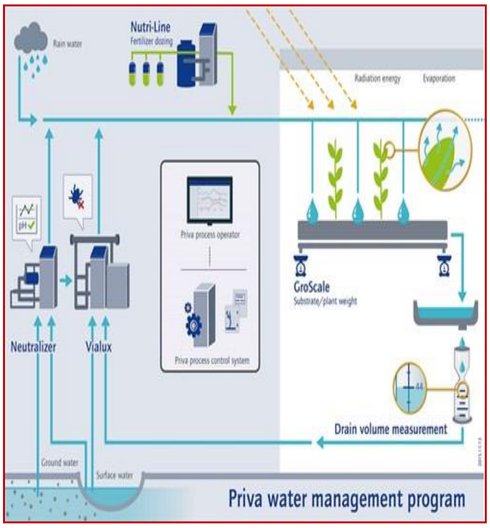
Water Management in Horticultural Crops



6. Water Management in Horticultural Crops (HNW 100) 2(1+1)

Importance of water, water resources in India. Area of different crops under irrigation, function of water for plant growth, effect of moisture stress on crop growth. Available and unavailable soil moisture – distribution of soil moisture – water budgeting – rooting characteristics – moisture extraction pattern. Water requirement of horticultural crops – lysimeter studies – Plant water potential climatological approach – use of pan evaporimeter – factor for crop growth stages – critical stages of crop growth for irrigation. Irrigation scheduling – different approaches – methods of irrigation – surface and sub-surface pressurized methods viz., sprinkler and drip irrigation, their suitability, merits and limitations, fertigation, economic use of irrigation water. Water management problem, soils quality of irrigation water, irrigation management practices for different soils and crops. Layout of different irrigation systems, drip, sprinkler. Layout of underground pipeline system.

Practical: *Measurements of irrigation water by using water measuring devices, use of common formula in irrigation practices, practicing of land leveling and land shaping implements, layout for different methods of irrigation. Estimation of soil moisture constants and soil moisture by using different, methods and instruments, scheduling of irrigation, different approaches, practicing use of instruments, estimation of irrigation efficiency and water requirements of horticultural crops, irrigation planning and scheduling, soil moisture conservation practices.*

Lecture No.1

Water - the base for life. Functions described. Water resources of India and the region

Water – the base for life

Water is the basis of all forms of life and all these originated in sea water. All organic processes occur in watery medium. Cell, the basic unit of life, contains as high as 95-98per cent water. Cellular metabolism is controlled by content of water. No life can survive long without water. It is as necessary for our life and health today as it was for our prehistoric ancestors. Water is bound up with man's destiny in countless ways. Water has shaped and will continue to shape man's destiny.

Functions of water

Solar radiation is the activating force on the earth. The spheres of the earth - lithosphere, hydrosphere, atmosphere and biosphere - one way or other constantly in the processes and functions through the abundant but important component of the earth, the water. The biosphere, besides solar radiation and hydrosphere, depends on lithosphere and atmosphere for its functions.

Water is available in three phases. The most abundant is in liquid phase on the surface mostly and also below the surface. The other phases are in the atmosphere as vapour and solid phase which is common in polar and low temperature regions. The changes in phases are brought out by solar radiation. The conversions by the phases make vast scope in utilizing this resource for the welfare of mankind.

Biosphere in relation to hydrosphere, atmosphere and lithosphere

Hydrological cycle

Life is influenced by the earth's unending moisture cycle known as the hydrological cycle. Moisture is constantly circulating among the land, the ocean and the atmosphere. The cycle has neither a beginning nor an end. But the concept of the hydrological cycle commonly begins with the water of the oceans. Radiation from the sun evaporates water from the oceans into the atmosphere. The water vapour rises and collects to form clouds. When the air rises, it gets cooled and precipitation (Rain, hail, sleet or snow etc.) occurs.

Precipitation, on reaching earth's surface, is intercepted by vegetation, may infiltrate, flow over or evaporate. Evaporation may be from the surface of leaves, soil or free water bodies. A part of the precipitation runs off over the land to streams. Another part soaks into the soil and retained in the root zone. This water may rise by plants by capillary action or percolates down due to gravity.

In the hydrological cycle, soil acts as a reservoir; water is always in transitory storage in the soil. Considerable time may elapse before this stored water flows underground to the stream or is returned to the atmosphere by evaporation. Eventually, however, all water temporarily stored in the soil must cover the transitory part of the hydrological cycle. There are many opportunities to influence the hydrological cycle and affect water conservation in agriculture.

The hydrological cycle is not systematic and causes the problems of drought and flood affecting food production.

What is irrigation?

Irrigation is defined as the artificial application of water to land for growing crops. It is a profession as well as a science. A crop requires certain amount of water at certain fixed intervals throughout its period of growth. In tropical region heat and light are available in abundance, but the third, that is, moisture needs to be supplemented frequently by artificial application of water.

Need for irrigation

When rainfall is insufficient to meet the water requirement of crops throughout their period of growth, need for irrigation water is unavoidable. Where rainfall is sufficient but is not uniform, concentrated as it usually is in monsoon months, there is acute requirement of irrigation in other periods.

The rainfall and irrigation requirement are given in the following table.

Table1. Rainfall and irrigation requirement

S.No.	**Rainfall (cm)**	**Irrigation requirement**
1	100	Rainfall needs to be supplemented by irrigation.
2	100-50	Rainfall is helpful to crops but is insufficient. Irrigation is essential
3	50-25	Only crops tolerant to moisture stress can be grown. Irrigation is essentially required
4	Less than 25	No crop can be grown without irrigation.

Advantages of irrigation

Advantages of irrigation can be direct as well as indirect.

I. Direct Benefits

1. The grower has many choices of crops and varieties and can go for multiple cropping for cultivation
2. Crop plants respond to fertilizer and other inputs and there by productivity is high.
3. Quality of the crop is improved.
4. Higher economic return and employment opportunities. It makes economy drought proof.
5. Development of pisciculture and afforestation. Plantation is raised along the banks of canals and field boundaries.
6. Domestic water supply, hydel power generation at dam site and means of transport where navigation is possible.
7. Prevention of damage through flood.

II. Indirect Benefits

1. Increase in gross domestic product of the country, revenue, employment, land value, higher wages to farm labour, agro-based industries and groundwater storage.
2. General development of other sectors and development of the country

Disadvantages of irrigation

Irrigation is associated with the following disadvantages:

1. Over-irrigation coupled with poor drainage and seepage in an area where water table is high, leads to water logging of the area. Crop yield is drastically reduced as a result.
2. Salanization problems.

Water resources of India

Sources of all water are precipitation. The annual precipitation of India, including snowfall, is estimated at 1200 mm, which is equal to 4000 km^3 or 400 million hectare-metres (mha-m). Surface water bodies include rivers,canals,reservoirs, tanks, ponds , lakes and brackish water. In irrigated ecosystem, reservoirs account for 2.1 M ha, tanks and ponds 2.3 M ha, wells, lakes, and direct water bodies 1.3 M ha and brackish water bodies 1.2 M ha.

Replenishable ground water resource is mostly derived from precipitation. Out of 400 mha-m, 215 mha-m of rain water percolates in to the ground, out of which only 50 mha-m join the ground water and available for utilization.

History of irrigation development in India

Irrigation is a very ancient science. Irrigation has been practiced in India from time immemorial and so has been the construction of canals.

The Vedas are replete with references to wells, tanks, canals and dams. Samritis too contain evidence of early irrigation works.

The ancient rulers of India took keen interest in the provision of irrigation facilities. The early irrigation works were not primitive but had scientific basis. The most outstanding example of engineering talent in ancient time is manifest in the bold conception and construction of grand anicut across river Cauvery in the second century A.D.

The British started irrigation development in the nineteenth century. They constructed dams such as Periyar and Mettur; the Nizamsagar and Krishnarajasagar were constructed by the princes in their native states.

Further, the British introduced a definite irrigation policy in 1854 with the setting up of Public Works Department and instituting a separate fund for irrigation works.

Two categories of irrigation works, namely Minor works and Major works came into existence. Minor works which were undertaken in principle more for the sake of protecting the existing cultivation and revenue from retrogression than as revenue producing works continued to be financed out of the general revenues. Later minor irrigation works generally included private works (particularly their renovation) and private irrigation works formed a major constituent of Grow More Food Campaign.

Public tube wells were also included in the category of minor irrigation works when the department of agriculture was constituted in 1845. Major works were henceforth financed by raising public loans. Each major work was required to satisfy the productivity criterion.

Later the Famine Commission (1880) and the First Irrigation Commission (1928) laid great stress on encouraging private works (wells, tanks, etc.,) to overcome recurrent famines.

During the last 150 years, eight severe famines have occurred; the last one was in Bengal as late as in 1943. In tropical and subtropical countries like India, famines occurred due to drought conditions.

Planned Irrigation Development

On attaining independence, development of irrigation received a great fillip to meet the needs of the growing population. Thus the planned development of irrigation was set in motion in 1950-51. Irrigation schemes were divided into three categories viz., major schemes, medium schemes and minor schemes. The total irrigated area stood at 22.6 million ha in 1950-51, 9.7 million ha from major and medium irrigation projects and 12.9 million ha from minor irrigation projects. As a result of massive investment made in the successive plan periods, the total irrigation potential has been more than trebled. The ultimate irrigation potential planned to be created by the end of this century was 140 million ha. The significant and important projects undertaken and completed since the start of the planning era since 1950-51 are:

First Five Year plan: Bakra Nangal project in Punjab, Nagarjuna sagar project in AP, Kosi in Bihar, Chambal canal complex for Rajasthan and Madhya Pradesh, harike in Punjab, Bhadra and Ghataprabha in Mysore, Lower Bhavani in Tamil Nadu, Matatila in Uttar Pradesh and Mayurakshi in WB were initiated. Most of these projects initiated during the period were completed by the end of third plan period.

Second Five Year plan : Prominent irrigation projects under taken were Rajasthan canal, Gandak project for Bihar and UP, Tawa in MP, Rananaganga in UP, Parambikulam Aliyar in Tamil Nadu, Kabini in Mysore, Kansabti in WB, Kadam, Ukai, and Narmada in Gujarat, Purna , Girna and Mula in Maharashtra.

Third Five Year plan; Nine major and 86 medium irrigation projects were started while the thrust was for the completion of the pending ones.

In the subsequent plan periods thrust was given for completing the pending projects and the area under irrigation was increasing.

Perspective irrigation development

India is the seventh largest country of the world with a geographical area of 328 million ha supporting a sizeable population of more than 1000 million. Population of the country in the year 2020 A.D. is likely to be 1500 million, for which the requirement of food grains will be double the present production. Irrigation water is the most important input for increased agricultural production. During the last 60 years, there is an increase in the production of food grains from 55 million tonnes in 1950-51 to 240 million tonnes.

Based on present assessment, ultimate irrigation potential of 140million ha, 58.5 million ha from MMI, 17.4 million ha from surface water and 64 million ha from groundwater.

Questions

1. Plant processes are activated through hydrological cycle. (True / False)

   Ans: True

2. Artificial application of water to the land for growing crops is called irrigation.

   (True / False)

   Ans: True

3. Irrigation is must when the rainfall is less than 25 cm during the crop season.

   (True / False)

   Ans: True

4. Salanization adjacent to unlined canals is one of the problems of irrigation.

   (True / False)

   Ans: True

5. Irrigation potential of 140 m. ha is to be achieved by 2020. (True / False)

   Ans: True

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Lecture No. 2

Present day water requirement for man, agriculture and horticulture. Rainfall variability – Increasing demand with unchanging supply

Introduction

The average annual rainfall of the country as presented in the previous lecture is 119.4 cm which when considered over the geographical area of 328 mha, amounts to 391.63 mham. This may be rounded up to 400 mham including contribution of snowfall, which has not yet been assessed.

When rain falls, a portion evaporates, another portion infiltrates into the soil and rest runs off over the land surface. If the shower is very light (less than 2.5mm) it moistens the upper soil and evaporates rapidly. There are 130 rainy days in a year, on 75 rainy days, after the rains, the ground water is evaporated. On the remaining 55 days of rainfall, there is similar evaporation at the commencement of rainfall. Taking all these into consideration, it is estimated that out of the average annual rainfall of 400 mham about 70 mham is lost to atmosphere. Of the remaining 330 mham about 115 mham flows as surface run off and the rest 215 mham soaks into the ground.

Surface Flow

The Irrigation Commission of India (1972) has placed the total annual surface runoff of the country at 180 mham. It includes 20 mham brought by stream and rivers from catchments lying out side the country. About 45 mham pertain to regenerated flow from ground water. The remaining 115 mham constitutes the direct contribution from precipitation of which 10 mham is from snowfall.

Of the total surface water of 180 mham available in the country annually, about 15 mahm is stored in reservoirs and tanks. Evaporation from medium and major reservoirs is about 20 per cent and from tanks 40 per cent. Of the 165 mham that flows annually in the rivers, the utilization through diversion works and direct pumping aggregates to 15 mham. The remaining 150 mham goes to the sea and to adjoining countries. On full development the use of water through diversion works or direct pumping may be up to 45 mham, the rest 105 mham will continue to flow to the sea and outside the country

Ground water Recharge

Of the annual rainfall of 400 mham, about 215 mham infiltrates into the soil. About 165 mham is retained as soil moisture. Water in excess of field capacity percolates down and adds to ground water. About 12.5 per cent of the total precipitation infiltrates into the ground water table. Thus, out of 215 mham that infiltrates, only about 50 mham percolates into water table. In course of time due to improved technology the contribution to groundwater from rivers and streams will be the order of 60 mham.

Transpiration

The amounts of transpiration from irrigated and unirrigated crops have been estimated to be 13 mham and 42 mham respectively, that from forest and other vegetation 55 mham. Thus, total transpiration from all such vegetation is 110 mham. On full development of irrigation, the transpiration is expected to be 35 mham from irrigated crops,35 mham from unirrigated crops and 55 mham from forests and other vegetations, the total being 125 mham.

It has been planned that the entire utilizable quantum of water resources would be fully developed by 2000-2050 AD and 50 per cent of cultivated area will be brought under irrigation. Though the water resources appear to be plenty, in due course of time it will be found insufficient to meet the requirements for agriculture, industry and others.

Rain fall variability

All the agricultural regions are subject to significant temporal and spatial variability. The fact that water is not evenly distributed throughout the country also places a severe constraint on local availability per capita and also on the availability of the resource on a gross basis. Seasonally also, the available water resource of India is not evenly distributed. The south west monsoon it contributes to the major precipitation in the country is well known for the vagaries. The early or late commencement of the monsoon rainfall, prolonged breaks during the month of July or August, the cessation or continuation of rainfall and the rainfall may be very unevenly distributed.

Example of rain fall (in mm) for three years showing variations

Year	Actual	Normal	Per cent departure
2007-08	1180.2	1194.8	-1.2
2008-09	1075.0	1196.4	-10.1
2009-10	972.8	1195.6	-18.6

Water requirements of India

Traditionally, India has been an agriculture based economy. Hence, development of irrigation to increase agricultural production for making the country self sustained and for poverty alleviation has been of crucial importance for the planners. Accordingly, the irrigation sector was assigned a very high priority in the five year plans. Long-term planning has to account for the growth of population. Table 2.1. provides details of the population of India and per capita water availability as well as utilizable surface water for some of the years from 1951 to 2050 (projected). The availability of water in India shows wide spatial and temporal variations.

Table 2.1. Per capita per year availability and utilizable surface water in India (in m^3)

S. No.	Year	Population (millions)	Per-capita surface water availability	Per-capita utilizable surface water
1.	1951	361	5410	1911
2.	1955	395	4944	1746
3.	1991	846	2309	816
4.	2001	1027	1902	672

5.	2025 (projected)	a. 1286 (low growth)	1519	495
		b. 1333 (high growth)	1495	
6.	2050 (projected)	a. 1346 (low growth)	1451	421
		b. 1581 (high growth)	1235	

a) Domestic use

Community water supply is the most important requirement and it is about 5 per cent of the total water use. About 7 km^3 of surface water and 18 km^3 of groundwater are being used for community water supply in urban and rural areas. Along with the increase in population, another important change from the point of view of water supply is higher rate of urbanization. According to the projections, the higher is the economic growth, the higher would be urbanization. It is expected that nearly 61 per cent of the population will be living in urban areas by the year 2050 in high-growth scenario as against 48% in low growth scenario. Based on these norms and projection of population, it is estimated that by 2050, water requirements per year for domestic use will be 90 km^3 for low demand scenario and 111 km^3 for high demand scenario. It is expected that about 70 per cent of urban water requirement and 30 per cent of rural water requirement will be met by surface water sources and the remaining from groundwater.

b) Irrigation

The irrigated area in the country was only 22.6 million hectare (Mha) in 1950–51. Since the food production was much below the requirement of the country, due attention was paid for expansion of irrigation. The ultimate irrigation potential of India has been estimated as 140 Mha. Out of this, 76 Mha would come from surface water and 64 Mha from groundwater sources. The quantum of water used for irrigation by the last century was of the order of 300 km^3 of surface water and 128 km^3 of groundwater, total 428 km^3. The estimates indicate that by the year 2025, the water requirement for irrigation would be 561 km^3 for low-demand scenario and 611 km^3 for high-demand scenario. These requirements are likely to further increase to 628 km^3 for low-demand scenario and 807 km^3 for high-demand scenario by 2050.

The net area sown during 2007-08 was 140.9 mha out of which 62.2 mha was under irrigation. This area includes 20.66 mha under horticultural crops which may be taken as being raised under irrigated condition. The area under horticultural crop is slowly expanding.

c) Hydroelectric power

The hydropower potential of India has been estimated at 84,044 MW at 60 per cent load factor. At the time of independence, the installed capacity of hydropower projects was 508 MW. By the end of 1998, the installed hydropower capacity was about 22,000 MW. India has plans to develop 60,000 MW additional hydropower by the twelfth five year plan. It includes 14,393 MW during the tenth five-year plan (2002–2007); 20,000 MW during eleventh (2007–2012) and 26,000 MW during the twelfth (2012–2017) five-year plans.

d) Industrial water requirement

The present water use in the industrial sector is of the order of 15 km^3. The water use by thermal and nuclear power plants with installed capacities of 40,000 MW and 1500 MW (1990 figures) respectively, is estimated to be about 19 km^3. In view of shortage of water, the industries are expected to switch over to water efficient technologies. If the present rate of water use continues, the water requirement for industries in 2050 would be 103 km^3; this is likely to be nearly 81 km^3 if water saving technologies is adopted on a large scale.

Total water requirements

The total annual requirement of water for various sectors has been estimated and its break up is given in Table 2.2. With the increasing population as well as all round development in the country, the utilization of water has also been increasing at a fast pace. In 1951, the actual utilization of surface water was about 20 per cent and 10 per cent in the case of groundwater. The utilizable water in river basins is highly uneven. For example in the Brahmaputra basin, which contributes 629 billion m^3 of surface water of the country's total flow, only 24 billion m^3 is utilizable.

Table 2.2. Annual water requirement for different uses (in km^3)

Use	Year 1997-1998	Year 2010			Year 2025			Year 2050		
		Low	High	%	Low	High	%	Low	High	%
Surface water										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Inland navigation		7	7	1	10	10	1	15	15	1
Environment-Ecology		5	5	1	10	10	1	20	20	2
Evaporation losses	36	42	42	6	50	50	6	76	76	6
Total	399	447	458	65	497	545	65	641	752	64
Groundwater										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic	13	19	19	2	25	26	3	42	46	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total	230	247	252	35	287	298	35	332	428	36

Grand total	629	694	710	100	784	843	100	973	1180	100
Total water use										
Irrigation	524	543	557	78	561	611	72	628	807	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inland navigation	0	7	7	1	10	10	1	15	15	1
Environment-Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation losses	36	42	42	6	50	50	6	76	76	7
Total	**629**	**694**	**710**	**100**	**784**	**843**	**100**	**973**	**1180**	**100**

Questions

1. The amount of water received over the geographical area of 328 mha through rainfall approximately amounts to 400 mham. (True / False)

   Ans:True

2. Total transpiration from all vegetation is estimated to be 125 mham. (True / False)

   Ans:True

3. The ultimate irrigation potential of India has been estimated as 140 Mha. (True / False)

   Ans:True

4. The estimates indicate that by the year 2025, the water requirement for irrigation purpose would be 561 km^3 for low-demand scenario. (True / False)

   Ans:True

5. The present water use in the industrial sector is of the order of 15 km^3(True/ False)

   Ans:True

Lecture No. 3

Role of water in plant growth – Optimum, excess and shortfall in water availability, Soil water relations – available and unavailable concept

Water plays a vital role in plant life. It is essential to plants in the following ways:-

1. Water is a structural constituent of plant cells and it maintains the cell form through turgor pressure. When plenty of water is available, cells are turgid and plants retain their structural form. Water accounts for the largest part of the body weight of an actively growing plant and it constitutes 85-90 per cent of body weight of young plants and 20 to 50 per cent of older or mature plants.
2. Water is a source of two essential elements, oxygen and hydrogen required for synthesis of carbohydrate during photosynthesis.
3. Water serves as a solvent of substances and a medium in plants allowing metabolic reactions to occur. It also acts as a solvent of plant nutrients and helps in uptake of nutrients from soils. Plants also absorb nutrients through leaves from nutrient sprays.
4. Water acts as a carrier of food materials synthesized in plants.
5. Transpiration is a vital process in plant and it occurs at a potential rate as long as water is available in adequate amount.
6. Adequate supply of water maintains the turgor pressure of guard cells helping stomata to open fully. Water deficit, on the other hand, closes stomata partially or completely reducing water loss through transpiration.
7. Water deficit slows down the growth processes.
8. Leaves get heated up with solar radiation. Plants dissipate heat by increased transpiration. Water act as a buffer against high or low temperature injury as it has high heat by vaporization and high specific heat.

9. Water, when available in plenty, encourages good growth, development and yield of plants. Conversely, plants die when water supply is curtailed down.

Plant – water relations

1. Plant-water potential

Energy status of water in plant cells is determined by three major factors *viz.*, turgor pressure (p) imbibitional pressure (m) and solute or osmotic pressure (s). Pressures arising both from gravitational forces and intercellular pressure can be included in the turgor pressure term. Total potential of water in plants can be expressed as indicated below:

$\Psi = \psi_p + \psi_m + \psi_s$

Where, ψ=total water potential

Ψ_p= turgor potential (equivalent to pressure potential in soils)

Ψ_m= imbibitional potential (equivalent to matric potential in soils) and

Ψ_s=solute or osmotic potential.

1.1. Relative Water Content

Relative water content (RWC) is the ratio of actual water content to water content at saturation (fully turgid) and is generally expressed as percentage. Actual water content is obtained by subtracting dry weight (DW) of the sample from the fresh weight (FW). Water content at saturation is the difference between saturation weight or turgid weight (TW) and dry weight.

Major areas of water-plant relationships in irrigation water management are:

- Water absorption and
- Water loss or transpiration.

1.2. Water absorption by plants

Plants absorb water from soil through roots, rain and water sprays through foliage.

Young roots offer largely the water absorbing surface in actively growing annual plants, while they offer relatively a small fraction of the total absorbing in old perennial plants and trees.

A young growing root tip consists of a root cap, a zone of maximum meristematic activity, region of rapid cell elongation and a region of quick cell differentiation and maturation.

A rapid absorption of water occurs through younger part of the root immediately basal to the meristematic region. It is usually the area where root hairs grow extensively; Root hairs are thin walled protuberances of the epidermal cells. They present relatively large absorbing surface. The xylem elements develop to conduct water up the plant system. Suberization of cell walls reduces the permeability to water. But a considerable volume of water is absorbed, though slowly, through suberized roots in older plants. The role of such roots in water absorption is very important as they comprise the largest portion of a root system in older plants and trees and offer relatively large water absorbing surface.

1.3. Water absorption processes

Water absorption by plants occurs by two processes namely active absorption and passive absorption. In active absorption plants play an active part. In passive absorption water is absorbed mechanically through roots without plants playing an active role and plants present simply the absorbing surfaces.

1.4. Factors affecting water absorption

Water absorption by plants is influenced by atmospheric, soil and plant factors.

1.5. Water conduction

Water is conducted from the root surface to leaf surface through the plant body. The difference of ψ air and ψ root surface results in the ascent of water. The transpiration from leaf surface sets up imbibitional forces in the mesophyll cells that are transmitted through the hydrodynamic systems in the plant to the root surface. Water moves in liquid form from the soil to leaf cells through root cells and the conductive system of xylem. It moves in vapour form from leaf cells to the air through intercellular spaces in the leaf and stomatal openings.

The xylem functions in water conductivity. The water conduction is based on the cohesion theory.

2. Transpiration

Transpiration is the process by which plants loss water in vapour form into the air through their aerial parts, mainly leaves. It involves nearly 99 per cent of the volume of water absorbed by young plants.

Usually about 95 per cent of the water absorbed is transpired and only about 5 per cent is used by the plant for metabolic purpose and making the body weight.

About 90 to 95 per cent of transpiration occurs during the day time and 5 to 10 percent during the night time. Pineapple which is a Crassulacean acid metabolism (CAM) plant is the exception in which most of the stomata remain open during the night time and the major transpiration takes place at night.

Transpiration rate in the morning is less. It increases with the increase in temperature during the day time and reaches the maximum at around 2 pm local time.

Transpiration is usually expressed by transpiration ratio or transpiration coefficient that refers to the volume of water transpired by a plant to produce a unit quantity of dry matter.

The factors affecting absorption also affect transpiration, besides the chemical and cultural factors.

3. Water and plant process

Plant processes starting from germination to maturity of fruits or grains is affected by the water supply. They are germination, seedling emergence, root development, shoot growth and photosynthesis.

3.1. Causes of moisture stress in plants

Water content in the plants decreases due to soil, plant and environmental factors. The main reason being the extent of transpiration which is affected by leaf size and composition, size and distribution of stomata on leaf, atmospheric humidity, temperature, wind velocity and day length.

The term moisture stress is generally applied to the stomata opening and transpiration increases with time until they close due to high temperature. Loss of water from the leaf extends to the cell walls, from cell walls to protoplasm, from it to vacuole and gradually to the roots through xylem. In turn water ascends to the site of transpiration in this path. Along the path the water has to confront resistances and the steady state of flow gets imbalanced and transpiration loss cannot be met by absorption. This leads to wilting of leaves.

High atmospheric temperature due to intense sun and increased transpiration causes closure of stomata and wilting of leaves even if soil moisture content is not limiting (ψ_m very high). This deficit is made up during night due to decreased transpiration.

In plants, moisture content decreases either due to increased transpiration or reduction in absorption or both.

