

Enhancing productivity through water management

in hot arid Rajasthan

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Water is a limiting factor for crop production in hot arid zone of Rajasthan. Availability of water is likely to decrease in near future to meet the demand of other sectors. Under such circumstances there is urgent need to improve the natural availability of water through efficient rainwater harvesting and management. Rainwater harvesting like tankas, nadi, farm pond etc. can significantly improve the availability of water. Besides availability, improving water productivity i.e. more production per drop of water is also important. Water productivity can be improved by adoption of appropriate crops and cropping to enhance on-farm water use efficiency, reducing water loss by adoption of efficient irrigation methods like sprinkler and drip irrigation systems, application of fertilizer and manures, use of efficient mulches for reducing evaporation loss etc.

Key words: Environments. Hot arid, Productivity, Water management

RAINFALL is the principal source of water in arid areas, which augments soil moisture, groundwater and surface flows. Agriculture and several of the other economic activities in arid areas depend on rain. In absence of any well-defined perennial river system in this region, every drop of water becomes precious. Of the total water use about 85% of water is used for irrigation and remaining 15% is used for drinking, industrial and other purposes. About 65% of irrigation water and 30 to 40% of drinking water is subjected to serious losses. Hence, increasing water use efficiency coupled with increasing availability of water through rainwater harvesting and management is of prime importance for sustainable development of arid areas.

Enhancing water availability

Since primary source of water in arid zone is rainwater, so for any

improvement in availability of water, catchment conditions become crucial. Catchment is the base for harvesting rainwater as runoff which is highly dependent on catchment's shape, size, slope, type etc. Besides rainfall characteristics some general modifications can help in enhancing the runoff from catchments are:

- Simple earth smoothing and compaction helps increasing runoff from catchment areas. Success is generally greater on loam or clay loam soils.
- Removal of stones, boulders, and unproductive vegetation from catchment helps in uninterrupted flow, enhances runoff to collection site.
- Land shaping into roads and collection of water in channels.
- Sandy soils have low water-holding capacity. Spreading of clay blanket to the soil surface reduces the infiltration and consequently accelerates runoff.

Rainwater harvesting through tankas

Tankas are underground tanks, found traditionally in most part of western Rajasthan. *Tankas* are lined with fine polished lime for collection of rainwater primarily from roof top of individual house. The water collected in small *tankas* is generally used for drinking purposes, however, bigger *tanka* can be used for providing supplemental/life saving irrigation to horticultural plants. CAZRI has designed underground *tanka* of 10 to 600 m³ capacities for different rainfall and catchment conditions. These *tankas* were successfully constructed in Jhanwar, Sar, Baorali-Bambore (Jodhpur district) and Kalyanpur (Barmer district) villages. Harvested water of these *tankas* was used to provide life saving irrigation to plants. Benefit: cost of *tankas* ranged from 1.25 to 1.40 under different uses.

Circular *tanka* was more economical than rectangular *tanka* of same capacity in cost of materials and



Fig. 1. Improved *nadi* with inlet and outlet

life span. Cement concrete is preferred over masonry construction especially for larger *tanka* of capacity over 100,000 liter. A 21,000 liter capacity *tanka* is sufficient to meet the drinking water requirement of a family of 6 persons for round the year. Approximately 300 m² area is needed as catchment under assured minimum rainfall of 180 mm with a runoff coefficient of 0.4 to fill. Between 5 and 10 cm sand filling between masonry wall and earth is recommended for longer-life span of *tanka* particularly under clay and heavy soils. To avoid entry of any pollutant from outside, *tanka* is covered at top with stone slabs and cement concrete flooring with an opening for withdrawal of water. Inlet and outlet is provided with weld mesh to avoid entry of any foreign material and small ruminants. A uniform slope of 2 to 3% towards *tanka* is provided for harvesting maximum possible runoff. The improved design of *tanka* has a life span of more than 30 years. The cost of construction of *tanka* varies from ₹ 5 to 6/litre.

