22 % in subminors,25-27 % in distributaries and 28-29% by percolation and evaporation. The designed irrigation intensity of the project is 76 percent (21% in Kharif and 55% in Rabi). During 1973-74 it was 69.14 percent and 1,61,784 ha area was irrigated. Over the years this has increased significantly and maximum irrigation intensity recorded was 135.76 percent during 1996-97, it was 130 percent in 2005-06, and during 2008-09 it was 117.78 percent.

Table 1 : Particulars of canal system

Particulars	Canal system	
	Right Main Canal (RMC)	**Left Main Canal (LMC)**
Cultivable command area (CCA), (lac ha)	1.27	1.02
Discharge at head gate, (Cumec)	190	42.7
Length of main and branch canal, (km)		
Main	124	2.74
Lined	10	2
Branch	1376	1248
No. of distributaries	12	2

Climate : Climate of the area is subtropical and semi-arid, with three distinct seasons; the Kharif (monsoon), which extends from July to September; the Rabi (winter) from October to February and the Zaid (hot) dry period from March to June. Annual rainfall ranges from 600-1400 mm, with an average of 734mm. Approximately 90 per cent of the rainfall occurs during three-month monsoon period (July–September). Significant variation in rainfall can occur among years and among sites within the Chambal command area. The air temperature during the summer (May-June) may reach 49ºC, while during the winter months (December - January) the temperature may fall to 4ºC. The mean annual potential evaporation is approximately 2650 mm based on 35 years of data (1957-1991) at the Kota weather station. Potential evapotranspiration is calculated at about 1800 mm. During the year 2009, evaporation varied from 1.0 mm/day to 16.0 mm/day in the months of January & June respectively. Evapotranspiration and evaporation rates generally exceed precipitation in all months except during the monsoon season. The total rainfall recorded at centre was 302.56 mm, with total 30 rainy days out of which 24 rainy days were in the months of July and August.

IMPROVEMENT IN WATER USE EFFICIENCY WITH THE BACKUP OF TECHNOLOGICAL DISSEMINATION

Improved water supply management : Better timing of water supplies can reduce stress at critical crop-growth periods, leading to increased yields. By increasing reliability of supply, farmers tend to invest more in other agricultural inputs leading to higher output per unit of water.

Improved on-farm water management: Controlling salinity through water management practices at project or field level can prevent reductions in water productivity. Mulching, direct seeding of rice and greenhouses reduce evaporation. Stopping water deliveries during rainy periods, or raising field bunds in rice areas captures more rain that may otherwise flow to sinks.

Deficit, supplemental and precision irrigation: With sufficient water control, it is possible to utilize more productive on-farm practices. Deficit irrigation is aimed at increasing productivity per unit of water by irrigation strategies that do not meet full evaporative requirements. Irrigation supplementing rainfall can improve productivity of water when a limited supply of water is made available to crops at critical periods. Precision irrigation, including drip, sprinkler and level basins, reduces non-beneficial evaporation, applies water uniformly to crops, reduces stress and thus can lead to increases in water productivity. The experimental research findings of the water management project, Kota, are disseminated to the farmers by means of Operational Research Programme(ORP). Through ORP, the farmers of the area are educated to schedule irrigation at appropriate crop growth stages and to apply appropriate quantity of irrigation water avoiding the chances of over and under irrigation. This enables the farmers to use more efficient methods of irrigation to reduce water application losses and to have uniform distribution of applied irrigation water to cover more area with less labour and time requirement. Research findings also help farmers to select most remunerative cropping sequences and intercropping systems best suited to their irrigation resources.

Assessment of water availability at distributaries

The water supplied in the distributary during the Rabi months i,e, February, March, April and during Kharif months-May, June, July, August and September. It was minimum in October (4850 hacm) and maximum in November (17856 hacm). The relative water supply in November was 68 % whereas in October with 10 days canal running it was 48 %. The canal water availability at field level during Rabi 2007-10 ranges between 22971-31438 hacm(Table2).

Reconciliation of demand at field level

The total water requirement of the area was calculated based on the total irrigation water, farmers applied for a particular crop and then by adding the quantity of irrigation water applied to all the crops. In Rabi wheat, garlic and vegetables consumed most of the water while in Kharif paddy and vegetables. The season wise water availability at field level through canal as well as water requirement of the crops were worked out and given in table 2. The total water deficit was 915 to 2564 ha cm during kharif and was 6279 to 14715 ha cm during Rabi seasons of 2005-10.

