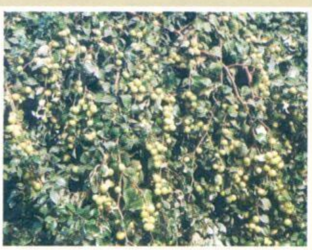
Drought Mitigation and Management



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Strategies for Limited Water Use in Field Crops

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INTRODUCTION

Efficient use of water in agriculture is an important issue throughout the world. Agriculture, the largest water user, is facing a challenge to produce more food with minimum water. This requires improvement in water productivity (WP) and water use efficiency (WUE). This is more pertinent to tropical country like India that experiences the variation in climate and rainfall. India, though has achieved self-sufficiency in food with the help of efficient management of her natural resources leading to green revolution but arid and semi-arid regions are still lagging behind. It is necessary to optimise the use of water and at the same time increase the water productivity (Saxena et al 2014). This can be achieved by optimizing irrigation, improving water delivery, application methods and rain water conservation. Water can be conserved at a watershed or regional or local level for other uses only if evaporation, transpiration, or both are reduced. Precision irrigation technologies for sprinklers and micro-irrigation system enables farmers to apply water and agrochemicals more precisely. The most effective means to conserve water is deficit irrigation strategies that are supported by advanced irrigation system.

Harsh climatic conditions in arid regions lead the farmers to grow only one crop during rainy season that to depending on the rainfall. The average annual rainfall of western arid region of India is 317 mm. The rainfall is highly variable and erratic with frequent drought spells. The number of rainy days vary from 10 to 25. Groundwater is very deep, saline at many places and expensive to use. Injudicious water use on undulating highly permeable sandy soils through conventional irrigation resulted in fall of groundwater by 0.6 – 1.0 m annually. The situation of overexploitation of groundwater is more serious in the region where out of 11 districts, 6 are in category of over exploited and remaining 5 are

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in category of semi critical zone. On the other hand indiscriminate use of scarce water through conventional irrigation management practices led to exhaustion of ground water resources and development of water logging in canal command area. Hence, conservation and efficient management of limited water is the need of the hour for achieving sustainable production for longer period on light textured soils of arid and semi-arid regions.

The first option concerns to the need for improving crop yield; the second one intends to increase the transpiration of water supply against the evaporation; the third aims to utilize efficiently the water resources (reservoirs, streams or groundwater sources). All these lead to the improvement in management practices which use less water for irrigation, decrease evaporation losses, optimize fertilizer supply, pest control, energy consumption, soil conditions, etc. This has more importance in arid and semi-arid regions with limited water supply, where the farmers are frequently constrained to apply deficit irrigation strategies and manage water supply in accordance with the sensitivity of crop's growing stages to water stress. There are several approaches for improving the crop productivity of water including replacing high water consuming crops with lower-consuming ones and adopting management and systems improvements to increase productivity per unit of water consumed. Efficiencies are increased when the total amount of water consumed by crops, evaporation and other users can be reduced. The available water resource within a basin or sub basin can also be effectively conserved for other uses by improving efficiencies to reduce the unusable water losses.

WATER FOOTPRINT

The water footprint of a product is the total volume of freshwater used to produce the product, summed over the various steps of the production chain. The water footprint of a product refers not only to the total volume of water used; it also refers to where and when the water is used.

Green water footprint: Volume of rainwater consumed during the production process. This is particularly relevant for agricultural and forestry products where it refers to the total rainwater evapotranspiration.

Blue water footprint: Volume of surface and groundwater consumed as a result of the production of a good. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product.

Grey water footprint: The grey water footprint of a product is an indicator of freshwater pollution that can be associated with the production of a product over its full supply chain.

The intrinsic characteristic of water dynamics in soil cannot be altered to a large degree but availability can be modified enormously by water conservation and water management practices. During the complete life cycle of a plant the most dynamic property is water content of soil. Since water that is conserved or supplemented becomes available to the plant through the soil, monitoring of water content under field condition is of paramount importance. The whole life cycle of plant revolves around extraction of water from the soil through its root network and transpiring through the leaves in response to evaporation demand set up by the atmosphere. Any shortage of water in the soil is ultimately reflected by the growth of the plants in some form or another. Increasing water supply available to plants or enhancing water use relative to other losses and making efficient use of limited water are the three major concepts in optimizing water use in agriculture.

