Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Editorial
Volume 47 Issue 2 March 2026 pp. i-ii
DOI: http://doi.org/10.22438/jeb/47/2/Editorial

J. Environ. Biol., 2026

Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Climate-smart water harvesting approaches for sustainable horticulture in arid regions

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Soil, water, vegetation and production systems are the most important natural resources in any agro-ecosystem. For production systems to be sustainable, they must be in harmony with the environment. The arid ecosystem covers roughly 0.70 km^2 in cold arid conditions and 0.32 million km^2 in hot arid conditions. The entire arid region, which includes the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab, Haryana, Karnataka, and Maharashtra, makes up around 12% of the nation's land area; however, Rajasthan (62%) and Gujarat (20%) make up the majority of this region (Faroda *et al.*, 1998). The climate of the region is characterized by low and erratic rainfall, extreme temperature variation (-5.7°C to 50°C), long sunshine durations (6.6-10 hours), low relative humidity (30-80 %), high wind velocity (9-13 km^{-1}), and high evapotranspiration (1600-1800 mm) (Rao, 2009). In addition to the above, other factors that inhibit agricultural production in this region include poor soil fertility, high rates of wind erosion, water scarcity, and poor quality irrigation water. Water scarcity is one of the most pressing issue affecting agricultural production sustainability in arid and semi-arid regions. It has resulted in over-exploitation of groundwater for indiscriminate use of irrigation (Goyal *et al.*, 2007), and at the same time majority of this is saline with very poor water quality. Excessive use of such water in saline/sodic degraded land results in increased amounts of secondary soil salinization. Therefore maintaining agricultural productivity and livelihoods in this fragile environment will require efficient management of natural resources, especially water and energy. Towards complementing low and erratic rainfall, the region needs enhanced total water supply for irrigation to enable farmers to produce. Water management techniques that can be used to enhance total supply of water for irrigation include tillage, mulching, soil moisture barriers, contour bunds and water harvesting. Hence, conservation and efficient management of limited water is the need of the hour for achieving sustainable production for longer period. Since per unit returns from horticultural crops are higher, their inclusion in the production system improves the net return of farm lands and would impart resilience to aberrant weather. Arid fruit species have some special adoptive features viz. deep tap root system, modified structures and lower water needs during their critical growth phases (Chundawat, 1995). Integrating hardy and water economizing fruit species like ber, pomegranate, fig, and other regional horticultural crops into farming systems will allow better utilization of harvested rainwater (Singh *et al.*, 2017). Consequently, aligning water availability and crop needs will play a large role in improving total water productivity and ensuring sustainability in growing regions that have limited amounts of water. It is also necessary to choose the type of crops and their varieties according to the atmospheric moisture and rainfall. It requires the integration of suitable technologies according to the potential water availability, resource inventory, and available technologies, along with activities related to sufficient runoff generation, its movement, and storage in the reservoirs by means of better design and development of farm plan. At present, the stored water is mainly utilized as an additional source for irrigation in the kharif season and for growing post-monsoon crops (Meghwal *et al.*, 2022; Singh *et al.*, 2017). Land configuration for field water management for inter-row rain water harvesting is a very good approach to increase the potential runoff generation in the field, even in light textured sandy soil. This technique consists of land leveling, contour bunding, mulching, and developing alternate ridge and furrows to minimize runoff losses (Goyal and Sharma, 2000).

Micro-catchment is one of the major forms of direct water conservation systems. They are relatively effective growing trees and shrubs. In micro-catchment based cropping, rainwater is concentrated in a small portion of the cultivable area. Sandy soil have meagre water storage capacity so fruit crops are prefered over seasonal field crop in this system owing to deep-rooted system, fruit crop can utilize the moisture stored in the sub-stratum. Deep rooted tree crops can utilize moisture stored in the sub-stratum forming a better option for micro-catchment based farming in sandy soil. Circular micro-catchments with inward slopes have been found effective for crops like ber, lasora, bael, improving soil moisture by around twenty percent (Ojasvi *et al.*, 1999).

Covering these catchments with plastic sheets can further enhance water conservation by reducing infiltration losses and evaporation. In fruit orchard, rows and inter rows may be mulched with polythene mulch during rainy season to enhance runoff. In a study conducted by Singh *et al*. (2017) at Central Arid Zone Research Institute, it was observed that mulching had significantly enhanced the run off capacity of a field, which was three times higher in row and inter row mulching compared to no mulching.

Rain water harvesting, in specialized designed water harvesting structure, is an integrated approach in farm pond lined with polyethylene and equipped with solar pumping system to operated micro-irrigation system for enhancing water productivity vis-à-vis farm productivity. One such innovative energy and water harvesting model has been developed by the Central Arid Zone Research Institute, with solar PV based ferti-drip system (Singh *et al*., 2017). The model has provision of harvesting rain water of pomegranate field in low cost HDPE lined farm pond having storage capacity of 4.5 lakh litre. For enhancing run off, proper field levelling at around 1 percent slope followed by mulching of row and inter rows with plastic mulch. Anti evaporative material (Thermocol balls of two different sizes) are spread on the pond water surface to reduce water loss from farm pond through evaporation. Harvested rain water is applied through ferti-drip system operated by solar PV pumping system with regulated deficit irrigation. There is also a provision of covering individual plant or rows of plants with non-woven polypropylene sheet (17gsm) to reduce transpiration loss from plant and also to create favorable micro-climate. These coverings reduce transpiration losses, protect fruits from environmental stress and pest damage, and improve fruit quality and marketability (Kim *et al*., 2003).This system is able to irrigate pomegranate trees spread across one acre land with 30% higher water productivity without affecting crop productivity. Best quality pomegranate fruits with minimum agrochemical residue are being harvested which enhanced marketable yield. The system has proved its potential in non-traditional areas where ground water quantity and quality are not much suitable for cultivation of pomegranate. This model may also provide opportunities to resource poor farmers of water scarce areas in cultivating high value crops for enhancing their livelihood and net returns.

Pictorial view of functional water and energy harvesting model

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