Table 2 : Availability, requirement and deficit of water at field level, Manasgaon distributary

Year	Crop season	Available water (ha cm)	Rain (ha cm)	Requirement (ha cm)	Deficit / Surplus in water supply (ha cm)
2007	Rabi	31438	4405	50557	- 14715
	Kharif	19711	44919	65545	- 915
2008	Rabi	38847	2642	48509	- 7020
	Kharif	4027	49543	52492	- 1079
2009	Rabi	22971	-	29250	-6279
	Kharif	0	38640	41204	-2564

Impacts of Water Management Technologies

There are serious concerns in Chambal command about the efficiency of the irrigation system. At scheme level, overall efficiency (storage and conveyance efficiencies) dose not exceed 40 %. At on-farm level, water use efficiency includes distribution uniformity and application efficiency of the irrigation method. It could very from 50 % with surface irrigation techniques to70% with sprinkler irrigation, to 85 % with drip irrigation. Drip irrigation system has been the most efficient irrigation technique and has the highest distribution uniformity with comparison to sprinkler and surface irrigation techniques. In any irrigation scheme, the three components of the overall irrigation efficiency, i.e. storage efficiency, conveyance efficiency and on-farm efficiency, should be improved. Moreover, uniformity of water application is necessary to increase efficiency. This implies controlled water application associated with good land preparation and leveling. Adequate design of head and field ditches with appropriate flow rates also remain essential in surface irrigation. For sprinkler and drip systems, good design, operation and maintenance of performing equipment are key factors to be evaluated.

EFFICIENT IRRIGATION METHODS AND IRRIGATION SCHEDULING

Border strip method :

Border strip method of irrigation is the most common method for irrigating the crops. A border system (basin and/or limited flood irrigation) involves wetting almost all the land surface and is normally not an efficient irrigation method if fields are not leveled. However, if the water conveyance system is consisting of pipes instead of open canals, in such a way to deliver water into the furrows by means of gated pipes or siphons, in this case the efficiency of the system could be improved. However, the use of traditional irrigation methods is not satisfactory because they consume huge volumes of water. For wheat a 4m wide and 50 m long border strip irrigated by a stream size of 2 lps/m border width and at a stream cut off ratio of 90% produced highest mean grain yield and water use efficiency. It also recorded highest water application and distribution efficiencies (Table 3).

Table 3 : Grain yield of wheat as influenced by border width, cut off ratio and stream size

Treatments	Grain Yield(q/ha) 1988-89	Grain Yield(q/ha) 1989-90	Mean water use efficiency (kg/ha/cm)	Water application efficiency (%)	Water distribution efficiency (%)	Water Storage efficiency(%)
Border width (m)						
4 × 50	38.94	33.41	16.99	77.16	78.71	59.65
6 × 50	37.09	31.66	16.43	74.67	76.63	56.75
8 × 50	34.87	29.20	15.64	72.52	75.02	55.56
CD at 5%	0.67	0.52				
Cut Off ratio (%)						
80	36.28	30.65	16.31	75.83	75.74	57.38
90	37.65	32.2	16.40	73.81	77.87	58.56
CD at 5%	0.55	NS				
Stream size (lps/m)						
1	35.80	30.06	15.08	75.76	76.06	55.80.
2	38.13	32.79	16.93	73.86	78.45	58.41
CD at 5%	0.55	0.43				

Furrow irrigation :

In this method field is laid out in alternate ridges and furrows. Water is applied in furrows seeps into ridges which are moistened to top by the capillary action of soil. The bulk density of the ridges remain low, inspite of flooding the furrows. This helps in a proper balance between soil water and soil air in the root zone. The furrows should have a uniform and gentle slope down their length. The length of furrows, varies with the intake of soil and percentage slope and may be determined experimentally. Water should never overflow the ridges as this seals the surface soil pores, thereby raises its bulk density and leads to anaerobic conditions. The ridges may be wetted to about two-third of the height leaving the rest to be moistened by capillary movement of water. Water application efficiency was maximum for 50 m furrow length, irrigation in alternate furrow with cut off ratio of 80 per cent. Under conditions of water scarcity, saving in irrigation water was observed by applying water to alternate furrows in alternate irrigation with some yield compensation. Water distribution efficiency was affected by furrow length, method of irrigation but not by cut off ratio. However storage efficiency was more in 100 m furrow length with 90 per cent cut off ratio in vertisols of Kota (Table 4).