RAIN WATER MANAGEMENT

In arid and semi-arid parts, experiencing rainfall from 150-350 mm and 350-550 mm respectively, crop production is adversely affected due to low and erratic distribution. In last two decades researcher and planners have given lot of attention to dry land farming in such areas. Various regions specific agro-techniques have been evolved.

Choice of crops based on rainfall and moisture availability period

Improving on-farm irrigation efficiencies will usually not save water and in fact increase total water use because both higher irrigation uniformities and increased inputs improve total yields. Farmers shift to higher value, higher water-using crops because the improved irrigation system renders it more feasible. In dryland areas crop production depends on amount and distribution of rainfall. The options may be to include drought-tolerant cultivars, by increasing farmer's ability to optimize irrigation amounts in time and space utilizing site-specific irrigation techniques and by including deficit irrigation. In arid and semi-arid areas where frequent partial season droughts occur, crops that mature more quickly such as small grains, various pulse crops, deep rooted, drought-resistant crops would be grown to maximize use of precipitation stored in the soil. Most of the farmers still grow long duration traditional varieties under conventional practices. The productivity of these crop varieties is affected due to uncertain rainfall. Hence, there is a need to develop short duration varieties and agronomic practices matching to rainfall pattern. On the basis of climatic data all over India, suitable crops and varieties for early, normal and late onset of monsoon, improved inter cropping, time of sowing and agronomic practices have been identified and developed. In arid part of Rajasthan short duration varieties of pearl millet, clusterbean, moth bean, mung bean and sesame have been developed to minimize the risk of crop failure. With the early onset of monsoon, pearl millet and sesame get preference. While with the late onset of monsoon clusterbean, mung bean, and moth bean get preference. Since the moisture evaporates very fast, it has been suggested to complete the sowing immediately after rains. Certain simple agronomical practices like optimum tillage, administration of organic manure, suitable cropping pattern, and strip cropping are effective in retaining soil fertility as well as giving satisfactory crop yield.

Increasing water use relative to other losses

Evaporation of water directly from soil surface is an important component of the total water use of crops. Evaporation constitutes 19-46% of the total water on vertisols, 21% on alfisols and 12-18% on loamy sand soils. Reducing the evaporation mulching is an effective tool. Soil evaporation can be substantially reduced through minimum tillage (Saxena et al 1997) and mulching using materials or crop residues. Mulching of open land surface is achieved by spreading stubble, trash or any other vegetation. The objectives of mulching are to minimize splash influence of rain drops on base surface; reduce evaporation; increase absorption of the rainfall; obstruct surface flow thereby retarding erosion and allow microbiological changes to occur at optimum temperature. Soil evaporation can also be reduced by achieving a rapid ground cover through early crop vigour and fertilizers have been shown to help. Top surface of loamy sand soils acts as self-mulch after drying. In such conditions, mulch may not be useful practice in arid region, however, many a times droughts occur early in the vegetative stage. In such situation use of mulch immediately after sowing delay the process of top soil surface drying which helps in promoting better plant establishment and results in higher yield. Polyethylene mulch was highly effective in controlling evaporation losses (Table 1, Gupta 1978, 1980). Daulay et al (1979) also reported beneficial effects of mulch in pearl millet. Application of grass mulch (6 t ha^{-1}) brought 200 per cent increase in the yield of green gram, dew gram and clusterbean (Gupta and Gupta, 1983). The best opportunity for water saving lies in methods increasing transpiration relative to other losses from the soil surface due to canopy shading. The elimination of weeds, optimum plant population and spacing and application of fertilizer/manure helped in better canopy growth and higher WUE of crops. Generally close row spacing and higher plant population is recommended in high rainfall areas or irrigated condition, but in arid region wide row spacing and low population is recommended. Paired row planting system helps in better canopy growth and hence evaporation from soil surface is restricted.

