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Irrigation management in various crops to improve productivity

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Abstract : For efficient water management schedule of time, place where to give and system of irrigation should be managed accordingly. Integrated farming system is beneficial approach in effective utilization of the available water resources. Various irrigation methods are employed in orchard like flood irrigation, border strip method, check basins method, ring basin method, furrow method, pitcher irrigation along with pressurized irrigation methods like sprinkler and drip irrigation. Fertigation is the process in which fertilizers can be applied through the system with the irrigation water directly to the root zone of the crop. In Fruit crops, micro irrigation has a large impact as it helps in water saving and yield also increase to large extent.

Water management refers to artificial ways and means to provide a specific quantity of water at an appropriate time to the effective root zone of crops deriving maximum water for higher application efficiency and water use efficiency.

Indispensable water: Leonardo da Vinci, "Water is the driver of life". Water is indispensable input for the life of animals as well as plants. It is said to be the liquid of life or elixir of life. It constitutes about 35 per cent to 95 per cent of the different portions of the plant. The leaves of the plant contains 35 per cent to 95 per cent water, roots contain 60 per cent to 90 per cent and fleshy fruits contain 70 per cent to 90 per cent water.

The growth and productivity of a fruit plants as well as profitability of the orchard enterprise depend on the moisture relations and irrigation practices. Irrigation is very important in fruit crops as sufficient moisture must be maintained in the soil for obtaining the optimum yield of good quality fruits. For a profitable orchard enterprise, a well-planned irrigation system and efficient water management practice having utmost importance. The aim of irrigating a fruit tree should be to wet the entire root zone without allowing any wastage of water beyond the root zone. The irrigation systems have to be properly devised so the water requirement of the trees is met at the minimum expenditure without any wastage of water. By definition, irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall. And efficient water management refers to artificial application of water *i.e.* irrigation in crop root zones in case of soil moisture deficit and removal of water *i.e.* drainage from the root zone in case of excess so as to provide the crops a most optimum soil moisture regime for best production. It means how best we are in irrigating and dewatering our fields so that plants are protected from stress as well as water logging. Various factors such as soil type, crop type, planting density, water quality, irrigation equipment and economic factors such as the capital and operating costs will all determine the ultimate decision for choosing the type of orchard irrigation systems.

Role of water in plant system:

– Water is a means of thermal regulation of temperature inside the plant.

– Water is a means of transportation of nutrients from roots to shoots and *vice-versa.*

– Water forms the source of hydrogen from the reaction of carbon dioxide in the process of photosynthesis.

– Many organic constituents of plants such as carbohydrates, protein, nucleic acid and enzymes etc. are denatured in absence of water.

– Water is essential for maintaining turgidity and it is essential for survival of plants.

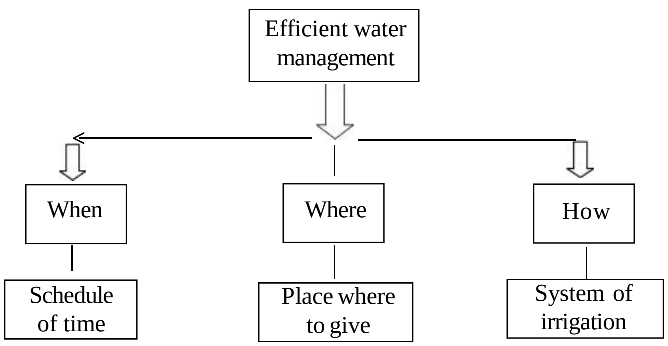
Crop water management: Crop water management studies are grouped into 4 categories of research issues:

– Effective development of genotypes to accelerate improvement of crop water productivity.

– Institutional arrangements at the farming –systems level, which promote farmer's adoption of technologies that enhance water productivity.

– Opportunities for enhancing water productivity at regional and agro – ecological systems.

– New opportunities and technologies for integrated crop and natural resources management at field and farm level.



How much to irrigate: Water requirements vary depending on :

– Crop
– Soil conditions
– Soil conditions
– Method of application
– Season

When to irrigate: The three approaches which are available for scheduling irrigations are based on :

– Morphological and physiological conditions of the plant.

– Soil moisture condition.

– Weather parameters.

