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Review Article

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Deficit Water Management- A Review

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ABSTRACT

Water deficit is a most important characteristic of dryland tracts of India. Which limit the growth and yield of crops. For managing these conditions there are many practices are followed. In which soil management practices, crop management practices, rain water storage, watershed management and stored water used as supplement irrigation or life saving irrigation.

Key words: *Water deficit, Tillage, Mulching, Rain water*

INTRODUCTION

Water deficit is an any situation where a plant functions at less than optimal rates because of reduced water availability. Water is a major crop production limiting factor in semi-arid areas of India. Rainfall is characterized by spatiotemporal variability and often inadequate to supply full crop water requirements of major crops grown in the area. Irrigation is often used to supplement rainfall to increase crop productivity. To cope with these limited water supplies, producers need to adjust their cropping systems by planting a mix of crops with the goal being to optimize net economic returns[1].

With constrained water supplies, producers need strategies to optimize water allocation and efficiently schedule irrigation during the growing season. Optimizing water allocation could enhance water productivity and profitability of water-limited irrigated cropping systems[6 & 16]. Improved water allocation could also result in enhanced environmental sustainability such as extending the usable life of overexploited aquifers. Producers need recommendations or decision support tools to help them improve the allocation of limited water resources to land and crops. Producers need recommendations or decision support tools to help them improve the allocation of limited water resources to land and crops. Use of conventional field experiments alone to generate such recommendations is time-consuming, costly and cannot be easily generalized as results are affected by site-specific characteristics such as soil, weather during the experimental period, agronomic management, *etc*. Cropping system models provide a means to evaluate the effect of the interactions between crops (genotype), soil, weather, and management on yield.

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Crop models have been applied to evaluate crop yield response to a wide range of climates, planting dates, soils, crop genotypes and management such as irrigation and fertility[6]. Liu *et al*.[12] also used GEPIC model for assessing yield and water productivity of wheat. Gallardo *et al*.[5] used VegSyst simulation model to calculate crop N and water requirements for tomato. Todorovic *et al*.[24] used different types of crop models ranging from radiation, carbon assimilation, and to water-based models in the simulation of sunflower growth under different water regimes. Since the focus of this study was to assess crop yield response to water, a water-driven model called Aqua Crop was selected [11, 20, 21 & 23]. The model has been reported to be suitable in assessing crop response to water[11, 20, 21 & 23]. The model requires less number of inputs[11, 20, 21 & 23] compared to other models such as DSSAT [10], and APSIM[13 & 14]. Aqua Crop[11, 20, 21 & 23] performance has also been verified in various studies[4, 6, 8, 24 & 2].

Possible reasons of water deficit:

- High rate of evapotranspiration at low rainfall.
- Water bound osmotically in soil (saline soils).
- Frozen soil, and
- Thin layer, under developed root system.

Effect of water deficit on plant growth

- Yellowing of leaves, shrinkages and droppage of leaves
- In severe deficit accompanied by high temperature may cause burning of tip of leaves
- Reduced number of flowers, fruits
- Withering away flowers, buds fruits
- Improper maturity of fruits/ grains/economically useful parts
- Reduced branching
- Proliferated rooting at the cost of above ground growth
- Reduced biomass yield, Reduced economic yield
- Deficit during vegetative phase causes poor photosynthesis, reducing leaf area and nitrogen fixation
- Deficit during seed filling causes reduction in seed size, seed number, seed quality and abortion of seed takes place

Water deficit management:

Techniques or measures followed to save the crop during limited water supply or mitigate the adverse effect of water deficit on crop growth and development.

Water deficit management practices:

Soil management practices:

Tillage:

Tillage of the soil consists of breaking the hard compact surface to a certain depth and other operations that are followed for plant growth. Tillage is the physical manipulation of soil with tools & the tilling of land for the cultivation of crop plants *i.e.* the working of the surface soil for bringing about conditions favourable for raising of crop plants. Tillage is the manipulation of soil with tools & implements for loosening the surface crust & bringing about conditions favourable for the germination of seeds and the growth of crops.

Tillage effects on soil:

- Loosens the soil which favours the germination and growth of crop.
- Improves the soil structure due to alternate drying and cooling.
- Improves soil permeability, soil aeration and soil inversiom.
- Facilitates the movement of water in soil.
- Results in soil and water conservation through higher infiltration, reduce run-off and increase depth of soil for moisture storage.
- Holds more water in the soil.
- Increased soil aeration helps in multiplication of micro-organism.
- Organic matter decomposition is hastened resulting in higher nutrient “availability”.
- Increased aeration helps in degradation of herbicide and pesticide residues and harmful allelopathic chemicals exuded by roots of previous crops or weeds.