Table 1. Mulching improves Yield and WUE of Pearl millet

Mulch	Water Use (ET) mm	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
Polyethylene	279	2900	10.4
Bajra husk	269	2300	8.5
No mulch	291	1740	6.0

Tillage makes soil loose and hence prone to erosion. Adoption of minimum tillage practices also help with early and rapid sowing. As a result, better matching of crops and environment, coupled with the responsive cultivars to increased inputs, disease control and other agronomic changes, yields improvement can be achieved. Timing and depth of tillage are the two important factors, which need special attention (Saxena et al 1997). Tillage should be done immediately before the crop season to take advantage of one or two early showers for land preparation. In arid region, land tilled into ridges and furrows across the wind direction has been found to reduce the effects of wind erosion during the summer months. Farm lands should be levelled for efficient management of water. Level lands allow more infiltration, thus increasing soil moisture and leaching. This in turn reduces run-off and hence soil erosion. Levelling of irregular land is done by the cut and fill method. Soil from the elevated portions is removed and placed in the depressed portions to obtain a level land. In strip cropping two or more crops are grown in alternate strips preferably across the slope. One strip of erosion permitting crop should be alternated with another strip of relatively more erosion-resisting crop. In strip cropping, the entire land remains in a kind of balance. Soil eroded from one strip is retained by the next strip and the overall fertility of the land is maintained.

Management of limited irrigation water

In arid region water is limited and land is vast, hence water management aims to maximize production per unit of water rather per unit of land. Some of the technologies like modest, extensive, deficit and pressurized irrigation have been developed to maximize the production in arid region.

Rules for Extensive and Deficit irrigation

- Practice extensive/deficit irrigation only on relatively deep soils that have moderately high water holding capacity
- Increase the contribution of precipitation to crop water needs
- Consider modifying cultural practices
- Flexible planting dates
- Deep tillage for deeper rooting
- Selection of irrigation system (Drip, Sprinkler)

Extensive irrigation: Extensive irrigation approach seeks to apply a small quantity of water over a large area rather large quantity of water over a small area. Production per unit land may decrease but production per unit water may increase. Water requirement of wheat and mustard is 840 and 250 mm per hectare to produce maximum yield. When the same water applied optimally in 3, 1.5 and 4.0 ha land in wheat and mustard, respectively gave less production per unit of land but total productivity per unit of water was more by bringing larger area under irrigation. Singh (1997) observed that under given water supply the area brought under irrigation in pearl millet was more in subnormal rainfall years than low rainfall years, however, the production enhanced in both the situations by bringing larger area under irrigation in pearl millet.

Deficit irrigation: Deficit irrigation approach seeks to avoid irrigation at less critical stages of crop growth and apply less water at the end so as to eliminate water stored at harvest. One has to be well versed with the crop growth stages less sensitive to moisture stress and proper balancing between water given and ET demand of crop. Shoot growth is very sensitive to mild soil moisture deficits and more sensitive than photosynthetic rate. Owing to this shoot growth sensitivity, it is common in many production systems to supply excess irrigation water to ensure rapid and extensive canopy development and thereby maximize radiation interception and biomass accumulation. There are three general scenarios for reducing water supplies to agriculture:

1. Season long drought management: a given volume is available for distribution within a fixed land area over the course of the growing season as the grower seems fit
2. Partial season drought management: a limited volume of water may be available over a fixed land area for only for a specific time period over a fixed land area
3. Spatial optimization strategies can be adopted such as moving production of specific crops to areas with greatest yield potential because of water availability or climatic and soil conditions

WATER HARVESTING

Water harvesting approaches is appropriate in dryland regions, by harvesting water on larger areas and channelling it onto crops. This is, in effect, a form of irrigation that has been practiced traditionally in some regions. The approach of water harvesting is capturing more water for crop transpiration. In arid and semi-arid parts rainfall varies from 150-350 mm and 350-550 mm respectively. Rainfall is not sufficient to ensure a good crop. In dryland farming, the solution to soil moisture problem lies in the storage of rainfall in the potential root zone of the soil by the water harvesting methods. Therefore, water harvesting would be an alternative to leave land fallow for increasing the available water supply for plant growth by way of -

(A) *In-situ* rainwater conservation: Water stored in soil profile itself using (1) Inter plot water harvesting, (2) Inter row water harvesting and (3) Pit and trench method for vegetable and fruits

(B) *Ex-situ* rainwater conservation: Water stored in reservoir or pond for recycling

Water harvesting is used to increase the total water supply available to crops. It is practiced in a variety of ways depending upon topography, soil and rainfall. 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 (Singh 1988). Integration of regular row (RR) and double row (DR) plant geometries into water harvesting system on yield and water use efficiency of pearl millet best suited to runoff farming (Singh, 1988). Higher water storage in the 120 cm profile supported the pearl millet crop during ear emergence and grain development period thereby significantly increasing the yield attributing characters. Water harvesting proved well particularly in low rainfall years. The yield of pearl millet was almost three times with water harvesting compared to conventional sowing. In low rainfall situation in-situ water harvesting helped in making efficient use of limited rainfall and N-fertilizer in pearl millet (Singh 1985).