Available soil moisture: It has been convention and even now it is a customary to consider "the amount of soil moisture held between the cardinal points *viz.*, field capacity (0.33 bars) and permanent wilting point (15 bars) as available soil moisture".

$$\text{Available soil moisture} = \frac{(FC - PWP) \times pb \times ds}{10}$$

where ,

FC = Field capacity (%) on oven dry weight basis

PWP = Permanent Wilting Point (%) on oven dry weight basis

pb = Soil bulk density (g/cc)

ds = Depth of soil (cm)

Available soil moisture in mm/depth of soil

Crop water requirement: It is a function of surface area covered by plants, evaporation rate and infiltrations capacity of the soil. At first irrigation, water requirement has to be calculated for each plant and thereafter for whole plot based on plant population for the different seasons. The maximum discharge required during any one the 3 seasons is adopted for design purpose.

$$V = Ep \times Kp \times Kc \times Wp \times Sr \times Sp$$

V = Volume of water (litre /day /plant)

Ep = Open pan evaporation (mm/day)

Kp = Pan factor (0.7)

Kc= Crop co-efficient (depends on crop growth stage)

Wp = Wetted area

Sr = Row to row spacing

Sp= Plant to plant spacing

Water use efficiency : Water use efficiency (WUE) is the amount of biomass produced per unit of water. The WUE increases are mainly aimed at higher productivity per mm of water applied. There exists an upper limit beyond which the WUE units will not increase at the same proportion. Hence, an alternate phenomenon is to increase the water productivity aimed at higher monetary returns per mm of water used. A banana crop may have higher water requirement in comparison to grapes, yet the monetary returns the grape crop fetches could be higher per unit of water. As such it becomes essential to diversify the crops to suit to local conditions / market demands when water productivity is the major consideration. Likewise, a pomegranate crop having export potential could be an ideal crop for higher productivity compared to banana. Instead of mono-cropping, choosing / growing a crop which can yield more in a given period time and can fetch higher returns to the farmer is a better proposition for higher water productivity.

How to enhance the WUE:

– Irrigation scheduling
– Irrigation methods
– Reallocation of water by using limited water
– Partial root drying techniques
– Integrated farming system.

Integrated farming system : A farming system approach is beneficial in effective utilization of the available water resources. Multiple cropping system or a relay cropping system involving long duration – short duration deep rooted - shallow rooted – low canopy – medium canopy – high canopy crops when grown can effectively utilize the entire water distributed in a soil profile at the same time check evaporation losses. Due consideration has to be given to economic returns rather than higher productivity alone. A banana crop will definitely fetch higher returns when the produce is available during festive seasons. During the initial stages of banana growth, the water need will be less (40% of evaporation replenishment) and increases with grand growth and fruit development (80%ER) finally tapering to lower demand for water as it approaches maturity (40%ER). Around 4-5 months of crop growth, the water demand for banana will be 50 per cent of the total water requirement (1700 mm). This water could be effectively utilized / diverted to grow some other short duration vegetable crop or to crops which need critical irrigations. Likewise, in pomegranate, exposure of plants to stress is desirable for induction of flowering and fruiting. The average annual irrigation is around 200mm. A stress period of 10 -15 days in each of this bahars (mrigbahar of June –July), haste bahar of September – October and ambebahar of January – February) could a saving in total water use of around 50 mm which can be utilized for other crops.

Irrigation scheduling : Scientific irrigation scheduling is a technique providing knowledge on correct time and optimum quantity of water application at each irrigation to optimize crop yields with maximum water use efficiency and at the same time ensuring minimum damage to the soil properties.

Methods of irrigation: The choice of the irrigation method depends on the following factors :

– Size, shape, and slope of the field.
– Soil characteristics.
– Nature and availability of the irrigation water supply.
– Types of crops being grown and age of the trees.
– Initial development costs and availability of funds.
– Preferences and past experience of the farmer.

