Resource conservation through micro water harvesting for Rainfed horticulture

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Success in commercial Horticulture largely depends upon availability of rain or supplemental irrigation, particularly during critical periods of tree growth and development. Feasibility of a rainfed orchard, therefore, exists only in areas having normal and well distributed rainfall to meet the tree requirement. At present nearly 50 % of the fruit production in India is contributed by such areas despite their low productivity coupled with poor quality fruits. However, scientific management of water using techniques such as water harvesting and moisture conservation can maximize productivity and increase water use efficiency of these orchards. Initial water applications during the establishment phase of the orchard may be required. Wherever possible, during drought years, supplemental irrigations at critical stages may also be essential not only to prevent mortality of the trees but also to maintain a required vigor for normal productivity.

Commercial production of major fruits is at present done only in areas having assured irrigation sources like rivers, canals, lakes, ponds and wells. Here, optimum use of available water determines the growth, vigor and productivity of the tress. Excess or scarcity of water often causes considerable losses both in quantity and quality of fruit production. Thus, development and adoption of efficient water management practices are of great importance in both rainfed and irrigated orchards. The research work has done on the use of these water management practices in India have been scanty.

Soils : Physical and chemical properties of a few representative soils.

Depth (cm)	Clay %	pH (1:25)	EC (dsm-1)	OC (%)	$CaCO_3$ (cmol(p+)Kg-1
Udic Rhodustalf (Patancheru Series)					
0-25	18.2	6.5	-	0.8	8.2
25-50	33.5	6.7	-	0.8	14.3
50-100	39.5	7.8	-	0.5	18.3
Typic Pellusterts (Kasireddypalli Series)					
0-25	53.7	8.8	0.1	2.0	0.7
25-50	58.4	9.4	0.1	9.5	0.5
50-100	67.4	9.4	0.4	20.0	0.3

Deccan plateau hot arid eco-region comprises of mixed red and black soils. Red loams represented by Garnimitta series comprising Typic Rhodustalfs and the black soils are represented by Raichur series comprising Typic Pellusterts. They are highly susceptible to erosion and frequent drought. Sub soils is very hard when dry and acts as hard pan for root penetration and infiltration of water. Representative soils of Garnimitta sandy loams are slightly acidic to neutral with depth and clay content abruptly increases in the sub-surface layer. The Raichur soil series are very deep, dark Grey and moderately alkaline in soil reaction

Water requirement

The irrigation water quantity can be calculated on the basis of water deficit, root zone depth, soil type and salt content in soil. Most of the fruit crops have deep tap roots and their effective root zone commonly extend to over 1.5 m depth. However, the results on moisture extraction pattern indicate that maximum moisture is extracted from the top 40 to 60 cm profile depending on fruit species. The quantity of water to be applied for normal growth and production of a crop under filed conditions at a place is called water requirement (WR).

This consists of ET plus non-available losses in run-off, seepage, deep percolation, weed growth, etc., (Wa), water needs for special functions, such as leaching of salts, land preparation and transplanting (Ws), and the quantity needed for metabolic activities (Wm). Before supplying irrigation water (Wi), however the contribution of effective rainfall (Wr) and that for soil profile (Ws) through capillary rise, ground water (Wg), from atmosphere in the form of dew, stem flow (Wd), etc., are reduced from the quantity. Therefore, WR = ET + Wa + Ws + Wm or Wi + Wr + Ws + Wg + Wd.

The water requirement for individual fruit crop would, thus, depend on its irrigation needs besides the several factors, which contribute, to losses and gains of water in the orchard. However, the optimum water requirement is that which results in maximum yield. This varies at different stages of tree growth and development. Precise data on water requirement of various fruits are not available. During the initial period after planting, regular irrigation to young plants is vital. In established orchard, the critical stages for irrigation are during fruit set and development besides at the time of fertilizer application. Estimates of water requirement for bearing orchard of different fruits have been made. (Table).

