

***In situ* moisture conservation**

in diverse rainfed agro-ecologies

A K Nema*, S L Patil, S K Upadhey, S K Behera, B S Parmar, Pradeep Kumar, Ch Murali Krishna, Sreedhar Chauhan, M L Jadav and Mintu Job

All India Coordinated Research Project on Dryland Agriculture Centre, Varanasi, Uttar Pradesh 221 005

Rainfed agriculture is practiced in a wide range of rainfall zones and soil types. Rainfed crops suffer from moisture stress during the crop growing season. Rainwater is the key input for successful rainfed agriculture. In situ moisture conservation measures, either as preparedness or real-time contingency, play a vital role in dry spell mitigation, increasing the productivity and profitability of rainfed crops. The network centres of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) developed and demonstrated agro-ecology specific in situ moisture conservation practices across the country. These measures have been integrated into various national, state and district programmes, particularly watershed programmes benefitting the small holders.

Keywords: *In situ* moisture conservation, Rainfed areas, Rainfed crops

THE success of rainfed agriculture depends on the efficient utilization of rainwater. In rainfed areas, in general, even after adoption of primary terrace level practices to conserve soil and water, still an estimated 25–40% of the rainwater remains unconserved. In rainfed regions, due to the temporal and spatial variability, and skewed distribution of rainfall, crops invariably suffer from moisture stress at one or the other stages of crop growth. Since, water being the critical input for rainfed agriculture, effective rainwater management, particularly, *in situ* moisture conservation, is critical for successful rainfed agriculture. The focus should be on building *in situ* moisture reserves to tide over the recurring drought spells, disallowing subsequent loss of soil-profile stored moisture and in avoiding inundation/waterlogging. Agroecology-specific (soil type, rainfall pattern and physiography based), *in-situ* moisture conservation (IMC) measures are promoted on seasonal basis for improved and adequate rainwater retention and distribution. The IMC measures can be for a) enhancing moisture with more opportunity time for infiltration such as tillage, contour cultivation, conservation furrow, green manuring, mulching, raised and sunken bed system, broad bed and furrows system, compartmental bunding, cover cropping, scooping etc.; b) to reduce/minimize loss of soil stored moisture like efficient cropping systems (intercropping, strip cropping etc.),

mulching, wider row spacing with frequent deep inter-cultivation etc and c) to permit safe disposal of runoff (in a situation when rainfall exceeds infiltration capacity of the soil) through furrow systems (graded/contour/wider furrows). *In-situ* moisture conservation practices improve soil structure, porosity, increase infiltration and hydraulic conductivity, and consequently increase the soil water storage that helps the crops to withstand moisture stress (Table 1).

***In situ* moisture conservation**

Leveling and bunding: Leveling of the soil and bunding is the simplest and most important operation required to effectively utilize the rainwater and for uniform distribution of fertilizers and seeds under rainfed situations. Different types of bunds are suggested depending on soil type and rainfall pattern. For Alfisols having slopes more than 1.5%, contour bunding is found to be the most promising. Graded bunds are suggested in areas having higher rainfall with less permeable, deep heavy soils.

Contour cultivation: It is recommended for all types of soils having rainfall up to 1000 mm and slope varying from 0.5–4%. In some situations, it's desirable to provide a small slope along the row (cultivation across the slope) to prevent runoff from a large storm breaking over the small ridges formed during the contour cultivation.

Table 1. Recommended *in-situ* moisture conservation measures for various rainfall zones in India

Seasonal rainfall (mm)			
<500	500–700	750–1000	>1000
Contour cultivation with conservation furrows	Contour cultivation with conservation furrows	BBF (Vertisols)	BBF (Vertisols)
Ridging	Ridging	Conservation furrows	Field bunds
Sowing across slopes	Sowing across slopes	Sowing across slopes	Vegetative bunds
Mulching	Scoops	Tillage	Graded bunds
Scoops	Tied ridges	Lock and spill drains	
Tied ridges	Mulching	Small basins	
Off-season tillage	Zing terrace	Field bunds	
Inter-row water harvesting systems	Off-season tillage	Vegetative bunds	
Small basins	Broad bed and furrow system (BBF)	Graded bunds	
Contour bunds	Inter-row water harvesting system	Zing terrace	
Field bunds	Small basins		
	Modified contour bunds		
	Field bunds		

Tillage: Summer/off-season tillage has been found to be useful in increasing rainwater infiltration, retention of rainwater and minimizing the water evaporation by mulching effect. In medium deep black soils in southern Rajasthan, summer deep ploughing with raised bed of 40 cm width is recommended. On Alfisols, the problem of crusting and sealing is encountered during early stages of crop growth resulting in uneven germination and plant stand. Under stress conditions, shallow tillage as an additional inter-cultivation has been found to be effective in breaking up the crust, improving infiltration and reducing moisture losses through evaporation by creating dust mulch. Deep ploughing has been taken up to break hard pan and improve physical characteristics of black soils. It is done to a depth of 22 cm (tractor plough) in Vertisol once in 3 years for faster penetration of rain water and to eradicate pernicious weeds which in turn result in higher crop yields. Deep tillage in alternate year and deep ploughing in alternate set row furrows up to 25 cm depth and application of FYM @5 t/ha is recommended for northern Saurashtra for obtaining higher yield of groundnut. Primary tillage with Vibro chisel plough in maize is recommended for southern zone of Rajasthan.