On the contrary, if the atmosphere is humid and dew cover is substantial the plants may not show wilting sign even if soil moisture content is low. Roots are more sensitive to decrease in soil water potential than the leaves. Thus moisture in the plant is governed by soil moisture potential and atmospheric conditions.

3.2. Available Water

The water held by soil between field capacity and wilting point and at a tension between 0.33 and 15 atm is available to plants and is termed as available water. It comprises the greater part of capillary water. Availability of water to plants is more in the upper range of available water that is, at field capacity or near to it. It decreases sharply as the water content approaches the wilting point. It means that at field capacity the available water is 100 % whereas at PWP the available water is 0%.

3.3. Unavailable water

There are two situations at which soil water is not available to most plants.

- When the soil water content falls below the permanent wilting point and is held at a tension of 15 atmosphere and above.
- When the soil water is above the field capacity and is held at a tension between 0 and 1/3 atmosphere.

Water in the former situation is held tenaciously by soil, while that in the latter situation moves downward under gravity. Water under both the situations, is termed as unavailable water.

3.4. Soil water deficit and plant stress condition

All pants experience some amount of water stress during the growth period. The plant water stress may be severe when the soil water potential is low and environment or plant factors interfere severely with the absorption of water.

3.4.1. Classification of water stress based on RWC and plant water potential.

A drop of relative water content (RWC) of a plant by 8 to 10 percent is termed as mild stress, 10 to 20 per cent as moderate stress and > 20 per cent as severe stress compared to normal condition. This corresponds to a drop of plant water potential by – 5 to -6 bars,-12 to -15 bars and >-15 bars respectively for the mild, moderate and severe stress conditions.

3.4.2. Classification based on period of plant water stress

The stress occurring during 24 hour period of day and night is referred to as diurnal stress. It increases with a rise of temperature during the day time, reaches its peak at around 2 PM local time and drops gradually attaining its lowest level early in the morning. It is directly related to the rate of transpiration that follows the diurnal temperature curve.

The lag between absorption and transpiration is minimum at early morning and maximum at 2.0 p.m. This is very often exhibited by plants showing signs of wilting during the hottest part of the day and recovering during the night and this condition of plant is known as temporary wilting and is also known as incipient wilting and mid-day depression.

The stress that occurs gradually and increases progressively with advance of time after irrigation till the next irrigation is referred to as critical water stress. The stress increases to maximum just before the irrigation and it disappears following irrigation.

4. Effect of moisture stress on crop growth

Water stress affects particularly every aspect of plant growth: modifying anatomy, morphology, physiology and biochemistry. Some of the adverse effects of deficit soil moisture stress on plant growth, development and yield are:

- Loss of turgidity leading to cell enlargement and stunted growth
- Decrease in photosynthesis due to decreased diffusion of CO_2 with the closure of stomata to conserve water and reduced leaf area.
- Increase in respiration resulting in decreased assimilation of photosynthates
- Break down of RNA, DNA and proteins
- Inhibition of synthesis and translocation of growth regulators
- Hydrolysis of carbohydrates and proteins leading to increase in soluble sugars and nitrogen compounds
- Affects germination, cell expansion, cell division, growth of leaves, stems ,fruits and root development. The duration of crop in general is increased when the stress occurs before flowering and decreased when occurs after flowering.
- The degree and duration of moisture stress at these stages finally dictates the economic yield. The dry matter, number of fruits and individual grain weight are affected.
- Delaying the first irrigation for some days after germination in order to impose some amount of water stress encourages deeper penetration of roots that enables the crops to explore water from deeper layers of soil and withstand drought conditions better.

5. Effects of Excess soil moisture stress

- Excess water also causes stress on plants by poor soil aeration, inhibiting normal aerobic respiration and microorganisms activity. High water table curtail root penetration and inhibit crop growth and production. It also causes accumulation of soluble salts in the root zone.

Questions

1. Water is a source of hydrogen and oxygen, two essential elements required for synthesis of carbohydrate during photosynthesis. (True / False)

   Ans: True

2. Relative water content (RWC) is the ratio of actual water content to water content at saturation (fully turgid) and is generally expressed as percentage (True/False).

   Ans: True

3. The volume of water absorbed by a plant depends largely on the growth of root system. (True / False)

   Ans: True

4. Transpiration is the process by which plants lose water in vapour form into the air through their aerial parts, mainly leaves. (True / False)

   Ans: True

5. A drop in RWC by 10 to 20 per cent compared to normal condition indicates a moderate stress in plants. (True / False)

   Ans: True

Lecture No. 4

Soil type, depth and water holding capacity - Rooting characteristics and moisture extraction patterns

When dry soil is crushed in the hand, it can be seen that it is composed of all kinds of particles of different sizes.

Most of these particles originate from the degradation of rocks; they are called mineral particles. Some originate from residues of plants or animals. These are called organic particles or organic matter. The soil particles seem to touch each other, but in reality have spaces in between. These spaces are called pores.

When the soil is "dry" the pores are mainly filled with air. After irrigation or rainfall, the pores are mainly filled with water. Living material is found in the soil. It can be live roots as well as beetles, worms, larvae etc. They help to aerate the soil and thus create favourable growing conditions for the plant roots.

Soil Profile

If a pit is dug in the soil, at least 1 m deep, various layers, different in colour and composition can be seen. These layers are called horizons. This succession of horizons is called the profile of the soil.

A very general and simplified soil profile can be described as follows:

a. The plough layer (20 to 30 cm thick): Rich in organic matter and contains many live roots. This layer is subject to land preparation and often has a dark colour of brown to black.
b. The deep plough layer: Contains much less organic matter and live roots. This layer is hardly affected by normal land preparation activities. The colour is lighter, often grey, and sometimes mottled with yellowish or reddish spots.
c. The subsoil layer: Hardly any organic matter or live roots are found. This layer is not very important for plant growth as only a few roots will reach it.
d. The parent rock layer: Consists of rock, from the degradation of which the soil was formed. This rock is sometimes called parent material.

The depth of the different layers varies widely: some layers may be missing altogether.

Physical properties of soils

1**. Colour:** Colour is one of the most useful and important characteristics for soil identification. Concentration of organic matter imparts a grey, black or dark-brown colour to the soil. Diffusion of iron oxides imparts red and yellow colour to the soil. Manganese dioxide and hydrated iron oxides may also contribute red colour. A light grey colour may indicate a very low content of organic matter and iron. Soil colour changes with moisture content.

2. **Texture:** The size of particles comprising the soil determines its texture. The texture of a soil is perhaps its most nearly permanent characteristic. The texture commonly refers to the fineness or coarseness of soil as a whole as to the proportion of the particle groups of different sizes.

The mineral particles of the soil differ widely in size and can be classified as follows:

Name of the particles	**Size limits in mm**	**Distinguishable by naked eye**
Gravel	Larger than 1	Obviously
Sand	1 to 0.5	Easily
Silt	0.5 to 0.002	Barely
Clay	Less than 0.002	Invissible

The supply of water to plants is relatively more in soils of moderately fine texture than in those of coarse texture. The amount of water available to plants increases with the capacity of the soil to hold water in available form. The textural class and available water are presented in the table 1.

Table 1.Textural class and available water (cm/m)

Textural class	**Available water**
Sand	1.5
Loamy sand	7.4
Sandy loam	12.1

Loam	19.1
Silt loam	23.4
Silt	25.6
Sandy clay loam	20.9
Silty clay loam	20.4
Sandy clay	8.5
Silty clay	18
clay	15.6

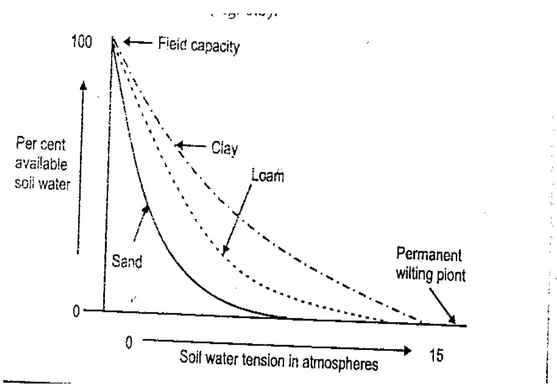
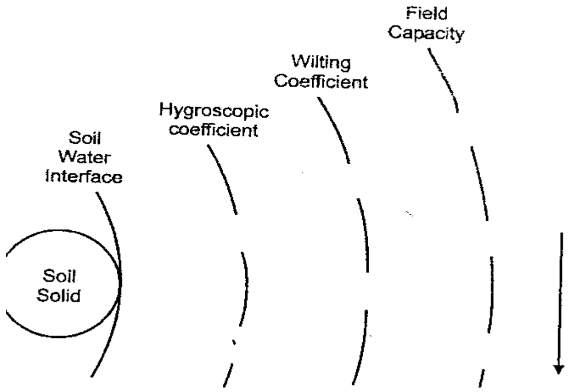


Fig. Soil type and moisture retention curves

3. Structure: The capability of any soil for growth of plants and its response to management depends as much on its structure as on its fertility. The common types of soil structure are granular, prismatic, columnar, platy and laminar. Fine grained soils have granular structure and are desirable for irrigation as large voids provide space for circulation of air. From the standpoint of agriculture, permeability of soil to water, air and roots provided by favourable soil structure is important.

4. pH value: pH value or hydrogen ion concentration is a measure of the intensity of acidity or alkalinity of a soil. Its value ranges from 0 to 14, of which 7 is neutral in the sense of chemical reaction. Below 7 the soil is acidic, above 7 it is alkaline.

5. Soil organic matter: It has role on the physical properties of the soil. It improves infiltration rate and water holding capacity.



1000 atms 31 atms 15 atms 1/3 atms Flow with gravity

Fig Physical relations of Soil -water

Requirements of an ideal irrigated soil

1. Sufficient depth of soil for the storage of irrigation water and penetration of roots is essential.
2. Provide proper air circulation to a suitable depth for the development of root system
3. Suitable for providing anchor for plant roots, more infiltration rate, resistant to soil erosion or soil depletion under the cropping system of plants.
4. Suitable for the use of agricultural implements.
5. Free from harmful concentration of soluble salts and Pathogens and promote beneficial organism
6. It should be fertile soil to supply nutrients for crop yield.
7. pH of the soil should be in the neutral range. Most irrigated soils have pH values ranging between 6.0 and 8.5. Soil productivity increases as pH approaches neutrality.

Plant characteristics

To design a successful irrigation system, it is essential to know the plant rooting characteristics, moisture extraction pattern and moisture sensitive stages.

Root characteristics

Root systems in the field are seldom uniform with depth. Root penetration is seriously affected by a hard pan or compacted layer in the soil profile. In a shallow soil, roots may be confined to a thin layer of soil irrespective of their usual pattern. Similarly, high water table limits normal root growth. Crops with extensive and dense roots can utilize soil moisture more effectively and lower residual soil moisture than crops with sparse and shallow roots.

Rooting depth of annual field crops on deep well drained soils range from 0.30 to 2.0 m. In general, the root zone depth of crops on clayey soils is reduced by 2.5 to 35 per cent and on sandy soils increased by 2.5 to 35 per cent.

Table2. Rooting depths (m) of annual crops on deep well drained soils.

Shallow		Medium		Deep	
Onion	0.3 - 0.5	Chillies	0.6 – 0.9	Maize	1.0 – 1.6
Cabbage	0.4 - 0.5	Peas	0.6 – 1.0	Soybean	1.0 – 1.5
Cauliflower	0.3 - 0.5	Tomato	0.7 – 1.5		
Potatoes	0.4 – 0.6				

The soil depth from which the crop extracts most of the water needed to meet its evapo-transpiration requirements is known as effective root zone depth (table 2.). It is also called as design moisture extraction depth, the soil depth used to determine irrigation water requirements for design. It is the soil depth in which optimum available soil moisture level must be maintained for high productivity of crops. If two or more crops with different rooting characteristics are to be grown together, the design depth should be that of the crop having the shallower root system.

Moisture extraction pattern

For most plants, concentration of absorbing roots is greatest in upper part of the root zone and near the base of plants. Extraction of water is most rapid in the zone of greatest root concentration and under favorable environmental conditions

Usual moisture extraction pattern show that about 40 per cent of the extracted moisture comes from upper quarter of the root zone, 30 per cent from second quarter, 20 per cent from third quarter and 10 per cent from fourth bottom quarter. This general pattern of extraction slightly varies with irrigation frequency. With higher the frequency of irrigation, the moisture extraction is greater from first quarter of the root zone than the others. Low frequency irrigation leading to depleting soil moisture results in more moisture extraction from lower quarter of the root zone soil depth.

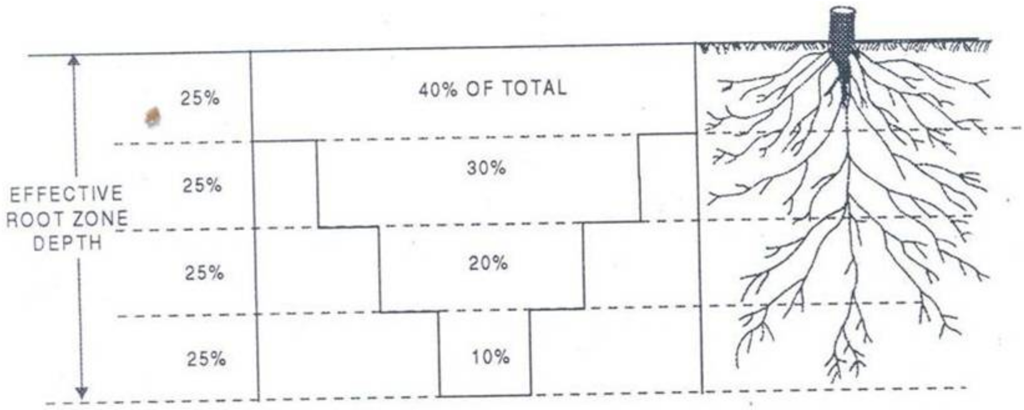


Fig. Moisture extraction pattern

Soils of India

Soils of India have been formed over different geological periods from parent rocks of varied origin. They are derived from a wide variety of minerals.

Alluvial Soils

They are the transported soils carried away and deposited by the tributaries of Ganges and Brahmaputra system of rivers. These soils vary in character according to the nature of soils that occur in the region of their transportation. Generally they are deep soils. The Indo-Gangetic alluvium is the most productive soil and the largest of all soil groups in India and occupies thickly populated areas of the country.

Black Soils

These are clay soils varying from clay to loam with clay content 40 to 50 per cent. Their thickness varies from 1 to 4 m or more. These soils vary in colour from dark grey, black or blue black. Black soils are fine grained containing high water holding capacity but suffer from poor drainage and consequent on drying. Thus swelling and shrinkage with increase or decrease in moisture content is characteristic of black soils. Black soils are distinguished into shallow (30 cm or less) medium (30-100 cm) and deep (over 100 cm).

Red Soils

These are red in colour due to the presence of iron oxide. The colour varies from red to black with intermediate shade of dark brown. Red soils are mostly sandy loam or sandy clay in texture. They are deficient in nitrogen, phosphorous, lime and organic matter. They are responsive to farming practices manures, fertilizers and irrigation.

Laterite Soils

These are formed as a result of decay of many types of rocks. They are red in colour. They are deficient in nitrogen, phosphorus, potassium and lime. These soils are developed on the summits of hills of Karnataka, Kerala, Madhya Pradesh, Orissa and Assam.

The principal crops are barley, great millets, coffee, tea, potato, fruits, etc. They are poor in production.

Forest and Hill Soils

The soils, typical of forests and mountains, occur along the slopes or in depressions and valleys in forested areas. They are very shallow, steep and stony. They show high content of organic matter and nitrogen and are developed in Himachal Pradesh, Punjab and Tamil Nadu.

These soils are deposited as a result of their movement through water erosion of the Himalayan ranges. They lie at the foot of the Himalayan range. They are deep and moderately fertile soils but become highly productive with the provision of drainage.

Desert Soils

These are sandy soils occurring in low rainfall areas of Gujarat, Rajasthan and parts of Punjab. They are abundant in soluble salts but low in organic matter. They are productive when irrigated.

Saline and Alkaline Soils

Saline soils contain toxic concentration of salts in root zone. Electrical conductivity is taken as a measure of salts. If the solution extracted from the saturated paste of a soil has an electrical conductivity of more than 4 mmhos/cm (dSm^{-1}) the soil is termed as saline. High salt content in soil result in reduction in yield. In alkali soils exchangeable sodium constitutes more than 15 per cent of total exchangeable cations. pH value of these soils is usually more than 8.5.

Questions

1. In coarse textured soils sand particle is predominant, whereas in fine textured soils clay particle is predominant. (True / False)

   Ans:True
2. The available soil water increases with the decrease in the size of soil particles (True / False)

   Ans:True
3. Presence of organic matter improves the infiltration and water holding capacity of the soil. (True / False)

   Ans:True
4. The soil depth from which the crop extracts most of the water needed to meet its evapo-transpiration requirements is known as effective root zone depth. (True / False)

   Ans:True
5. Shallow soils require frequent irrigation for optimum growth of crops (True / false)

   Ans:True

Lecture No. 5

Water requirement of crops. Lysimetry in assessing water requirement. Annual, biennial and perennial crops. PET and AET applications in water and irrigation requirements

The estimation of the water requirement (WR) of crops is one of the basic needs for crop planning on a farm and for the planning of any irrigation project.

Water is mainly needed to meet the demands of evapotranspiration (ET) and the metabolic activities of plant, both together known as consumptive use (C or U). Since the water used in the metabolic activities of the plant are negligible, ET is practically considered equal to Cu.

Water requirement defined

Water requirement may be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place.

Water requirement, includes the losses due to ET (or CU) plus the losses during the application of irrigation water and the quantity of water required for special operations such as land preparation. It may be formulated as follows:

WR= ET or CU + application losses + special needs.

Based on the sources of water supply to meet the water requirement, numerically it is represented as, WR=IR+ER+S *i. e.,* Irrigation water (IR), effective rainfall (ER) and soil profile contribution (S).

Classification of consumptive use of water

Daily consumptive use: The amount of water consumptively used during 24 hour period is called the daily consumptive use.

Peak period consumptive use: The average daily consumptive use during a few days (usually 6 to 10 days) of the highest consumptive use in a season is called the peak period consumptive use.

Seasonal consumptive use: The amount of water consumptively used by a crop during the entire growing season or crop period is called the seasonal consumptive use.

Classification of ET

Potential evapo-transpiration (PET): The term denotes the highest rate of evapo-transpiration (ET) by a short and actively growing crop or vegetation with abundant foliage completely shading the ground surface and abundant soil water supply under a given climate. It integrates the evaporating demand of the atmosphere and refers to the maximum water loss from the crop field.

Reference crop evapo-transpiration (ETo): The term is used to express the rate of evapo-transpiration from an extended surface of 8-15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water. The ET is corrected for day and night weather conditions to ETo (adjusted reference crop ET) by multiplying with the adjustment factor.

Actual crop evapo-transpiration (ET crop): Refers to the rate of evapotranspiration by a particular crop in a given period under prevailing soil, water and atmospheric conditions. It involves the use of a crop factor called, crop co-efficient while computing it from reference crop ET (ET_o) estimated by different empirical formulae or evaporation rates from evaporimeters. The ET crop varies under different soil, water and atmospheric conditions and at different stages of crop growth, geographical location and season of the year.

Factors affecting ET

Climatic factors: Radiation, precipitation, relative humidity, temperature and wind.

Soil factors

Soil factors such as texture, hydraulic conductivity, water holding capacity, crop residues on the soil surface, colour and rough surface of the soil affects the ET.

Plant factors

Plant morphology, crop, variety, crop geometry, extent of plant cover, stomatal density, duration of the crop, rooting characteristics, growth phase, crop growing season, etc.

Cultural practices

Weed control is necessary to reduce the water loss through transpiration by weeds. Fertilizer application increases the ET and CU by producing greater biomass and developing a deeper and extensive root system. However, the CU does not vary widely between well-fertilized and under - fertilized crops.

Mulching reduces the ET by reducing the evaporation from the bare soil, reflecting the solar radiation and reducing the weed infestation. Mulching has a greater effect in reducing the ET when the crop cover is relatively small.

Methods of estimating evapo-transpiration

Various methods are employed to estimate the crop ET or CU. The methods may be grouped into (i) direct methods, (ii) empirical methods and (iii) pan evaporimeter method

I. Direct Methods

Direct methods are the water balance or hydrologic methods and include (1) lysimeter, (2) field experimentation, (3) soil water depletion, and (4) inflow-outflow methods. They give reliable values, but require elaborate installations and precise measurements. They are however costly, laborious and time consuming.

1. Lysimeter method

The lysimeter method is very important in measurement of not only the ET but also the various components of water balance. A lysimeter is a device by which an experimental soil located in a container is provided with hydrologic separation from the surrounding soil. The method involves growing crops in lysimeters installed in crop fields to provide the crop environment and measuring the water balance during the crop growing period. Measurements of different components for water balance studies such as water added to lysimeters through precipitation and irrigations, change in soil water storage, and water lost through evaporation, transpiration, run-off and deep percolation are made. This can be expressed as,

$$ET = P + IR_n + \Delta SW - (R + PW)$$

Where,

P=precipitation, cm

IR_n = net irrigation requirement of crop, cm

ΔSW = soil water contribution (the difference between soil water contents at sowing and at harvest of crop in cm)

R = surface runoff, cm

PW = deep percolation, cm

or

$$CU \text{ or } ET = ER + IR_n + \Delta SW$$

Where,

ER = effective precipitation, cm

ER = P- (R+PW) = effective rainfall, cm

Increase with the development of canopy, the evaporation from the adjacent soil surface gradually decreases, while the transpiration and the resultant ET increase. Crop density influences the ET in the same way as the crop cover influences the ET. The plant population and other crop management practices that affect the net radiation at the soil surface, change the ET unless the soil surface and plants get constant water supply. With lower plant population, the ET is low. Plant height increases ET by greater interception of advective heat.

Root spread governs the ET to the extent roots encounter water in the soil profile, when the soil water is limiting in upper part of the soil. This is quite important particularly in arid and semi-arid areas where deep-rooted crops have higher ET than shallow rooted ones.

Lysimeters are installed in fields with a fairly large guarded area having the same crop as in the lysimeter. The guarded areas are irrigated whenever the lysimeter crop is irrigated. The soil is placed in the lysimeters as close to *in-situ* condition as possible.

Both the weighing and nonweighing type lysimeters are used for measurement of ET. When very short period (daily or hourly) estimates are wanted, the weighing type lysimeter is installed. In weighing type lysimeters, the container is placed inside a tank containing some suitable liquids (water or $ZnCl_2$ solution) so that the lysimeter container remains floating to ease the weighing. An overhead portable balance may be used for weighing. The changes in the buoyancy or in the hydraulic load are calibrated to estimate the loss in weight of the lysimeter owing to evapotranspiration. The loss in weight gives the measure of the evapotranspiration. A deduction is made for any loss due to deep percolation.

Estimates of consumptive use by nonweighing type lysimeters are made following the soil water depletion method as discussed later in this chapter. Soil water measurements may be made by neutron scattering meter or gravimetric method. The former is preferred. Determination of soil water content by gravimetric method requires replicated soil sampling. The change in soil water content is worked out by using equation.

2. Field experimentation method

Field experiments with treatments having varying levels of irrigation are carried out to estimate the seasonal consumptive use of irrigated crops. The water table should be at a considerable depth (at least 3 metres deep for field crops). Measurements of water supplied to the crop through effective rainfall and irrigation and changes in the soil water reserve during the growing season are made. The water thus supplied to the crop under treatments of varying levels of irrigation is correlated with the yields obtained. The quantity of water used to produce the yield that appears most profitable is taken as the CU.

3. Soil water depletion method

Consumptive use of crops may be determined by soil water depletion studies on a fairly uniform soil. Water table should be deep enough (at least 3 m deep) so that it does not influence the soil water fluctuations in the root zone. Soil water content in different layers of the root zone are measured just before and after irrigation or rainfall (immediately, as early as soil sampling is possible after irrigation) and during the period between two successive irrigations as frequently as possible depending on the degree of accuracy desired. Frequent soil water measurements give more accurate information. The soil water depletion during any short period is considered as the consumptive use (CU) and is obtained by summing up soil water depletion or losses of soil water during the different periods of measurements in the growing season.

4. Inflow-outflow methods

The inflow – out flow method is applied for estimating the yearly CU over large area. It is also called water balance method. It may be formulated as follows.

$$CU= P+I= GW - R$$

Where,

CU = Yearly consumptive use over a large area, hectare metres

P= Yearly precipitation, hectare meters

GW= Change in ground water storage, hectare metres

R=Yearly outflow from the area, hectare metres

The change in soil water storage in the profile is not included as it is considered negligible. It is assumed that the subsurface inflow into the area is the same as the subsurface outflow.

Estimation of water requirement for horticultural crops

Annuals and biennials

The vegetable crops are mostly annuals and their duration extends from two to five months or a single season. Some may be biennial and the season may get extended. The vegetable crops are sensitive to water stress. The water requirement is normally expressed for the entire period of the crop in the field. The crop water requirements are worked out for this period. The requirement could be estimated by all the methods.

Perennial

Fruit crops are mostly perennials. When an orchard is first established, transpiration is very low because of the small crop canopy. Most water lost from the soil is by evapotranspiration from among the trees. With the increase in years the trees grow and a large canopy is established. The water is expressed for one year or daily basis. The water requirement of perennial crop through lysimeter is not a practical proposition. Hence other methods may be used to assess the water requirements.

Questions

1. Water is mainly needed to meet the demands of evapotranspiration and the metabolic activities of plant, both together known as CU. (True / False)

   Ans: True

2. The factors which affect the ET of the crop are atmosphere, plant and soil. (True / False)

   Ans: True

3. Actual evapotranspiration refers to the rate of evapotranspiration by a particular crop in a given period under prevailing soil water and atmospheric conditions.(True/False)

   Ans: True

4. Lysimeter is a device by which an experimental soil located in a container is provided with hydrologic separation from the surrounding soil. (True / False)

   Ans: True

5. The weighing type lysimeter is installed, when very short period (daily or hourly) estimates are wanted. (True / False)

   Ans: True

Lecture No.6

Climatological approach for estimating water requirement. Use of pan evaporimeter, Pan Factor, Crop factor. Factor for different growth stages

It is necessary to conduct field experiments for precise data on crop water requirements. In view of the difficulties associated with direct measurement of crop water requirements, some methodologies have been developed to predict the water requirements, primarily, based on climatological factors. The FAO group of scientists screened 31 empirical formulae for predicting the ET and recommended four for use under different climatic conditions.