Tillage effects on crop growth:

- Tillage loosen the soil thereby favours the germination and establishment of seedlings.
- Tillage helps in maintaining the optimum plant stand.

- Increases depth of root penetration.
- Roots proliferate profusely in loose soil and increase the growth of seminal and lateral roots.
- Reduce the competition within crop and weeds for light, water, nutrients, and space thereby helps in better growth of crop.
- Tillage reduce the pest attack on succeeding crop, and
- Tillage helps in availability of nutrients to crop in proper amount.

Modern concepts of tillage:

Tillage is time consuming, laborious and costly, owing to this new concepts like minimum tillage and zero tillage are introduced.

Minimum tillage:

It is aimed at reducing tillage operations to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand and favourable growing conditions, Tillage can be reduce by:

- Omitting operations which do not give much when compared to the, and
- Combining agricultural operations like seeding and fertilizer application.

Advantages:

- Improve soil condition due to decomposition of plant residues in situ.
- Higher infiltration caused by decomposition of vegetation present on soils and channels formed by decomposition of dead roots.
- Less resistance to roots growth due to improved structure.
- Less soil compaction by reduced movement of heavy tillage vehicles.
- Less soil erosion compared to conventional tillage.

Disadvantages:

- Less seed germination.
- More nitrogen has to be added as rate of decomposition of organic matter is slow.
- Nodulation may affect in some legumes.
- Sowing operations are difficult with ordinary implements.

Zero tillage:

It is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation in the row zone only. It is followed where:

- Soils are subjected to wind and water erosion,
- Timing of tillage operations is too difficult, &
- Requirements of energy and labour for tillage are too high.

Advantages:

- Soils are homogenous in structure with more number of earth worms.
- Organic matter content increased due to less mineralization.
- Surface runoff is reduced due to presence of mulch. Several operations are performed by using only one implement. In these weeds are controlled by spraying of herbicides.

Disadvantages:

- Higher nitrogen is too applied due to slower mineralization of organic matter.
- Large population of perennial weeds appears.
- Build of pests is more.

Stubble mulch tillage:

The soil is protected at all times either by growing a crop or by crop residues left on the surface during fallow periods. It is year round system of managing plant residues with implements that undercut residue, loosen the soil and kill weeds. Soil is tilled as often as necessary to control weeds during the interval between two crops. However, it presents the practical problem as the residues left on the surface interface with seedbed preparation and sowing operations. The modern methods of tillage are not practiced in Indian condition because:

- Left over residues is a valuable fodder and fuel.
- Limited use of heavy machinery and therefore problem of soil compaction is rare.

Conservation tillage:

It is disturbed the soil the soil to the minimum extent and leaving crop residues on the soil. It includes minimum and zero tillage which can reduce soil loss up to 99% over conventional tillage. In most cases, it reduces soil loss by 50% over conventional tillage. Conventional tillage includes ploughing twice or thrice followed by harrowing and planking. It leaves no land unploughes and leaves no residues on the soil.

Fallowing:

Traditional dry land cropping of deep vertisols involve leaving the land fallow during rainy season and raise the crop in post rainy season on profile soil moisture. The main intension of fallowing is to provide sufficient moisture for the main post rainy season crop. The monsoon rain, even in drought year usually exceeds the storage capacity of root zone soil depth. This system probably provides some level of stability in the traditional system, though in year of well distributed rainfall, the chance of harvesting a good crop is lost. Probably poor drainage, tillage problem and weed control have forced the farmer to adapt post rainy season cropping. Since the soil has to be kept weed free during rainy season the problem of erosion and runoff increases considerably.

Mulching:

It is defined as the application of any plant residues or other material to cover the top soil surface for:

- Conserving the soil moisture.
- Reducing the runoff and thereby to control soil erosion.
- Checking weed growth.
- Protecting from winter climate.
- Improving the soil temperature.
- Modifying the micro-environment of soil to meet the needs of seeds for their good germination and better growth of seedlings.

The mulching is known to attribute the suppression of the weed growth conservation of moisture by checking evaporation and runoff to protect the soil against erosion (mainly from wind) to increase infiltration of water to fluctuate the soil temperature to enhance mineral availability to enhance nitrification to add nutrients and organic matters derived from decomposing of residues or other materials used as mulch to preserve or improve the soil structure. Mulching also improves the soil aeration creates better biological activates and thus to make a consequent beneficial effect on the soil fertility.