Irrigation water can be applied to crop lands using one of the following irrigation methods :

Traditional /Surface irrigation:

– Uncontrolled (wild or free) flooding method
– Border strip method
– Check basins method
– Modified/ring basin
– Furrow method
– Pitcher irrigation

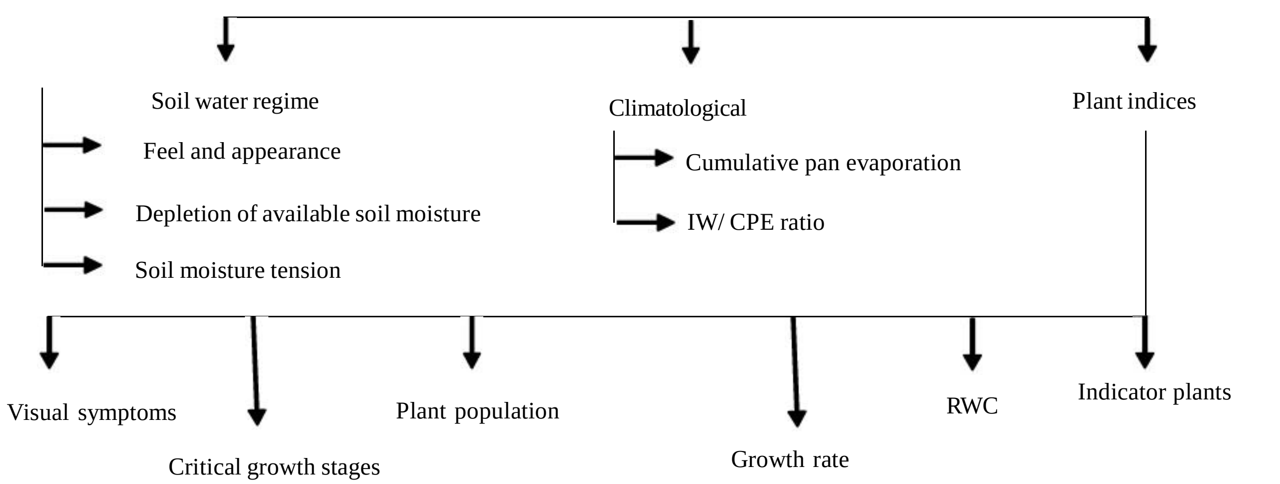
Advanced / Pressurized methods:

– Sprinkler irrigation
– Trickle (Drip) irrigation
– Talca irrigation management system (TIMAS)
– Partial root zone drying (PRD)
– Bubbler irrigation.

Surface irrigation: In all the surface methods of irrigation, water is either ponded on the soil or allowed to flow continuously over the soil surface for the duration of irrigation. Although surface irrigation is the oldest and most common method of irrigation, it does not result in high levels of performance. This is mainly because of uncertain infiltration rates which are affected by year to-year changes in the cropping pattern, cultivation practices, climatic factors and many other factors. As a result, correct estimation of irrigation efficiency of surface irrigation is difficult. Application efficiencies for surface methods may range from about 40 to 80 per cent.

Uncontrolled flooding : This system is very simplest and

Irrigation scheduling criteria



easiest to practice. The water is allowed for irrigation without making any beds, basins or any other structure. In uncontrolled, wild or free flooding, water is applied/ flooded to the orchards without any preparation of land and without any levees to guide or restrict the flow of water on the field. The advantage of this method is the low initial cost of land preparation. This method is suitable when water is available in large quantities, the land surface is irregular and the crop being grown is unaffected of excess water. In this method, water is brought to field ditches and then admitted at one end of the field thus letting it flood the entire field without any control. Uncontrolled flooding generally results in excess irrigation at the inlet region of the field and insufficient irrigation at the outlet end. Application efficiency is reduced because of either deep percolation (in case of longer duration of flooding) or flowing away of water (in case of shorter flooding duration) from the field. The application efficiency would also depend on the depth of flooding, the rate of intake of water into the soil, the size of the stream and topography of the field. This method is not economical as well as not suitable for the crops which are very sensitive to water logging like papaya.

Border strip method: This is a controlled surface flooding method of applying irrigation water in the orchard. In this method, the farm is divided into a number of strips. These strips are separated by small ridge or raised area. Water from the supply ditch is diverted to these strips along which it flows slowly towards the downstream end and in the process it wets and irrigates the soil. When the water supply is stopped, it recedes from the upstream end to the downstream end. The border strip method is suited to soils of moderately low intake rates and low erodibility. This method, however, requires preparation of land involving high initial cost.