Rainwater harvesting through *Nadis*

Nadis are village ponds used to store runoff water from adjoining natural catchments during the rainy season. In arid Rajasthan *nadi*-system of water harvesting is the oldest practice and still the principal source of water supplies for human and livestock consumption. Across Rajasthan, most *nadis* have a capacity of between 1,200 and 15,000 m³. Water availability in *nadi* ranged from 2 to 12 months after the rains. Since *nadis* received runoff from sandy and eroded rocky basins, large quantity of

sediments used to deposit regularly in them, resulting in quick siltation. High evaporation and seepage losses through porous sides and bottom, heavy sedimentation due to biotic interference in the catchment and contamination are major bottlenecks. Evaporation losses ranged from 55 to 80% of the total losses in various environments. Seepage losses are greatest during the rainy season (July-September) when *nadi* is completely filled. To overcome these problems, CAZRI has developed design for improved *nadis* with LDPE lining on sides and bottom keeping surface to volume ratio 0.28 and provision of silt trap at inlet.

The site selection of *nadi* is based on availability of natural catchment and its runoff potential (Fig. 1). The location of the *nadi* had a strong bearing on its storage capacity due to catchment and runoff characteristics. *Nadis* are 1.5 to 4.0 m deep in dune areas and those in sandy plains vary from 3 to 12 m. Besides, planting suitable tree species around the *nadi* creates an oasis in the desert and improves the local environment.

Rainwater harvesting through micro-catchment technique for tree establishment

Micro-catchment technique is suitable for establishment of trees. In this technique a circular catchment of 1 to 1.5 m radius is constructed around the tree. The catchment is compacted by roller or any other heavy machine. A slope of 5 to 10% is provided in catchment towards tree for directing flow of water. The catchment can also be lined with locally available materials such as polythene sheets, lime mortar, stone

pieces, grasses etc. for higher runoff generation. The plants with micro-catchment have better chances of establishment in rainfed conditions than conventional plantation technique.

Contour vegetative barriers for better moisture regime

Contour vegetative barriers are hedgerows of perennial grasses or shrubs planted at a regular interval on contours for conserving soil and water in sloping lands. The contour vegetative barrier moderates the velocity of overland flow and traps silt at low cost, and augment production of food, fuel and fodder or fiber from lands by growing suitable vegetation species. The spacing between plant-to-plant and row-to-row is governed by vegetation species to be planted as barrier. In general the plant-to-plant spacing is kept at 20 to 30 cm. Pre-determined or 0.5 to 1 m vertical interval between the barriers was found effective for soil and water conservation. Among grasses *Cenchrus ciliaris*, *Cenchrus setigerus*, *Saccharum bengalense*, *Vetiver zizanioides*, *Lasiurus indicus*, *Panicum antidotale* and *Panicum turgidum* can be effectively used for soil and water conservation in arid areas. Shrubs like *Leptadenia pyrotechnica*, *Ipomoea carnea* and *Euphorbia antisiphylitica* can also provide good protection against water and wind erosion. Contour vegetative barriers of *C. jwarancusa*, *C. ciliaris* and *C. setigerus* transplanted at 0.30 m apart on contours at 0.6 to 1.0 m vertical interval in sandy loam soil of Jodhpur performed well and formed effective barriers in reducing soil

Table 1. Comparative performances of surface and pressurized irrigation methods in arid regions of Rajasthan.

Locations	Crops	Irrigation methods	Effects
Sriganganagar	Indian mustard	Boarder strip and sprinkler	The sprinkler system had 42% higher WP than boarder strip method
	Chickpea	Flood and sprinkler	Sprinkler method had 12% higher WP than flood method
	Onion	Flood and micro-sprinkler	The micro-sprinkler method had 74% higher WP than flood method
	Brinjal	Flood and drip	The drip irrigation had 14% higher WP than flood method
Jodhpur	Potato	Furrow and drip	Drip irrigated crop had 54% saving in water use with only 5% reduction in yield
	Tomato	Check basin and drip	Drip irrigated crop had 23% higher yield and 44% higher WP than check basin
	Muskmelon	Check basin and drip	Drip irrigated crop had 18% higher yield and 37% higher WP than check basin
Pali	Cotton	Furrow and drip	Drip irrigation had 43% higher yield with 27% less water than furrow irrigation

erosion and increasing soil moisture storage. Runoff volume and specific peak discharge were reduced by 28 to 97% and 22 to 96%, respectively. In another study conducted at Kalyanpur (Barmer district) during 1998, vegetative barrier of *L. indicus*, *Saccharum munja* and *Cassia angustifolia* were established at horizontal interval of 30 m. The moisture data revealed 36.5, 72 and 54.2% higher moisture storage as compared to control in *C. angustifolia*, *L. indicus* and *S. munja*, respectively.