Mulching material:

The followings are used as mulching materials:

- Cut grasses or foliage.
- Straw materials.
- Wood chips.
- Saw dusts.
- Papers.
- Sand stones.
- Glass woods.
- Metal foils.
- Cetto phanes.
- Stones.
- Plastics.

Type of mulches:

The mulches may be following types:

1. Natural mulch.
2. Synthetic mulch.
3. Petroleum mulch.
4. Conventional mulch.
5. Inorganic mulch, and
6. Organic mulch.

In-situ moisture conservation measures:

- In the past, emphasis was given to contour bunding as potential tool for soil and water conservation which was never widely adopted by dryland farmer due to:
- Substantial yield reduction in the near the bund due to removal of surface soil during construction of bund. Even when the advantage was there, it was only marginal.
- Quantity of water held by the soil did not increase due to water trapped near the bund.
- Delay in cultural operation and crop damage due to stagnant water above the bund considerably reduced the yield.
- Increase in yield to the effect of bunding could not compensate of the yield reduction due to area removed (5-10%) by the bund and soil excavation, and
- Bunding may be the last line of defense and the land between bunds should be

treated culturally for effective moisture conservation. Approximately land configuration like broad beds and furrow, inter row and intra plot water harvesting system *etc*. hold great promise in situ moisture conservation.

Broad bed furrow (BBF):

These are effective on black soils. Beds of 120-180 cm separated by furrow on grade are effective for in-situ moisture conservation. Bed function as mini bunds at a grade normally less than maximum slope of land. When runoff occurs, its velocity is reduced and infiltration opportunity time increased excess water is removed in a large number of small furrow. Crops are sown on broad beds.

Function: To control erosion and to conserve soil moisture in the soil during rainy days.

General information: The broad bed and furrow system is laid within the field boundaries. The land levels taken and it is laid using either animal drawn or tractor drawn ridgers.

Salient features: Conserve soil moisture in dryland and control soil erosion. Act as drainage channel during heavy rainy days.

Compartmental bunds:

They convert the area into small square/ rectangular blocks. They are useful for temporary impounding of water and improving the moisture status of soil. These can be made with bunds former or country plough size. Size of the bund depends on their bunded land area.

Dead furrow: Dead furrow on counter at 2.4 to 3.6 m are effective in shallow red soils of Anantpur (A.P.) for increasing groundnut yield. Dead furrow are formed between two rows of the crop before the start of heavy rain (sept.-oct.). They increase infiltration opportunity time besides reducing soil erosion.

Scoops: They are small pits on soil surface. Main aim of forming small scoops is to increase opportunity time for water infiltration into the soil and reduced soil erosion by trapping the eroded sediments that would otherwise lost from the field.

Subsurface moisture barrier: An artificial of a material with less permeability placed at 60-70 cm depth, can retain water over the barrier for longer period of crop use. This concept is based on the observation that sandy soil with clay content is more productive soils. Subsurface barrier of bentonite clay and pond or tank sediment can be effective used for orchard crop and establishment of tree in arid region, though not for field crop on large scale.

Crop management practices:

Plant population and arrangement (geometry):

Plant populations are generally kept lower in water-limited dryland system than irrigated systems for several reasons. First, yield potential is naturally lower in water-limited dryland cropping systems and farmers are served by plant populations optimized for yield potential. Second, plant transpiration increases as leaf surface area increases up to a maximum of approximately for using a metric called leaf area index. Keeping the plant canopy lower, particularly with row crops, can reduce ET during vegetative growth, saving soil moisture for reproductive growth stages and grain fill later in the growing season.

Selection of crop and varieties:

- Avoid growing of drought prone crops like maize, cotton etc.
- Growing drought resistant grain crops like sorghum, pearl millet, finger millet, fox tail millet etc.
- Growing drought resistant legume crops like pigeon pea, green gram, horse gram etc.
- Growing of oil seed crops like castor, sunflower, Niger, sesame, safflower etc.

The crops selected under water deficit conditions having following characteristics:

- Early closure of stomata.
- Increased photosynthetic efficiency.
- Low rate of cuticular transpiration.
- Deposits of lipid layers.
- Reduction in leaf area.
- Waxy leaf surface.
- Stomatal frequency and location.
- Effect of awns.
- Accelerating water uptake.