Check-basin method: The check basin method of irrigation is based on rapid application of irrigation water to a level or nearly level area completely enclosed by dikes. In this method, the entire field is divided into a number of almost levelled plots surrounded by levees. This method is suitable for a wide range of soils ranging from very permeable to heavy soils. The farmer has very good control over the distribution of water in different areas of his farm. Loss of water through deep percolation (near the supply ditch) and surface runoff can be minimized and adequate irrigation of the entire farm can be achieved. Thus, application efficiency is higher for this method. Besides, there is some loss of cultivable area which is occupied by the levees. Sometimes, levees are made sufficiently wide so that some row crops can be grown over the levee surface.

Furrow method: Previously furrow system of irrigation is attributed as one of the best systems for irrigating the mature trees. This method is also practiced in newly established orchards. This method is an alternative to flooding. In this method of irrigation, the entire land surface is to construct in small channels along the primary direction of the movement of water and letting the water flow through these channels which are termed furrows, creases or corrugation. Furrows are small channels having a continuous and almost uniform slope in the direction of irrigation. Water infiltrates through the wetted perimeter of the furrows and moves vertically and then laterally to saturate the soil. Furrows are used to irrigate crops planted in rows. Furrows necessitate the wetting of only about half to one-fifth of the field surface. This reduces the evaporation loss considerably. However, the depth, length and width of furrows depend on nature of the soil and spread of root system of the fruit plants. Furrows provide better on-farm water management capabilities for most of the surfaceirrigation conditions and variable and severe topographical conditions. For example, with the change in supply conditions, number of simultaneously supplied furrows can be easily changed. In this manner, very high irrigation efficiency can be achieved.

Ring basin method: This is very useful method of irrigating the young tree in the orchard. In this method, a circular ring in the periphery is prepared to irrigate the plants. While preparing, care is taken that ring is prepared away from tree trunk towards outer periphery of the tree. In between two ring-basins, a sub channel connecting the ring basin of the tree is prepared. The water flow through central channel and move ahead naturally after flooding two ring basins at a time.

Pitcher irrigation: This system is very suitable for those areas where water scarcity exists. The pitcher filled with water buried in the periphery of individual tree where feeding roots are confined. It is similar to drip irrigation but less expensive to install. The pitchers are the round earthen containers used in rural areas for water storage, ranging from 10 to 20 lit. in capacity. This kind of irrigation is ideal for saplings, promoting deep root growth. Soluble fertilizers can also be mixed with water and applied through the pitcher. If the water used for irrigation has high salinity, the pitcher location should be changed in every 3 years. To increase the depth of irrigation, a wick can be added to the pitcher.

Pressurized methods: Advanced techniques for increasing water use efficiency broadly divided in two groups:

Subsurface irrigation: Subsurface irrigation (or simply sub irrigation) is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. In natural sub irrigation, water is distributed in a series of ditches about 0.6 to 0.9 meter deep and 0.3 meter wide having vertical sides. These ditches are spaced 45 to 90 meters apart. Sometimes, when soil conditions are favourable for the production of cash crops (*i.e*., high-priced crops) on small areas, a pipe distribution system is placed in the soil well below the surface. This method of applying water is known as artificial sub-irrigation. Soils which permit free lateral movement of water, rapid capillary movement in the root-zone soil and very slow downward movement of water in the subsoil are very suitable for artificial sub-irrigation. The cost of such methods is very high. However, the water consumption is as low as one-third of the surface irrigation methods. The yield also improves. The conditions which favourable sub irrigation are as follows:

– Impervious subsoil at a depth of 2 meters or more,
– A very permeable subsoil,
– A permeable loam or sandy loam surface soil,
– Uniform topographic conditions and
– Moderate ground slopes.

Micro- irrigation: A scientific method of irrigation carrying desired water and nutrients direct to the root zone of the plant, drop by drop. Micro-irrigation systems apply water to the tree line of the orchard only, whereas other irrigation methods also wet the traffic-lane between rows. Irrigating only the tree line ensures traffic access to the orchard at all times for such essential operations as spraying and harvesting. The amount of water applied by micro-irrigation systems can be closely managed to match the requirements of the crop. Therefore, the frequency and volume of application are factors that can be used to control the growth of the crop to maximise marketable yield. Fertiliser can also be readily applied through the pipe network of micro-irrigation system so that the nutrient solution is applied directly to the active root zone. This reduces the losses of fertilizer that would occur through percolation or uptake by weeds. The main problem that can occur with micro-forms of irrigation is the blockage of the emitter. Blockages can be prevented provided attention is paid to installing adequate filtration and chlorination systems and operating them in accordance with the manufacturer's instructions. Micro-irrigation has a number of advantages over conventional methods of irrigation. The choice between types of micro-irrigation is not as easy and comes down to choosing with a wide choice of wetting pattern size and shape. There are different systems of micro-irrigation but care has to be taken in selection of irrigation method. Following methods of micro-irrigation are widely used in orchards according the requirement and availability of recourses.