Mulching: Mulching is referred as spreading of various covering materials on the surface of soil to minimize

moisture losses and weed population to enhance crop yield. It also has some other positive environmental effects such as temperature regulation of soil and plant roots, minimizes nutrient losses, cuts down soil erosion and compactness, and improves physical conditions of soil. Mulches are of different types, including soil mulch, stubble mulch, straw or stover mulch, live mulch, plastic mulch and vertical mulch. Mulching with groundnut shell in guava at Rajkot increased soil moisture content and fruit yield. *In situ* moisture conservation with plastic and organic mulching in radish, yam bean and okra helped in conservation of moisture, suppression of weeds and resulted higher vegetable yield in eastern ghat zone of Odisha.

Subsoiling: Subsoiling in Vertisols in alternate year with horizontal spacing of 1.5–2.0 m is recommended for Marathwada region of Maharashtra and it increased the yield of soybean. In scarcity zone of Andhra Pradesh, subsoiling in Alfisols with chisel plough @1 m distance for every two years increased the yields of pigeonpea, castor, groundnut, pearl millet, cluster bean and castor.

Conservation furrows: Conservation furrows are made by opening furrows parallel to rainfed crop rows across the land slope in 3–4 weeks after the germination of the main crop. During runoff, the rainwater gets concentrated within these furrows, infiltrates into the soil (root zone) and is available to the crop for meeting the evapo-transpiration demand. Large scale demonstrations in Karnataka proved that finger millet + pigeonpea intercropping system (8:2) with staggered moisture conservation furrow gave higher net returns (₹14198/ha) as compared to no conservation furrow. In scarce rainfall zone of Andhra Pradesh, *in situ* moisture conservation through opening of conservation furrows recorded 9% higher seed yield of pigeonpea.

Groundnut + pigeonpea (8:1) intercropping system along with formation of conservation furrow at every row recorded higher groundnut equivalent yield (1528 kg/ha), which is 35.3% higher compared to groundnut + pigeonpea (8:1) intercropping system without conservation furrows (1129 kg/ha).

Set furrow cultivation: It is another effective micro-



Primary tillage with Vibro chisel plough



Conservation furrows in finger millet + pigeonpea

site improvement process which conserves rainwater effectively and offers excellent drought proofing. In this technique, crop rows are set permanently by opening deep furrows of 25–30 cm at a wider distance (135 cm) and all the inputs (crop residues, manures and fertilizers) are applied in the set furrows before sowing. In Vertisols of northern dry zone of Karnataka, set furrow with residue incorporation + *glyricidia* (5 t/ha) in pigeonpea + groundnut intercropping (2:4) is recommended, which provides pigeonpea equivalent yield (1864 kg/ha) and net returns (₹71931/ha) than farmers' practice (1479 kg/ha).

Ridge and furrow systems: Opening of furrows at 50–60 cm apart across the slope in medium to deep black soils, after completion of primary tillage, during the second fortnight of June helps to lay out the field into ridges and furrows. This can be done through a ridger/plow attached to either tractor or bullocks. Cultivation of crops under ridge and furrow system across the major land slope with a gradient of 0.2–0.4% in land having 1–3% slope will conserve more rainwater *in situ*. This



Ridge and furrow system

is suitable for widely spaced crops with 60 cm or more row spacing. A field length of 60–90 m is optimum for cultivation of crops with ridges and furrows.

Broad bed and furrow system: On black soils, the problem of water logging and water scarcity during the same cropping season is quite common. There is a need for an *in situ* rainwater conservation and proper drainage technology on deep black soils to protect the soil from erosion throughout the season and to control runoff. A raised land configuration, broad bed and furrow (BBF) system has been found satisfactory to attain these goals. This technology is more successful in medium to deep black soils having mean annual rainfall varying from 500–1300 mm with a maximum slope up to 5%. The BBF system consists of a relatively raised flat bed or ridge approximately 95 cm wide and shallow furrow of about 55 cm wide and 15 cm deep across the slope on a grade of 0.2–0.6% for optimum performance. The bed width also depends on the crops, soil type and rainfall. After the direction of cultivation has been set out, furrow making is done based on the topographic survey.