Micro-catchment or farm pond water harvesting system

Heavy rains resulting in the heavy down pours is not uncommon resulting in runoff even in dry land regions. About 15-30% runoff water could be capitalized for water harvesting and runoff recycling. Efficient utilization of harvesting water requires an elaborate consideration of selection of site, runoff inducement, storage, seepage, evaporation losses, water lifting and conveyance devices and their efficiencies. A farm pond of 150m^3 capacity with side slopes of 1.5:1 is considered sufficient for each hectare of catchments area in the black soils with a provision of emptying it to accommodate subsequent events of runoff.

Water requirement estimations in fruit crops

Fruits	Number of irrigations									* Quantity of water (cm)	Critical period	Adapted from (Author(s))
	Feb	Mar	Apr	May	June	July - Sept.	Oct.	Nov. – Jan.	Total			
Aonla	-	-	2	2	2	-	2	2	10	60	Apr.-June Oct.-Dec.	Bajpai & Shukla 1985
Fig	-	3	3	1	-	-	1	4	12	72	Mar-May	--

* The quantity of water has been calculated based on 6 cm water per irrigation (3 cm in papaya **) to be given by border or flood methods which could be further reduced by following furrow or ring and bubbler systems to the extent of 50 & 70 % respectively and much more by trickle irrigation.

Merits and demerits of some orchard irrigation methods

Method	Merits	Demerits
Ring basin	Limited area is wetted to economise water. Useful during early establishment of trees. Less risk of spread of disease, ponding of water and stagnation.	Interculture is difficult. High loss of water through seepage and evaporation. High labour requirement.
Check basin	Layout is simple	Interculture is difficult. High loss of water through seepage and evaporation. High risk of stagnation and salinity build up. High labour requirement. Water distribution is less uniform.
Border strip	-do-	-do-
Furrow	Water losses are lesser than in check basin or ring. Labour requirement is also lesser. More uniform water distribution.	Water losses are high but lower than in check basin. Requires proper land grading.
Sprinkler	Seepage and erosion losses are avoided. Land leveling is not required. Interculture is easy. Fertilisers, insecticides and fungicides can be applied with irrigation water. Builds up humidity between the trees. Labour cost is less.	Unsuitable in areas with high wind velocity. Evaporation losses are high. Irrigation water must be clean. Cannot be used during fruit maturation. Increases risk of spread of diseases. High cost.
Bubble	Cuts conveyance losses of water. Does not restrict root growth. Cheaper than sprinkler or trickle methods. Does not interfere with interculture or intercropping.	Requires careful inlaying of pipes with suitable gradient. Installation cost is high. Evaporation from tree basins occurs. Restricts root growth.
Trickle	High water use efficiency.	Very expensive.
	Keeps down the weed growth. No seepage or evaporation losses.	Requires high skill in maintenance.
	Fertilisers, insecticides and fungicides can be applied with irrigation water. Labour cost is less.	Requires clean irrigation water.

Aonla

Aonla is very drought hardy. It is very susceptible to water logging (Singh, 1974). Young plants require watering during summer at fortnightly interval till they have fully established. Irrigation to bearing trees is essential during April to June at biweekly interval to secure higher fruit set and reduce fruit drop and again during October to December at 20 days interval helps in better development of fruits (Bajpai and Shukla, 1985).

Fig

Fig trees must be regularly and judiciously irrigated to obtain satisfactory production of good quality fruits. In western India, trees are irrigated rather sparingly after the rest period in September, i.e. 2-3 times at an interval of 3-4 days, but subsequently good irrigations may be given every 8-15 days depending on soil and climatic conditions, every 8-10 days during October-November, every 12-15 days during December-February and every 8-12 days during March-May (Nagpal, 1966). In Deccan, regular irrigations are given from October-May. Singh *et al.,* (1963) suggested irrigation every 10-12 days during summer months. While good irrigation is necessary when fruits are developing, the frequency must be reduced near maturity. Excessive irrigation or rains during ripening result in fruit cracking. However, water stress results in small hard fruits.