Table 4 : Grain yield of wheat as affected by border width, cut off ratio and stream size

Treatments	Grain Yield (q/ha)	Water application efficiency (%)	Water distribution efficiency (%)	Water Storage efficiency (%)
Furrow length(m)				
100	21.50	75.32	81.05	37.47
75	19.40	78.60	82.37	34.37
50	18.80	81.95	83.75	30.65
CD at 5%	0.45	0.50	0.67	2.16
Cut off ratio (%)				
80	19.50	79.36	82.21	33.18
90	20.35	77.88	82.56	35.15
CD at 5%	0.25	0.33	1.13	1.43
Method off irrigation				
Each furrow	21.40	76.30	84.65	39.63
Alternate furrow	18.40	80.95	80.13	28.70
CD at 5%	0.25	0.33	1.13	1.43

An experiment was conducted at ARS,Kota(2006-09) on FIRB system revealed that the IW/CPE 1.2 was found significantly superior than IW/CPE 1.0 in producing wheat equivalent yield (Table5). Furrow irrigated raised bed system gave significantly higher wheat equivalent yield as compared to flat sowing wherein 3 rows of wheat produced highest wheat equivalent yield and water expense efficiency.

Table 5 : Effect of irrigation scheduling and planting methods on productivity of lucerne + wheat system

Treatments	Wheat Equivalent Yield (q/ha)				Mean WEE
	2006-07	2007-08	2008-09	Mean	(kg/ha/cm)
Irrigation Schedules					
IW/CPE=0.8	54.20	51.03	58.02	54.42	175.4
IW/CPE=1.0	59.50	64.88	68.72	64.37	148.1
IW/CPE=1.2	67.52	73.91	85.40	75.61	131.0
CD(P=0.05)	4.80	7.34	14.93	9.02	
Planting Methods					
FIRB 2 ROWS	53.90	53.69	64.77	64.77	117.2
FIRB 3 ROWS	66.75	63.84	70.57	70.57	145.0
FIRB 4 ROWS	58.45	60.09	62.91	62.91	128.4
Flat sowing	54.56	53.20	84.62	84.62	108.6
CD(P=0.05)	6.10	7.94	6.06	6.06	

Sprinkler irrigation

Sprinkler system, if properly designed and operated, gives uniform distribution of water without compacting the soil surface and reduces water losses in terms of deep percolation. The rate of water application is regulated according to the infiltration rate of the soil. The uniformity of application is assured by overlapping pattern of spray from different size nozzles. Sprinkler irrigation was also beneficial on frosty nights, as a preventive measures against frost because it reduced frost incidence . Sprinkler system could be used in special situations where surface irrigation methods are not possible. Such situations includes- undulating topography , sandy soils with high water intake rate or fine textured soils with very low intake rates and costly and scarce water supply but assure returns. The system is expected to economize on water by about 40 -50 %. However the initial cost of the system consisting of pipes, risers and sprinklers heads with a pressure pump is high and technical know-how is required to install and operate the system efficiently but farmers can use these, as state government provides subsidy on the sprinkler system. Pressurized automated or mechanized sprinkler systems have the advantage of reducing significantly the number of operators directly involved in irrigation, with comparison to mechanized sprinklers (portable sprinklers) which are hand operated systems. Furthermore, sprinkler systems are more sensitive to water quality than surface irrigation methods, mainly for clogging problems in sprinkler heads. Potential toxicity effects on plant health can also occur when water is saline and contains toxic elements (Na^+ and Cl^-). Usually, sprinklers can be used on the condition salinity level is acceptable and within the ranges of use. Due to sticky nature of soils in Kota region, transportability may be a problem to some extent but this can be minimized by the use of PVC lines and mini-sprinklers can be used and are found satisfactorily better than aluminum pipes. At research station, Kota an experiment was carried out (2009-12) to see the performance of wheat crop under mini-sprinkler irrigation and fertigation with varying dose of nitrogen. The maximum and significantly higher wheat yield was observed under irrigation at IW/CPE ratio of 1.0 and 75% N through fertigation (Table 6).