Enhancing water productivity

The proposition of ensuring food security for the growing population by improving crop productivity at given or even at less water availability necessitates developing apposite strategies to maximize the crop water productivity (WP). In agriculture, the water productivity mean amount of output produced per unit of water involved in the production. Some of the important ways to enhance water productivity are discussed here.

Selection of crops and cropping sequences: Selection of suitable crops and their cultivars matching with rainfall pattern and available soil moisture improves the WP of rainfed crops. The water use efficient cropping sequences for different agro-ecological zones were identified. The results of a 4-year study conducted by CAZRI demonstrated that legume-based rainfed cropping sequences (moth bean and cluster bean) is more water product. Intercropping is a suitable strategy for optimizing resource uses and minimizing risks in water limited

environment. It helps in increasing WP by virtue of reducing evaporation losses, weed control, more yield/area and also extract more water from a large volume of soils. Growing of pulses in the interspaces of the row of cereals and millets improve WP in rainfed arid and semi-arid regions. Many studies conducted by CAZRI in hot arid regions showed that pearl millet-legume intercropping had higher WP of than sole crop.

Groundnut-wheat is an important cropping system of irrigated area of western Rajasthan. Results of an experiment conducted at Bikaner by CAZRI showed that diversification of groundnut-wheat cropping system by moong bean or cluster bean improved WP (Fig. 2). Substitution of groundnut by moong bean improved the physical and economic WP by 13.5 and 88.5%, respectively. Substitution of groundnut by cluster bean recorded 20 and 32% higher physical and economic WP , respectively.

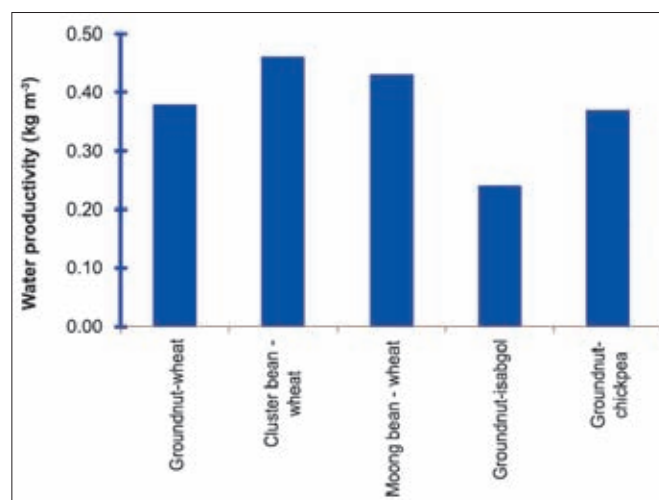


Fig. 2. Water productivity of different irrigated cropping systems at Bikaner, Rajasthan

Irrigation management: The pressurized irrigation method (sprinkler and drip) is more efficient than surface methods of irrigation. The overall efficiency of surface, sprinkler and drip irrigation is 30-35, 50-60 and 80-90% respectively. Sprinkler irrigation in field crops and drip irrigation in vegetable crops improved WP substantially (Table1). In canal command area of Sriganganagar field crops showed that sprinkler irrigation had 12-42% higher WP than surface methods of irrigation. In vegetable crops, the results of drip irrigation were encouraging. The results showed that drip irrigated okra, tomato and muskmelon gave 18 to 38% higher yield with 37 to 44% higher WP compared to check basin irrigation method.

The time of irrigation is an important determinant of yield and WP of irrigated crops. The crop-specific optimum schedule of irrigation for various agro-climatic zones of arid region were identified. For cotton, irrigation at 30 to 35 days after sowing, square formation, flowering, boll formation and boll development or irrigation at IW/CPE 0.7 to 0.8 is suitable. For groundnut, irrigation at vegetative, flowering, pegging and pod

formation stages is suitable in canal command areas of Sriganganagar. In the *kharif* legume crops 2-3 irrigations are suitable. For cluster bean, 2 irrigations at branching and pod development stages, for chickpea 2 irrigation at vegetative and pod formation stages, and for moongbean 3 irrigations at vegetative, flowering and pod development stages are suitable. In wheat, irrigation at IW/CPE 0.7 or 5 to 6 irrigations at 20 to 25 days intervals are suitable. For Indian mustard, irrigation at vegetative, flowering and pod formation is suitable.