– Sprinkler irrigation
– Drip irrigation
– Others system like Talca Irrigation Management System (TIMAS), Partial Root Zone Drying (PRD) and Bubbler irrigation.

Sprinkler irrigation: Sprinkling is the method of applying water in the form of a spray which is somewhat similar to rain. In this method, water is sprayed into the air and allowed to fall on the soil surface in a uniform pattern at a rate less than the infiltration rate of the soil. This method started in the beginning of this century and was initially limited to nurseries. In the beginning, it was used in humid regions as a supplemental method of irrigation. Sprinkler irrigation usually wets the whole orchard floor. Sprinkler systems offer reasonable control of irrigation run time. Rotating sprinkler-head systems are commonly used for sprinkler irrigation. Each rotating sprinkler head applies water to a given area, size of which is governed by the nozzle size and the water pressure. Alternatively, perforated pipe can be used to deliver water through very small holes which are drilled at close intervals along a segment of the circumference of a pipe. The trajectories of these jets provide fairly uniform application of water over a strip of cropland along both sides of the pipe. With the availability of flexible PVC pipes, the sprinkler systems can be made portable too. Sprinklers have been used on all types of soils on lands of different topography and slopes, and for many crops.

The following conditions are favourable for sprinkler irrigation:

– Very previous soils which do not permit good distribution of water by surface methods,

– Lands which have steep slopes and easily erodible soils,

– Irrigation channels which are too small to distribute water efficiently by surface irrigation,

– Lands with shallow soils and undulating lands which prevent proper levelling required for surface methods of irrigation.

There are so many advantages with the sprinkler system of irrigation like low water loss (efficiency upto 80%), saving in fertilizer, suitable for any topography, no soil erosion, better seed germination, free aeration of root zone and uniform application of water. The main difference between sprinkler systems and drip systems of irrigation is the wetting of a larger soil volume by the spray or jet emitters. This occurs by virtue of the water being distributed over a larger area of soil but the drip systems apply water to the one point and rely on the soil properties for distribution of the water. The wetting of a larger surface of soil is important on sandy soils where little lateral movement occurs within the soil and on some clay soils where cracking of the soil is severe. The wetting of a larger soil volume should result in bigger trees but not necessary more productive trees. Wetting a larger soil volume makes for a safer system in case the interval between irrigations is longer and hence, there is less risk from excessive soil dryness. Some disadvantages also exists with this system of irrigation like high initial cost, cannot adopt by ordinary farmers, poor application efficiency in windy weather and high temperature, high evaporation losses, water should be free of debris, equipment's need careful handling, physical damage to crops by application of high intensity spray and power requires forerunning pumping unit etc.

Trickle (Drip) irrigation: Drip irrigation has enabled farmers, nurserymen and landscapers to conserve water for decades. Drip irrigation, also known as trickle irrigation or micro irrigation or localized irrigation, is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is done through narrow tubes that deliver water directly to the base of the plant. This is primarily because, in contrast to gravity or sprinkler irrigation, drip irrigation technology applies water slowly and directly to the targeted plant's root zone. In addition, drip irrigation technology has extremely high application uniformity, even when pressures vary from hilly terrain or long lengths of run, or where planted areas are oddly shaped. Trickle irrigation (also known as drip irrigation) system comprises main line, sub mains, laterals, valves (to control the flow), drippers or emitters (to supply water to the plants), pressure gauges, water meters, filters to reduce clogging of the emitters (to remove all debris, sand and clay), pumps, fertilizer tanks, vacuum breakers, and pressure regulators. The drippers are designed to supply water at the desired rate directly to the soil. Low pressure heads at the emitters are considered adequate as the soil capillary forces causes the emitted water to spread laterally and vertically. Flow is controlled manually or set to automatically either to deliver desired amount of water for a predetermined time or to supply water whenever soil moisture decreases to a predetermined amount. Today it is more important than ever to use water resources wisely and to irrigate intelligently. Consequently, many farmers have turned to drip irrigation and have enjoyed improved profitability by increasing crop yield and quality while at the same time reducing costs from water, energy, labour, chemical inputs and water runoff. Many farmers have also enjoyed significant water and capital investment savings using drip irrigation, while simultaneously improving plant vigour by delivering water and nutrients directly to the plant roots and avoiding unnecessary wetting of plant leaves.