Mango

The critical periods for irrigation in mango are either during the establishment of orchard or during the period from flowering to fruit harvest in the bearing trees (Gandhi, 1959; Katyal and Chadha, 1960; Singh and Arora, 1965). Water stress during these periods adversely affects the growth and fruiting. Irrigation at 10 days interval to 5 year old trees of eight mango cultivars including Rumani and Banglora improved fruit set and increased yield in peninsular India (Purushotham and Narsimhan, 1981) which are otherwise not irrigated during February-May. Regular irrigation during fruit development period also reduces fruit drop and increases fruit size (Majumder and Sharma, 1985). More frequent irrigations, however, cause fruit cracking owing to rise in relative humidity (Singh and Arora, 1965). High relative humidity was associated with occurrence of cracking in Dashehari (Teaotia *et al.,* 1971). During the first year after planting, watering should be done at 2-3 days interval in the dry season. The interval is kept 4-5 days upto 5 years age and is then increased to 10-15 days in grown-up trees (IIHR, 1985b).However, in high rainfall areas (>1000 mm), irrigation is not required normally during rainy season and winter, particularly in retentive soils, eg., alluvial soils of Indo-Gangetic plains, lateritic soils of Konkan and red soils of Dharwar (Singh, 1969; Gandhi, 1959). Thus, about 4-5 irrigations are required in bearing orchards during February-June. In case monsoon recedes earlier, or in areas with scanty rainfall or shallow soils, one to two irrigations during November-December will induce good flowering (Gandhi, 1959). Irrigations must be stopped at least 2-3 months before flowering period since irrigations during this period is likely to promote vegetative growth to the detriment of flowering (Mujumder and Sharma, 1985; Singh, 1969).

Papaya

Papaya, in general, requires heavy irrigations both for establishment of young plants as well as for proper growth and fruiting (Singh, 1969) but can not stand water logging and would develop `wet feet'. In the hilly regions of east and west coast of south India, papaya is found growing under rainfed conditions due to well distributed rainfall from south-west and north-east monsoons (Gandhi, 1957b). In most parts of India, grown-up trees may be watered at 10-12 days interval in winter and at 6-8 days interval during summer and only once or twice during long breaks in monsoon (Gandhi, 1957b). Singh (1969) recommended irrigations at 10 days interval in winter and every week in summer provided there was no rain. At IIHR (1986c), interval of 8-10 days in winter and 6 days in summer have been recommended. Fruitfulness in papaya depends on maintaining proper soil moisture. Lower soil moisture levels shifted plants towards sterility and male floral characters, while higher moisture resulted in excessive production of undesirable carpelloid types (Muthukrishnan and Irilappan, 1985). Prolonged water stress results in stunted growth and poor fruit set (Gandhi, 1957b).

Phalsa

Phalsa is very drought hardy but requires adequate water for proper growth and fruiting. Irrigations are required during February-May when growth and fruiting takes place. One irrigation after every 15-20 days from early spring until the advent of monsoon and once after every 4-6 weeks after rainy season until start of winter are required (Singh, 1964). During flowering and fruiting period, the interval of irrigation is reduced to once or twice a week to obtain good size fruits having high juice content. Singh (1978) recommended irrigation at 15 days interval during March-May.

Water harvesting

The practice of water harvesting is said to be 4000 years old in the Middle East and at least few centuries old in India. The Khadins or Kharins in Jaisalmer are believed to be 300-500 years old (Pareek, 1978). Scientific management of such formations utilizes run-off effectively for fruit growing in both low as well as high rainfall areas. This can be done either by micro-plot or *in-situ* water harvesting or by recycling the run-off.

***In-situ* water harvesting**

The techniques is most effective since the deep rooted, perennial fruit trees can draw the run-off water concentrated even in the deep soil profiles from the few rainfall incidences. The run-off generation, however, depends upon several characteristics of the catchment, eg. size, slope, soil texture; covers such as plastic, metal foils and butyl rubber; asphalt, silicons, latexes, wax, heavy duty oil and bitumen based sealants; and surface characters, such as compaction, smoothness, vegetation and wetness besides the rainfall pattern (intensity and duration, etc) of the region. Therefore, the catchment size, its slope and other characters would vary in different regions.

The watershed area is divided into microcatchments considered optimum either for a tree or a group of trees, arranged in a row or other patterns suited to the location. In nearly flat areas, catchment could be provided on two sides of a tree row or around each tree. On hill slopes or on undulating lands, the tree is planted at the lowermost corner of the microcatchments.