Deficit irrigation (DI), defined as the application of irrigation water below the full crop ET, is an important strategy to increase the WP. The deficit irrigation, if properly designed and implemented results in substantial improvement in WP with acceptable yields. The CAZRI identified suitable deficit irrigation schedule for wheat, groundnut and cotton. The results showed that moderate deficit irrigation caused substantial enhancement in WP with slight reduction in yield (Table 2).

Nutrient management: Adequate nutrition helps to improve the availability and utilization of water by crops, and thus improve WP. Adequate nutrient application encourages root growth, increased absorption of water, and thus higher yield and WP. Among the nutrients, the N is most limiting factors in hot arid regions. The results of various studies showed that application of fertilizer and manures to rainfed crop like pearl millet, mustard, sesame increased WP. Areas where water is limiting factor the application of the higher dose of inorganic N fertilizer is restricted. Under these conditions the application of farmyard manure and biofertilizer is more appropriate. The benefits of addition of organic matter include: more efficient use of water, release water slowly, facilitates proper crop growth and thus increases yield and WP of crops.

Tillage: Suitable tillage increases water storage via increasing infiltration and facilitate better utilization of water by crops due to enhanced root growth. Tillage

Table 2. Yield and water productivity of crops with different irrigation levels in hot arid regions of Rajasthan.

Crops	Locations	Irrigation method	Irrigation levels (ETc)	Yield (kg ha ⁻¹)	WP (kg m ⁻³)
Cotton	Pali	Drip	1.0 (FI*)	2,482	0.39
			0.8	2,323	0.41
			0.6	1,884	0.38
Groundnut	Bikaner	Sprinkler	1.0 (FI)	3,154	0.42
			0.8	2,957	0.47
			0.6	1,888	0.34
Wheat	Bikaner	Sprinkler	1.0 (FI)	3,413	1.05
			0.8	3,241	1.17
			0.6	2,109	1.05

*FI represents full irrigation

roughens the soil surface and breaks any soil crust and leads to increased water storage by enhanced infiltration and reduced evaporation losses from deeper layers of the soil. In many rainfed environments, the crop does not use all the water available in the soil profile because of soil mechanical impedance. Sub-soiling or deep tillage facilitate root expansion and soil moisture abstraction by breaking soil hard pan. Deep ploughing showed enhanced yield and rainfall use efficiency on deep sandy soils. The results of several experiments conducted in hot arid regions demonstrated that deep tillage improved soil moisture storage, yield, and WP (Table 3).

Minimizing unproductive loss of water: Evaporation, percolation and water used by weeds are major unproductive losses of water in crop production. Evaporation losses can be minimized by use of mulches. Application of grass mulch @ 6 tonne/ha significantly increased the yield of green gram, moth bean and cluster bean. In another study pearl millet husk and polyethylene mulch application improved the yield and WP of pearl millet. The yield under no mulch, pearl millet husk and

polyethylene mulch were 1.7, 2.3 and 2.9 tonne/ha, respectively, and the corresponding WP were 0.60, 0.85 and 1.04 kg/m³, respectively. Application of paddy-straw mulch @ 6 tonne/ha found to increase WP in cotton, sugarcane and Indian mustard between 9 and 40 % in the canal command area of Sriganganagar. Mulches were found suitable for winter crop raised on rainy season conserved moisture. Availability of suitable materials and uneconomical operation restricts its large-scale adoption.

Weeds compete for water, nutrients, space and light with crop plants. Generally weed transpire more water than crop plants for producing equal amount of dry matter. Water transpired by weeds enhanced soil moisture deficits and increased the crop drought stress in dry periods, resulting in a decrease in crop WP. Therefore timely control of weeds is essential for improving the crop and water productivity. Efficient weed management is essential to maximize WP in both irrigated and rainfed crop production. It was formed that weed control resulted in a marked increase in yield and WP of pearl millet (Table 4).

Table 3. Effects of tillage on yield and WP of crops in hot arid regions of Rajasthan.