Table 1: Traditional and alternate efficient crops in deficit water conditions in different regions of India[7]

S. No.	Region	Traditional crop	Alternate efficient crop
1.	Deccan Rabi season	Cotton, wheat	safflower
2.	Malwa Plateau	wheat	Safflower, Chick pea
3.	Uplands of Bihar Plateau and Orissa	Rice	Ragi, Black gram, Groundnut
4.	South-East Rajasthan	Maize	Sorghum
5.	North Madhya Pradesh	Maize	Soybean
6.	Eastern UP	Kalitur	Chick pea
7.	Sierozems of North-west India	Wheat	Mustard, Taramira (*Eruca sativa*)

Windbreaks or shelterbelts:

In arid zones, the harsh conditions of climate and the shortage of water are intensified by the strong winds. Living conditions and agricultural production can often be improved by planting trees and shrubs in protective windbreaks and shelterbelts which reduce wind velocity and provide shade. Windbreaks and shelterbelts, which are considered synonymous in this manual, are barriers of trees or shrub that are planted to reduce wind velocities and, as a result, reduce evapotranspiration and prevent wind erosion; they frequently provide direct benefits to agricultural crops, resulting in higher yield, and provide shelter to livestock, grazing lands and farms.

Antitranspirants:

Antitranspirants are the materials or chemicals which decrease the water loss from plant leaves by reducing the size and number of stomata. Nearly 99% of the water absorbed by the plant is lost in transpiration. Antitranspirants and is any natural applied to transpiring plant surface for reducing water loss from the plant. There are for types:

1. Stomatal closing type: *e.g.*PMA, atrazine.
2. Film forming type: *e.g.* Ethyl alcohol, wax.
3. Reflectance type: *e.g*. Kaolin (5%)
4. Growth retardant: *e.g.* Cycocel (CCC)

Nutritional management:

Among the major nutrients, potassium and magnesium are found to be highly deficient due to water deficit conditions. Therefore, application of potassium enhances the water uptake as well as the water relations in the plant tissues by osmoregulation processes, by acting as a potent osmoregulator (osmolyte), thereby the solute potential is reduced. Besides, potassium nutrition also helps in the favourable stomatal regulatory mechanisms, which regulate the water balance of the plants. This has also reduced in the increased WUE of the plants. Similarly, magnesium is component of chlorophyll, its content and uptake is drastically reduced due to the water stress effect. This is most prominent in Mg-loving crops like cotton.

Therefore, foliar application of the following nutrients depending upon the occurrence of their deficiencies will mitigate the water-stress induced nutritional imbalance in crops.

- 2% DAP.
- 0.5% Potassium chloride.
- 0.5% Zinc sulphate.
- 0.5-1.0% Ferrous sulphate 1% urea, and
- 0.3% Boric acid.

Agro-techniques for mitigate water stress:

Foliar spray of 2%DAP + 1% KCL (MOP) during critical stages of flowering and grain formation.

- 3% kaoline spray at critical stages of moisture stress.
- Foliar spray of 500 ppm cycocel.
- Mulching with 5 tones of sorghum/ sugarcane trash.
- Split application of N and K fertilizers as in cotton at 45 and 60 DAS.
- Use of bio fertilizers *viz*., Azospirilum or phosphobacteria @ 10 packets ha^{-1} along with 25 kg of soil or FYM.

Table 2: Critical moisture sensitive periods for various crops and their symptoms of water stress[15]

Crop	Critical period	Symptoms of water stress
Small grains	Boot and bloom stages	Dull green colour, firing of lower leaves, plant wilt and leaves curled
Barley	Jointing, booting and heading, early drought stress may cause more tillering than usual	Erect leaves rolled toward the midrib, stress after heading causes plants to wilt, darken in colour and ripen prematurely
Wheat	CRI, During and after heading	Leaves wilt, yellow and then burn. Tillers abort prior to flowering, empty bleached white heads or partial heads.
Corn	Tasseling, silking until grain is fully formed	Curling of leaves by mid-morning, darkening colour
Sunflower	Heading, flowering and pollination	Weakened stalks may lodge
Beans (dry)	Bloom and fruit set	Wilting
Sugar beet	Post-thinning	Leaves wilt during the heat of the day
Potato	Tuber formation to harvest	Wilting during heat of the day
Alfalfa	Early spring and immediately after cutting	Darkening colour, then wilting
Grass hay	Early spring through 1st harvest and start of regrowth	Dull greyish green colour
Annual forages	Any extended period of limited water	Reduction of forage production or quality
Cool season grasses	Early spring, early fall	Dull green colour then wilting

Other water management techniques:

Every drop of water will make a difference during drought and so efficient conservation of rain water is key to mitigate drought. The different methods of conserving water are:

- Building storage tanks, ponds and reservoirs.
- Building earth percolation ponds to store rain water.
- Desilting all water storage structures.
- Building check dams, and
- Rooftop rain water harvesting.