The optimum catchment area is worked out considering the water requirement and root architecture of the fruit species on one hand, and the expected water input through rainfall and run-off on the other. The objective is to meet the water deficits in rainfall through run-off from these microcatchments ensuring that it is stored in the soil profile having roots of the fruit tree. Thus, the catchment size should be such that the run-off from it, at one recharge, does not ordinarily exceed the moisture storage capacity of this effective soil profile under the tree canopy. Thus, Pareek (1977, 1982) gave estimates of the catchment area required per tree and trees per hectare for different fruits for growing in sandy and rocky catchments of Jodhpur region using the formula, A=RS " RC, where A is catchment area per tree m^2, T is canopy area of the tree in m^2, S is run-off supplement required in mm per tree to meet the rainfall deficit, R is average annual rainfall in mm and C is run-off coefficient of the soil.

Ber plantation has been raised with *in-situ* run-off concentration system under hot arid agro-climatic conditions of north-west India. The fruit yield in Gola and Seb cultivars of ber increased with increase in degree of slope and decrease in length of run as a result of increase in run-off and moisture storage in a 3 m soil profile (Sharma *et al*., 1982, 1986b; Yadav *et al.,* 1980). The highest fruit yields were obtained when 0.5 and 5% slopes respectively had 8.5 and 7 m length of run and 72 and $54m^2$ catchment area per tree giving 2 and 1.5 contributing/planted area ratios (Table). Rough linear relationship existed between fruit yield and soil moisture storage. Similar work done at Aruppukottai in Tamil Nadu andAnantapur in A.P. also indicated the usefulness of water harvesting for ber production (Anon., 1989).

Even under the high rainfall conditions of Doon Valley, *in-situ* water harvesting of post-monsoon (January-April) rains from Class-V to VII land surfaces significantly improved the productivity of lemon (Ghosh, 1982), sweet orange and plum orchards.The fruit yield in sweet orange was maximum when the trees were grown in rows at the bottom of slopes of V-shaped microcatchments having 5% of inward slope on either run-on sides. Bhattacharya *et al.,* (1966) found contour ditching to be beneficial in citrus. In plum, the maximum production was obtained by providing 5% inward slope to circular basins which were covered with mulch.

Moisture conservation

The practices like placement of subsurface barriers, weed control and mulching with the available organic waste materials, polythene and chemical covers, spreaders, etc., help to conserve moisture in orchard soils by checking evaporation and weed growth, and lowering the soil temperature.

Mulching

Mulching minimizes water losses from soil surface as a result of solar radiation and wind action and by suppressing weed growth. Mulch also prevents erosion and adds organic matter to the soil and keeps it cool (Aiyappa *et al.,* 1966). Materials such as hay, straw, cutgrass, dry leaves, weed materials and polythene have been found effective.

Effect of run-off concentration of fruit yield of ber (*Zizyphus mauritiana* Lamk.)

Catchment slope (%)	Flat	0.5	0.5	0.5	5	5	5	10	10	10
Slope length (m)	0	8.5	10.75	14.5	7	8.5	10.75	5.12	7	8.5
Catchment/planted area ratio	0	2	2.7	4	1.5	2	2.7	0.87	1.5	2
Contributing area (m^2/tree)	0	2	99	144	54	72	99	31.5	54	72
Trees per plot	15	5	4	3	6	5	4	8	6	5
Total catchment area (m^2)	0	360	396	432	324	360	396	252	324	360
[1]Total seasonal run-off (% of rainfall)	6.6	10.91	19.91	18.61	41.1	36.0	36.8	41.5	38.9	39.7
[2]Moisture storage in 3m soil profile (mm)	312	342	368	313	348	410	380	472	418	372
[2]Fruit yield per tree (kg)	4.3	17.5	16.8	17.0	18.3	19.7	21.1	19.3	17.8	16.5
Fruit yield per plot (kg)	44.7	52.6	43.5	43.8	83.4	60.0	75.9	104.3	89.6	69.9

[1]Average of 5 years (1975-79), [2]Average of 3 years (1976-77 to 1978-79).