Drip irrigation is the targeted, intelligent application of water, fertilizer and chemicals that when used properly can provide great benefits such as water use efficiency is maximal so water saving, maintaining high soil-water potential in root zone, partial soil wetting so no interference with agro technical practices, lesser number of weeds, no wetted canopy that may cause disease, even low quality water can be utilized, can be operational under heavy winds, easy application of fertilizer, herbicides and pesticides through drip lines, adaptation to marginal plot, high uniformity in water and fertilizer supply and comparatively pressure requirement is low in this system. In spite of the fact that drip irrigation has so many potential benefits, there are a certain limitations also like sensitivity to clogging, moisture distribution problem and salinity hazards, high cost compared to furrow, high skill is required for design, install and operation and not suitable for closely planted crops.

Others systems like TIMAS uses weather data in combination with soil water content measurements to provide farmers with information required to manage the irrigation scheduling. The Partial root-zone drying (PRD) method of irrigation is a modified form of deficit irrigation, involves irrigating only one part of the root zone in each irrigation event, leaving another part to dry to certain soil water content before rewetting by shifting irrigation to the dry side, therefore, PRD is a novel irrigation strategy since half of the roots is placed in drying soil and the other half is growing in irrigated soil. Originally, the concept of PRD was first used in USA on field cotton in alternate furrow irrigation. Wetting and drying each side of roots are dependent on crops, growing stage, evaporative demands, soil texture and soil water balance. Yet there is little understanding on mechanism of PRD effects on crop growth, therefore, no definite solid procedure exist on determining the optimum timing of irrigation for each side. Therefore, in PRD, roots sense the soil drying and induce ABA that reduce leaf expansion and stomatal conductance and simultaneously the roots in wet soil absorb sufficient water to maintain a high water status in shoot. Practically, PRD can be used in different ways depending on the cultivated crops and/or soil conditions, environmental conditions and method of irrigation. PRD has been used by surface and subsurface drip irrigation. Partial root-zone drying irrigation is the novel deficit irrigation strategy that is generally adapted in the last decade to a vast kind of agronomic and horticultural crops to increase the water productivity. However, the amount of saved irrigation water and improved water productivity strongly depends on crop, soil, and site specifications. Moreover, cumulative results revealed that partial root-zone drying irrigation could not be effective in reproductive crops that are sensitive to water stress. Therefore, partial root-zone drying is recommended for irrigation of farms and gardens in arid and semi-arid areas which are suffering from lack of fresh water resources for agricultural production. Partial root-zone drying practices can be viable and advantageous option compared with full irrigation to prevent crop yield reduction when and if there is water shortage or to improve crop quality. It is noteworthy that studies on PRD are still continuing and in future new results will be available from other crop species, probably from horticultural and tree crops with a high irrigation water requirement.

Another less popular system like bubbler irrigation which is a localized, low pressure, solid permanent installation system used in tree groves. Each tree has a round or square basin which is flooded with water during irrigation. The water infiltrates into the soil and wets the root zone. The water is applied through bubblers. These are small emitters placed in the basins which discharge water at flow rates of 100–250 lit./hr. Each basin can have one or two bubblers as required. With bubbler irrigation the percentage of the root soil volume wetted is about 80 per cent. Bubbler irrigation is mainly applied in fruit tree orchards. Bubbler emitters discharge water on the same spot of ground at high rates. Thus, for a uniform distribution over the basin area, a minimum of land preparation is needed. This Bubbler system having high irrigation application efficiency (upto 75%), resulting in considerable water savings, with absolute control of the irrigation water from the source to the tree basin. The entire piping network is buried so there are no field operations problems. The technology is simple and no highly sophisticated equipment is used. This system can be operated by unskilled farmers and labourers.