Table 6 : Wheat yield under mini-sprinkler irrigation and fertigation

Treatment	Grain Yield (q/ha) Pooled	Mean WEE (kg/ha/cm)
Surface irrigation at 1.0 IW/CPE ratio + Entire NPK as soil application	49.0	154.5
Irrigation at IW/CPE 0.6 + 75% N through fertigation	46.1	250.1
Irrigation at IW/CPE 0.6 + 100% N through fertigation	44.4	239.9
Irrigation at IW/CPE 0.8 +75% N through fertigation	52.1	178.6
Irrigation at IW/CPE 0.8 +100% N through fertigation	51.7	177.2
Irrigation at IW/CPE 1.0 +25 % N as basal & 75% N through fertigation	56.9	164.3
Irrigation at IW/CPE 1.0 +100% N through fertigation	55.1	159.8
CD at 5%	1.84	

Studies)revealed that onion crop under micro sprinkler irrigation and fertigation perform better. The maximum bulb yield obtained micro sprinkler irrigation at 100% PE and 100% nitrogen through fertigation being micro sprinkler irrigation at 100% PE and 50% nitrogen through fertigation and 50 % as basal dose. Maximum water use efficiency (818.56 kg/ha/cm) was in micro sprinkler irrigation at 60% PE and 100% nitrogen through fertigation. Sprinkler irrigation at 60% PE + 100% nitrogen through fertigation found remunerative and water saving was 48.4 per cent in onion.

Drip irrigation

Drip/ trickle irrigation has the advantage due to its high application efficiency and distribution uniformity to be the most efficient technique because it irrigates more lands with less water volumes with comparison to other irrigation techniques. This method involves slow application of water in the root zone of the plant and is not influenced by the climatic factors that increase water evaporation from the soil, as in sprinkler and surface irrigation. The losses of water by deep percolation and evaporation are minimized when compared to furrow and basin methods. A precise amount of water is applied to replenish the soil water deficit at frequent intervals. The system enables not only application of water but also of fertilizers at an optimum rate needed by the plant. The amount of water applied to the soil is almost equal to the daily consumptive use. This helps in maintaining a low soil moisture tension. Continuous supply of water results in better fertilizer utilization by the crop. About 50 % less irrigation water is required under drip irrigation system with comparable yields over furrow and check basin irrigation methods. Moreover, drip irrigation tends to reduce weed development and control by restricting the wetted area to the root zone. Furthermore, drip irrigation requires less pumping pressure and energy cost with comparison to sprinkler and surface irrigation techniques. When initial investments are provided, drip irrigation seems to be more profitable irrigation to farmers and to the farming systems. Drip irrigation, in general, might be the one to be recommended for irrigation in semi-arid regions. In sprinkler irrigation , a considerable volume of water is lost by wind drift in windy places, so that undesirable plots are wetted, making the water waste more. Under drip irrigation, such waste doses not exist since water application is localized near the plants stem. However, when water quality for irrigation is low, the high concentration of suspended solids may interfere with the flow of water in pipes and emitters and clogging of emitters becomes a serious concern. Therefore, water quality is of primary importance in the design operation and maintenance programme of sprinkler and drip systems because clogging induces growth of fungus and bacteria in emitter orifices or supply lines, as do by heavy concentration of algae and suspended solids. For this reason, suspended solids should be removed as much as possible before water could reach the drippers, using sand and screen filtrations and chemical treatments of system frequently.

Experiment conducted at ARS,Kota on drip irrigation in potato, keeping spacing of drip laterals 90 cm and dripper spacing 20 cm revealed that the maximum tuber yield was observed under drip irrigation at 100% PE + 100% N through fertigation. However this treatment was statistically at par with drip irrigation at 75% PE + 100% N through fertigation, drip irrigation at 100% PE + 75% N through fertigation and drip irrigation at 75% PE + 125% N through fertigation with respect to potato yield. The remunerative yield and water saving point of view drip irrigation at 75% PE + 100% N through fertigation found suitable in vertisols (Table 7).