1. Blaney – Criddle method
2. Radiation method
3. Modified Penman method
4. Pan evaporation method

Three major steps involved in the estimation of ET are

- Estimation of PET or reference evapotranspiration (ET_o)
- Determination of crop coefficient (k_c)
- Making adjustments to location specific crop environment

The choice of prediction method for the determination of ET_o is primarily determined by the available climatic data.

1. Blaney-Criddle method

The original Blaney-Criddle prediction method for determining ET_o was modified to improve the accuracy.

$$ET_0=C\ [P\ (0.46T+8]$$

Where,

ET_o = reference evapotranspiration (mm day^{-1}) for the month considered

C = adjustment factor depending on RH_{min}, daytime wind velocity and ratio of actual sunshine hours to maximum possible sunshine hours.

T=mean daily temperature (^{o}C) for the month under consideration

P=mean daily percentage of total annual daytime hrs.

The ETo may be computed with any one of the empirical formulae proposed by Blaney – Criddle, modified Penman, radiation and pan evaporation methods using mean climatic data for the period desired. To find out the crop ET (ET crop) the ETo values calibrated by the relationship called crop coefficient (Kc).

2. Radiation method

The crop evapotranspiration is estimated by the formula

$ET_{o} = C\ (W.Rs)$

Where,

C=the adjustment factor made graphically on W.Rs using estimated values of RH mean and day time wind velocity

W = the temperature and altitude dependent weightage factor

Rs = the solar radiation in equivalent evaporation (mm/day)

Rs can be measured directly by solar monitor with pyranometer sensor. It can also be obtained from measured sunshine duration records as

Rs = (0.25+0.50 n/n) RA

Where,

R_A= the extra terrestrial radiation in equivalent evaporation in mm/day

n = actual measured bright sunshine hours

N= maximum possible sunshine hours

3. Penman formula

Penman (1948) suggested a formula using the important climatic parameters such as solar radiation, temperature, vapour pressure and wind velocity to compute the evaporation from open free water surface. Estimates of crop ET are obtained by multiplying the estimated values of evaporation by crop coefficient. Doorenbos and pruit (1975) proposed a modified penman method for estimating fairly accurately the reference crop ET and gave tables to facilitate the necessary equation. The penman method is quite satisfactory for both humid and arid regions under calm weather conditions. It has the advantage over other two methods as it uses many climatological parameters for the estimate off crop ET. Drawbacks are that the method requires many climatological parameters that may not be available in many meteorological stations and the computation procedure is cumbersome.

4. Pan Evaporimeters

Seasonal consumptive use of crop (CU) is determined by using (USWB) Class-A Pan Evaporimeter, sunken Screen Pan Evaporimeter or Piche Atmometer. The USWB class-A pan evaporimeter is however most widely used.

4.1. USWB Class-A pan evaporimeter

The standard USWB Class-A pan evaporimeter is the most widely used evaporimetr in the world for finding evaporation from the free water surface. It consists of a 121.5 cm diameter and 25.4 cm deep pan made of 20 gauge galvanized iron sheet with a stilling well. A vertical pointer is provided in the stilling well to show the level of water maintained in the pan. The pan is painted white and is placed on a wooden frame so that air may circulate beneath the pan.

Daily evaporation rate is given by the fall of water level in the stilling well during 24-hour period. Measurements of the fall of water level may be made at closer intervals to know the evaporation rate during different parts of a day. Water levels in the stilling well are measured by hook gauge. Adjustments are made to the evaporation values if rain occurs during a period of measurement.

The rainfall is measured by standard rain gauge. Evaporation loss may also be computed from the measured quantity of water added to bring the water level to the tip of the pointer in the stilling well. The amount of water added is divided by the surface areas of pan and stilling well together to find out the depth of water added which is taken as the daily evaporation rate. After measuring the fall in water level each time, water is added to the pan to bring back the water level to the original position of pointer tip level.

As the rate of evaporation from pan evaporimeter is higher than that over a large free water surface, the pan evaporation value is multiplied by 0.7 to obtain the evaporation rate over the large free water surface (E_o). The relationship between actual evaporation and pan evaporation rates may be presented as,

$$E_o = K_p \,.\, E_{pan} \quad \text{or,} \qquad K_p = E_o / E_{pan}$$

Where,

K_p = Pan evaporation coefficient (a commonly used value of 0.7)

E_{pan} = Evaporation value from pan evaporimeter

4.2. Sunken screen pan evaporimeter

Sharma and Dastane (1968) developed the sunken screen pan evaporimeter that provides evaporation values more close to crop ET values than the USWB Class-A pan evaporimeter. The crop coefficient values in a sunken screen pan evaporimeter was found to be 0.95 to 1.05 in New Delhi, while that in a USWB Class-A pan evaporimeter varied from 0.5 to 1.3 for different crops in different locations. However, this device requires extensive evaluation under varying climatic and crop conditions.

The evaporimeter consists of a 60 cm diameter and 45 cm deep pan made of 20 gauge galvanized iron sheet and stilling well of 15 cm diameter and 45 cm depth attached to the pan with a tube. The pan and the well are painted white and screened at the top with 6/20-mesh wire net. The stilling well has a pointer inside at the centre. The pan with the well is buried in the soil with 10 cm edge over the soil surface. The fall of water level in the well during 24-hour period is taken as the measure of the evaporation rate per day. Further, evaporation rate may be computed from the measured quantity of water added daily to bring the water level to the pointer tip level after each measurement. Tip of the pointer should be at level with the soil surface while installing the evaporimeter. The pan is located in the field with no obstruction to wind movement over the pan.

4.3. Piche atmometer

Piche atmometer is sometimes used to measure the evaporation rate. It consists of a graduated tube 1.5 cm in diameter and 30 cm long with one end open and a flat horizontal disc of drier paper placed to the open end. The tube is filled with water and then the drier paper placed to the open end. The tune is filled with water and then the drier paper is placed in position and held to the tube by a metallic device. Atmometer is laid in an inverted position for evaporation measurement in the field. Water from the tube wets the paper slowly and evaporates from the paper. The loss of water is read on the graduated tube that gives the measure of evaporation.

The rate of evaporation from atmometer is usually higher than that obtained from USWB Class-A pan evaporimeter and is poorly correlated with the crop ET. It tends to overestimate the wind effect and grossly underestimate the radiation effect. The evaporating surface of the unit is often subjected to contamination by dust, oil and other foreign materials interfering with the evaporation process.

Kc values of crops

Crop coefficient is the ratio between crop ET and potential ET. Crop coefficient depends on soil cover, soil moisture and crop height. At early stage crop covers only a fraction of soil and covers as it matures. The rate at which plants grow and cover the soil depends on the crop. In the early stage main component of ET is evaporation, while under fully covered condition transpiration is the main component. ET of a crop depends on plant height and leaf area index. Tall plants with high LAI transpire more water than short plants with low LAI. The relationship between ETo and ETc is expressed as

$$ETc = ETo \times Kc$$

ETc is also known as maximum evapotranspiration ET (max). Kc value is inbuilt with crop and soil characteristics and management practices and varies with in the crop duration. For a precise estimate duration of (annual) crop is divided into four stages: (i) seedling stage which represents germination and early growth when the soil surface is hardly covered by the crop.The ground cover is less than 10 per cent (ii) active vegetation stage form the end of initial stage to attainment of effective full ground cover which is less than 80 percent coverage,(iii)reproductive stage from attainment of full ground cover to first sign of maturity as indicated by discolouration of leaves ,leaf falling etc.,and (iv)maturity stage from reproductive stage to full maturity.

Crop coefficients vary with relative humidity and wind velocity. Strong winds and low RH cause more transpiration. In brief Kc values vary with crop development stage of the crop and to some extent with wind speed and RH. For most of the crops, Kc value increases from a low value at the time of emergence to a maximum value during the period when the crop reaches flowering and declines as the crop approaches maturity.

Crop coefficients for different growth stages

Crop coefficient (Kc) value varies with the development stage of the crop. For most crops the value for total growing period is between 0.85 and 0.9 with the exception of higher value for banana, coffee and cocoa and lower value for citrus, grape, sisal and pineapple.

In general, Kc is higher in hot, windy and dry climates than in cool, calm and humid climates. The values vary among crops due differences in reflectivity, crop height and roughness, degree of ground cover and canopy resistance to transpiration. In the case of annual crops , kc typically increase from a low value at seedling emergence to a maximum when the crop reaches full ground cover, continues at that value during the stage of full activity and declines as the crop matures.

For further reading the students may refer

Doorenbos J and Pruit WO1977.Crop water requirements. Irrigation and drainage paper 24. FAO,Rome, Italy.

Doorebos J and Kassam AH 1979.Yield responses to water. Irrigation and drainage paper 33. FAO,Rome, Italy.

Questions

1. The climatic factors influencing the evapotranspiration are Temperature, humidity and ----------------------------------

2. Three major steps involved in the estimation of ----------------------are reference evapotranspiration (ET_o), crop coefficients (k_c) and adjustments to location specific crop environment
3. More meteorological parameters used in the ----------------------------- for estimating water requirement of crops
4. The standard USWB Class-A pan evaporimeter is the most widely used in the world for finding evaporation from the --------------------------.
5. Sharma and Dastane (1968) developed the -------------------------------- that provides evaporation values more close to crop ET values than the USWB Class-A pan evaporimeter.

Lecture No.7

Critical stages of crop growth – Water stress sensitivity stages, methods to overcome

Water molecules are integral part of living systems being the solvent for metabolites and structural component of proteins and nucleic acids. Transpiration lowers water potential at evaporative sites within leaves, and this effect is immediately translated to root system through creating tension in plants vascular system. This demand of water must be satisfied continuously to maintain leaf water potential. The internal water balance of plants depends on relative rates of water absorption and water loss. Despite stomatal resistance, the steep gradient in vapour pressure from leaf to air favours transpiration rate well in excess of CO_2 fixation. Transpiration rate normally ranges from 500 to 2500 mg H_2O/dm^2-h, whereas CO_2 fixation rates range generally 5 to 25 mg CO_2/dm^2-h. This physiological phenomenon amply justifies high water requirement to maintain high dry matter productivity. For this reason, actively growing plants as the case of all the vegetable crops need to maintain liquid phase continuity from soil water through its vascular system and all the way to evaporative sites in leaves. Vegetables contain large amount of water and the product qualities like tenderness, succulence, crispness and flavor are very much related to water supply at proper stages. In fact, texture of vegetables is determined by combination of tissue structure, cell wall properties and turgor pressure.

The phenology of the growing plant can be characterized by vegetative, flowering, fruiting and other distinctive characteristics in vegetative stage like, curding in cauliflower, heading in cabbage and lettuce, bulbing in onion and garlic and tuberization in potato and sweet potato. During vegetative stage, consumptive use continues to increase till the end of this stage of growth and flowering occurs near and during the peak of consumptive use. The fruiting stage is accompanied by a decrease in consumptive use until the transpiration ceases during the later part of development of seeds inside the fruit.

Stomata are the compulsory passage way for CO_2 and H_2O gas exchange between plant and atmosphere. Therefore, to fix carbon, the plant losses water to the atmosphere, the ratio being variable depending on species and growing conditions. This ratio is called water use efficiency i.e. quantity water transpired/ unit of carbon fixed in drymatter. Water use efficiency increases as amount of water required /unit of dry matter production decreases. Transpiration ratio is used express water use efficiency. Transpiration ratio refers to the quantity of water transpired by plant to accumulate 1 g of dry matter. This ratio ranges from 200 to 1000 (200:1 to 1000:1) depending on crop species, cultivation conditions and vegetation period. Vegetable crops can be categorized in to four groups according to such index of water exchange. Leaf vegetables require more water to produce 1 g dry matter than pumpkin. Vegetable crops showing high transpiration ratio can not endure water stress, and any shortage of water during the period of growth severely affects yield. On the other hand, vegetable crops characterized by very low transpiration ratio can somewhat endure water stress condition and can give satisfactory yield even in moisture deficit condition.

Critical stages of crop growth

Optimal soil moisture for plant growth varies with the stage of crop growth. Certain periods during the crop growth and development are most sensitive to soil moisture stress compared with other. These periods are known as moisture sensitive periods. The term critical period is commonly used to define the stage of growth when plants are most sensitive to shortage of water. Inadequate water supply during moisture sensitive periods will irrevocably reduce the yield and provision of adequate water and other management practices at other growth stages will not help in recovering the yield lost.

In case of vegetables, when they are young, though transpire less water, need a stress free moisture condition because of the very weak root system which is sparsely distributed and located in upper 15 to 20 cm layer of soil that gets quickly dried. Vegetable crops utilize and transpire more water in the later stages of growth during which moisture stress markedly reduces yield.

Critical soil moisture periods of crops

Crop	Available soil moisture (%)	Critical soil moisture stage of crops
Chillies	50	Tenth leaf to Flowering and fruit development and after periodical harvests
Potato	65	Stolon formation, Tuberization and tuber enlargement
Onion	60	Bulb formation and bulb enlargement
Tomato	60	Flowering and fruit development and each harvest
Peas	40	Flowering and pod development
Cabbage	60	Head formation and enlargement
Cauliflower	70	Curd formation and enlargement
Brinjal	50	Flowering and fruit development and after each harvest
Cucumber	50	Flowering and fruit development
Bhendi	45	Flowering and pod development
Leaf vegetables	70	Entire crop duration
Fruit crops	For fruit crops 50% Available soil moisture is taken as critical limit	
Citrus		Flowering, fruit setting, fruit growth
Banana		Early vegetative period flowering and fruit formation
Mango		Start of fruiting to maurity

Pine apple		Vegetative growth
Grape		Vegetative growth. Frequent irrigation during vegetative stage may cause rotting of friuts
Guava		Period of fruit growth
Ber		A drought resistant plant ; irrigation is required during fruit growth

All the stages of growth is equally sensitive to soil moisture stress for crops where vegetative parts are of economic importance. Total growth and yield of perennial plants are the summation of effects of stress at each growth stage. However, adequate water supply is essential at flower bud initiation, flowering and fruit set. Flower bud formation, however, increase due to restricted water supply prior to flower bud initiation in the case of citrus and mango.

For realizing maximum benefit from the scarce irrigation water, irrigation is to be scheduled at moisture sensitive periods by withholding irrigations at other periods of lesser sensitivity. Such irrigation schedules along with improved practices increase the water-use efficiency in crop production.

Peak Consumptive use and critical period

These stages do not usually coincide with the periods of peak consumptive use by crops. It is not appropriate to consider the crops, at these critical stages, require more water as their water needs are at the higher. Critical stages of water requirement are usually the turning points in plant life cycle. This can be represented by a sigmoid or S-shaped curve. The curve shows two most important points of change in the growth rate, viz., the point of inflection and the point of deflection.

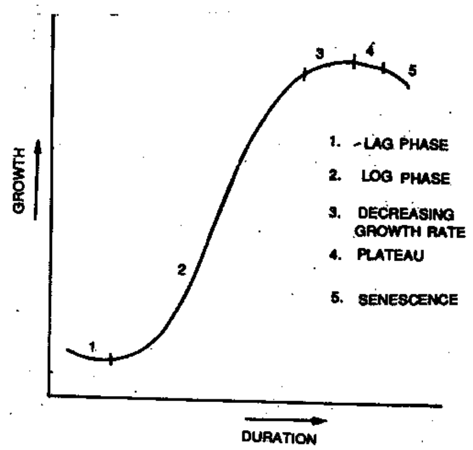


Fig1. S - shaped growth curve

The point of inflection indicates a sudden spurt in vegetative growth and the point of deflection represents the slowing down of vegetative growth and initiation of the reproductive phase. Crops demand adequate water at these stages and can not afford to stand water stress without serious reduction in growth and yield. These two stages of crop life, therefore, considered as the most critical stages of water requirement.

Crop stages and critical period

When the crop plants are young and delicate, they are not able to stand and demand a liberal supply of water. Again, with the start of grand growth period, crop puts up a faster rate of vegetative growth and transpiration and bio-chemical activities in plants occur at higher rate. This leads to tremendous increase in water need of the crop and the supply of water should be adequate to maintain the normal rate of active growth and evapo-transpiration. Water stress at the sensitive stages causes a serious retardation in growth process that ultimately depresses the yield. The sensitive stages differ from one crop to the others. Water stress at these stages causes lower branching, tuber bulking, inadequate flowering, flower drops, poor setting of fruits and serious fruit drops.

It is true that crops require adequate water supply through out their life cycle for best growth and yield. Only in the later stages of crop maturity, water supply is reduced or stopped to obtain uniform and quicker crop maturity. Crops may be allowed to stand water stress to some extent during certain periods of life excepting at the critical stages to save some water under situations of water scarcity.

Determination of critical periods of water need

It assumes importance to use irrigation water judiciously when water supply is limiting. For this purpose, a crop is subjected to pre-determined water stress at different stages of growth and then the corresponding yield reductions are considered. It is then related to the crop that has not been subjected to any water stress and irrigated according the normal schedule. Another way to decide the critical periods is to miss irrigation at different stages of the crop and then relating the corresponding the yield reductions with the yield from control plot which is irrigated normally. Periods at which yield reductions are significant are considered as the critical periods of water need in the life of the crop.

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.

Questions

1. Certain periods during the crop growth and development are most sensitive to soil moisture stress compared with other and are known as critical stage. (True / False)

   Ans: True

2. Leafy vegetable crops should not have water stress during entire period of their life span. (True / False)

   Ans: True

3. The moisture sensitive period in chilies is flowering and fruit development. (True / False)

   Ans: True

4. Critical stages of water requirement are usually the turning points in plant life cycle. (True / False)

   Ans: True

5. Determination of critical stage of water need assumes importance to use irrigation water judiciously when water supply is limiting. (True / False)

   Ans: True

Lecture No. 8

Scheduling of irrigation – Different approaches in scheduling – Scheduling for different crops and methods of irrigation

Proper irrigation management demands application of water at the time of actual need of the crop with just enough water to wet the effective root zone soil. The principal aim is to obtain maximum crop yield by making the most efficient and economic use of water.

Time of Irrigation

Time of irrigation is usually governed by two major conditions namely, (1) water need of crops and (2) availability of irrigation water. Water need of crops is, however the prime consideration to decide the time of irrigation.

Availability of Irrigation Water

Irrigation water is often 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 greater crop production in areas of limited water supply. In areas where water is scarce, farmers are not able to apply normal irrigation to crops and are forced to skip some irrigation.

Criteria for scheduling irrigation

The optimum scheduling of irrigation should be based on crop needs to avoid both over and under-irrigation and to ensure high water use efficiency.

A thorough understanding of the soil-water - atmosphere relationship is essential for proper scheduling of irrigation, since irrigation needs of crops are decided by the evaporative demand of the atmosphere, soil water status and plant characteristics. The criteria for scheduling irrigation, as attempted from time to time, may be grouped into three categories, namely, (1) plant criteria, (2) criteria based on soil water status and (3) meteorological criteria.

1. Plant Criteria

Plants show up certain characteristic changes in their constitution, appearance and growth behavior with changes in available soil water and atmospheric conditions. Different plant criteria considered to schedule irrigation are presented below:-

1.1. Plant appearance

With water stress, some characteristic changes usually occur in the general appearances of plants. There may be changes in the normal colour of plant or distortions of plants such as wilting or drooping of plants and curling or rolling of leaves. Some crops like leafy vegetables are very sensitive to soil-water changes and develop scarcity symptoms easily, while others do not. Changes in colour appear first in the lower leaves. Water stress is also shown by temporary wilting of plants, as with sugar beet during the hottest part of the day. Fruit plants do not easily show up water stress by changes in appearance until serious retardation in growth takes place. However an experienced orchardist can detect early signs of stress by the appearance of the foliage especially during the period of peak transpiration demand. Young leaves are the most sensitive part in this regard. This technique is however quite simple and rapid, but suffers from many deficiencies. Changes in colour may be misleading since nutritional disorder, insect damage, disease attack and varietal character cause variable changes in foliage colour.

1.2. Plant water potential and water content

Some crops show strong correlation between the water content of leaf or leaf sheath and the available soil water. The relative leaf water content (RLWC) and leaf water potential change with variations in soil water availability or owing to lag between water absorption by plants and evaporative demand of the atmosphere. Adverse physiological and growth phenomena specific to plant species have been reported with fall in the RLWC and water potential below certain critical limits. As mentioned in the 3rd schedule a drop of 8-10% moisture(-5 to -6 bars of leaf water potential)causes a mild stress and crop is to be irrigated before the critical RLWC is reached. The RLWC and leaf water potential (LWP) values for the individual crops and their stages are to be standardized for scheduling irrigation. However, sophisticated equipment, intricate measuring devices, high cost and lack of proper standardization of instruments deter the use of this technique on a large scale.

1.3. Plant growth

Cell elongation is considered as the growth process that suffers first with water stress in plant. Subsequently, retardation in growth of height or internodal length occurs. Timing of irrigation can be set as and when the normal growth rate is observed to decline. This is, however, possible in places where a continuous measurement of plant growth is maintained. This technique offers many difficulties owing to unavailability and high costs of equipment and so on. The serious objection to this approach of scheduling irrigation is that the plants suffer before they show any retardation in growth processes.

1.4. Critical crop stages of water need

Irrigation scheduling may be decided based on stages of growth more conveniently in crops in which the physiological stages are distinct to locate the critical periods of water need. Scheduling of irrigation based on these critical stages is most convenient for ordinary Indian farmers who may need, at the most, some guidance or education initially. However, it may be a little difficult in crops where stages are not so well defined.

1.5. Indicator plant

There are some plants sensitive to soil-water variations. They may be used for detecting the water stress in crops that do not show symptoms of water stress easily or exhibit the same when they have already suffered seriously. Sunflower plants are often used as indicator plants in onion crop. An indicator plant for irrigation should be such that it shows the water stress before the crop has suffered from it. When an indictor plant is grown in a crop field, care should be taken not to shade the plant by crop plants.

1.6. Stomatal aperture and Leaf diffusion resistance

Opening of stomata in plants is regulated by soil water availability. Stomata remain fully open when the supply of water is adequate, whereas they start closing with scarcity of water in soils to restrict the transpiration. Water deficit in plants is directly related to availability of soil water and that may be used for scheduling irrigation in crops.

A close relationship exists between leaf diffusion resistance (LDR) and plant water stress. LDR is a sensitive index of internal water balance in the mild to moderate stress range and holds a promise for scheduling irrigation.

1.7. Plant temperature

Solar radiation received on earth heats up leaf tissues besides causing evapotranspiration and heating up the ambient air. With water deficit in plant the temperature of leaf tissues rises. Many investigations have shown that leaf or canopy temperature is a sensitive index of plant water status.

2. Criteria based on soil water status

Scheduling irrigation based on soil water content is the most accurate and dependable method. Determination of available soil water is rather more important than estimating the total water content of soils. For the purpose, information on the optimum water regime of crops and the available water holding capacity of soils is essential. Irrigation is applied when the soil water content reaches the lowest point of optimum soil water regime. The optimum water regime for a crop in a place is determined experimentally by correlating yield with the water contents of soils.

Various methods are used to determine the soil water status and farmers may choose any of the methods according to their needs, accuracy wanted and facilities available for estimating soil water.

The criteria based on soil water status attempted or used to schedule irrigation to crops are discussed here.

2.1. Soil water content

Early attempts were made to schedule irrigation when the soil water content reached a certain value. The idea did not succeed since there existed a wide variation in the water content retained by the different classes of soils. However later a new concept of scheduling irrigation based on the lower limit of soil water content for potential evapotranspiration of crop was made. In this approach it was assumed that the growth of crop was likely to suffer below a level of soil water. This threshold limit could be decided for various crops, soil types and atmospheric evaporability. In the fruit crops, irrigation is more effective if applied before soil moisture becomes limiting. As a rule of thumb, water should be applied when 50% of the available water in the root zone has been depleted. If further depletion is allowed, the plants may be subjected to a level of stress that might cause an appreciable reduction in yield.

2.2. Depth-interval of irrigation

Since the water retentive capacity of soils varies widely with soil types and soil physical conditions, and root zones of crops vary with types of crops and their rooting characteristics at different growth stages, the depth and interval of irrigation require modifications in different soils and at various crop growing periods. The drawback of this method is that an arbitrarily fixed depth or interval of irrigation has misleading effects on crop growth and yield.

2.3. Critical level of available soil water

As stated earlier, the critical level of soil water denotes the level of available water below which the crop growth and yield decline drastically. It is the lowest level of the optimum soil water regime. This level once established experimentally for various crops in different soil types and soil conditions can be profitably used for scheduling irrigation. This approach has been widely suggested for adoption. A periodical determination of soil water content is made to know the time when the soil water is likely to reach the critical level. This criterion is synonymous with the concept of available soil water depletion for deciding the time of irrigation. The depth of irrigation however needs revision upwards every time with increasing vegetative growth and rooting depth of an actively growing crop.

In fruit trees more than 80% of water is drawn from 0 – 90 cm layer and amount water to be added to fill only this depth of soil. But during summer the depth of soil to be taken for consideration extends up to 120cm.

The critical ASM limit for crops like brinjal, chilli and cucumber is 50%; Tomato, onion, garlic and cabbage is 60% and cauliflower and leaf vegetables is 70%.

2.4. Soil water tension

Many scientific workers have used this criterion for scheduling irrigation to crops in various parts of the world. Tensiometer techniques are used for irrigation. In many countries, the tensiometer has been considered as a useful device for scheduling irrigation to orchard and vegetable crops, particularly on coarse textured soils where most of the available water is held at low tensions.

The use of tensiometer for controlling irrigation did not find much favour with common farmers since the device presents certain difficulties in its use. The tensiometer can be used only in the lower tensions up to 0.85 bars. It does not show the actual soil water content for direct calculation of the depth of irrigation to be applied. The water content is calibrated from the soil tension curve. Again, there exists a time lag in tension-equilibrium between the porous cup and the surrounding soil that makes the tensiometer showing the energy status of soil water earlier to the existence of the actual soil water content.

2.5. Electrical resistance

The concept of electrical resistance that varies inversely with the water content in soils was also tried to schedule irrigation. For this purpose, resistance blocks made of gypsum, nylon, nylon-resin etc, were used. Crops were irrigated when the electrical resistance reached a certain value. The value could be decided experimentally for various crops by using the resistance blocks. This method has however many limitations and did not become popular. The limitations are that resistance blocks cannot be used at low tension at which most of the available water is held by soils, difficulty in deciding the depth of irrigation as resistance blocks do not directly show the prevailing soil water content and the existence of a time-lag in tension-equilibrium between the porous block and the surrounding soil which causes showing up the energy status of soil water earlier.

3. Meteorological criteria

Criteria based on the climatic approach are dealt in the subsequent classes.