In Marathwada region of Maharashtra, planting of 4 rows of soybean (45 cm × 15 cm) on broad bed (width 180 cm, height 15 cm; furrow width 20 cm, depth 15 cm) with BBF planter gave seed yield of 1460 kg/ha and rainwater use efficiency of 3.50 kg/ha-mm compared to flatbed system (945 kg/ha; RWUE-2.26 kg/ha-mm). Further, planting of cotton + soybean intercropping (2:2), cotton and soybean on BBF helped in higher yields. BBF helped in mitigating dry spells and also draining out excess water from fields.



Sowing of soybean with BBF Planter

Raised bed and furrow system/raised and sunken bed system: Raised and sunken bed system consists of alternate raised and sunken beds and the width of sunken



Performance of soybean on raised bed and furrow system



Automatic tractor drawn compartmental bund former



Water impounded in the compartment bunds

beds varies with mean annual rainfall. For example, in high rainfall areas (>1000 mm), 8 m wide raised beds alternated with 4 m wide sunken beds having elevation difference of 150–200 mm are suggested. The runoff from raised beds (upland *kharif* crop) is captured in the adjacent sunken beds supporting a relatively high water tolerant crop (rice). This system is advocated for Vertisols of high rainfall regions (>1000 mm). In Malwa region of Madhya Pradesh, sowing of soybean cv. JS 20-34 and JS 95-60 on raised bed and furrow system gave higher seed yield which was significantly superior to broad bed furrow and sweep blade type seed drill.

Compartmental bunding: In scarcity zone of Maharashtra and northern dry zone of Karnataka, after receipt of southwest monsoon, the fields having slope of less than 1% are harrowed for weeds removal. Compartmental bunds of 4.5 m × 4.5 m and 3 m × 3 m on lands having slopes of 2% and 3% respectively, are formed either with tractor drawn/bullock drawn bund former. This technology ensures rational moisture distribution as well as optimum moisture for better germination of seeds. In *kharif* fallowing, this practice enhances the rain water retention in the soil profile for raising *rabi* crops like sorghum, sunflower, safflower and chickpea on the conserved moisture.

Continuous contour trenches: Contour trenches are in all slopes irrespective of rainfall conditions and for varying soil types and depths. Trenches can be continuous or interrupted and their size depends upon the soil's depth. Normally 1,000–2,500 cm² in cross section are adopted. The contour line was demarcated in the centre of the selected fields and parallel to these contour lines, continuous contour trenches (CCT) were excavated with a cross section of 60 cm width and 30 cm depth. The interval between two adjacent CCTs depends on the recommended row spacing of selected crops. CCTs helped in higher productivity of agri-horti systems in Vidarbha region of Maharashtra. Also, in high rainfall intensity events, CCTs can be useful for draining excess runoff provided that all the CCTs should be joined at the end to the common drain.

Soil amendments: Soil amendment is any material added to a soil to improve its physical properties, such

as water retention, permeability, water infiltration, drainage, aeration, structure and to provide a better environment for plant roots and crop growth. Unless the infiltration rate is improved through improvement of soil structure, moisture conservation continues to be a problem in the Vertisols of Deccan Plateau with higher clay content (>50%). Studies in this direction indicated severe water intake problem in soil having Exchangeable Sodium Percentage (ESP) >7.0. This problem could be overcome by reducing ESP to <7 through gypsum application. Application of tank silt to soils with sandy clay and sandy clay loam texture improved soil moisture content and other physical and chemical properties, and gave higher yield of rainfed crops, viz. *rabi* sorghum in Solapur, vegetable crops and mulberry in Kolar district of Karnataka, castor and cotton in Telangana and groundnut in Andhra Pradesh. However, the precaution should be taken for quantified application of tank silt by analyzing the silt and soil texture of the application site since the quality of silt varies with each tank, which is primarily a function of soil type and land use of the catchment.

SUMMARY

In situ moisture conservation is necessary to mitigate dry spells and to obtain higher productivity of rainfed crops cultivated particularly in small farm holdings. The *in situ* conservation measures are agro-ecology specific which means everything doesn't work everywhere. Therefore, these measures have to be prioritized and implemented both as preparedness like off-season tillage, subsoiling, BBF, compartment bunding, raised bed and furrow system etc. and as real-time measures during dry spells or within season drought such as opening conservation furrows. All these measures can be implement/demonstrate with right farm machinery/ implements. Therefore, there is a need to scale out these measures by converging with national and state schemes and programmes such as MGNREGA, RKVY, Watershed programmes, Farm mechanization schemes, Custom hiring centres etc.

*Corresponding author's e-mail: anupamnema@gmail.com