Table 7 : Drip irrigation and fertigation in potato crop

Treatment	Tuber yield (q/ha)		
	2005-06	2006-07	Mean
Surface irrigation IW/CPE ratio 1.5 + Entire NPK as soil application	174.00	162.33	168.17
Drip irrigation at 100% PE + 75% N through fertigation	234.62	330.67	282.64
Drip irrigation at 100% PE + 100% N through fertigation	256.67	376.42	316.55
Drip irrigation at 100% PE + 125% N through fertigation	254.09	370.60	312.34
Drip irrigation at 75% PE + 75 % N through fertigation	211.33	275.42	243.38
Drip irrigation at 75% PE + 100% N through fertigation	236.87	327.67	282.27
Drip irrigation at 75% PE + 125% N through fertigation	233.23	330.00	281.62
Drip irrigation at 50% PE + 75 % N through fertigation	202.17	214.33	208.25
Drip irrigation at 50% PE + 100% N through fertigation	206.33	215.67	211.00
Drip irrigation at 50% PE + 125% N through fertigation	208.80	215.67	212.23
CD (P= 0.05)	29.55	39.96	35.25

In the kharif seasons water expense efficiency and equivalent yield (Table 8) were also higher in the intercropping systems of soybean + maize (4:2) when irrigated at IW/CPE ratio 0.8.

Table 8 : Effect of irrigation levels on soybean + maize productivity under intercropping systems

Treatments	Soybean Equivalent Yield (kg/ha)				Water Expense Efficiency (Kg/ha/cm)			
	2006	2007	2009	Mean	2006	2007	2009	Mean
Irrigation levels								
IW/CPE 0.6	1736	2243	2102	2027	34.04	45.77	46.87	42.23
IW/CPE 0.8	2340	2657	2636	2544	45.88	54.20	64.17	54.75
CD at 5 %	587	290	245					
Inter cropping systems								
2:2 (Soybean + Maize)	2138	2361	2240	2246	41.92	48.18	54.63	48.24
3:2 (Soybean + Maize)	2357	2755	2794	2635	46.21	56.22	68.17	56.87
4:2 (Soybean + Maize)	2648	3080	2916	2881	51.92	62.85	71.27	62.01
Sole Soybean	1503	2212	2408	2041	29.47	45.14	58.73	44.45
Sole Maize	1546	1843	1486	1625	30.31	37.61	36.29	34.74
CD at 5 %	516	493	580					

Irrigation scheduling and nutrient management

An experiment was conducted on vertisols during kharif 2001-2003 to evaluate the schedule of irrigation and levels of potash for turmeric cultivation. IW/CPE of 1.0 gave maximum tuber yield of turmeric (263.61 q/ha) which was statistically at par with IW/CPE of 0.8.Among potassium levels, 150 kg K_2O/ha gave maximum yield (245.13 q/ha) but was found at par with the yield (244.87 q/ha) at 100 kg K_2O/ha. Maximum Water expense efficiency (436.10 kg/ha/cm) was obtained under IW/CPE of 0.6.

Table 9 : Effect of seed rate, irrigation schedule and nitrogen levels on grain yield of late sown wheat.

Treatment	Grain yield (q/ha)			WEE (kg/cm/ha)		
	2001-02	2002-03	Mean	2001-02	2002-03	Mean
Seed rate						
125 kg/ha	48.47	46.64	47.55	142.55	137.17	139.86
150 kg/ha	51.57	48.22	49.89	151.67	141.82	146.74
P=0.05	1.17	0.72		-	-	
Irrigation schedules						
IW/CPE=0.6	44.07	44.79	44.43	157.39	159.96	158.67
IW/CPE=0.8	52.87	46.90	49.88	155.50	137.94	146.72
IW/CPE=1.0	54.63	47.18	50.90	136.57	117.95	127.26
P=0.05	2.17	0.44		-	-	
Nitrogen levels (kg/ha)						
90	43.35	42.87	43.11	122.50	126.08	124.29
120	46.74	45.08	45.91	137.47	132.58	135.02
150	50.95	47.99	49.47	149.85	141.41	145.63
180	52.06	47.79	49.92	153.11	140.55	146.83
P=0.05	3.48	0.75		-	-	

Irrigation scheduling and Integrated nutrient management

Field experiment conducted at ARS,Kota during 2008-09 and 2009-10 revealed that irrigation schedule at IW/CPE ratio 0.6 and 0.8 were non-significant with respect to yield of coriander. Different organics significantly affected the seed yield of coriander wherein vermicompost (3.33 t/ha) + azotobacter + PSB cultures gave the highest seed yield but was at par with the FYM (10 t/ha) + azotobacter + PSB. Similarly both organics gave higher WEE as compared to control. Application of 30 kg/ha sulphur significantly increased the seed yield and water expense efficiency. Organic and sulphur fertilization also improved the volatile oil content of coriander.