Questions

1. Plants show up certain characteristic changes in their constitution, appearance and growth behavior with changes in available soil water and atmospheric conditions and are valuable pointers to the time of irrigation. (True/False)

   Ans: True

2. An indicator plant for irrigation should be such that it shows the water stress before the crop has suffered from it. (True/False)

   Ans: True

3. Optimum water regime for a crop in a place is determined experimentally by correlating yield with the water contents of soils. (True/False)

   Ans: True

4. The critical level of soil water denotes the level of available water below which the crop growth and yield decline drastically and is the lowest level of the optimum soil water regime.(True/False)

   Ans: True

5. The concept of electrical resistance that varies inversely with the water content in soils was also tried to schedule irrigation.(True/False)

   Ans: True

Lecture No.10

Cimatological approach – atmospheric demand – factors affecting ET– The concept of IW/CPE ratio in scheduling irrigation

Attempts have been made from time to time to use meteorological parameters, which are the major factors demanding atmospheric moisture, for estimating the evapotranspiration and consumptive use for controlling irrigation.

For this purpose, empirical formulae using different meteorological parameters have been developed. Penman (1948), Thornthwaite (1948), Blaney–Criddle (1950) and Christiansen (1968) developed formulae for estimating potential evapotranspiration and then used the estimated evapotranspiration for scheduling irrigation by water budget method. The daily evapotranspiration loss is deducted from the soil water reserve in root zone soil after irrigation and a balance is worked out. When the balance show that the soil water is depleted to a predetermined level, say, the lower level of optimum soil water regime, irrigation is applied to replenish the water lost through evapotranspiration. The adoption of empirical formulae for irrigation control demands the knowledge of water holding capacity of soil and a continuous record of rainfall and other meteorological parameters. This approach of scheduling irrigation to crops is complicated for an ordinary farmer.

Frequency and interval of irrigation

The terms, frequency of irrigation and interval of irrigation are closely related and are often interchangeable. With higher frequency of irrigation, the interval between two irrigations decreases in a given period, while with lower frequency the interval between two irrigations increases. The term, interval of irrigation indicates the time gap, usually expressed in days, between two subsequent irrigations. The total amount of water required by a crop for producing an optimum yield is termed as delta of water and it is synonymous with water requirement of crop.

Immediately after irrigation when the soil is wet, evapotranspiration occurs at a potential rate. It starts declining some days after irrigation as the surface soil dries up. Dry and loose soil surface helps to reduce evaporation. Since soil water declines progressively owing to continuous evapotranspiration, the rate of evapotranspiration also declines progressively with the advance of time after irrigation. Therefore, the longer is the interval between irrigations, the greater is the saving of water. Besides, a longer interval between two irrigations cuts down the number of irrigations during the growing season. Care should, however, be taken not to cause any water stress beyond a certain limit by making the irrigation interval unduly long unless compelled to do so for reasons of water scarcity. Irrigation is usually advised at the lowest limit of the optimum water regime, as already stated earlier. The interval between two irrigations should normally be the time taken by crops to reduce the soil water from field capacity to the lowest level of optimum soil water regime.

Factors affecting frequency of irrigation

The factors which affect the ET have been dealt in the earlier schedule (Lecture No.5). The effect on affecting the frequency of irrigation is briefly explained hereunder.

The two main consideration namely, water need of crops and the availability of irrigation water decide the irrigation frequency. Once these two are known, the frequency of irrigation is influenced mainly by climate, soil characteristics, crop characteristics and management practices.

i. Climate

Climate is responsible for causing variations in consumptive use rate and frequency of irrigation. High temperature, low humidity, high wind velocity and greater solar radiation in a place emphasize the need to irrigate crops more frequently as evapotranspiration takes place at a higher rate due to greater evaporative demand of the atmosphere. This is particularly evident in arid regions and during summer season. On the other hand, higher rainfall and greater relative humidity during the rainy season reduce the irrigation requirement of crops and irrigations may be applied at longer interval, if it becomes necessary.

ii. Soil characteristics

Water retentive capacity of soil is considered as the most important soil factor deciding the frequency and interval of irrigation. A soil with greater water retentive capacity serves as a bigger water reservoir for crops and can supply water for longer duration. Consequently, frequency of irrigation is lower and interval of irrigation is longer. On the other hand, the frequency is higher in porous sandy soils with coarse texture, poor structure and low organic matter content. Retention of greater amount of available water is considered more important than total quantity of water retained by a soil.

Depth of soil is another factor that influences the frequency of irrigation. A shallow soil cannot hold enough water to meet the crop demand for a longer period. Necessarily, frequent irrigations are required with smaller depth of water each time. Irrigations at longer interval is applied to deep soil that has a greater water storage capacity. Such a soil can supply water for longer duration particularly when the root system is quite deep and extensive.

iii. Crop characteristics

Crops vary in their consumptive use of water, sensitivity to water stress, water extraction capacity and optimum water regime. Frequency of irrigation thus varies with crops. Crops like vegetables, onion and sugar beet that require a higher level of water to be maintained in the soil need frequent irrigations than other field crops.

Many crops have varieties that are either sensitive or tolerant to drought conditions. Varieties sensitive to drought conditions require frequent irrigations compared to tolerant varieties.

Rooting characteristics of crops such as shallow or deep, fibrous or tapering, vertically or laterally extensive root systems decide the frequency of irrigation. When the root system is shallow and fibrous, crops are not able to utilize water from deeper soil layers and are frequently irrigated with smaller depth of water to wet only the upper soil layers. Crops with deeper and extensive root system command a greater depth of soil and water reserve and require irrigations at longer interval. Sometimes, they may get water from water table which is not deep enough. Shallower water table reduces the irrigation requirements and help to increase the interval between irrigations. Besides, the concentration and relative proportion of the root mass in different soil layers decides the water extraction capacity. They represent the extraction capacity of crops from different depths of soils.

Irrigation frequency varies with stages of crop growth. The consumptive use rate, sensitivity to water stress and rooting characteristics of crops change at different stages. A crop when young and delicate needs frequent irrigations. Subsequently, the consumptive use rate gradually increases and at the same time the root system also develops. Irrigations can then be applied at longer interval, as roots are able to draw water from greater volume of soils. When a crop approaches maturity, the demand for water greatly declines because of steep fall in consumptive use rate.

iv. Management practices

Soil water conservation practices such as artificial or soil mulching and crop cultural practices like weeding and hoeing help to reduce the evaporation loss and conserve more soil water for crops use. Thus, there is a reduction in irrigation requirement of crops. Method of irrigation, depth of water applied each time and the water distribution efficiency influence the frequency of irrigation.

v. Irrigation period

Irrigation period is the time, usually expressed in days, that can be allowed for applying one irrigation to a given design crop area during the peak consumptive use period of the crop. It is a function of the peak-period consumptive use rate. It is considered for designing the irrigation system capacity and equipment. The irrigation system must be so designed that the irrigation period is not greater than the irrigation interval.

Climatological approach using irrigation water depth and evaporation relationship

Evaporimeter

Evaporimeters like United States Class-A open Pan Evaporimeter, Sunken Screen Open Pan Evaporimeter and atmometer may be used for irrigation control. They are employed to measure the evaporation loss, which is used to determine the consumptive use by crops by multiplying the evaporation values with crop coefficient values. The coefficient varies from 0.6 to 0.8 for most crops at their different stages. Irrigation is applied when crops consume the available soil water to certain limit, calculated on the basis of consumptive use rate as determined by evaporimeters. Sunken screen evaporimeter value can be used from the period of 25 per cent ground coverage by crops till their maturity. The values of pan evaporation for this purpose are found for various crops at their different growth stages under different soil and climatic conditions.

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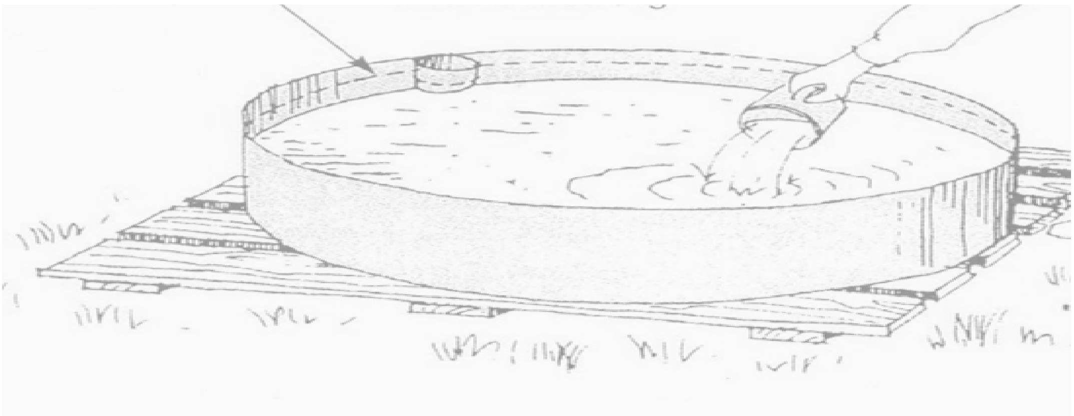


Fig1. USWB Open pan evaporimeter

Depth of irrigation

Depth of irrigation is a function of the water retentive capacity of root zone soil and extent of soil water depletion at the time of irrigation. It refers to the depth to which the applied water would cover an area. The net depth of irrigation is decided by the amount of water required to bring the soil water content just before irrigation to field capacity in the root zone soil. The water content of soil just before irrigation must be known to calculate the net depth of water required to be applied. It is calculated by the following formula,

$$D= \sum_{i=l}^{n} \frac{Fci - M_{bi}}{100} \text{ x } a_{si} \text{ x } d_i$$

Where,

D= net depth of water to be applied or net irrigation, cm

F_{ci} = field capacity of the i-th layer of soil in per cent by weight

M_{bi} = water content of the i-th layer of soil just before irrigation, per cent by weight

a_{si} = apparent specific gravity of i-th layer of soil, g/cm^3

d_i= depth of i-th layer of soil in the root zone, cm

n = number of soil layers in the root zone d

Usually, the soil zone that accounts for 90 per cent of the root mass needs to be wetted by irrigation when the crop is fully grown, but for an actively growing crop the soil little below the actively growing roots should be made moist. The depth of irrigation required for different soil types when soil water is depleted to 50 per cent availability are given in the following table.

Irrigation depths required for different soils at 50 Per cent Soil Water Depletion

Soil class	**Depth of irrigation in millimeters per metre depth of soil**
Sandy soil	40
Sandy loam soil	60
Loam soil	80
Clay loam soil	100
Clay soil	125

Irrigation water/Cumulative pan evaporation ratio (IW/CPE ratio)

The use of IW/CPE ratio is suggested as a practical basis of scheduling irrigation. The approach is based on the close and direct relationship of crop evapotranspiration with pan evaporation. When irrigation is applied, water is lost from the soil through evapotranspiration in the same way as the evaporation occurs from an open pan evaporimeter. It is ratio of the amount of irrigation water (IW) applied to cumulative pan evaporation (CPE). The pan evaporation values are added up every day till it is equal to certain ratio of the amount of water applied as irrigation. The ratio for various crops is determined experimentally by estimating the evapotranspiration by lysimeter studies.

The IW/CPE ratios for various crops at different agro climatic conditions in India have been determined under ICAR Coordinated Project for Research on Water Management.

Questions

1. The IW/CPE ratio approach is based on the close and direct relationship of crop evapotranspiration with pan evaporation (True/False).

   Ans: True

2. The frequency of irrigation is influenced mainly by climate, soil, crop and water management practices. (True/False).

   Ans: True

3. Climate is responsible for causing variations in evaporation rate and depth of irrigation. (True/False).

   Ans: True

4. Irrigations at longer interval are applied to deep soil that has a greater water storage capacity. (True/False).

   Ans: True

5. A greater depth of water is applied each time to an actively growing crop so that roots grow deeper and a smaller depth of water is applied to crops that have maturity stage. (True/False).

   Ans: True

Lecture No.11

Methods of irrigation – Surface and Sub – surface methods - suitability to crops – minimizing conveyance losses

Crop plants need adequate water for their growth and yield. When rainfall is not sufficient, the plants must receive additional water from irrigation to maintain optimum moisture in the root zone. Water is conveyed from a source to the root zone by different ways. Each one is a method and they are broadly grouped under the following headings and they are used for different situations depending on their suitability.

Classification of irrigation methods

Methods of irrigation are broadly grouped under:

1. Surface irrigation
2. Subsurface or sub irrigation
3. Overhead or sprinkler irrigation
4. Drip irrigation

Methods of irrigation coming under different groups are as follows:

1. Surface irrigation

Surface irrigation method is most widely practiced. In this method water is conveyed to the point of infiltration directly onto the soil surface in channels that vary in shape, size and hydraulic characteristics. The channels may vary from corrugation to long narrow strips or large fields where water is impounded. On the basis of their conveyance size and shape, surface irrigation may be of following types.

A. Methods involving complete flooding of the soil surface

a. Wild flooding

In this method water flows from the ditch directly to the field without much control on either side of the flow. It covers the entire field and moves almost unguided. The rate of advancing front is controlled by the topography of the field. Land leveling is not precisely followed. The depth of water sheet at different points may not be same, somewhere deep causing water logging and somewhere very shallow leading to water scarcity a few days after drying. Uneven distribution of water and low water application efficiency are the common drawbacks of this method. But the method is easy and inexpensive. Close growing crops are generally irrigated by this method.

b. Border Irrigation

Borders are usually long, uniformly graded strips of land, separated by earthen bunds. The bunds so formed are not to contain the water from ponding but to guide it as it flows down the field.

Border irrigation is generally best suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. Borders can be upto 800 m or more in length and 3-30 m wide depending on a variety of factors. It is less suited to small-scale farms involving hand labour or animal powered cultivation methods.

Border slopes should be uniform, with minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion. Deep homogenous loam or clay soil with medium infiltration rates is preferred. Close growing crops such as pasture, alfalfa are preferred. Borders may be either laid along the slope (straight) or across the slope (contour).

c. Check or Check Basin Irrigation

Check method consists of dividing the field into several relatively level plots called checks surrounded by low bunds. They are irrigated with comparatively large flow of water. Small checks are levelled while bigger ones are slightly sloping along the length. A check is also termed as check basin. There are two methods of check irrigation, rectangular check method and contour method.

i. Rectangular check irrigation

In a relatively uniform land with a gentle slope, checks may be rectangular and sometimes square. They may be a few square meters in size for vegetable crops. The size of a check is a function of the water intake rate of soil, land slope and the available stream size. In lighter soils the size of a check may necessarily be small to achieve uniform wetting and in heavier soils the size may be large.

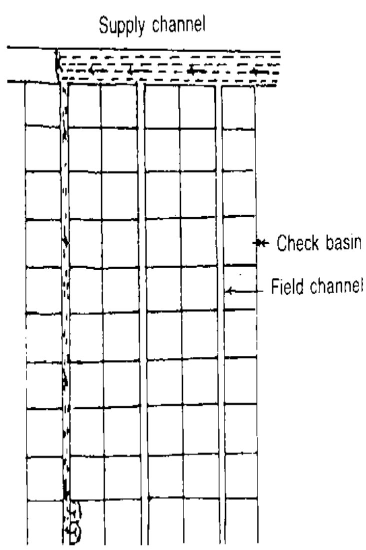


Fig 1. Rectangular check irrigation

Water is conveyed to checks by a system of supply channel, laterals and field channels. Laterals or field channels are laid out in such a way that a channel passes through a set of two rows of checks. Such a channel is used to irrigate checks on both the sides. A supply channel is constructed on the upper reach of the field and laterals usually follow the slope, if there is any.

Check method is adopted for irrigating row crops as well as closely spaced grain crops, fodder and vegetables in a wide range of soils having moderate to slow infiltration rates.

Advantages and limitations

Advantages of the method are that (i) variable size of streams can be effectively used (ii) it can be adopted for wide range of soils (iii) water application efficiency is high. Principal limitations are (1) precise land leveling is necessary (2) considerable land is wasted by bunds and channels (3) labour requirement is high for preparing the land for irrigation (4) movements of farm animals, implements and machinery are often restricted by bunds and channels.

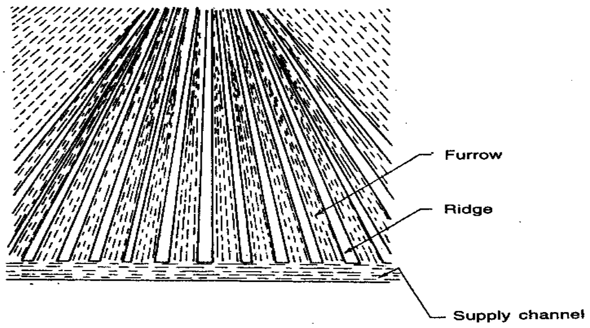
ii. Contour check irrigation

In slopping and rolling lands contour checks are constructed by rising bunds or ridges along contours having vertical intervals of 15 to 30 cm. Checks at the end of the adjoining contours may sometimes be joined at suitable places to make them continuous. They are almost uniformly level or gently sloping and are often small. A contour checks is also termed **contour check basin.** Contour checks are suitable for growing vegetables.

B. Methods involving partial flooding of the soil surface

a.Furrow Irrigation Methods

Fig 2.Furrow irrigation method



Furrow irrigation refers to irrigating land by constructing furrows between two rows of crops or alternately after every two rows of crops. It wets the land surface only partly and water in the furrow moves laterally by capillarity to the unwetted areas below the ridge and also downward to wet the root zone of soil. Furrow irrigation is adopted to irrigate all row crop such as potato and vegetable crops on ridges. Plantation and fruit crops are also irrigated by furrow method.

Principal limitations of the method are: (i) land requires precise grading to a uniform slope (ii) labour is necessary to control water in furrows (iii) this method is unsuitable for light irrigation.

Classification of furrow irrigation methods

Furrow irrigation methods may be classified based on the types of furrows employed and the pattern of irrigation adopted. The methods are: (a) straight graded furrow irrigation (b) straight level furrow irrigation (c) contour furrow irrigation (d) alternate furrow irrigation and (e) raised bed and furrow irrigation. The first two types are formed as explained earlier (Furrow methods), with or without slopes for easy flow of water. The other types are as follows.

i. Contour furrow irrigation

Contour furrow method of irrigation is adopted in an uneven and rolling topography. When the longitudinal slope exceeds the safe limits for graded furrow, furrows are constructed along the contour.

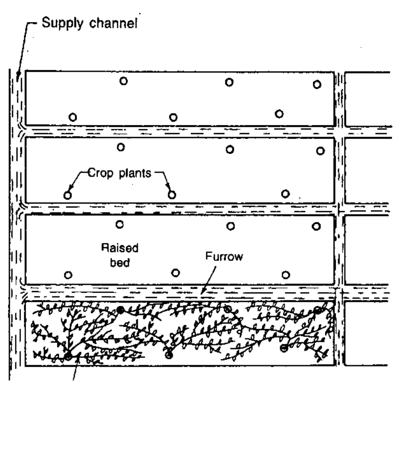
ii. Alternate furrow irrigation

When the supply of water is limited, irrigation is applied through alternate furrows. Besides, this alternate furrow method is adopted where salt is a problem. Water is discharged in alternate furrows keeping the in-between furrow dry. In the subsequent irrigation, water is allowed to flow through the alternate furrows that had been kept dry on the previous occasion. This method saves quite a good amount of water and is very useful and crucial in areas of water scarcity and salt problems.

iii. Raised bed and furrow irrigation

Raised beds of 1 to 1.5m width alternating with furrows are often constructed for growing vegetables crops, particularly those vegetable crops that creep on soil surface. Fruits of such vegetables get damaged on coming in contact with the moist soil. Two rows of plants are usually raised on two sides of a bed or ridge. A furrow runs between two rows of the adjacent ridges of beds and supplies water to the plant rows. The method assures saving of a large amount of water. The surface soil of beds or ridges remains dry and the creeping plants and their fruits are not damaged. Water from furrow moves laterally into the soil below the bed or ridge to meet the crop need.

Fig 3. Raised bed and furrow



It prevents accumulation of salts at the base of plants and reduces the salt injury to crop in areas where salt is a problem.

iv. Corrugation irrigation

Corrugations are miniature furrow adopted for irrigating close growing crops such as grain, forage and pasture crops. Crops may be line sown or broadcast and corrugations may bear any definite relation to crop rows. This method is used for fine to moderately coarse soils, especially soils that forms crust. Corrugations reduce crusting as they wet only a part of the land surface. They are not suitable for sandy soils as corrugations get smooth quickly due to collapse of ridges, particularly in moderate to high rainfall areas. The method is advantageous when the available stream is small.

Principal advantages of the methods are that (i) it saves quite a good amount of water (ii) small supply stream is used (iii) used for soils with crusting problems and (iv) high water application efficiency.

b.) Basin and ring irrigation

Fruit crops in orchards are irrigated by constructing basins or rings around trees. Basins are usually used for small trees, while rings are used in bigger trees which are widely spaced.

Basin irrigation

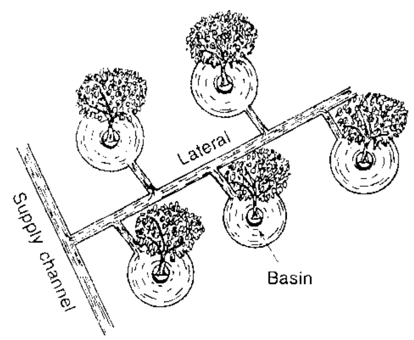


Fig.4. Circular basins

A basin is usually made for one tree sapling but it may include more than one tree sapling when they are not spaced very wide. Basins may be square, circular or rectangular.

Basins are made longer and wider as saplings grow in size. The land inside basins is flat with the base area of trees kept little raised so that the sapling stems do not come in direct contact with water. Only a part of the total land surface is flooded. Water is supplied through laterals and each basin may be connected with another one by a small furrow to get the water supply. A lateral or field channel passes between two rows of trees alternately supplying water to individual basins on both sides. A basin usually covers the complete area under the tree canopy. Desired quantity of water is allowed into a basin for complete infiltration.

Advantages and limitations

Advantages are that (i) a considerable amount of irrigation water is saved (ii) water application efficiency is very high (iii) entire area excepting the basin area does not require precise land leveling, (iv) the labour requirement and the cost of making basins are low and (v) no land is wasted. This method is adaptable for fruit trees or shrubs in orchards and plantations. The principal disadvantage is that working with implements and machineries is prevented.

Ring irrigation

Ring method consists of irrigating fruit trees in orchards by constructing circular trenches around trees. Ring trenches are smaller in both depth and width around small trees and are larger around bigger trees. Usually a ring is laid out at the periphery of the tree canopy. The ring trenches are usually made 30 to 50 cm wide and narrow furrows. Laterals pass through a set of two rows of trees supplying water into rings on both sides. Water supply process is essentially the same as with the basin irrigation. Water in desired quantity is allowed to stand in the trenches for infiltration.

c.) Surge Irrigation

Surge irrigation is defined as the intermittent application of water to field surface under gravity flow which results in a series of “on and off” modes of constant or variable time spans. Large intermittent flows rather than continuous ones are used in two sets of furrows and gated pipes laid in the “Tee” configuration. Water is switched alternatively from one set of furrows to the other by a valve and automatic time controller until irrigation is completed. The cycle time (irrigation period plus the rest period) can be made to vary from 30 minute to several hours.

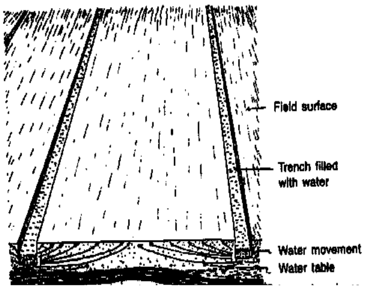
2. Subsurface irrigation methods

Subsurface irrigation, also designated as sub irrigation, involve irrigation to crops by applying water from beneath the soil surface either by constructing trenches or installing underground perforated pipe lines or tile lines. Water is discharged into trenches and allowed to stand during the whole period of irrigation for lateral and upward movement of water by capillarity to the soil between trenches.

Underground perforated pipe or tiles in which water is forced, trickle out water through perforations in pipes or gaps in between the tiles. Water moves laterally and upward to moist the root zone soil under capillary tensions. Pipelines remain filled with water during the period of irrigation. The upper layers of soil remain relatively dry owing to constant evaporation while lower layers remain moist. The essential pre-requisite for sub-irrigation are: (1) existence of a high water table or an impervious sub-soil above which an artificial water table can be created (2) highly permeable root zone soil with reasonably uniform texture permitting good lateral and upward movement of water (3) irrigation water is scarce and costly and (4) soil should not have any salinity problem.

It might be ensured that no water is lost by deep percolation. The artificial water table is created to a depth of 30 to 120 cm depending on crops to be grown, nature of soil capillarity and the depth of impervious soil layer. Uniform topographic conditions and moderate slope favour sub-irrigation. In places where sprinkler irrigation is expensive, sub irrigation is adopted. Sub-irrigation is made by constructing a series of ditches or trenches 60 to 100 cm deep and 30 cm wide, the two sides of which are made vertical. Ditches are spaced 15 to 30 m.

Fig 5. Sub – irrigation (trench method)



The crops, particularly with shallow root system are well adapted to sub irrigation. Sometimes, sub irrigation is made to high priced vegetable crops by installing a perforated pipe distribution system below the soil surface but within the crop root zone. This is often termed the artificial irrigation. A good quality water supply must be available throughout the growing season and an outlet for drainage is provided, particularly in high rainfall areas.

Advantages and limitations Advantages of this method of irrigation are (i) soil water can be maintained at a suitable tension favorable for good plant growth and high yields (ii) evaporation loss from soil surface is minimized (iii) cost of water application is very low and (iv) it can be used for soils having a low water holding capacity and a high infiltration rate where surface method cannot be adopted and the sprinkler irrigation is expensive.

Irrigation water conveyance

Surface methods involve conveying water through earthen channels and are subject to water loss. The methods which minimize losses during conveyance are dealt in the subsequent topics.

Questions

1. Border irrigation is generally best suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. (True/False)

   Ans: True

2. When the longitudinal slope exceeds the safe limits for graded furrow, furrows are constructed along the contour. (True/False)

   Ans: True

3. Raised beds of 1 to 1.5m width alternating with furrows are often constructed for growing vegetables crops, particularly those creep on soil surface. (True/False)

   Ans: True

4. Vegetable crops in orchards are irrigated by constructing basins or rings around. (True/False)

   Ans: True

5. Surface irrigation involves irrigation to crops by applying water from beneath the soil surface. (True/False)

   Ans: True

Lecture No.12

Pressurized methods - Sprinkler method and suitability for crop, soil, topography and climate -Merits and demerits

Introduction

Sprinkler irrigation or overhead irrigation is the application and distribution of water over the field in the form of spray created by expelling water under pressure from an orifice (nozzle). It is a simulated series of rainfalls of controllable frequency, duration, intensity and range of drop sizes. In contrast to surface irrigation, sprinkler systems are designed to deliver water to the field without depending on the soil surface for water conveyance and distribution. Sprinklers are designed and arranged to apply water at rates lower than the soil infiltration rate to prevent ponding and surface run off.