Table 3: Other management practices for deficit water management[15]

Practice	Benefits
Row length	Proper length improve uniformity.
Stream size	Should be adjusted for slope and texture, and rate doubled when using linear polyacrylamide (PAM).
Length of set	Allows irrigation ability to control volume of application.
Furrow packing	Can increase advance rate 15-20% on some soils.
Alternate row irrigation	Reduce gross irrigation by 46% and net irrigation by 329%. Allows for rainfall storage in dry soils.
Surge irrigation	Can greatly improve uniformity and can improve efficiency by 10-30%.
Crop residue	Increase infiltration, reduce evaporation loss and runoff loss of water.
Polyacrylamide	Reduces erosion by up to 90%, increase lateral wetting and infiltration.

Watershed management:

Watershed is defined as a geohydrological unit draining to a common point by a system of drains. All lands on earth are part of one watershed or other. Watershed is thus the land and water area, which contributes runoff to a common point.

A watershed is an area of land and water bounded by a drainage divide within which the surface runoff collects and flows out of the watershed through a single outlet into a larger river or lake.

Check dams:

A check dam is generally constructed on small streams and long gullies formed by the erosive activity of water. The ideally a check dam is located in a narrow stream with high banks.

A check dam serves many purposes:

- It cuts off the runoff velocity and reduces erosive activity.
- The water stored improves soil of the adjoining areas and allows percolation to recharges the aquifers.
- While constructing a series of check dams on along stream course, the spacing between two check dams should be beyond their water spread. The height of the check dam should be such that even during the highest flood, water not spill over the banks.

Rain water harvesting:

The principle of collecting and using precipitation from a catchments surface. An old technology is gaining popularity in a new way. Rain water harvesting is enjoying a renaissance of sorts in the World, but it traces its history to biblical times. Extensive rain water harvesting apparatus existed 4000 years ago in the Palestine and Greece. In ancient Rome, residences were built with individual cristerns and paved courtyards to capture rain water to augment water from city's aqueducts. As early as the third millennium BC, farming communities in Baluchistan and Kutch impounded rain water and used it for irrigation dams.

Rain water harvesting is essential because:

- Surface water is inadequate to meet our demand and we have to depend on ground water.
- Due to rapid urbanization, infiltration of rain water into the sub-soil has decreased drastically and recharging of ground water has diminished.

Roof and terrain water harvesting systems:

Purpose:

- To recharge the wells particularly abandoned wells by a runoff collection system.

- Direct on use of collected water if storage facility is available.

Features:

- PVC pipe collectors with different diameters collecting from a cluster of building in a given area.
- Normal size of filter bed (2 m × 2 m × 2 m) with stones and pebbles is sufficient for removing sedimentation and other impurities.
- Open channels/ grased channels under slopy terrains preferred to the pipes for the sack of economy. Evaporation is negligible.

Irrigation method

- Drip irrigation
  - Surface drip
  - Subsurface drip
- Sprinkler
- Alternate furrow irrigation

Alternate crop establishment

- ✓ SRI
- ✓ Aerobic rice
- ✓ Furrow irrigated raised bed

Table 4: Yield response to deficit irrigation in sugar beet [15]

Irrigation treatment	Yield	
	$t\ ha^{-1}$	Reduction (%)
Normal watering in all 4 stages	81.4	0
Stress in all 4 stages	30.0	63
Traditional practice	64.1	21
Stress in stage 1 (Initial)	79.4	2
Stress in stage 2 (Veg. dev.)	75.1	8
Stress in stage 3 (yield formation)	61.9	24
Stress in stage 4 (Initial)	71.8	12
Stress in stage 1 and 2	69.4	15
Stress in stage 2 and 2	45.4	44
Stress in stage 3 and 4	37.7	54

Fig. 1: Precision nozzles increase irrigation efficiency under limited water supply[19]

CONCLUSION

Crop management practices, Soil management practices and alternate crop or crop substitution are the efficient ways to overcome the deficit water problem. Collecting rain water and used as protective irrigation also help in increase in crop yield in water deficit situations.

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