Crops	Locations	Effects of tillage practices on WP
Pearl millet	Jodhpur	Deep tillage (ploughing followed by two harrowings) improved the soil moisture storage, WP and grain yield. Yield with deep tillage (ploughing followed by two harrowings) and conventional tillage (two harrowing, cross) was between 23.2–30.7 and 10.2–13.3% higher than minimum tillage(one harrowing).
Wheat (Irrigated)	Pali	Deep tillage significantly enhanced yield and water productivity than conventional tillage. The Deep tillage had 11–17% higher WP than conventional tillage.
Cotton	Sriganganagar	Total ploughing + harrowing and MB ploughing + harrowing had 36 and 39 % higher WP than harrowing.

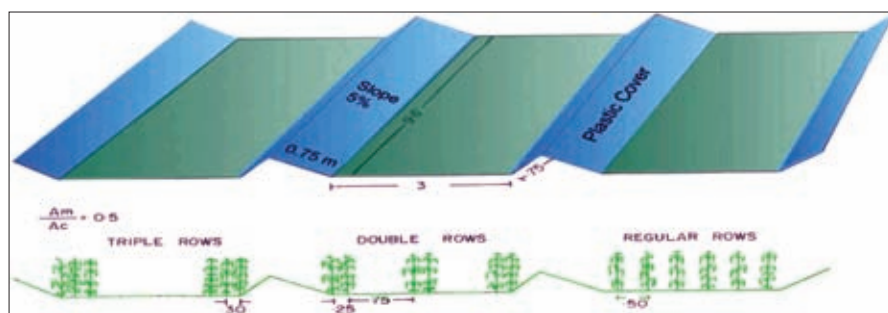


Fig. 3. In-situ water harvesting system

Table 4. Effect of weed control on yield and WP of pearl millet

Treatments	Good rainfall (548 mm)		Low rainfall (252 mm)	
	Yield (kg ha ⁻¹)	WP (kg m ⁻³)	Yield (kg ha ⁻¹)	WP (kg m ⁻³)
Weedy	1,672	0.31	1,053	0.42
Weed free	1,868	0.34	1,521	0.60

Planting geometry and planting density

Planting density and patterns were profound influence on soil water balance, and determine the efficiency of water utilization by crops. High planting density enhance crop water use and decreases evaporation from soil. Higher planting density is advocated to reduce the evaporation in relation to transpiration in moisture adequate environment. In moisture constrained-environment, the higher planting densities may be disadvantageous as it may exhaust the soil moisture quickly and exposed plant to moisture stress. Paired row planting was found more productive and water use efficient than uniform row planting in many crops under rainfed conditions. Conducive micro-climate for plant growth, efficient use of water, better weed suppression, reduction in evaporation and better

utilization of moisture at reproductive stage are factors responsible for higher productivity and WP under paired row planting than uniform row planting. Rectangular planting is more effective in rainfed areas than square planting for raising crop under conserved soil moisture condition. When plants are spaced closely within row and increasing the distance between rows, the soil moisture supply is not exhausted as rapidly as narrow rows.

Inter-plot water harvesting: Inter-plot water harvesting that uses a portion of land with 5% slope as catchment to generate runoff and divert it to adjacent area was found highly beneficial to improve the yield of many crops. CAZRI has developed water harvesting technique with 3 m cropped area and 1.5 m catchment area (catchment to crop

area ratio = 0.5) with 5% slope on both sides (Fig. 3). Response of pearl millet to water harvesting system was studied at CAZRI. Crop water supply, over the check, ranged from 23 to 60 mm in the extremely dry season and 108 to 286 mm in the season with a good rainfall. As a result, in water harvesting plot a yield of 3,717 kg/ha was obtained with 69% of normal rainfall. This ratio (0.5) was found optimum for the type of soil, climate, and surface sealing pond sediment.

SUMMARY

Agriculture is the largest consumer of available water resources. Therefore, better and efficient utilization of water in agriculture is the prime need of the hour. Adopting rainwater harvesting practices like *tankas*, *nadis*, micro-catchment for tree establishment and contour vegetative barriers can significantly improve the availability water. The productivity of available water can further be improved by adoption of appropriate choice of crops and cropping which increases on-farm water use efficiency, using more efficient irrigation methods like sprinkler and drip irrigation systems, application of fertilizer and manures, use of efficient mulches by reducing evaporation loss etc.

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