Suitability of sprinkler irrigation system

- Shallow and sloping soils which can not be irrigated by surface methods without leveling.
- Sandy soils requiring excess applications with surface methods.
- Low moisture retentive soils requiring frequent, light and uniform application.
- In places of water scarcity.

Merits over surface systems

- Elimination of channels, bunds and their maintenance and conveyance losses of water.
- Controlled application leading to higher application efficiency.
- Areas at higher elevation than the source can be irrigated.

Limitation over surface systems

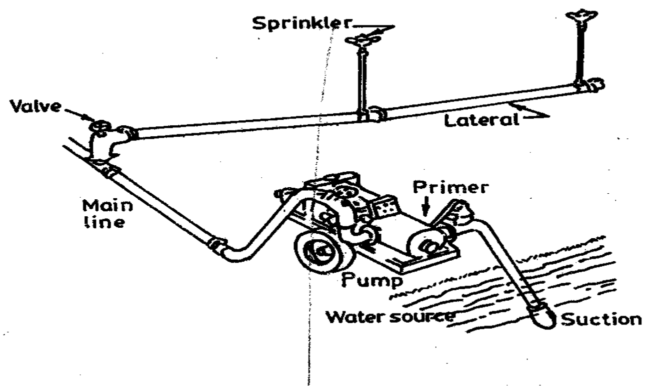
High initial capital cost, high maintenance requirements and high operating pressure.

During day time, when air is warm and dry and the droplets are small and application rate is low, application efficiency is affected by high wind speed. Sensitive crops to soluble salt concentration may suffer leaf scorch because of salt deposit on leaves as the intercepted irrigation water containing appreciable amount of soluble salts evaporates.

Components of sprinkler system

A typical sprinkler system consists of the following four components (Fig.1)

1. **Pumping unit**
2. **Main line**
3. **Lateral pipe**
4. **Sprinkler unit**



1. **Fig 1. Sprinkler irrigation system with a centrifugal pump**

The type of pumping unit for sprinkler system depends on source of irrigation water. Both vertical turbine and centrifugal pumps can be used. Booster pumps may be necessary to develop required pressure in the case of centrifugal pumps. Main lines may be permanent or portable depending upon the situation. Lateral lines are usually portable for movement after each setting. Light weight aluminum pipe can be conveniently used for mains and laterals. Quick setting couplers enable movement of laterals quickly during irrigation.

Types of sprinkler system

On the basis of arrangement for spraying irrigation water, there are two major types of sprinkler systems.

Rotating head system

Small pipe nozzles are placed on riser pipes at uniform intervals along the length of lateral pipe. They are rotated through 90° by hand or hydraulic pump to irrigate a rectangular strip. The most common device to rotate the sprinkler heads is a small hammer activated to the thrust of the water striking against a vane connected to it. The spacing between lateral lines is 15 m when operating at a pressure of 1.7 to 2.8 kg/cm^2 (17 to 28 m of water head).

Nozzle line sprinkler system

It consists of one or more pipes of relatively small diameter having a single row of fixed small nozzles spaced at uniform intervals along the entire length of pipes and supported on rows of posts at a height convenient to spray over crops and can be rotated through 90°. Water is sprayed at a pressure of two to three atmospheres at right angles to the pipeline and at an angle of 45° to the horizontal plane.

Fixed head sprinkler system

Nozzles in this system remain stationary and spray water is in one direction only to which the spray nozzle is directed. The system is used extensively in orchards and nurseries. It has high water application rates. The spray is usually fine which is helpful for irrigating seedlings in nurseries.

Propeller type sprinkler system

The system includes a number of sprinklers mounted on a horizontal pipeline which is held above the crop by a horizontal super structure centrally pivoted over a wheeled platform in a wing like fashion sprinkler pipeline with the super structure propels slowly and sprays a wide area.

Perforated pipe system

This method consists of holes perforated in the lateral irrigation pipes in a specially designed pattern to distribute water fairly uniformly. This system is usually, designed for low operating pressures of about 1.0 kg cm^2 (10 m of water head). The pressure is so low that the system can be connected to an over head tank to obtain the necessary pressure head. The sprays are directed on both sides of the pipe and can cover a strip of 10 to 15 m wide. This system is well suited for irrigating lawns, gardens and small vegetable fields.

Based on the portability, the sprinkler systems are classified into the following types.

Permanent system

This system has stationary water source and pumping unit. Mains, sub mains and laterals are usually buried. Sprinklers are permanently located on each riser. Such systems are costly and suited to automation of the system with moisture sensing devices.

Semi permanent system

This system has portable lateral lines, permanent main lines and sub mains and a stationary water source and pumping unit. Mains, sub mains and laterals are usually buried, with riser for valves located at suitable intervals.

Portable system

This system has portable main lines, laterals and a portable pumping unit. It is designed to be moved from field to field or to different pump sites in the same field. For portability the unit is equipped with wheels.

Semi-portable system

It is similar to portable system except that the location of water source and pumping units are fixed. It can be used on more than one field where there is extended main line, but may not be used on more than one farm unless there are additional pumping units.

Solid set system

This system has enough laterals to eliminate their movement. Laterals are positioned in the field early in the season and remain in the field for the season. It is used for crops requiring frequent irrigations.

Sprinkler irrigation for different horticultural systems

Ground cover landscape irrigation

Sprinklers waters a large area. They are particularly useful in irrigating ground covers. The objective in designing a superior landscape irrigation system is to apply the same amount of water over the area being irrigated within the same window of time; this concept is called distribution uniformity. It is a key element for a high quality irrigation design.

Poor uniformity results in over watering in some areas and under watering in other areas. The amount of water is applied in terms of depth per unit area and time to the surface. The amount of water applied must not exceed the 'infiltration rate' and will vary greatly based on soil type and degree of compaction. Different areas of the landscape may well have different infiltration rates and water holding capabilities, therefore will have differing water requirements. Beds are different than sod, for example. For this reason a basic rule of landscape irrigation design is to never water beds and sod at the same time (in the same zone). It is impossible to do both things well simultaneously.

Bedding plants

Bedding plants are typically grown on benches or on the floor with walk isles between the blocks of plants. Installation required for designing a system includes the width of other tables or blocks, length of the tables or blocks and the height of the plant material at maturity. This scenario usually calls for an overhead device being installed on lengths of tubing called drops. Sprinklers that produce small droplets are installed on the drops and spaced appropriately for the performance of the sprinkler.

It is desirable that the pattern of the sprinkler be confined to the width of the table or block. These sprinklers are also equipped with anti-leak devices to assure that they start and stop simultaneously. Since cycle times are usually short, it is important that the best possible distribution uniformity be achieved. This is done by carefully selecting the flow rate of the device, the diameter of its pattern and the spacing required down the lateral to achieve the desired uniformity.

Propagation Systems

Propagation systems are similar in all respects to bedding plants except that the irrigation device is most often some type of mister or fogger. In this application it is desired only to keep a small amount of moisture on the surface of what is being grown. The media is not saturated. This is where cycles of five seconds on, five minutes off from six o' clock in the morning until six o'clock at night is followed. Since the droplet size of the devices available for this application is so small great care must be given to proper spacing of the devices. Typically the diameter of a mister would be limited to 150 cm (5 feet). If there is any wind movement in the green house it will greatly affect the pattern of the system.

Plantation crops

Tea

Irrigation is found to increase yield in mature tea. In young tea, yield increases due to sprinkler irrigation when compared to sub-soil irrigation. Among different methods of irrigation, sprinkler irrigation is suitable for both young and mature tea.

Questions

1. Indicate the physical characteristics of farm suitable for sprinkler irrigation method
2. What are the four major components of a typical sprinkler system?
3. How does a sprinkler rotate?
4. Write the points to be considered for the capacity of the pump.
5. Application efficiency of sprinkler system is affected by high wind speed.(True/False)

   Ans: True

Lecture No.13

Drip irrigation – Suitability for crop, soil, topography and climate

Introduction

Drip irrigation is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 litres/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied close to plants so that only part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involves wetting the whole soil profile. With drip irrigation, water applications are more frequent (usually every 1-3 days) than with other methods and this provided a very favorable high moisture level in the soil in which plants can flourish.

A typical drip irrigation system consists of the following components:

- Pump unit
- Control head
- Main and sub mainlines
- Laterals
- Emitters or drippers

The pump unit takes water from the source and provides the right pressure for delivery into the pipe system.

The control head consists of valves to control the discharge and pressure in the entire system. It may also have filters to clear the water. Common types of filter include screen filters and graded sand filters which remove fine material suspended in the water. Some control head units contain a fertilizer or nutrient tank. These slowly add a measured dose of fertilizer into the water during irrigation. This is one of the major advantages of drip irrigation over other methods.

Suitable crops

Drip irrigation is most suitable for row vegetables, soft fruit trees and vine crops where one or more emitters can be provided for each plant. Generally only high value crops are considered because of the high capital costs of installing a drip system.

Suitable slopes

Drip irrigation is adaptable to any farmable slope. Normally the crop would be planted along contour lines and the water supply pipes (laterals) would be laid along the contour also. This is done to minimize changes in emitter discharge as a result of land elevation changes.

Suitable soils

Drip irrigation is suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

Suitable irrigation water

One of the main problems with drip irrigation is blockage of the emitters. All emitters have very small waterways ranging from 0.2-2.0 mm in diameter and these can become blocked if the water is not clean. Thus it is essential for irrigation water to be free of sediments. If this is not so then filtration of the irrigation water will be needed.

Blockage may also occur if the water contains algae, fertilizer deposits and dissolved chemicals which precipitate such as calcium and iron. Filtration may remove some of the materials but the problem may be complex to solve and requires an experienced engineer or consultation with the equipment dealer.

Drip irrigation is particularly suitable for water of poor quality (saline water). Dripping water to individual plants also means that the method can be very efficient in water use. For this reason it is most suitable when water is scarce.

Modifications of drip irrigation system

In recent years, several modifications of drip system have been developed in the continuing effort to improve water use efficiency. The modifications are surface drip irrigation, sub-surface irrigation, low – head bubbler irrigation, micro-spray irrigation, mechanical move irrigation and pulse irrigation.

Drip irrigation for different horticultural systems:

1. Nursery irrigation to field grown nursery stock

The length of the row will determine the size of tubing required. The objective is to evenly wet the row and manage the water in the root zone. Water that move out of this target zone is lost to the plant and represents a wasted resource. In most cases, it is difficult to apply all of the water needed in a day without losing water from the root zone. Hence water has to be applied more than once a day and as many times as necessary to supply the total amount required. It is called pulse irrigation. Fertilizer and other materials can be applied with safe limits and precautions.

2. Container Irrigation

Irrigation of containers is different from field grown crops in that it has a confined space above ground subject to temperature extremes, artificial growing medium such as pine bark, excessive air movement around containers, and the force of gravity.

Problem is, it takes the same amount of water to grow a crop in a container as it does in the field: however there is no reservoir to store the water except for the medium, which is usually very coarse. If too much water is applied at one time, or in only one place in the container, the water will quickly channel through the media and out of the pot.

To help prevent channeling, small spray sticks are often used to spread the water over the surface of the container. However, these devices are not pressure compensating. In effect, the amount of water that flows from each one depends on the pressure forcing it. The amount of water can vary significantly down a line of pots causing variations in flow of as much as 50% from one end of a line to the other. This variation means that containers getting the least amount water have to be watered longer to satisfy their needs thereby over watering the containers getting more (higher pressure). If the grower is injecting fertilizer into his system, the problem is compounded by over applying fertilizer in some containers while not getting enough in others.

3. Greenhouse Irrigation

There are many variations of greenhouse irrigation system layouts. The critical thing is to establish what crops will be grown. The total volume of water required is dependent on what is being irrigated. Irrigation in containers generally required relatively low flow rates per greenhouse, while propagation and bedding plants generally require overhead irrigation with comparatively higher flow rates per house.

Control of greenhouse irrigation: Since all greenhouse irrigation applications require high frequency irrigation, automation of these types of systems using an irrigation controller is the rule rather than the exception. Depending on the specifics of the crop, the controller should offer the capability of multiple programmes, and in the case of propagation the option to programme in seconds and minutes for a given window of operation time (called a loop). It is virtually impossible to irrigate greenhouse crops efficiently without the use of automation. The cost of automation is minuscule compared to the cost of labour to effectively irrigate greenhouse crops.

i) Hanging baskets: Hanging baskets are most effectively watered using a dripper with a flow rate 2.25 litres /hr installed on the lateral line attached to a structural member of the greenhouse. A small diameter tube is attached to the outlet of dripper. At the other end a plastic weight rests in the basket.

The dripper should be pressure compensated and equipped with a device that allows the watering to begin instantly when the pressure rises above a certain point. It should also shut off instantly when the pressure drops to that point. All devices connected to that particular valve will start and stop irrigating at precisely the same time.

All baskets will be watered evenly. Greenhouse growers almost always inject fertilizer through their water. The equipment described above assures 94% distribution uniformity. Each pot gets the same amount of water and nutrient. Uniformity in irrigation leads to uniformity in production. Uniformity in production means a higher value crop. The goal of the grower should be to produce as uniform a crop as is technically possible.

ii) Bench pot watering systems: The most beneficial selection of product for this application is to choose a dripper 2 to 10 litres per hour and divide its flow rate among multiple containers (4-8). A pressure compensating device and attachment of a multiple outlet adapter to the outlet of the dripper is considered.

Small diameter tubes are then connected to the multiple outlets of the adapter and run to each individual container. A small stake, which serves as a secondary dripper, is put into the tubing and installed in the pot. Each pot receives the same amount of water in the same amount of time. Flow rates may range from as low as 0.6 l/ hr to 1.2 l/hr per container.

4. Watering the established woody landscape

Soaker hoses

Soaker hoses can be snaked through a landscape planting and hidden from sight with mulch. Rubber soaker hoses ooze water to provide a slow application.

Watering bags

Watering bags are useful for newly transplanted trees located where watering is not easily done. Tiny holes in the bag allow the water to slowly seep in to the ground.

Soil watering needle

Soil watering needles supply water directly to the root zone of the plants. The needle is inserted a number of times around the tree or shrub to assure thorough watering.

Microirrigation

This method is a closed type characterized by low operating pressure and small orifice size. It is much preferred in areas of local rainfall. Once established this method is very efficient. Runoff and evaporation losses are minimized.

Questions

1. Generally only high value crops are considered because of the high capital costs of installing a drip system.
2. Mention the components of a typical drip irrigation system.
3. Drip irrigation is the best choice to maximize efficiency in irrigation system. A properly designed and installed drip system can deliver up to 95% efficiency.
4. How does container irrigation differ from field irrigation?
5. Explain briefly the necessity for automation of green house irrigation.

Lecture No.14

Concept of fertigation -fertilizers and instruments - time of application - advantages

Introduction

"Fertigation" is a word of recent origin and is a combination of clipped words of fertilizer and irrigation. So also this method combines the application of water and plant nutrients effecting both water and fertilizers saving and enhancing yields and quality of crops simultaneously.

Advantages of Drip fertigation

1. Improves efficiency in fertilizer use. Generally 60 to 80 per cent of the recommended dose of fertilizers through water soluble form was observed to be sufficient and secure equivalent yields of crops as obtained with the application of 100 per cent straight fertilizers.
2. High nutrient availability due to maintenance of soil moisture near field capacity under drip irrigation.
3. Fertilizers could be applied as frequently as possible and at those stages of crop growth when the demand is maximum.
4. Higher water use efficiency and 30 to 40 per cent economy in the use of irrigation

Characteristics of fertilizers for fertigation

The success of fertigation depends primarily on the characteristics of the fertilizers used.

1. Must be completely soluble in water (< 0.02% insoluble in water) and have quick dissolution in water with minimum content of conditioners.
2. Must not react with dissolved elements in water especially calcium and magnesium salts.
3. High nutrient content in the saturated solution must not get leached down easily from the soil.
4. Should not change the pH of water leading to precipitation and clogging

5. Should avoid corrosion of the system.
6. Should be safer for field use and for mixing with other chemicals.

Sources of nutrients

1. Nitrogen: Urea, ammonium nitrate and ammonium sulphate nitrogenous fertilizers are suggested for fertigation. The content of nutrients in solid form and under saturated liquid form is given in the Table 1.

2. Phosphorus: Generally the application of phosphatic fertilizers through the drip irrigation system is not recommended because in majority of the cases basal application of phosphorus satisfies the plant P needs. Applied phosphorus creates chemical and physical precipitation leading to clogging problems.

Phosphoric acid being soluble with low pH, no clogging occurs with orthophosphate. Inorganic phosphorus like Mono Ammonium phosphate and Di ammonium phosphate are the other sources of phosphorus for fertigation.

3. Potassium: Potassium is easily soluble in water, easily leached in sandy soils and can be fed through drip irrigation to maintain a proper N: K ratio for crop production. Potassium as potassium sulphate, potassium chloride, potassium nitrate and mono potassium phosphate may be used through drip irrigation since these are soluble in water and do not cause any precipitation problem.

Among the different fertilizers, sulphate containing fertilizers can cause problems if irrigation water contains lot of calcium by forming insoluble calcium sulphate. Chloride containing fertilizers should not be used on certain crops like strawberry and tobacco. Phosphatic fertilizers can also become insoluble at high pH, of forming relatively insoluble calcium and magnesium phosphate.

Table 1.Nutrient (N, P_2O_5, K_2O) content of common fertilizers suitable for fertigation in their solid and saturated liquid forms

Nutrient	Fertilizer	$N:P_2O_5:K_2O$ under solid form	$N:P_2O_5:K_2O$ Under saturated liquid form
Nitrogen	Urea	46:0:0	21:0:0
	Ammonium Nitrate	33:0:0	21:0:0
	Ammonium Sulphate	21:0:0	10:0:0
Phosphorus	Phosphoric acid	-	0:61:0
	Mono Ammonium Phosphate	12:61:0	4:18:0
	Di Ammonium Phosphate	18:46:0	7:25:0
Potassium	Potassium Chloride	0:0:60	0:0:15
	Potassium Nitrate	13:0:46	4:0:12
	Potassium Sulphate	0:0:50	0:0:6
	Mono-Potassium Phosphate	0:52:34	0:10:7

4. Liquid fertilizers: Liquid fertilizers contain one or more plant nutrients including micronutrients. The raw materials used in liquid fertilizer production are mainly bulk fertilizers such as ammonium sulphate, ammonium nitrate, Urea, ammonium phosphate, phosphoric acid, potassium nitrate, potassium chloride, potassium sulphate etc. The liquid fertilizers are pure and do not precipitate. Normally the liquid fertilizers are acidic (pH 5.5-6.5) and help in correcting the soil pH to some extent and also help in the prevention of clogging of emitters. For acidic soils, liquid fertilizers with neutral pH or even higher pH could be used.

5. Chloride free fertilizers: These fertilizers are produced by using Urea, ammonium nitrate phosphate and potassium nitrate as basic ingredients and are useful for high value crops and crops which are more sensitive to the chloride injury. Ex: Tobacco, grapes, citrus, arecanut and vegetables.

6. Normal fertilizers: These are produced by using ammonium nitrate, urea, ammonium phosphate, ammonium sulphate, phosphoric acid, potassium chloride etc.

7. Micro nutrients: Micronutrients are generally applied separately to plants in most soils as their application through fertigation would react with salts in the irrigation water and cause precipitation and clogging. Chelated micronutrients are highly water soluble and can be applied through fertigation since they cause very little clogging or precipitation.

8. Fertilizers unsuitable for fertigation: Some fertilizers like (1) Aqueous ammonia (2) Calcium nitrate (3) Calcium ammonium nitrate (4) Potassium sulphate (5) Zinc nitrate and (6) Ferric sulphate are not suitable for using in fertigation due to precipitation and clogging problems

Concentration of nutrients

For proper growth, plants need to be supplied with following nutrients either alone or combination at appropriate concentrations viz., nitrogen (150-200 ppm), Phosphorus (50 ppm), Potassium (200-400 ppm), Calcium (150-200 ppm), magnesium (50 ppm), boron (0.2 ppm), zinc (0.1 ppm) Copper (0.1 ppm), Manganese (1 ppm), iron (5 ppm) and molybdenum (0.05 ppm).

Precautions to be taken during fertigation

- Perfect design of irrigation system. Every emitting point must deliver the same volume of water.
- The material used must be free from deposits or residues and must not cause corrosion of system.
- Constant operating pressure to facilitate uniform mixing of water and fertilizers.
- Selection of most appropriate fertilizer, injection system and crops for fertigation.

- Fertilizer injection should not begin until all lines are filled with water and emitters are working.
- Drip irrigation system should be allowed to its working pressure prior to fertilizer injection.
- Fertilizers/pesticides/chlorine should not be injected at the same time.

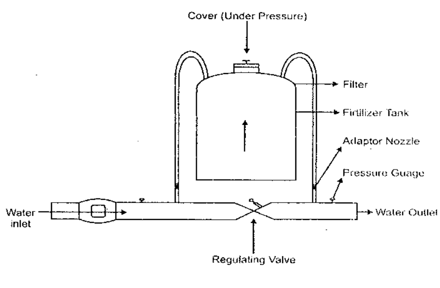
Time of application

Since plant nutrients are the source of food for growth, development and yield of crops, their application must be ensured as and when they require to attain the potential yield of crops envisaged. The frequency of fertigation is governed by the nature of crop, duration, growth habit and yielding ability. Generally fertigation is done daily, weekly, fortnightly and can be considered depending on crop response.

Fertigation equipments

1. Pressure differential method or By-pass tank system

In this system solid fertilizers soluble in water and liquid fertilizers can be injected into the system. A tank containing fertilizer solution is connected to the irrigation pipe at the supply point. A small part of the irrigation water is diverted through the tank diluting the nutrient solution and returning to the main supply pipe. The concentration of fertilizer in the tank becomes gradually reduced with time.



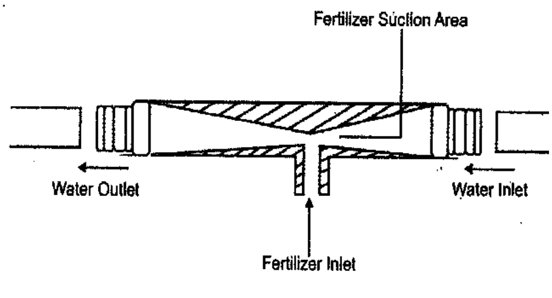


Fig Installation of a bye-pass tank Fig Cross section of a ventury pump

2. Ventury or vacuum pump

This system is ideal for liquid fertilizers. It has low discharge rate. The nutrient concentration and quantity controls are medium. It delivers fertilizer at constant concentration which depends on the water flow. It should be connected in parallel with the pipe line. It is a cheap system but there will be pressure drop in the system.

3. Displacement pump

This system is also for liquid fertilizers. The concentration of nutrient and quantity control is good. The automatic control is of higher order. It is more accurate but the cost is high. Fertilizer solution is prepared in a tank from which it is pumped and injected into the irrigation system. The fertilizer solution is delivered at a constant concentration. The impeller and casing of such a pump must be made of non-corrosive material such as nylon or polycarbonates. It needs separate power source.

4. Hydraulic dosing pumps or non electric proportional injectors

The injection mechanism is driven by the water supply under pressure. The injection rate is factory pre-set or may be chosen by an adjustable setting on injector body. The injection rate is proportional to the flow of water passing through. The resulting solution strength is constant even though the water flow varies.

Disadvantages of fertigation

- Uneven nutrient distribution occurs when the irrigation system is faulty. It leads to over fertilization or leaching of nutrients when excess water is applied to crops.
- Chemical reactions of fertilizer with calcium and magnesium, bicarbonates in water, which can lead to chemical clogging.
- Suitable for readily soluble or liquid fertilizers. Phosphatic fertilizer and some micronutrients may precipitate in micro-irrigation system.
- Corrosion resistant fertigation equipments are needed.
- Potential chemical backflow into the water supply source.

Fertigation through sub-surface irrigation

The high labour requirement in spreading and collecting laterals every season, and the deterioration of exposed drip lines limit further expansion. Subsurface location of trickles may solve these problems. Further more, it would position the supply of nutrients in the centre of root system, where the water content is relatively high and steady with time. Nutrients introduced via sub-surface trickles can move in a spherical volume around the emitter, while transport in surface application is bounded within a hemisphere below the point source. The higher moisture content, greater root density, and larger soil volume favours P uptake to a significant level. It was observed that weed growth in sub-surface treatment was considerably lesser than surface placement

Questions

1. Drip method of irrigation is most suitable for applying fertilizer through irrigation water (True/False)

   Ans: True

2. In fertigation the saving of nutrients is possible (True/False)

   Ans: True

3. Application of phosphatic fertilizers are recommended through irrigation water (True/False)

   Ans: True

4. Sulphate containing fertilizers are more suitable for fertigation (True/False)

   Ans: True

5. Ventury pump is ideal for applying liquid fertilizers (True/False)

   Ans: True

6. Application of nitrogen fertilizers should have a concentration min the range of 150-200 ppm(True/False)

   Ans: True

Lecture No.15

WUE – Factors affecting – Methods to improve economic use of water for irrigation – Water use for maximum profit of garden/orchard ecosystem

Water use efficiency is defined as the yield of marketable crop produced per unit of water used in evapotranspiration. It is expressed as WUE=Y/ET

Where WUE is water use efficiency (Kg/ha-mm); Y the marketable yield(kg/ha) and ET is evapotranspiration (mm).

Factors affecting WUE

I. Nature of the plant

II. Climatic conditions

III. Soil moisture content

IV. Fertilizers

V. Plant population

Methods to improve economic use of water for irrigation:

1. Unlimited water supply conditions

a. Conservation of water

1. Reduce conveyance losses by lining channels or preferably by using closed conduits.
2. Reduce direct evaporation during irrigation by avoiding midday sprinkling and minimize foliar interception by under canopy by overhead sprinkling.
3. Reduce run-off and percolation losses due to over irrigation.
4. Reduce evaporation from bare soil by mulching and by keeping inter – row strips dry.