Table 10 : Effect of irrigation schedule, organics and sulphur on productivity and quality of coriander

Treatments	Seed Yield (q/ha)			WEE (kg/ha/cm)			Oil (%)	
	2008-09	2009-10	Mean	2008-09	2009-10	Mean	2008-09	2009-10
Irrigation schedule								
IW/CPE 0.6	11.75	13.07	12.41	53.4	59.4	56.4	0.30	0.31
IW/CPE 0.8	13.27	15.10	14.19	47.4	53.9	50.7	0.29	0.31
CD at 5%	NS	NS					NS	NS
Organics								
FYM (10 t/ha) + Azotobactor + PSB)	12.62	14.63	13.63	50.5	58.5	54.5	0.30	0.31
Vermi compost (3.33 t/ha) + Azotobactor + PSB	13.38	15.45	14.41	53.5	61.8	57.7	0.29	0.31
Control	11.53	12.19	11.86	46.1	48.8	47.4	0.27	0.29
CD at 5%	0.77	0.88					0.02	0.02
Sulphur (kg/ha)								
0	11.31	12.93	12.12	45.3	51.7	48.5	0.27	0.29
15	12.45	13.97	13.21	49.8	55.9	52.8	0.28	0.30
30	13.76	15.37	14.56	55.1	61.5	58.3	0.30	0.32
CD at 5%	0.89	0.90					0.01	0.01

Increasing soil water storage capacity : Incorporation of farmyard manure, green manure or vermicompost not only increase moisture retention capacity of soil but also imparts resistance in the plant to tolerate drought. Deep ploughing improves soil water storage capacity by increasing hydraulic conductivity and infiltration rate. This resulted in increased root growth and pushed yield. Deep soil with better soil physical conditions stored more water in soil profile than the eroded one. The maximum and significantly higher seed yield of soybean was observed in broad bed furrow (BBF) three rows at ARS, Kota during 2010.

Water efficient varieties : Crop varietal improvement plays an important role in developing varieties that yield more mass per unit transpiration. For example, by reducing growth period while keeping the same yield, production per unit evapotranspiration increases. Changing the partitioning between green matter and grain yield increases water productivity when evapotranspiration is kept constant. At ARS,Kota,wheat variety HI-8498 performed best by giving highest mean yield of 43.66 q/ha, irrespective of irrigation schedules. Mean maximum water expanse efficiency was recorded under irrigation at 40% depletion followed by two irrigations at CRI and milk stage, one irrigation at CRI, irrigation at 60% depletion and four irrigations at critical stages. On the analysis of last five years (2005 to 2009) data of temperature and evaporation it was observed that both the evaporation and daily mean maximum temperature shoots up abruptly from the month of february onwards which leads to forced maturity in wheat resulted reduction in crop yield. Therefore, irrigation schedules of the zone were slightly modified to cope up this situation and to avoid moisture stress at critical stages. Based on this, following new schedule for irrigation of wheat crop in the zone proposed.

Another experiment conducted for scheduling of important varieties of soybean in Chambal command. Five years (2004, 2005, 2006, 2007 & 2008) data indicate that among irrigation schedules, irrigation at 40 %, depletion of available soil moisture (ASM) also recorded highest yield (19.01 q/ha.Pratap Soya–1 variety gave maximum seed yield (18.75 q/ha) followed by JS-335. Water production function is the relation is non linear polynomial, the equation derived $Y = -0.0361x^2 + 38.306x - 8293.3$ with $R^2 = 0.9898$.

Table 11: Effect of Irrigation scheduling on the yield of Soybean varieties (Pooled 2004-2008)

Treatment	Seed yield (q/ha)	Mean WEE (kg/ha-cm)
Irrigation schedules		
40 % depletion of ASM	19.01	36.87
60 % depletion of ASM	18.43	35.44
Branching & pod development	17.50	37.03
Pod development	16.36	37.16
Control	13.66	34.26
CD (P = 0.05)	1.98	
Varieties		
NRC –37	16.82	32.85
MACS – 450	14.83	28.49
Pratap Soya- 1	18.75	36.40
JS-335	17.49	34.30
CD (P = 0.05)	2.36	

Impact Assessment of ORP Area

The impact assessment study on different crops (Rabi and Kharif) in the ORP area was done the year 2009. In Rabi the main crops were wheat and mustard while in Kharif soybean and paddy. It was noticed that most of the farmers are adopting the recommended practices of the package, but in some cases, they are using the inputs in excess of recommended. For example recommended seed rate of normal sown wheat is 100 kg/ha but farmers are using 130 –150 kg/ha seed rate. The per cent adoption of recommended package specially with respect to depth of irrigation water applied, method of irrigation, chemical weed control, application of zinc and potash in wheat and paddy and sulphur in mustard was less. However farmers were using seeds of improved variety and adoption varied from 88 to 95.3 per cent. Similarly in case of nitrogen fertilizer application, more than 76.3 per cent farmers adopted recommendations in all the crops studied except soybean where the adoption in this regard is only 14 per cent.