Quality of irrigation water: Surface water, ground water, and suitably treated waste waters are generally used for irrigation purposes. Irrigation water must not have direct or indirect undesirable effects on the health of human beings, animals and plants. The irrigation water must not damage the soil and not endanger the quality of surface and ground waters with which it comes into contact. The presence of toxic substances in irrigation water may threaten the vegetation besides degrading the suitability of soil for future cultivation.

The various types of impurities, which make the water unfit for irrigation, are classified as:

– Total concentration of soluble salts in water

– Proportion of sodium ions to other ions

– Concentration of potentially toxic elements present in water

– Bacterial contamination

– Sediment concentration in water.

Fertigation for fruit crops: Fertigation is the process in which fertilizers can be applied through the system with the irrigation water directly to the region where most of the plant roots develop. It is done with the aid of special fertilizer apparatus (injectors) installed at the head control unit of the system, before the filter. The element most commonly applied is nitrogen. However, application of phosphorus, potassium and other micro-nutrients are common for different horticultural crops. Fertigation is a necessity in drip irrigation. The main objectives of fertigation are :

– Uniform and timely application of fertilizers.

– Water and nutrient saving.

– Optimizing yield.

– Quality improvement.

– Minimizing pollution.

The rational for fertigation are as under:

– Irrigation and fertilizers are the most important management factors through which farmers control plant development and yield.

– Water and fertilizers have important synergism which is very well used investigation.

– Timely application of water and fertilizers can be controlled through fertigation.

Principles of fertigation: It is to feed the plant in appropriate time, quantity and location. These three things can be controlled through fertigation. The plant yield and the quality depend on all thesethree factors.

Advantages of fertigation:

– Amount and concentration of nutrient can be adjusted according to the stage of development and climatic considerations.

– Deeper penetration of nutrients into the soil.

– Avoiding ammonia volatilizing from soil surface

– Application restricted to the wetted area where the active roots are concentrated.

– Reduced time fluctuation in nutrient concentrations.

– Crop foliage is kept dry, thus, retarding the development of plant pathogens and avoiding leaf burn.

– Allows fertilization in the rainy season when the soil is in wet condition without stepping on it and destroying the structure.

– Convenient use of fertilizers.

– Remote control operation.

– Convenience in saving manpower.

– Low losses in transportation and storage.

– The system may be used for additional applications.

Managing the available irrigation water: Irrigation is in short supply in most locations and therefore, demands a careful and economic use. Economy of water helps to bring more areas under protective irrigation and leads to a greater crop production in areas of limited water supply. On areas where water is scarce, farmers are not able to apply normal irrigation to crops and are forced to skip some irrigation.

It is therefore, necessary to decide a priority of stages of crops when irrigations are to be applied and the stages when one or more irrigations can be skipped. The critical stages of water need of crops receive the foremost attention. It is necessary to simultaneously consider and weigh the relative importance of the various stages for irrigation and the availability of water. A preferential status of crop stages according to their relative importance to yield should be considered for irrigation in areas of water scarcity.

Irrigation depth for various fruit crops

Crops	Depth to irrigate (cm)
Apples	90
Cherries	60
Grapes	90
Peaches	60
Pears	60
Raspberries	60
Strawberries	30

Impact of micro-irrigation in fruit crops

Crop	Water saving (%)	Yield increase (%)
Banana	35-45	5-30
Ber	19	24
Coconut	65	12
Custard apple	50-55	20
Grapes	47	19
Papaya	54-68	19-77
Pomegranate	3-24	49-60
Sapota	20-25	15-20
Guava	19	27
Kagzi lime	24-64	10-44

Critical stages in fruit crops

Apple	Early fruit set , during flower formation and during final fruit swell
Pear	Early fruit set , during flower formation and during final fruit swell
Peaches	Early fruit set , during flower formation and during final fruit swell
Plums	Early fruit set , during flower formation and during final fruit swell
Nectarines	Early fruit set , during flower formation and during final fruit swell
Cherries	Early fruit set , during flower formation and during final fruit swell
Blueberries	Berry swell to end of harvest and at bud formation for next year’s crop (late July and August)
Raspberries	Bloom and as berries are sizing before first picking
Blackberries	Bloom and as berries are sizing before first picking
Strawberries	At planting , during runner formation during flower bud formation before harvest begins

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