5. Reduce transpiration by weeds, keeping the inter-row strips dry and applying weed control measures where ever needed.

b. Enhancement of crop growth

1. Select most suitable and marketable crops for the region.
2. Use optimal timing for tillage, planting and harvesting
3. Use appropriate insect, parasite and disease control
4. Effective fertilization
5. Conserving soil and avoiding progressive salinization for long-term sustainability
6. Irrigating at high frequency and at amount required

Irrigation is practiced to achieve maximum yield per unit of land and ultimately the profit. When water is becoming scarce maximum yield per unit of water utilized is the concern. A grower is usually concerned about maximizing profit. When water is plentiful and inexpensive this is nearly the same as irrigation for maximum yield. However as irrigation rates approach those needed for maximum yields, water use efficiency declines. If water is scarce or very expensive the interest shifts toward obtaining maximum yield per unit of water applied. This shift usually involves deficit irrigations and the duration of stress, the marketable plant product and the stage of growth when stress occurs. One must consider the economics of deficit irrigation by comparing the savings that result from reducing deficit irrigation to achieve the reductions and the value of crop yield lost that may accompany reduced irrigation.

2. Limited water supply conditions

The following points may be considered for managing limited or deficit water supply for getting maximum yield and profit.

a. Deep soils that have moderately high water holding capacities are suited to deficit irrigation.
b. Drought resistant crops
c. Crop growth stage at which irrigation deficits are imposed

d. Pre-plant irrigation is needed or not, conveyance and application efficiency, water infiltration rates and runoff, thus reducing required application amounts

e. Precipitation need to be considered for crop water requirements

f. Cultural practices need to be modified to reduce the ET.

a. Deep soils that have moderately high water holding capacities

The amount of water stored in the soil profile and available to a crop to supplement low irrigation rates during high water use periods is an important factor in limited irrigation. Moderate to high amounts of stored water allow water deficits to develop gradually and thus improve the plants' ability to stand water stress. Small amounts of water allow rapid development of stress within the plant and increase the risk of yield reduction. Low storage may be due to shallow root restricting layers, coarse-textures or subsoil depleted of available water. A soil with a coarse surface texture but underlaid by fine material may store enough profile water to be productive under deficit irrigation.

b. Use of drought resistant crops

Drought resistance is the ability of a crop to grow satisfactorily in areas subject to deficit water. Mechanisms or adaptations have evolved in higher plants that favour survival and growth with inadequate or irregular water supplies. These mechanisms have been classified as drought escape, avoidance and tolerance.

c. Growth stages of the crop

Water is essential for the growth of plants from germination through physiological maturity but the sensitivity to water deficit changes during the growing season.

Increased water-use efficiency can be achieved though selection of the crops to be grown according to the expected water supplies (rain and irrigation) and by consideration of the stage of plant growth at which water stress is imposed. Crop production should be timed so that the most sensitive stages of plant development will be completed when deficient water is least likely. A major factor is the marketable plant product, whether vegetative growth, a seed, or a fruit. Because of the great variation among species in the harvested plant part and in the sensitivity to water stress at various growth stages, it is appropriate to discuss crops in general groups.

i) Crops grown for seed or grain

Growth stages for this group can be classified roughly as early vegetative, reproductive and seed fill. The decrease in yield and quality of seed due to water stress is markedly influenced by the growth stage at which the stress occurs. It is generally accepted that water stress causes the most crop injury and yield reduction when it occurs during reproduction, especially during pollination. Excess water stress at this time can irreversibly damage crops to such an extent that yields are reduced, regardless of later water regimes. Flowering and pollination are usually associated with high rates of water-use so internal water stress can develop rapidly if soil water is deficient. The early vegetative and seed maturation stages of development are only slightly sensitive to water stress.

ii) Vegetable crops

Vegetable crops are sensitive to water stress because the marketable product is usually a fresh fruit, tuber or vegetative growth. In these crop products the water content at harvest is an important quality item. They are more sensitive to water deficits than crops grown for dry matter. These crops can tolerate mild stress and then resume near normal growth when the stress is alleviated.

Potatoes are considered to be high water users and the marketable product is the tubers. Deficit irrigation during tuber development will cause small tubers and reduce yields. Both total yield and quality (marketable yield) are affected by water stress and this effect varies greatly with the cultivar.

Tomato production is sensitive to water deficits in the flowering stage. Stress at this time can cause shedding of young fruits.

iii) Fruit trees

Irrigation requirements for fruit trees differ from those of field crops in several important aspects: (1) several years usually are required from planting until a marketable yield is produced (2) water is major component of the commercial product, the fleshy part of the reproductive organ (3) there is a long-term cumulative response of fruit trees to water regime and (4) the crop is relatively high-valued compared to the cost of irrigation. Proper irrigation according to specific requirements of the tree under specific climatic and soil conditions will have a marked effect on the yield and quality of product.

When an orchard is first established, transpiration is very low because of the small crop canopy. Most water is lost from the soil by evaporation and the transpiration is minimum from the trees. Considerable savings in irrigation water can be achieved by eliminating this superfluous ET. One way to do this is by using drip irrigation. With drip irrigation only a small volume of soil near the tree is kept wet, eliminating any application between trees. Roots are effectively restricted to the wetted volume and this has caused apple trees to set fruit one or two years earlier than when sprinkler irrigation was used. After a full canopy had developed, differences in irrigation water requirements due to the method of application were small.

A successful flowering and pollination period is essential to a fruit crop. With deciduous trees, this stage of growth occurs before leaf development, while ET is low and there usually is soil water available from winter precipitation. Water stress during blossoming and fruit setting is less likely than during fruit development and maturation.

A recent development in fruit production is the manipulation of the root/shoot ratio through use of regulated deficit irrigation. By withholding or reducing irrigation during the early season, when fruit growth is slow, excessive vegetative growth is controlled. Resumption of full irrigation when the fruit grows rapidly assures a high quality fruit. The period of deficit irrigation stimulates later fruit growth with the result of more fruit on a smaller tree, compared with full season irrigation.

It is essential that soil water be easily available during the time of rapid fruit growth and maturation. Fruits that mature under a water deficit are small with low water content and high soluble solids. This negative effect of water stress on fruit size and water content may be more important in the market place than the total yield.

An evergreen fruit crop such as citrus requires water throughout the year. They are also grown widely in arid and semiarid regions so that more consideration must be given to an adequate soil water supply during blossoming and fruit setting than with deciduous trees. Water requirements for citrus vary widely both among species and with differences among locations. The cumulative response of citrus to wet and dry irrigation regimes was demonstrated in Israel for a young grove. Yields at all irrigation levels increased each year but the rate of increase was much higher with adequate than with inadequate irrigation.

d. Preplant irrigation

Pre-plant irrigation accomplishes several objectives. Three are important (i) Storing water in the soil profile for later crop use (ii) Germinating weed seeds so the seedlings are killed in the preparatory tillage before planting and (iii) Providing adequate seed zone water for germination, emergence and early crop development.

e. Precipitation needs to be considered for crop water requirements

The precipitation is to be taken into account in working out water needs of crops. The contribution of precipitation in reducing the irrigation requirement is achieved by using it for stand establishment, partial wetting of the profile for intake of rain water, reducing runoff due to precipitation and withholding irrigation at the time of precipitation and timely withdrawal of irrigation at the end of growing season.

f. Cultural practices need to be modified to reduce the ET

Conservation tillage, residue management, moderate plant densities, flexible planting dates, short duration crops and use of fallow are some of the cultural practices considered under limiting irrigated situations to reduce the ET.

Water use for maximum profit of garden/orchard ecosystem:

The returns for the water applied can be calculated as rupees per ha-cm of water applied. A higher level of return is possible by enhancing the profit and reducing the water utilized. This may be achieved by the following way.

- Selection of high value crop and high yielding varieties
- Optimum plant population
- Optimum production packages for higher yield
- Minimizing water loss during irrigation

- Suitable method of irrigation for minimizing irrigation water requirement
- Scheduling of irrigation by following scientific principles
- Reducing cost of production

Questions

1. Weed management is an essential part of crop production for reducing transpiration losses besides minimizing the competition for nutrients and sun light. (True /false)

Ans: True

2. Irrigation is practiced to achieve maximum yield per unit of water and ultimately the profit but when water is becoming scarce maximum yield per unit of utilized is the concern.(True /false)

Ans: True

3. Deep soils that have moderately high water holding capacities are suited to deficit irrigation.(True /false)

Ans: True

4. Vegetable crops are sensitive to water stress because the marketable product is usually a fresh fruit, tuber, or vegetative growth. (True/False)

Ans: True

5. Irrigation requirements for fruit crops differ from those of field crops in several important aspects like several years required from planting to production of marketable yield.(True /false)

Ans: True

Lecture No. 16

Water and irrigation management for different crops and soils. Water management for problem soils

Irrigation water is a manageable input in crop production. As such it should be managed on scientific lines to optimize crop production by avoiding excessive applications leading to water logging and wastage of scarce irrigation water. The objective of the water management is not always been in obtaining the highest yield per unit land area. In this present day context it is the sustained profit which assumes the prime importance. A it was discussed previously, The crop growing environment like climate and soil types vary from place to place. Hence the practices developed also vary from place to place and is also applicable on water management practices. The experiments conducted in these places and assessment of water requirement and scheduling can be taken as a guide for irrigation and water management.

In arid and semi-arid regions soils are affected due to rise in water table and accumulation of salts leading to unfavourable soil-water – plant relationships and decrease in crop productivity.

Water management for problem soils

a. Water logged soils

Water logging is caused in a location when the inflow of water into it exceeds the outflow resulting in progressive rise of water table. The inflow may be due to excessive and high intensity rainfall, seepage from canals, reservoirs, flood and over-irrigation. The outflow declines with impaired drainage, lack of adequate drainage, rise of water table owing to construction of reservoirs and rise in water level in rivers.

Signs of bad drainage

There may be a number of indications by which a land can be identified as badly drained land. Soil is very soft and wet. It sticks to farm implements and tools and feet of animals and shoes of farm labourers. Occurrence of spots or pools of free water and may be flowing out of the field from side of ditches or over the soil surface. Presence of good growth of bright green grasses or weeds in some places and aquatic and water loving plants are seen growing. When crops are sown, seedlings grow slowly. Many seeds may not germinate as there is excess water in the soil. Plants look usually yellowish or pale colour and unhealthy and are stunted in growth.

Effects of water logging and excess soil water on crops and soils

Water logging condition and presence of excess water in soil have various harmful effects on crops, soils and farm animals. The first and foremost effect is on the aeration of soil, which is essential for plants to carry on various vital activities. Root growth, availability of nutrients and their uptake, escape of carbon dioxide and other harmful gases produced in the soil, optimal activity of useful bacteria do not take place properly.

Methods of drainage

Two methods of land drainage are adopted and they are: (i) surface drainage and (ii) subsurface drainage. Besides, pumps may be used to drain out water from lower lands and to lower the high water table affecting crop growth.

Surface drainage

Surface drainage consists of disposal of surplus water by gravity flow from accumulating on the land surface and getting into the soil profile raising the ground water table to a problematic level.

Component drains of surface drainage system

A drainage system consists of main, sub mains, laterals and field drains for effectively disposing drain water. Besides, there is an outlet at the end of the main drain which is located outside the farm. Outlets are often provided with covers that prevent cattle getting into the farm.

Subsurface Drains

These drains are laid below the soil surface and are covered. They do not interfere with normal movement of farm implements and cultivation practices and no area is wasted for constructing drains. Different types of materials are used for construction of subsurface drains. These may be short clay, concrete or plastic pipes, fibrous wood materials, covered stone drains and bituminous fibrous materials.

Various other types of drainage devices

Setting up various other drainage devices can lower water table in an area. They may be mole drain bamboo or wooden pole drain, stone drain and drainage wells.

Mole drains

This type of drain is a continuous round passage at a depth of 75 cm ,10-12 cm in diameter and spaced 4-5 metres apart in the soil profile to drain water from the crop field in a grade of 0.05 to 0.10%. They are made with a mole plough. The suitable soil type is clay and may last for two to three years.

Bamboo or pole drains

A cheap way of making temporary underground drains is by using bamboo or wooden poles in the shape of triangles with 60-90 cm deep and 30-40 cm wide. It is enveloped with leaves, small twigs and pebbles and then covered with soil and connected to the main drain.

Stone drains

Small drains at 30-40 cm depths are dug and stone pieces are laid in a fashion to construct a continuous rectangular channel. Drains are covered with leaves, twigs and small pebbles and soil at the top allowing regular farming practices. The drains are more durable than bamboo or pole drains.

Drainage by wells and pumps

Construction of wells and then draining water can lower high water table. The well may be gravity wells located in an unconfined aquifer to remove water directly from the crop root zone, or well to tap an aquifer containing water under pressure.

Pumps can be successfully used to drain out accumulated water in lower lands or to lower the water table by pumping water out to another area or to a natural drainage passage. This water may be used for irrigation to crops in the surrounding area, if the quality of water is good or safe for use in crops.

b. Salinity

A soil may be rich in salts because the parent rock from which it was formed contains salts. Sea water is another source of salts in low-lying areas along the coast. A very common source of salts in irrigated soils is the irrigation water itself. Most irrigation waters contain some salts.

After irrigation, the water added to the soil is used by the crop or evaporates directly from the moist soil. The salt, however, is left behind in the soil. If not removed, it accumulates in the soil; this process is called salinization. Very salty soils are sometimes recognizable by a white layer of dry salt on the soil surface. Salty groundwater may also contribute to salinization.

i. Water Salinity

Water salinity is the amount of salt contained in the water. It is also called the "salt concentration" and may be expressed in grams of salt per litre of water (grams/litre or g/l), or in milligrams per litre (which is the same as parts per million, ppm) .However, the salinity of both water and soil is easily measured by means of an electrical device. It is then expressed in terms of electrical conductivity: millimhos/cm or micromhos/cm. A salt concentration of 1 gram per litre is about 1.5 millmhos/cm. Thus a concentration of 3 grams per litre will be about the same as 4.5 milliomhos/cm.

Irrigation water quality

The suitability of water for irrigation depends on the amount and the type of salt the irrigation water contains. The higher the salt concentration of the irrigation water, the greater the risk of salinization. The following table gives an idea of the risk of salinzation:

Salt concentration of the irrigation water in g/l	**Soil salinization risk**	**Restriction on use**
Less than 0.5 g/l	No risk	No restriction on its use
0.5-2 g/l	slight to moderate risk	Should be used with appropriate water management practices.
More than 2 g/l	high risk	Not generally advised for use unless consulted with specialists.

Higher the concentration of sodium present in the irrigation water (particularly compared to other soils), the higher the risk.

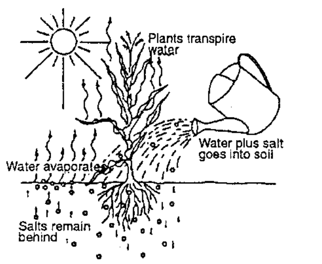


Fig. Salinization, caused by salty irrigation water

ii. Soil Salinity

The salt concentration in the water extracted from a saturated soil (called saturation extract) defines the salinity of the soil. If this water contains less than 3 grams of salt per litre, the soil is said to be non saline. If the salt concentration of the saturation extract contains more than 12 g/l, the soil is said to be highly saline.

Salt concentration of the soil in g/l	**water (saturation extract) in millimhos/cm**	**Salinity**
0 -3	0-4.5	non saline
3 -6	4.5-9.0	slightly saline
6 -12	9.0-18.0	medium saline

more than 12	more than 18	highly saline

Crops and saline soils

Most crops do not grow well on soils that contain salts.One reason is that salt causes a reduction in the rate and amount of water that the plant roots can take up from the soil. Also, some salts are toxic to plants when present in high concentration.

Some plants are more tolerant to a high salt concentration than others. Some examples are given in the following table:

Highly tolerant	Moderately tolerant	Sensitive
Date palm	Tomato	Peas
Sugarbeet	Potatoes	Beans
Asparagus	Carrot	Pear
Spinach	Onion	Apple
	Cucumber	Orange
	Pomegranate	Prune
	Fig	Almond
	Olive	Apricot
	Grape	Peach

The highly tolerant crops can withstand a salt concentration of the saturation extract up to 10 g/l. The moderately tolerant crops can withstand salt concentration up to 5 g/l. The limit of the sensitive group is about 2.5 g/l.

Improvement of saline Soils

Improvement of saline soils implies the reduction of the salt concentration of the soil to a level that is not harmful to the crops.

More water is applied to the field than is required for crop growth. This additional water infiltrates into the soil and percolates through the root zone. During percolation, it takes up part of the salts in the soil and takes these along to deeper soil layers, the water washes the salts out of the root zone. This washing process is called leaching. The additional water required for leaching must be removed from the root zone by means of a subsurface drainage system.

Prevention of salinization

Soils will become salty if salts are allowed to accumulate. Proper irrigation management and adequate drainage are not only important measures for the improvement of salty soils, they are also essential for the prevention of salinization.

c. Sodicity

Salty soils usually contain several types of salt. One of these is sodium salt. Where the concentration of sodium salts is high relative to other types of salt, a sodic soil may develop. Sodic soils are characterized by a poor soil structure and they have a low infiltration rate. They are poorly aerated and difficult to cultivate. Thus, sodic soils adversely affect plant's growth.

Improvement of sodic Soils

Improvement of sodic soils implies the reduction of the amount of sodium present in the soil. This is done in two stages. Firstly, chemicals (such as gypsum), which are rich in calcium, are mixed with the soil; secondly the calcium replaced sodium is leached from the root zone by irrigation water.

Irrigation management and drainage

Irrigation systems are never fully efficient. Some water is always lost in canals and on the farmers' fields. Part of these seeps into the soil. While this will help leach salt out of the root zone, it will also contribute to a rise of the water table: a high water table is risky because it may cause the salts to return to the root zone. Therefore, both the water losses and the water table must be strictly controlled. This requires careful management of the irrigation system and a good subsurface drainage system.

Management of poor quality waters

The poor quality water when used continuously the following management points are considered for a sustained crop production.

1. Dilution with good quality water
2. Flooding with good quality water once or twice to flush out salts beyond root zone
3. Gypsum mixing with water to reduce sodium hazards and also to improve soil structure
4. Providing drainage to remove salts
5. Using poor quality water in sandy soils
6. Growing salt tolerant crops
7. Adopting drip irrigation method for poor quality water

Lecture No.17

Lay out of irrigation systems - Comparison of costs

To choose an irrigation method, the farmer must know the advantages and disadvantages of the various methods. He or she must know which method suits the local conditions best. Unfortunately, in many cases there is no single best solution; all methods have the advantages and disadvantages. Testing of the various methods under the prevailing local conditions provides the best basis for a sound choice of irrigation method.

The present days with the modernization of cultivation practices of all the factors influencing on the selection of an irrigation system, the over all cost involved in laying out the method plays a major role. Hence a comparison is not only in terms of physical, biological and agronomical considerations but also on the socio economic consideration is required.

Factors affecting the suitability of an irrigation method

The suitability of the various irrigation methods, i.e. surface, sprinkler or drip irrigation depends mainly on the following factors:

a. Natural conditions
b. Type of crop
c. Type of technology
d. Previous experience with irrigation
e. Required labour inputs
f. Costs and benefits

a. Natural Conditions

The natural conditions such as soil type, slope, climate, water quality and availability have the following impact on the choice of an irrigation method:

Soil type

Sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. On loam or clay soils all three irrigation methods can be used, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation.

When a variety of different soil types is found within one irrigation scheme, sprinkler or drip irrigation are recommended as they will ensure a more even water distribution.

Slope

Sprinkler or drip irrigation are preferred above surface irrigation on steeper or unevenly sloping lands as they require little or no land leveling.

Climate

Strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation is suitable. Sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.

Water availability

Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation and so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.

If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods.

Sprinkler systems are more efficient than surface irrigation methods in leaching out salts.

b. Type of crops

Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high value crops, such as vegetables and fruit trees. They are seldom used for the low value staple crops.

Drip irrigation is suited to irrigating individual plants or trees or row crops such as vegetables. It is not suitable for close growing crops.

c. Type of technology

The type of technology affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. To maintain the equipment a high level of 'know-how' has to be available. Also, a regular supply of fuel and spare parts must be maintained.

Surface irrigation systems – in particular small- scale schemes- usually require less sophisticated equipment for both construction and maintenance (unless pumps are used). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.

d. Previous experience with irrigation

The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. The servicing of the equipment may be problematic and the costs may be high compared to the benefits.

Often it will be easier to improve the traditional irrigation method than to introduce a totally new method.

e. Required labour inputs

Surface irrigation often requires a much higher labour input for construction, operation and maintenance than sprinkler or drip irrigation. Surface irrigation requires accurate land leveling, regular maintenance and a high level of farmers' organization to operate the system. Sprinkler and drip irrigation require little land leveling. System operation and maintenance are less labour intensive.

f. Costs and benefits

Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options. On the cost side not only construction and installation, but also the operation and maintenance (per hectare) should be taken into account. These costs should then be compared with the expected benefits (yields). It is obvious that farmers will only be interested in implementing a certain method if they consider this economically attractive.

Basin, furrow or border irrigation

Flat lands, with a slope of 0.1% or less, are best suited for basin irrigation; little land leveling will be required. If the slope is more than 1% terraces can be constructed. However, the amount of land leveling can be considerable.

Furrow irrigation can be used on flat land (short, near horizontal furrows), and on mildly sloping land with a slope of maximum 0.5%. On steeper sloping land, contour furrows can be used up to a maximum land slope of 3%. A minimum slope of 0.05% is recommended to assist drainage.

Border irrigation can be used on sloping land up to 2% on sandy soil and 5% on clay soil. A minimum slope of 0.05% is recommended to ensure adequate drainage.

All soil types, except coarse sand with an infiltration rate of more than 30 mm/hour, can be used for surface irrigation. If the infiltration rate is higher than 30 mm/hour, sprinkler or drip irrigation should be used.

Furrow irrigation is best used for irrigating row crops such a vegetables and trees. Border irrigation is particularly suitable for close growing crops, row crops and trees.

Required depth of irrigation application

When the irrigation schedule has been determined it is known how much water (in mm) has to be given per irrigation application

Field experience has shown that more water can be applied per irrigation application when using basin irrigation, less with border irrigation and least with furrow irrigation. In practice, in small-scale irrigation projects usually 40-70 mm of water are applied in basin irrigation, 30-60 mm in border irrigation and 20-50 mm in furrow irrigation.

This means that if only little water is to be applied per application e.g. on sandy soils and a shallow rooting crops, furrow irrigation would be most appropriate.

If, on the other hand, a large amount of irrigation water is to be applied per application, e.g. on a clay soil and with a deep rooting crop, border or basin irrigation would be more appropriate.

The above considerations have been summarized in Table 1. The net irrigation application values used are only a rough guide. They result from a combination of soil type and rooting depth. For example, if the soil is sandy and the rooting depth of the crop is medium, it is estimated that the net depth of each irrigation application will be in the order of 35 mm. The last column indicates which irrigation method is most suitable. In this case medium furrows or short borders.

Table 1. Selection of an irrigation method based on the depth of the net irrigation application

Soil type	Rooting depth of the crop	Net irrigation depth per application (mm)	Irrigation method
Sand	Shallow	20-30	Short furrows
	Medium	30-40	Medium furrows, Short borders
	Deep	40-50	Long furrows Medium borders
			Small basins
Loam	Shallow	30-40	Medium furrows, Short borders

	Medium	40-50	Long borders Medium borders
	Deep	50-60	Long borders Small basins Medium basins
Clay	Shallow	40-50	Long furrows Medium borders
	Medium	50-60	Long borders, Small basins Medium basins
	Deep	60-70	Large basins

Relative costs of irrigation methods

The irrigation methods for most of the annual crops are of the combined form of seed bed cum irrigation methods. They last only for a season. No special materials are used. The cost depends on the labour requirement only. For perennial crops also the soil is used as irrigation structures (bunds) and is maintained by periodic rectification. Hence the cost for layout for three seasons may in general involve a higher cost than preparation for one season. The hi tech irrigation systems like sprinkler and drip system involves many of the components of high cost and tend to be more expensive initially than the surface methods. The savings of water relative to surface irrigation and saving of energy relative to sprinkler irrigation can reduce the long term comparative operating costs of drip systems.

Ex.No.1

Measurement of irrigation water : volumetric, 'V'notch, parshal flume, water meters.

Measurement of irrigation water is the prelude for the precise application to the crops and is useful to manage the over or deficit irrigation. In every irrigation project, water is supplied from the reservoir to the field through main canals, distributaries, branch canals, sub-canals and water courses. Different devices are used to measure water flow in channels.

Water Measurement

A. Measurement of still water

Water in storage stage are measured by volumetric method that involves determination of the volume by area occupied by the water multiplied by the average depth of water.

B. Flowing water measurement

Methods used to measure water in the farms can be grouped into (a) Volumetric method, (b) Volume metering method (c) Velocity area method, (d) Using measuring structures and (e) Tracer method.

a)Volumetric method

In this method the flow is collected in a container of known volume for a measured period of time. Only a bucket of known volume and a stop watch are required.

$$\text{Discharge} = \frac{\text{Volume of bucket (litres)}}{\text{Time required to fill up the bucket (second)}}$$

This method is used to measure small discharges of water applied to the field. This method can also be used to determine discharge from a pump or Persian wheel and calibrating orifices and weirs and deriving formula to calculate discharge through them. This method may also be used to measure the flow of water of a stream in to a tank or reservoir.

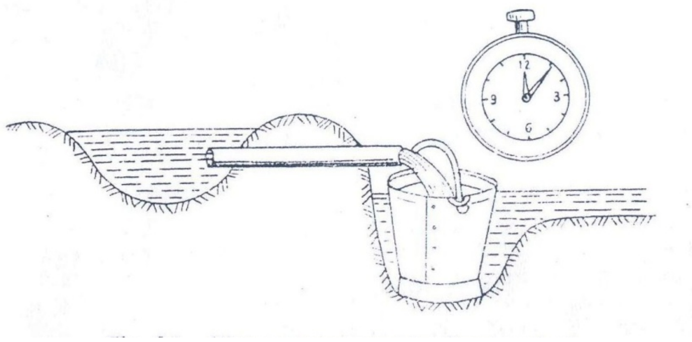


Fig1. Measurement of water by direct method

b) Volume metering methods

Water discharges through pipes may be measured in volume by meters such as water meters. These devices are in the pipe outlets.

Water meter

A water meter contains a multi -blade propeller that rotates in a vertical plane. The propeller is linked to a numerical counter which adds the flow and display in volumetric unit. The meter is fitted in water pipelines. The water flowing through should be free from debris. Water meters are costly and at farms this may not be preferred.

c) Velocity Area Method

The rate of flow passing a point in a pipe, a ditch or channel can be determined by multiplying the cross sectional area of water flow section at right angle to the direction of flow by the average velocity of water.