Table 12 : The average WUE of major crops grown in Operational Research Area of chambal command

Crop	Water Use Efficiency (kg/ha-cm)	
	After Technology	Before Technology
Paddy	31.62	19.93
Soybean	114	84.76
Wheat	130.88	84.00
Mustard	85.45	59.33
Potato	812.00	521.72
Coriander	65.00	32.50

Major Challenges and Problems to Improve WUE In Chambal Command Area

- On farm resource development will reduce the losses of irrigation water occurring at farmers field due to faulty irrigation structures and unleveled fields.
- Repair and maintenance of canal network, desilting of minor and water courses.
- Availability of irrigation water for head farmers and non availability to tail enders.
- Lack of Warabandi system in the chambal command areas.
- Less adoption of new irrigation technologies due to enough availability of canal water
- Poor and untimely availability of agricultural inputs.
- Poor irrigation delivery system.
- Few administrative powers to water user associations.

Water Management Related Problems in the Command Area

- Poor rainwater harvesting systems
- Land water management under scarce condition are lacking
- Limited technology regarding flow, frequency & fertigation etc. under modern pressurized irrigation systems
- Lack of integrated water management techniques for high value crops
- Less adoption of improved technologies by the farmers due to higher cost and enough availability of canal water at head
- Limited dissemination, demonstration, field days and farmers fairs on new water management technologies.
- Non availability of canal water at critical stage during later half of rabi season due to less storage in reservoirs

As farming is and has been a very risky business mainly depend on climatic conditions, weather changes and marketing problems. Production is becoming more expensive and farming life becomes more difficult. This can be attributed to many points among them some are:

Unknown Optimal water use : farmers often don't know the precise water needs of crops. What farmers know, however, is that shortage of water equals yield loss, whereas seldom damage is done by over-irrigation. In practice, irrigation is often related to the availability of water resources, regardless of actual water needs. Hence, water stocks are used inefficiently in time and place. If used carefully, limited-water resources approach, such as sprinklers and drippers are used.

Inefficient management of irrigation water services: In the case of irrigation, farmers must often deal with the constraints due to the need of sharing water within a network. In the region, however, water for irrigation purposes is in most of the cases used individually, without any participative interest to use water collectively from the part of the agricultural communities. This in reality is due on one hand to lack of collective irrigation networks established by the competent authorities and on the other hand to ineffectiveness of water user associations, which practically supervise the irrigation operations. These two factors contributed to the disorganization of the irrigation sector and increased the conflict to water in the command. Many irrigation systems operate on the "feed-forward" principle of trying to deliver water in *anticipation* of crop water needs, which is fraught with errors. This is why tube-well irrigation systems in India typically produce yields that are two to three times greater than canal irrigation systems. Tube well water is available virtually on the farmer's demand while in most Indian canal systems farmers must wait for their turn.

Technological inadequacy : Differences prevail in the technological levels at both the on-farm water management systems and the water conveyance and distribution systems. Adequate technology is a prerequisite both for high irrigation efficiency and for implementation of volume-related incentives. The general objectives of using modern irrigation techniques, such as sprinkler and drip systems, instead of using the traditional surface irrigation, are to ensure water saving policy based upon increasing the economic water use efficiency of the irrigated agriculture. This will be achieved by developing and testing a system to assess real water need and optimal water allocation. In combination with context-specific incentives aimed to improve water use efficiency and reduce wastage of water.

Unknown knowledge of exact crop water needs : Yields increase with water availability until a "saturation level", above which there is little effect of water application on yield. Therefore it is difficult for a farmer to tell at any given moment whether there is a water deficit or not. Since over abundant water, short of water logging, usually does not cause harm, growers tend to "play safe" and increase irrigation amount, especially when associated costs are low as in case of canal irrigation.

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