Micro-catchment systems are effective for use in growing trees and shrubs. In micro-catchment based cropping, rainwater is concentrated in a small portion of the cultivated area. The tree crops are deep rooted and can utilize the moisture stored in the sub-stratum and hence form a better option for micro-catchment based farming in sandy soil situations (Sharma et al 1986). Arid horticultural plants like pomegranate and ber can be successfully grown with appropriate micro-catchments in the water scarce regions. In micro-catchment systems, the catchment to collector area ratios may range from 1 : 1 to 20 : 1. The various sizes of micro-catchments have been used for different purposes. A number of catchment cropped area ratios and degree of slopes have been tried at CAZRI, Jodhpur. For ber, circular catchments of 1.5 m diameter and 5% inward slope with 54 m^2 of catchment has been found appropriate for conservation and proper utilization of rainwater (Sharma et al 1986). Increase in soil moisture by 20% was observed due to circular catchment or trenching than with any soil treatment (Ojasvi et al 1999). For further improvement in water use efficiency, these circular micro-catchments can be covered with plastic sheet (LDPE).

Ex-situ rainwater harvesting is a promising technology for enhancing the availability of water in arid areas. Ex-situ water harvesting involves collecting runoff originating from rainfall over a surface away from the field and storing it in surface storage systems for later use in the field. This type of rainwater harvesting provides supplemental or protective irrigation during dry periods of the cropping season.

IMPROVED IRRIGATION PRACTICES

Drip and sprinkler are the two examples of pressurized irrigation and both are able to save water as water is applied under pressure through a network of closed pipes, sprinkler nozzles and emitters. Sprinkler obtained significantly higher yield and WUE of wheat and potato. Sprinkler irrigation gained popularity in Sikar district of Rajasthan, as it is able to apply water on undulating type of topography. Other districts have also adopted this system of irrigation. But high wind velocity and saline water (>4 dSm^{-1}) restrict its utility in arid region (Singh et al 1978). Drip irrigation is the most efficient method of irrigating. While sprinkler systems are around 75-85% efficient, drip systems typically are 90% or higher. For this reason drip is the preferred method of irrigation in the desert regions. But drip irrigation has other benefits which make it useful almost anywhere. It is easy to install, easy to design, reduce disease problems associated with high levels of moisture on some plants but expensive. Drip irrigation works by applying water slowly, directly to the soil. The high efficiency of drip irrigation results from two primary factors. The first is that the water soaks into the soil before it can evaporate or run off. The second is that the water is only applied where it is needed rather than sprayed everywhere. The drip irrigation is neither affected by winds nor by saline water as it applies water directly in the rooting volume of crops. Studies conducted at CAZRI Jodhpur revealed that drip saves 30-50% water and provide 2-3 times higher yield than conventional irrigation. It is most suited to widely row spaced high value crops like vegetables, sugarcane, cotton, maize and plantation crops. With drip irrigation, a water with 3 dSm^{-1} was not so much detrimental to potatoes, while in tomatoes water up to 10 dSm^{-1} could be used successfully with drip irrigation (Singh et al 1978). Paired row planting system designed for each lateral minimized the installation cost and water use by 50%. This system is able to apply fertilizer with water, which ultimately led to higher yield of crops.

A variety of crops can be cultivated successfully with drip irrigation. These are: grapes, citrus, apples, pomegranate, pears, peaches, apricots, plums, bananas, dates, olives, mango, guava, tomato, green pepper, cucumber, lettuce, green pea, cauliflower, okra, cotton, sugarcane, corn, groundnut and onion, berries, melons, alfalfa, carnations, gladioli and roses.

Planting of seed or seedlings is done along the length of the lateral on one side or either side of it, irrespective of the position of the emitters on it. The emitters placed at a distance of 50 cm apart on a lateral line discharge the water at such rate that a continuous strip of about 40 cm width of soil remains wet throughout the length of the lateral. Different planting configurations (i) a single row (rectangular planting), (ii) double rows (square or equilateral planting) or (iii) triple row (hexagonal planting) were tried at CAZRI. The major objective of such different types of planting is to reduce the number of laterals, thereby reducing the cost of the system without reducing the plant population in the field. The results of the study revealed that equilateral planting with the side of 25 cm to 35 cm of a triangle performed the best in almost all the crops tried. Therefore, equilateral planting is advocated for vegetable crops like tomato, cabbage, cauliflower, turnip etc. (Singh and Singh 1978).