$Q = A.V$

Q = Discharge (m^3/sec)

A = Cross sectional area (m^2)

V= velocity (m /sec)

Velocity can be measured by float, current meter or tracer method.

i) Float Method

This method gives an approximate flow rate. When water is flowing in a uniform sized channel the cross sectional area is determined at different points of the channel. The channel should be fairly long (25-30 m long, 0.5-0.7 m wide). Place a small float (a wooden piece, a heavy cork with a nail at centre, etc. that will float partially and move uniformly in the direction of flow), a few meter up stream and record the time the float takes to reach a certain distance. Take several observations to reach at a good average velocity. Calculate the discharge (Q=A.V).

ii) Current Meter Method

Velocity can be accurately determined by a current meter. The current meter is a small instrument containing a revolving wheel or vane that turns by the movement of water. The current meter is suspended by a cable for measurement in deep streams or attached to a rod in shallow streams. The number of revolutions of the vane is recorded. These current meters, in general, provide more accurate measurements than the orifices and weirs do.

d) Direct discharge methods

i. Orifices

Orifice is an opening with closed perimeter and of a regular shape through which water flows. Generally, rectangular or circular orifices are constructed, which may of three types. They are of inlet at higher level than the outlet, inlet at a lower level than the out let and submerged type. If the stream of water coming out of orifice discharge in to air, the orifice is said to have free flow and if the discharge is under water, it is called submerged orifice. The depth of water producing discharge is called the head.

Free flow orifice: It can be used to measure relatively small streams like the flow in to border strips, furrows or check basins. The discharge is calculated by the formula:

$$Q= 0.61 \times 10^{-3} \times a \sqrt{2gh}$$

Where,

Q= discharge through orifice (lps)

a= cross sectional area of orifice (cm^2)

g= acceleration due to gravity (981 cm/sec^2)

H= head of the water causing the flow (cm)

Submerged orifice

Submerged orifices may be divided into two type: those having orifices of fixed dimensions and those in which the height of opening may be varied. A standard submerged orifice has fixed dimensions. The opening is sharp edged and usually rectangular, with the width being 2 to 6 times the height. Discharge through a standard orifice may be obtained using the above equation.

Submerged orifice can be conveniently used for measuring small discharges. They do not require a fall in the level of the bed of the channel as is required with weirs. Submerged orifices have the disadvantage of collecting debris, sand and silt above the orifice, preventing accurate measurements.

ii. Weir

A weir is a notch of regular form built across the stream through which water flows. Weirs may be built as stationary structures or these may be portable. In canals of moderately small flow, weirs are set to measure water. Weirs may be made of wood, strong tin plates, galvanized iron sheet or zinc plated canvas. Weirs may be rectangular, trapezoidal or triangular. Partially filled orifice is also a weir. It is desirable to install the weir at a point where there is a drop in the elevation of channel bed to make the flow free.

According to crest the weir may be sharp crested in which water is passing touches only a line, or broad crested having either a rounded up-stream edge or crest so broad that the water is passing comes in contact with a surface. The sharp crested weir is more accurate than broad crested ones.

A weir consists of a weir wall of concrete, timber or metal with a sheet of metal plate fixed to it. Weirs are divided into two broad groups. They are Sharp crested weirs and broad crested weirs. Sharp crested weirs of three types depending on the shape of the notch. Rectangular, trapezoidal and cipoletti weirs. Another type is 90^o triangular weir (V- notch). Rectangular and 90^o V-notch is commonly used on farms.

The basic formula for calculating discharge through a weir is

$$Q = C \times L \times H^m$$

Where,

Q= discharge

C= coefficient, depending up on the nature of crest and approach conditions

L=length of weir crest

H=head on the crest

M=exponent depending upon weir opening.

i) Triangular Weir (90^0 V notch)

The 90^0 triangular or V-notch weir has a greater practical value than any other weir. Since it requires a greater loss of head, it is better adapted to measuring flows not more than ½ litres per second. It is relatively accurate at very low flows. It is easy to construct and install.

$Q = 0.0138\ H^{5/2}$ (litres/sec)

H= Height above the crest (cm)

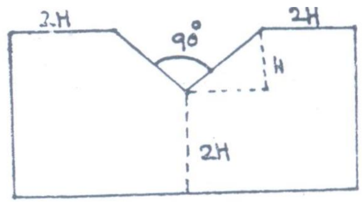


Fig-2 90^0 V-notch

Advantages and Disadvantages of Weirs and Orifices

Measurement of flow is easy and accurate through weirs. Weirs can be easily constructed by a local carpenter with cheap materials. Weir heads can be cleaned easily. Since a large fall of head is required, weirs are used in slopy land and not plain lands. To avoid accumulation of debris and silting up of the upstream continuous cleaning is necessary.

Orifices are usually larger in size than the weirs. These can also be constructed easily. These can be used in relatively plain lands to measure flow since loss of head required is less. This has also the problems of silting up and accumulation of debris as in weirs and needs continuous cleaning too.

Parshall Flume

The flume has three section, the upstream (converging section). The throat section and the downstream section (diverging section). The upstream section is the entrance section. The floor of the upstream section is level and the walls converge throat section. The walls of the throat section are parallel and the floor is inclined downward. The walls of the downstream section diverge towards the outlet and floor is inclined slightly upward. The down section is the discharge section.

The size of the flume goes after the width of the throat of the flume. Sizes ranging from 225 cm to several cm in throat width have been calibrated and tables of discharge developed. Parshall flume can be made to any capacity required.

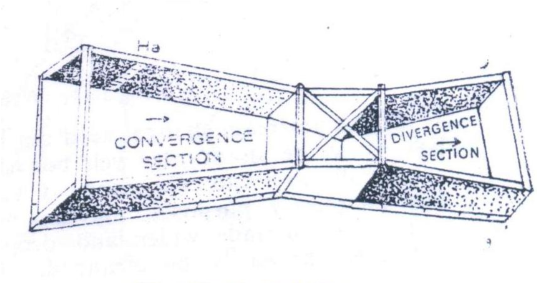


Fig-3 Parshall Flume

The discharge equation for the Parshall measuring flume is:

$$Q = C\,Wh^{n}$$

Where,

W is throat width

Q = the discharge, l/s

h = height at convergent section,

C is coefficient and n is the exponent

The generalized formula is

$$Q = 4\ W.ha^{1.522\ W^{0.226}}$$

Parshall flume of brick cement structure can be permanently made at the measurement site. Portable ones can be made of wood, thick tin or galvanized iron sheets. While constructing, sufficient care should be taken to maintain dimension of different sections, slope, width, etc. The calculated discharge needs to be calibrated with actual discharge and the equation adjusted in all weirs and flumes.

Cut throat Flume

This flume has no throat section. It is an improvement over Parshall flume. The flume has a flat bottom, vertical walls and zero length throat section. It is easy to construct and operate. Flow in this flume can also be free or submerged. Under free flow conditions vertical depth occurs in the vicinity of minimum width (W) which is called the flume neck. Upstream depth (ha) determines the discharge.

To measure flow in pipes venture tube, Collins flow gage or Cox flow meter is used. By these instruments flow is measured at one point in the pipe. Flow varies depending on if the pipe is flowing full or partially full.

Exercise

1. A farmer has no devices to measure a small stream to irrigate his vegetable plot. He used a drum of 0.9 m^2 having a depth of 1 m. It took 15 minutes to fill the tank. Find out the flow rate of the stream.

2. An area of one hectare is irrigated in 40 hrs with a discharge rate of 250 litres per minute, what is the average depth of irrigation?

3. Irrigation requirement of a 100 days duration crop is 40 cm. How much area can be irrigated with a flow rate of 20 litres per second for 10 hrs in a day?

Ex. No. 2

Use of commonly used formulae in irrigation practices and working out problems

The application of water for irrigation involves use of formulae and related units for solving the problems from its storage level to field through various conveyance means. Different units and their conversions help in understanding of the irrigation practical applications.

Water is measured only in its liquid form under two conditions under field conditions:

1. **At rest:** This is called volume measurement such as litre, cubic metre, hectare centimetre (ha-cm), hectare meter (ha-m), acre inch, acre foot, etc.

Water standing to a height of 1 cm over an area of one hectare (10,000 m^2) is called one hectare centimeter (100,000 litres = 100 cubic metre). Water standing to a height of 1m is called one hectare meter (10,000 cubic metre=10 million litres).

Water standing to a height of one inch over an area of one acre is called one acre inch, (3630 cubic ft = 102739 litres). If this water is spread over an area of one hectare it will stand to height of 1.027 cm (1 acre inch = 1.027 ha- cm).

2. **Water in Flow**: It is measured as flow volume per time, *i.e.*, litres/second, m^3/sec (cu mec), or cubic ft/second (cusec), ha cm/h, or acre inch/h. A flow of one cubic foot/ second for an hour is approximately equal to one acre inch. A flow of 27.80 litres per sec for an hour is equal to one ha cm.

Mass volume relationship in soils

Soil has volume and weight. Unlike solid substances considerable volume in the soil is occupied by air in pores. Hence, its mass volume relationship needs consideration

$$\text{Density (D)} = \frac{\text{Mass (g)}}{\text{Volume (cm)}^3} = \text{g cm}^{-3}$$

Sometimes density is expressed in terms of specific gravity which is the ratio of the weight of any volume of substance to the weight of an equal volume of water at 4^0C, *i.e.*

$$\frac{\text{Density of substance}}{\text{Density of water at } 4^0\text{C}} = \text{g cm}^{-3}$$

In the metric system since the density of water is 1, specific gravity is numerically equal to density.

i) Bulk Density

As mentioned above any volume of soil represents the volume of real soil particles and volume of pore space. Hence, the volume of only soil particles is less than the total volume occupied by the bulk of soil. Hence, density of soil expressed as

$$\text{Db} = \frac{\text{Mass of dry soil (g)}}{\text{Volume of soil (cm)}^3}$$

It is not the real density. Hence, it is called the bulk density *i.e* density of bulk soil. If mass of 1 cubic cm soil is 1.56 g its bulk density is 1.56 g/cm^3.

ii) Real Density (Particle Density)

If the particles in any volume of the soil are compressed they will occupy less volume; since their weight remains unchanged and the volume decreases, the density will increase. This density with reference to volume of particles only is called real or particle density.

$$\text{Particle Density (Dp)} = \frac{\text{Mass of soil (g)}}{\text{Volume occupied by soil particles only (cm}^3)} = \text{g cm}^{-3}$$

Bulk density varies with the moisture content in the soil. To avoid this, generally mass of the dry soil is taken. Due to variation in sand, silt and clay per cent and organic matter the bulk density of soils varies.

Total porosity can be defined as percentage of bulk volume not occupied by solids. Hence total porosity per cent (%).

$$= \frac{\text{Particle density} - \text{Bulk density}}{\text{Particle density}} \times 100$$

This represents the volume per cent of pore space but does not characterize the size distribution of pores. In an average soil, porosity varies around 50%. Sandy soil have usually less (25 – 45%) and loamy and clayey soils usually more (45-60%).Porosity varies with the size of the particles and state of aggregation.

iii) Moisture content

It refers to mass of water relative to mass of dry soil particles.

$$\text{Moisture per cent} = \frac{\text{Mass of water}}{\text{Mass of dry soil}} \times 100$$

This is also otherwise called as gravimetric water content.

iv) Volumetric water content (Vm) in percentage can be calculated if the soil bulkdensity (Db) is known.

$$Vm = \frac{Ww - Dw}{Dw} \times 100 \times Db$$

$$Vm = Sm \times Db$$

The amount of water in soil can be expressed in depth per unit soil depth.

Depth (cm) of water per unit soil depth (Dm) = Sm x Db x Ds = Vm x Ds

Relationship between duty and delta

Base period: It refers to the entire duration of the crop in days from first irrigation for preparatory cultivation to the last irrigation.

Delta: It is the total depth of water (cm) required by a crop during its duration in the field denoted by by the symbol Delta. It is calculated by dividing the volume of irrigation water by the area irrigated. It is expressed in hectare – metre (ha-m) or in million cubic metres (M m^3)

Duty: It is defined as the area irrigated per cumec of discharge running for base period B. It is usually represented by the letter D.

Determination of the surface area of canal cross sections

The cross section of the canal has a trapezium shape. Thus the formula to calculate its surface is similar to the formula used to calculate the surface area of trapezium.

Surface area of the canal cross section = 0.5 (base +top line) x canal depth = 0.5 (b+a) x h

Where

Base (b) = bottom width of the canal

Top line (a) = top width of the canal

Canal depth (h) = height of the canal or water depth

Determination of the surface area of farm

When the shape of the fields is regular and has, for example, a rectangular shape, it is not difficult to calculate the surface area once the length and width of the field is measured. In the case of fields having irregular shape, it should be divided into several regular shapes of square, rectangle, triangle, etc. and the formula is applied and the area of these shapes is summed to find the total area of the farm.

Units of volume

1 dm^3 = 1 litre and 1 m^3 = 1000 litres

Exercise

1. Find the porosity of a soil having a bulk density of 1.3 g/cc and real density of 2.6 g/cc.

2. What would be the quantum of water when 3 cm of rainfall occurs in one hectare area?

3. One cubic metre is equal to how many litres of water?

4. One hectare – centimeter (ha-cm) is the volume of water necessary to cover an area of one hectare to a depth of one centimeter. Find out the volume of water in litres.

Ex.No.3

Observations and practicing land shaping

Land refers to the soil surface and the below and above spaces of the surface. The above space is the atmosphere. The surface includes the topography, vegetation etc., a land need to be evaluated for the suitability for the irrigation projects involving various methods of applying water. Some of the factors influencing on the suitability for irrigation are, Soil depth, texture, water holding capacity, permeability, water table, topography , slope, soluble salt content, Exchangeable sodium percentage and a neutral P^H.

Keeping the land in its natural condition and preparing the same for irrigation may be very difficult as it will not result in efficient application of water. Natural conditions of land surface have to be changed essentially for the scientific method of water application. Hence the land has to be reshaped by grading and leveling it. The object in making and preparing a suitable field surface is to regulate and control the flow of water to check the possible soil erosion and to provide for surface drainage.

Development of land for irrigation includes land survey, land clearing, land shaping and finally the field layout.

Land survey

The first step in survey is to divide the land into grids. Grids are network of equally spaced horizontal and vertical lines especially for locating points when placed over a map. The size of the grids vary with unevenness and accuracy needed for leveling. The second step in survey is taking levels at each grid point with a dumpy level adopting the usual method. The levels at each grid point are marked on a map. For easy study, contour lines are marked on the map at suitable intervals. The interval of contour lines depends on the slope of the land.

Land clearing

The land needs to be cleared before its grading survey is taken up and subsequent land shaping operations. It covers removal of heavy vegetation cover , unwanted trees, bushes, trashes , boulders etc., land clearing may be done by manual labour or by employing bulldozers, root cutters, choppers and by suitable machineries.

Land leveling

Land leveling is modifying the surface relief of a field for efficient application of irrigation water. Usually the land is not given a true level surface but a grade is provided to meet the drainage requirement.

The operation of land shaping is a three stage programme. These are 1. Rough grading 2. Land leveling and 3. Land smoothing.

1. Rough grading is the removal of surface undulations such as mounds, dunes, depressions, gullies, pits etc., Land grading is done by tractor-drawn carrier – type scrapers, small scrapers drawn by tractor and by animal -drawn buck scrapers.

2. Land leveling reshapes the land surface to a planned grade which entails moving large quantities of earth over considerable distance.

3. **Land smoothing.** It is a very fine leveling of the field and flow of water and distribution will be uniform. Very small undulations which are not easily observable are further leveled.

Land characteristics considered for land leveling

The following characteristics are considered for land levelling.

1. Soil profile 2. Land slope 3. Rain fall 4.cropping pattern 5. Irrigation methods and 6. Other aspects

The land leveling can be taken up based on contour survey and by computation of cut and fill soil. Suitable implements both tractor or bullock drawn may be used and the cost may be planned to to kept at minimum.

Further land development programme is planned, prior to land leveling design, so that field arrangements, boundaries, irrigation channel and drainage systems and roads are known. Use of earth for field structures are adjusted from the near surface area which will be facilitated by a topographical map of the land to be developed for a garden. Field channels and underground pipelines to supply water to the fields are located along the upper reach of the irrigation runs. The supply channel or pipeline is laid perpendicular to the direction of surface irrigation methods. The canals should be little elevated for easy flow of water and the channels should have < 0.1 % slope.

Field arrangements or Lay out of the field

Laying out fields of workable size and shape is important to successful irrigation farming. The fields are laid out nearly rectangular or square without sharp bends. The field length is based on the maximum length to which irrigation water could run. The field lengths are limited by ownership boundaries, cropping pattern, operation schedule and type of farm equipment.

Irrigation water should flow correctly to all parts of fields. Field channels are normally run at right angle to the directions of irrigation. Water surface in the field channel should be 20-30 cm higher than the ground level to be irrigated and may be nearly level or less than 0.1% slope. Field roads are located above irrigation channels. The surface and sub- surface drains are provided wherever needed.

Field road system

Access to all areas of the farm for movement of farm machineries and equipments and transporting produces and convenience for operation of irrigation systems.

Drainage

Drainage of either open or closed type becomes essential to drain-off excess rainfall promptly to prevent salinity formations in the soil. This also helps to avoid damages to land due to seepage from the upper elevations. Planning of irrigation and drainage need to be finalized before land grading and leveling is taken up.

Laying of irrigation method is done for every season in the case of annual crops. Border strips, check basins, ridges and furrows are prepared every time before seeding or transplanting. In these type of field preparation the implements like bund former is being used.

Exercise

Visit a garden and observe the lay out and assess the land work that would have been carried out.

Ex.No.4

Study of land leveling implements

Land leveling can be done by using human labour, bullock power and mechanical power. The implements are also used according to the power sources available. Human labour is expensive and slow. Bullock power is economical provided the soil is not hard and haul is up to 45 m. Simple implements used are the wooden buck scraper ,wooden float, V-ditcher and A-frame ridger. Mechanical power is useful where the haul exceeds 45 m. The equipments used are dozers, scrapers, scoop and land planes. The bulldozer is useful for cuts of more than 15 cm, where the earth movement does not exceed 30 m.

1. Land grading

Land grading is done by tractor drawn carrier – type scrapers, small scrapers drawn by tractor and by animal drawn buck scrapers. Land smoothing is done by tractor – drawn land planes or bullock drawn wooden floats.

Bulldozers, consisting of crawler tractors equipped with dozer blades, are frequently employed in cutting and pushing earth to short distance. They are suitable for rough grading when the haul distance does not exceed about 25 metres.

Tractor - drawn scrapers

There are a variety of scrapers in land grading. They range in size from the terrace blade to heavy carrier type scrapers. The carrier type scraper is widely used for large scale land grading operations

Bottomless scrapers are used for medium and small scale leveling jobs. The bowl or bucket has little or no bottom and earth movement is accomplished with them by scraping a load, dragging it to a short distance and dumping it. To operate these scrapers, it is necessary to loosen the ground with a plough or harrow.

Tractor scoop is useful for digging, loading, hauling, dumping and spreading earth and is suitable for hauls over long distances.

Animal - drawn buck scrapers

Animal drawn buck scraper is the most efficient implement for land grading when animal power is to be used in the job and fields are of small to medium size. It may be used to move the soil loosened by ploughing or other tillage practices. it can be operated when the haul distance does not exceed about 60 metres.

2. Land leveling

Land plane

Land leveling jobs are finished by land planes, levelers and floats. The land plane is essentially a bottomless scraper provided with a long frame and mounted on four wheels. The blade is adjustable and is located at about the centre of the frame. The frame is at least 15 metres long and this great length makes it possible to finish a field to 15 metres long and uniform smooth surface. When in use, the blade is permanently set at a level which will maintain about one-third of the load in the bowl. With this adjustment properly made the machine will, as it is drawn across the field, automatically remove high spots and fill depressions. The machine is operated in diagonal directions and downfield. The machine, however, is suitable only to grade large fields.

Land smoothing is a finer work which further levels the surface to plane surface which is also termed as land floating and land plaination.

Levelers

The two-wheeled automatic type leveller is usually used for the fine grading of small and medium size fields. It can be operated by a medium size wheel tractor. The machine has an adjustable blade which is so constructed that it will drag a considerable volume of earth.

3. Land smoothing

Land smoothing is the final operation that removes small elevations and depressions formed while leveling.

Wooden float

The float is a long sled-like drag which is used for land smoothening with bullock power. Large size floats are sometimes used with tractors also. The machine operates on the principles of a carpenter’s plane. It has three blades-the cutting blade in the front, the spreading blade in the centre and the covering blade at the back. As the float is pulled forward, the cutting blade removes the high spots and pushes this soil into the low areas ahead. The other two blades assist in obtaining a uniform field surface. For best smoothing on flat field, it is desirable to float the surface three or more times by going across the field lengthwise, crosswise and diagonally.

Use of laser leveler

The field is to be ploughed and the rotovator may be used to make fine tilth. The laser transmitter is set. 25 point readings are taken per acre to identify the slope and average is worked out. The laser controller bucket is positioned to mean height fixed through automatic battery set in the tractor. For a slope difference of less than 20 cm one time leveling for more than 20 cm two times is done. Levelling is confirmed through point readings by resurveying.

4. Implements for surface irrigation structures

The bund former

The bund former is suitable for making small ridges suitable for check basins. The implement has two collecting mould boards which form the ridge when the implement is pulled forward.

The wooden A-frame ridger

The wooden A-frame ridger is a suitable implement for making ridges for border strips and check basins. The ridger is similar in principle to the bund former. However, it gather soil from a larger area and can make larger bunds.

The V-ditcher

The V-ditcher is a useful implement for the construction or cleaning of field channels for irrigation and drainage. The operation for the V-ditcher in constructing a channel is much like that of an over-size mould board plough. The channel line is first laid out. Then a mould board plough is used to make a furrow where the line has been staked. The plough is run again on the same furrow, but in the opposite direction, throwing the soil out on the other side. The V-ditcher is then used in the furrow to enlarge it into a channel.

The choice of equipment

The choice of equipment for land grading and field layout depends on the quantity of earthwork involved, type of power available, economic feasibility of the machine and the size of the farm. While animal-drawn equipments are suitable for small jobs, heavy earth moving equipment is needed for major works involving large areas to be leveled.

Exercise

Observe the garden, when time permits, on land leveling and lay out of different structures

Ex.No. 5

Layout for surface method and sub surface method of irrigation

Laying out the field properly results in an increased efficiency of the irrigation system. Designing aspect of some of surface methods are as follows. It may be noted that soil itself is used in most cases as layout structures under surface method of irrigation. It is a temporary structure for a season when it is laid for annual crops.

1. Wild flooding

In this method water flows from the ditch directly to the field without much control on either side of the flow. It covers the entire field and moves almost unguided. Close growing crops are generally irrigated by this method.

2. Border Irrigation

Suitable slopes: Border slopes should be uniform, with minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion.

Suitable soils: Deep homogenous loam or clay soil with medium infiltration rates is preferred. Heavy, clay soils can be difficult to irrigate with border irrigation because of the time needed to infiltrate sufficient water into the soil. Basin irrigation is preferable in such circumstances. Close growing crops are preferred for this method of irrigation.

Border layout

The dimensions and shape of borders are influenced in the same way as basins and furrows by the soil type, stream size, slope, irrigation depth and other factors such as farming practices and field or farm size.

For moderate slopes and stream sizes the following border strips are generally recommended.

Soil type	**Border length (m)**	**Slope (%)**
Sandy and Sandy loam	60-120	0.25-0.6
Medium loam	100-180	0.20-0.40
Clay	300-500	0.05-0.1
Clay loam and clay	150-300	0.05-0.20

Maintenance of borders: Maintenance of borders consists of keeping the border free from weeds and uniformly sloping. Whatever damage occurs to the bunds must be repaired and the field channel and drains are to be weeded regularly. By checking frequently and carrying out immediate repairs where necessary, further damage is prevented.

3. Furrow irrigation

Furrow irrigation is suitable for a wide range of soil types, crops and land slopes.

The crops that would be damaged by inundation, such as tomatoes, vegetables, potatoes, beans and fruit trees such as citrus and grape are suited.

Uniform flat or gentle slopes are preferred for furrow irrigation. The slope should not exceed 0.5%. Usually a gentle furrow slope is provided up to 0.05% to assist drainage following irrigation or excessive rainfall with high intensity. On undulating land, furrows should follow the land contours. However, this can be a difficult operation requiring very careful setting out of the contours before cutting the furrows.

Suitable soils

Furrows can be used on most soil types. However, as with all surface irrigation methods, very coarse sands are not recommended as percolation losses can be high. Soils that crust easily are especially suited to furrow irrigation because the water does not flow over the ridge, and so the soil in which the plants grow remains friable. Few examples of crops for their suitability for this method under the following topography , stream size and their influences on the size of the beds are as follows.

Method	**Crops to be irrigated**	**Topography**	**Stream size**	**Approximate size of bed (m)**	**Remarks**
Furrow (Alternate ridges and furrows)	Potato, Vegetables, Brinjal, cole crops	Flat and gentle slopes	Small to large supply	0.5-1.5m wide 10-50m long	Economic water use, facilitates, intercultural operations.
Corrugated method	Vegetables, Onion garlic, spinach	Slope perpendicular to the furrow	-do-	26m	Economizes water supply. Intercultural operations

					become difficult.

4. Basin and Ring irrigation

Fruit crops in orchards are irrigated by constructing basins or rings around trees. Basins are usually used for small trees, while rings are used in bigger trees which are widely spaced.

4.1. Basin irrigation

A basin is usually made for one tree sapling but it may include more than one tree sapling when they are not spaced very wide. Basins may be square, circular or rectangular. Basins are made longer and wider as saplings grow in size. The land inside basins is flat with the base area of trees kept little raised so that the sapling stems do not come in direct contact with water. A lateral or field channel passes between two rows of trees alternately supplying water to individual basins on both sides. A basin usually covers the complete area under the tree canopy. Desired quantity of water is allowed into a basin for complete infiltration.

4.2. Ring irrigation

Ring method consists of irrigating fruit trees in orchards by constructing circular trenches around trees. Ring trenches are smaller in both depth and width around small trees and are larger around bigger trees. Usually a ring is laid out at the periphery of the tree canopy. The ring trenches are usually made 30 to 50 cm wide and narrow furrows. Laterals pass through a set of two rows of trees supplying water into rings on both sides. Water supply process is essentially the same as with the basin irrigation. Water in desired quantity is allowed to stand in the trenches for infiltration.