CONCLUSION

The problem of shortage of water to rainfed crops could be resolved by increasing water supply available to crops and increasing transpiration relative to evaporation losses. In case of limited irrigation resources, modest irrigation, deficit/extensive irrigation and pressurized irrigation exhibited the efficiency to improve water use and make efficient use of other resources like seed and fertilizer. Adoption of these approaches will certainly make efficient management of scarce water in arid and semi-arid region. Further, researches on these aspects in relation to area specific conditions are needed to provide proper package and practice to the end users.

REFERENCES

Daulay HS, Singh HP, Singh RP and Singh KC 1979 Effect of different mulches on yield and moisture use of pearl millet (*Pennisetum typhoides*). *Annals of Arid Zone* **18** 108-115

Gupta JP 1978 Evaporation from a sandy soil under mulches. *Annals of Arid Zone* **17** 287-290

Gupta JP and Gupta GN 1983 Effect of grass mulching on growth and yield of legumes. *Agricultural Water Management* **6** 375-383

Gupta JP 1980 Use of an asphalt subsurface barrier for improving the productivity of desert sandy soils. *Journal Arid Environment* **3** 215-222

Ojasvi PR, Goyal RK and Gupta JP 1999. The micro-catchment water harvesting technique for the plantation of jujube (*Ziziyphus mauritiana*) in an agroforestry system under arid conditions. *Agricultural Water Management* **41** 139-147

Saxena Anurag, Goyal RK, Singh RK and Roy MM 2014 Water Management for Climate Resilience in Arid Region. Central Arid Zone Research Institute, Jodhpur, India, 52 page

Saxena A, Singh DV and Joshi NL 1997 Effect of tillage and cropping systems on soil moisture balance and pearl millet yield. *Journal of Agronomy and Crop Science* **178** 251-257

Sharma KD, Pareek OP and Singh HP 1986 Micro-catchment water harvesting for raising jujube orchards in an arid climate. *Transactions of the American Society of Agricultural Engineers* **29(1)** 112-118

Singh GB 1985 Prospects of irrigation in arid zone. In *Irrigated Agriculture in Arid Areas* (ed) SD Singh, WAPCOS, New Delhi, 490-498 pages

Singh S D, JP Gupta and Panjab Singh 1978 Water Economy and Saline Water Use by Drip Irrigation. *Agronomy Journal* **70** 948-951

Singh SD 1978 Effects of Planting Configuration on Water Use and Economics of Drip Irrigation Systems. *Agronomy Journal* **70** 951-954

Singh SD 1988 *Water Harvesting in Arid Tropics*. CAZRI Publication No. 37, Central Arid Zone Research Institute, Jodhpur. 68 pages

Singh SD and Singh P 1978 Value of drip irrigation compared with conventional irrigation for vegetable production in a hot arid climate. *Agronomy Journal* **70** 945-947

Singh YV 1997 Maximising water use efficiency for sustainable crop production in arid ecosystem. In *Recent Advances in Management of arid Ecosystems* (eds) S Kathju, RK Abhichandani, Amal Kar and NL Joshi), Jodhpur, AZRAI, Jodhpur, 135-136 pages.

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Drought is a natural hazard characterized by lower than expected or lower than normal rainfall having slow but widespread impact. This book focus on drought management and mitigation in agriculture and allied sectors. The chapters cover Basic concepts, assessment, monitoring, forecasting, early warning, vulnerability and adaptation to drought and mitigation and management strategies. Management of different land use systems under drought and finally socio economic impact and livelihood issues of drought are also focussed. It would be useful to a wide range of stakeholders, i.e. planners, researchers, students and interested public. This will also serve as text book as well as supplementary reading for courses in agronomy, ecology, geography and agro meteorology besides administration and disaster management units.

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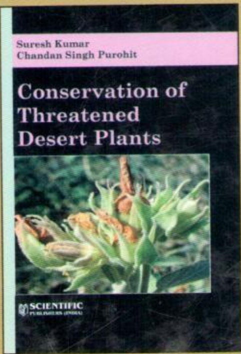

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