5. Check or Check Basin Irrigation

Check method consists of dividing the field into several relatively level plots called checks surrounded by low bunds. They are irrigated with comparatively large flow of water. Small checks are level while bigger ones are slightly sloping along the length. A check is also termed as check basin. There are two methods of check irrigation, rectangular check method and contour method.

5.1. Rectangular check irrigation

In a relatively uniform land with a gentle slope, checks may be rectangular and sometimes square. They may be a few square meters in size for vegetable crops. In lighter soils the size of a check may necessarily be small to achieve uniform wetting and in heavier soils the size may be large. Water is conveyed to checks by a system of supply channel, laterals and field channels. Laterals or field channels are laid out in such a way that a channel passes through a set of two rows of checks. A supply channel is constructed on the upper reach of the field and laterals usually follow the slope, if there is any. Check method is adopted for irrigating row crops and vegetables in a wide range of soils having moderate to slow infiltration rates.

5.2. Contour check irrigation

In slopping and rolling lands contour checks are constructed by rising bunds or ridges along contours having vertical intervals of 15 to 30 cm. Checks at the end of the adjoining contours may sometimes be joined at suitable places to make them continuous. They are almost uniformly level or gently sloping and are often small. A contour checks is also termed *contour check basin.* The design criteria and the method of water application is essentially the same as with the rectangular check method. Contour checks are suitable for growing vegetables.

6. Pitcher Irrigation

The method includes irrigating widely spaced vegetable crops with earthen pitchers of about 2 litres capacity each. The pitcher is porous with a small hole at the bottom. Water trickles out through the hole and irrigates the crop root zone. Pitchers are filled with water at 6 to 8 days interval before they are emptied. The method of irrigation and advantages are similar to the porous cup method and the method holds a promise in areas where water is scarce. It is however labour intensive and involves a higher labour cost of filling the pitchers at intervals.

7. Subsurface irrigation methods

Subsurface irrigation, also designated as sub irrigation, involve irrigation to crops by applying water from beneath the soil surface either by constructing trenches or installing underground perforated pipe lines or tile lines. Various types of crops, particularly with shallow root system are well adapted to sub irrigation. Crops like potato, beet, peas and fodder can be irrigated by sub-irrigation.

Exercise

1. Make an observation on the field lay out involving surface methods when you visit a garden.
2. Calculate the time required to irrigate a check basin of 20 m long and 15 m wide to a depth of 6 cm with a stream of 10 l/sec.
3. An irrigation stream of 20 l/s is diverted to a check plot of 10 x 8 m. Net depth of irrigation requirement is 10 cm. How long the irrigation stream be applied to irrigate the check plot?

Ex.No.6

Study of layout for sprinkler method

A sprinkler irrigation system to suit the conditions of a particular site is specially designed in order to achieve high efficiencies in its performance and economy. The different steps involved are discussed below.

1. Capacity of the sprinkler system (Pump)

The required capacity of a sprinkler system or the capacity of the pump used depends on the area to be irrigated, the depth of water to be applied at each irrigation, the time allowed to apply water to this depth and the application efficiency. The capacity of the system may be calculated by the formula

$$Q = \frac{2780 \times A \times D}{F \times H \times E}$$

Where,

Q = discharge capacity of the pump, l/s

A = Area to be irrigated, ha

D = depth of water application, cm

F = time allowed to complete one irrigation, days

H = actual operating hours of the pump/day

E = Water application efficiency, per cent

2780 the conversion factor to express Q in litres per second

2. Water application rate

The rate of water application by sprinkler is limited by the infiltration capacity of the soil. Soil type, crop cover and slope need to be taken into consideration in deciding the application rate. Application rate in excess of the infiltration capacity of the soil may result in runoff, poor distribution of water, loss of water and soil erosion.

The rate of water application or precipitation intensity for a single sprinkler may be decided by the formula

$$R_a = \frac{Q}{360 \times A}$$

Where

R_a = rate of water appl

Q = rate of discharge of sprinkler, l/s

A = wetted area of sprinkler, m^2

3. Selection of sprinklers for required discharge

The actual selection of the sprinkler is based largely upon design information furnished by the manufacturers of the equipment. The choice depends mainly on the diameter of the coverage required, pressure available and sprinkler discharge.

The required discharge of an individual sprinkler is a function of the water application rate and the two way spacing of the sprinklers. It may be determined by the formula

$$Q = \frac{S_1 \times S_m \times I}{360}$$

Where

Q = required discharge of individual sprinkler, l/s

S_1 = spacing of sprinklers along the lateral, m

S_m = spacing of laterals along the main, m

I = optimum application rate, cm/hr

4. Hydraulic design of sprinkler system

The hydraulic design of sprinklers is aimed at obtaining uniform irrigation coverage, the desired rate of application, the breakup of sprinkler drops necessary to minimize the structural deterioration of the soil surface and to maximize the area of coverage. The main hydraulic principles involved in a sprinkler system design are

a) Discharge of sprinkler nozzle

The discharge of a sprinkler nozzle may be computed as

$$Q = CA\sqrt{2gh}$$

Where

Q = discharge cm^3/sec

C = sprinkler discharge coefficient which vary from 0.80 to 0.95

A = Cross sectional area of nozzle or orifice, cm^2

g = acceleration due to gravity cm/s^2

h = Pressure head at nozzle, m

b) Water spread area of sprinkler

The area covered by a rotating head sprinkler can be estimated from the formula

$$R = 1.35\sqrt{dh}$$

Where

R = radius of the wetted area covered by sprinkler, m

d = diameter of nozzle, m

h = pressure head at nozzle, m

The maximum coverage is attained when the jet emerges from the sprinkler at an angle of 30° to 32°. Most rotating sprinklers are standardized at 30°.

Spacing of sprinkler

To achieve uniform sprinkling of water, it is necessary to overlap the area of influence of the sprinklers. The overlap increases with the increase in wind velocity.

Sprinklers are arranged along a lateral not more than 50 per cent of the coverage by an individual sprinkler. The distance between successive positions of laterals should not exceed 65 per cent of the diameter of the coverage by an individual sprinkler. If there is a wind of considerable speed, the spacing between sprinklers is further reduced.

The uniformity of water distribution obtained with a sprinkler can be experimentally determined.

Exercise

1. Collect information on soil type and application rate of the sprinkler and wind and water distribution from the sprinklers.

2. Work out the discharge capacity of a sprinkler system to apply water at the rate of 1.5 cm/h. Two sprinkler lines 200 m long each with 18sprinklers are spaced at 11 m interval on each line. The sprinkler lines are spaced at 16 m interval.
3. Two sprinkler lines, each 186 m long, are required with a spacing of 18m between the lines for irrigation. A total of 16 sprinklers are spaced at 12 m interval on each line. Find out the required capacity of the sprinkler system to apply water at the rates of 1.25 cm/hr.

Ex. No. 7

Layout for drip method

The object of drip irrigation is to achieve high application efficiency and uniformity of application of water and to maintain soil moisture in the root zone near field capacity for high crop yields.

For designing drip system knowledge on Quantity and quality of water and its elevation, climatological data for computation of ET, Soil type, daily consumptive use of crop, its spacing, slope and topography of land, water intake rate etc., are essential.

Steps in designing drip irrigation

1. Daily water consumption of the plant

Evaporation from the USDA class-A pan during the hottest day in the crop period of the plant or year in the case of the tree crop is taken and multiplied by pan and crop coefficient and crop coverage area (Plant spacing and row width).

Daily water use of each plant/ tree (q) = Evaporation (mm) x pan coefficient x crop coefficient and plant spacing (cm) and row width (cm).

2. Design application rate (DAR) = CU x A x K

CU= Peak consumptive use during the crop period/day

A = plant space area, K = coverage factor of plant

3. Number of emitters required for each plant

This depends on area of wetting (nearly 40% of the total area) and radius of wetted area of single emitter.

The number of emitters = A/ r^2

A = total area to be wetted

R = radius of wetted area of single emitter

4. Rate of flow of each emitter (E)

E = q/ nt

q = daily water requirement (mm)

n = number of emitters, t = time of operation (hr/day)

5. Irrigation interval

This depends on the quantity of water applied in each irrigation and the plant water requirement.

Ii = Idn/T

Ii = irrigation interval,

Idn = net depth of each irrigation (mm)

T = water requirement per day (mm)

6. Time of operation of each emitter

The emitter discharge rate and infiltration rate of the soil influence the time of each irrigation.

Lay out of drip irrigation

Mainlines, sub-mains and laterals supply water from the control head into the fields. They are usually made from PVC or polyethylene hose and should be buried below ground because they easily degrade when exposed to direct solar radiation. Lateral pipes are usually 13-32 mm diameter.

Emitters or drippers are devices used to control the discharge of water from the lateral to the plants. They are usually spaced more than 1 metre apart with one or more emitters used for a single plant such as a tree. For row crops more closely spaced emitters may be used to wet a strip of soil. Many different emitter designs have been produced in recent years.

The basis of design is to produce an emitter which will provide a specified constant discharge which does not vary much with pressure changes and does not block easily. Some types are short path, long path, short orifice, pressure compensating, self flushing and porous tubing emitters.

These designs can be grouped in to two types, point source and line source. Point source systems discharge water from individual or multiple outlets that are spaced at least 1m apart. Line source systems have perforations, holes or porous walls in the irrigation tubing that discharge water at close spacing or even continuously along a lateral line. Point source systems are used for widely spaced crops and line source systems for close growing crops. The self adjusting drippers discharge water within permissible limits even if there is pressure variation.

Operating drip systems

A drip system is usually permanent. When remaining in place during more than one season, a system is considered permanent. Thus it can easily be automated. This is very useful when labour is scarce or expensive to hire. However, automation requires specialist skills and so this approach is unsuitable if such skills are not available.

Water can be applied frequently (every day if required) with drip irrigation and this provides very favourable conditions for crop growth. However, if crops are used to be watered each day they may only develop shallow roots and if the system breaks down, the crop may begin to suffer very quickly.

A pump of suitable capacity is required to create pressure to force water through main up to emitter. The laterals may operate with pressures as low as 0.15-0.2 kg/cm^2 and as high as 1 to 1.75 kg/cm^2. The pressure gradually drops at the laterals and emitters. Water coming out of the emitters is almost at the atmospheric pressure. If desirable a fertilizer tank may be connected with the system to supply different nutrients to the crop with irrigation.

The emitters are provided at regular intervals on laterals. The water is emitted usually in drops. The emitters are of three types.

1. Water seeps out continuously
2. Water drips from emitters
3. Water sprays or drips from holes punched in the lateral.

The amount of water dripping down from the emitter depends on the pressure at the nozzle, size of the opening and frictional losses. The emitters usually discharge at the rate of 2 to 10 litres per hour. Nozzles may vary in their shape and size.

Wetting patterns

Unlike surface and sprinkler irrigation, drip irrigation only wets part of the soil root zone. This may be as low as 30% of the volume of soil wetted by the other methods. The wetting patterns which develop from dripping water onto the soil depend on discharge and soil type.

Although only part of the root zone is wetted it is still important to meet the full water needs of the crop. It is sometimes thought that drip irrigation saves water by reducing the amount used by the crop. This is not true. Crop water use is not changed by the method of applying water. Crops just require the right amount for good growth.

The water savings that can be made using drip irrigation are the reductions in deep percolation, in surface runoff and in evaporation from the soil. These savings, it must be remembered, depend as much on the user of the equipment as on the equipment itself.

Drip irrigation is not a substitute for other proven methods of irrigation. It is just another way of applying water. It is best suited to areas where quality is marginal, land is steeply sloping or undulating and of poor quality, where water or labour are expensive, or where high value crops require frequent water applications.

Designing drip irrigation system for a citrus garden

A farmer has an open well of 4 m diameter and 25 m depth fitted with 5 H.P. electric pump set. The soil is a clay loam with a slope of 0.5%. The farmer proposes to install drip irrigation system for a citrus plantation on a 1 ha plot.

The design of a drip irrigation system involves estimation of following parameters.

1. Area to be irrigated, land slope, type of plant, age, spacing and number per hectare
2. Peak water requirement of a plant per day or irrigation water requirement.
3. Design of main lines and lateral lines
4. Emitters : number and spacing
5. Water required to be pumped from the well
6. Horse power of pump set
7. Unit cost

Analysis of data

1. Number of plants = area/ spacing = 1000 m^2 / 6mx6m = 277 plants

2. Estimation of water requirement

Evapotranspiration of a crop can be estimated by Pan Evaporation method

$ET_{crop} = ET_o \times K_c$

ET_{crop} = evapotranspiration of the crop

ETo = reference evapotranspiration = pan evaporation (E_p) x pan coefficient (K_p)

Kc = crop coefficient which is 1.0 for fully grown citrus plant.

Water requirement of each tree = Spacing of plant x wetted area fraction x ET_{crop}

Water requirement of entire farm = Spacing x wetted area fraction x ET $_{crop}$ x number of plants

Wetted area fraction for widely spaced crop is 0.3, for closely spaced crops 0.7.

3. **Selection of emitters**

Depending upon the type of emitter and discharge required their number can be estimated. The water discharge rate per dripper is normally between 1 to 4 l/h though the discharge of emitters is upto 15 to 20 l/h. The rate of application of water through dripper is less than the infiltration rate of the soil.

Number of emitters per plant = Rate of delivery needed/ Average discharge of an emitter.

4. Mainline

The main line is designed to carry the maximum discharge required for total number of plants in the farm.

5. A lateral is so selected that the pressure difference from the proximate end to the last emitter does not exceed 10% of the normal operating head.

6. Capacity of pumpset

The horse power of the pump set required is based upon design discharge and total operating head.

7. Unit cost

The unit cost is to be estimated before installing the drip system for mobilizing the finance and the economics with other method of irrigation systems.

Water requirement of crops under drip irrigated condition

Taking average daily pan evaporation as 5 mm the water requirement for trees or the annual crops are tabulated under Coimbatore conditions.

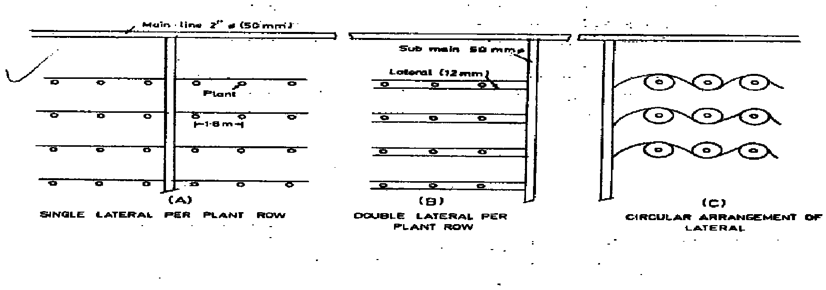
S.No.	Crop	Spacing (m)	Area of root spread		Wetted area fraction	Daily water requirement (mm)
			Radius of root (m)	Spread of root (m^2)		

1	Coconut	7x7	3.0	28.26	0.4	56.52
2	Sapota	8x8	3.0	28.26	0.3	42.39
3	Mango	10x10	4.0	50.24	0.28	70.34
4	Guava	5x5	1.5	7.1	0.28	9.94
5	Lime	4.5x4.5	1.5	7.1	0.35	12.43
6	Orange	6x6	2.0	12.56	0.35	21.98
7	Pomegranate	5x5	1.5	7.1	0.35	12.43
8	Banana	1.8x1.8	1.0	7.1	0.96	34.08
9	Grapes	1.8x1.8	1.0	3.10	0.96	14.88
10	Papaya	1.8x1.8	1.0	3.1	0.96	14.88
11	Onion	0.38x0.15	0.38x0.15	0.057	1.00	0.29
12	Water melon	3.0x0.9	0.8	2.0	0.74	7.4
13	Tomato	0.75x0.60	0.75x0.60	0.45	1.00	2.25
14	Chillies	03/0.6x0.3	0.45x0.3	0.135	1.00	0.68
15	Carrot	0.23x0.10	0.23x0.10	0.02	1.0	0.1
16	Cabbage	0.45x0.30	0.45x0.30	0.135	1.0	0.68
17	Potato	0.50x0.20	0.50x0.20	0.1	1.00	0.5
18	Tamarind	10x10	4.0	50.24	0.28	70.34

Row crop irrigation by drip, or trickle method

Drip irrigation is the best choice to maximize efficiency in irrigation system. A properly designed and installed drip system can deliver up to 95% efficiency, one-stop shop for irrigation systems, will put the water where the roots are, minimize surface evaporation, and inject the necessary nutrients to promote maximum yield or growth of crop.

Fig Drip lay out for orchard crops



Exercise

1. Draw a sketch of drip irrigation lay out for a vegetable crop
2. Designing of drip irrigation for pomegranate a model

Ex. No. 8

Measurement of soil moisture

Soil moisture is measured directly by thermo gravimetric method and indirectly by several improved techniques based on electrical resistance, slow down of fast neutrons, gamma ray attenuation, electrical conductance and back scattering coefficient as a function of water content

Direct methods

Direct methods of soil moisture measurements are

- Feel and appearance method
- Gravimetric method
- Alcohol burning method
- Hot air drying
- Gypsum sorption plugs
- Infrared balance

- Neutron moisture meter

These methods are usually adopted due to ease of handling, low cost and minimum technical skill required. However, these methods require relatively longer time for soil moisture estimation. Some errors creep in due to sampling, transporting and repeated weighing.

Feel and appearance method

Soil samples are obtained with soil probe or augur from representative depths in root zone and observed for colour, plasticity and cohesiveness. These parameters are a function of soil texture, structure and moisture content. With experience, accuracy is + / – 5 to 10 percent available soil moisture.

Gravimetric method

Soil samples are collected using soil probe or auger from the desired depth in tight moisture cans and kept in shade to avoid evaporation losses. Moist sample is oven dried at 105^0C to constant weight. The ratio of the weight loss in drying to dry weight of the soil multiplied by 100 gives the soil moisture percentage.

Merits of gravimetric method

- Ease of handling
- Low cost
- Minimum technical skill required
- It is the standard method of soil moisture determination with which other methods are compared.

Demerits of gravimetric method

- It requires relatively longer time for soil moisture determination
- Sampling and weighing errors limit the accuracy

- Soil sampling is destructive and may disturb experimental plots to distort the results.

Alcohol burning method

Soil moisture from the sample is evaporated by adding alcohol and igniting, provided the sample is not too large, the result can be obtained in 10 minutes. About 1.0 ml of alcohol per gram of soil sample at FC and 0.5ml at PWP is adequate for evaporating the soil moisture. This method is not recommended for soils with high organic matter.

Hot Air Drying

Hot air around 110^0 C is passed on a screen with weighed samples of moist soil. Hot air vaporizes the moisture and sends it out. Soil samples must be pulverized for using this method. It needs relatively expensive equipment.

Gypsum sorption plugs

Gypsum plugs placed in soil comes into equilibrium with surrounding soil moisture. They are removed and weighed to determine soil moisture content. It is necessary to calibrate the weight of porous cup with soil moisture content for different soils.

Infrared Balance

It gives fairly reliable moisture estimates in about 5 minutes. It consists of a 250 watt infrared lamp, sensitive torsion balance and auto transformer, all housed in an aluminum cabinet. The radiation emitted by infrared lamp quickly vaporizes the soil moisture. The instrument is directly calibrated in percent moisture.

Neutron moisture probe

Neutron scattering is most commonly used indirect method for measuring soil water content. It is based on the moderation of the speed of high-energy neutrons by hydrogen atoms of water molecules. The resulting slow neutrons are detected by an electronic scaler which register voltage pulses received over a given time interval. The number of pulses accumulated on the scaler per unit time results from ionization by the backscattered radiation. Since significant source of hydrogen in most soils is in the water, the technique offers a convenient means of estimating soil water content and expressed as a volume fraction cc/cc. In soil with high root density or high level of organic residues, the amount of organic hydrogen may affect the estimates. However this amount is small in comparison to hydrogen in soil water. Therefore, except in organic soil, it is a good method for soil moisture determination.

Exercise

Estimation of soil moisture content by thermo-gravimetric method

The principal method in common use is where the water is removed by oven dry method.

Materials

Sampling augers (screw/ post hole), aluminum moisture boxes, physical balance weighing up to 0.01 g and drying oven for 105^{o}C.

Procedure

Take a composite sample of soil not less than 100 g in moisture box and cover it immediately with its lid. Cover the boxes with a cloth to avoid heating in the field due to insolation, if the number samples are large. Transport the sample to laboratory. Tipping of some soil near the lid, weigh the sample on a physical balance, correct to two decimal places in g (WS_1). Dry the sample in an oven to a constant weight at 105^{o}C. This takes about 48 hours. As the boiling point of water is 100^{o}C, 105 ^{o}C is the optimum temperature for drying. Weigh the dried sample (WS_2). Calculate the moisture percentage (Pw) by the formula, on oven dry weight basis.

$$(pw) = \frac{\text{Wet wt} - \text{Dry wt}}{\text{Dry wt}} \times 100$$

Volumetric water content (pv) in percentage can be calculated if the soil bulk density ($\rho_{b)}$ is known.

$$pv = \frac{\text{Wet wt} - \text{Dry wt}}{\text{Dry wt}} \times 100 \times pb$$

$$pv = Pw \times pb$$

The amount of water in soil can be expressed in depth per unit soil depth.

Depth (cm) of water per unit soil depth (Ds) = pw x pb x Ds

$$= pv \times Ds$$

1. Find out the water content of a soil on weight and volume basis just before irrigation from the following data obtained from the thermo gravimetric method.

- Weight of the aluminum box – 30 g
- Weight of aluminum box with fresh soil sample– 90 g
- Weight of aluminum box with oven dry soil = 80 g
- Bulk density of the soil = 1.5 g/cc

2. Find out the soil moisture content per cent by weight, volumetric water content in per cent and depth of water in sampled depth with the following information.

- Weight of moisture can = 40g
- Weight of moist soil + can =150g
- Weight of dry soil + can =140g
- Soil bulk density = 1.4 g/cc
- Sampling soil depth = 30 cm

3. Find out the apparent specific gravity of 0.01 m^3 of oven dried soil weighing 2 kg.

4. A soil brought from the field weighing 48 g lost 8 g on oven drying. Find out the moisture per cent on volume basis if the bulk density is 1.5 g / cc.

Ex. No. 9

Estimation of soil moisture constants and water holding capacity for different soils

Water content in soil under certain standard conditions is termed as soil moisture constants.

Soil moisture constants refer to the status of the soil mass or changes occurring in the soil mass after irrigation or rainfall. In the real sense, soil moisture cannot be said to be constant since it is very dynamic and always tends to change due to potential gradient or pressure gradient. This phenomenon helps to find out the soil moisture status, availability of soil moisture, time and quantity of irrigation water to be applied etc.

The soil moisture constants are

1. Saturation capacity or maximum water holding capacity (MWHC)
2. Field capacity (FC)
3. Permanent wilting point (PWP)

4. Moisture equivalent

1. Saturation capacity or Maximum water holding capacity

Immediately after irrigation or rainfall, soil below the surface is completely filled with water. At this stage all the micro and macropores are filled with water. The soil at this condition is said to be under saturation capacity or maximum water holding capacity. At saturation capacity, the water is held without any force or tension and the tension is almost zero. This is equal to free water surface. At this point, the gravitational force tends to pull some water which move downwards and this water is known as gravitational water or free water.

2. Field capacity

This can be defined as the moisture content present in the soil after the drainage of water due to gravitational force is stopped or ceased or became very slow. Hence it is also be stated as the moisture content retained against the gravitational force.

At this point, moisture content in the soil is relatively stable and each soil particle is completely surrounded with thick film of water and form capillary. Hence it is known as capillary capacity.

At field capacity, the large soil pores are filled with air, the micro- pores are filled with water and any further drainage is slow.

The field capacity is the upper limit of available soil moisture to plants. Hence it is also known as full point.

Immediately after irrigation or rainfall, soil will reach its field capacity after two or three days depending upon the soil texture.

The soil moisture tension at field capacity varies from 1/10 to 1/3 atmosphere for coarse and fine textured soil.

3. Permanent wilting point

The permanent wilting point, also known as permanent wilting percentage or wilting coefficient is the soil moisture content at which plants can no longer obtain enough moisture to meet transpiration requirements and remain wilted unless water is added to the soil.

At PWP, the film of water around soil particles is held so tightly that root cannot remove the water at a faster rate to prevent wilting.

A moisture tension of soil at PWP is 15 atmosphere.

Range of water holding capacity of soils

Soil type	Percent moisture (dry weight basis)	
	Field capacity	PWP
Fine sand	3-5	1-3
Sandy loam	5-15	3-8
Silt loam	12-18	6-10
Clay loam	15-30	7-16
Clay	25-40	12-20

Available soil moisture is expressed in terms of depth dimension for the particular root zone depth and described as

$$ASM = \frac{FC - PWP}{100} \times bd \times d$$

ASM - Available soil moisture in root zone

FC - Field capacity (%)

PWP - Permanent wilting point (%)

bd - Bulk density of soil g/cc

d - Depth of root zone in cm

4. Moisture equivalent

Moisture equivalent is defined as the amount of water retained by a sample of initially saturated soil material after being subjected to a centrifugal force of 1000 times that of gravity for a definite period of time, usually half an hour.

In medium textured soils, values of field capacity and moisture equivalent are nearly equal. In sandy soils, the FC exceeds the moisture equivalent and clay soils FC is lower than moisture equivalent.

To estimate moisture equivalent, a small mass of soil sample is saturated with water and is subjected to centrifugal force of 1000 times that of gravity for half an hour and the soil moisture percentage is worked out by gravimetric method. This moisture percentage is equal to moisture equivalent.

Exercise

Determination of field capacity by field method

Materials

Straw mulch or a black polythene sheet, spade, water, soil auger, moisture boxes, physical balance and drying oven.

Procedure

Select a representative spot in the field. Ensure that water table is not within two metres from the layer of which field capacity is to be determined. Bunds an area of about 2.5 sq. metres on all four sides and removes all weeds to avoid transpiration.

Pour water till the desired layers gets sufficiently wet. Spread straw mulch of atleast 40cm thickness on the surface to prevent evaporation. A polythene sheet can be conveniently used in the place of a mulch.

Take soil samples from different layers upto the root- zone depth with auger and determine the soil moisture content at every 12 to 24 hours interval till the values of two successive samples are nearly equal. Plot the moisture content versus time curve on a graph paper. The lowest influx can be taken to represent the field capacity of soil.

The value for field capacity is less than that for maximum water holding capacity, since later measures the moisture present in a fully saturated soil resting on a water table, so that the soil pores are completely filled with water.

The moisture percentage of a loam soil at 24, 48, 72 and 96 hours interval after saturation were observed to be 37.5, 28.7, 24.8 and 24.7% respectively. As in above observation the moisture content after 72 hours is almost same as recorded at 96 hours. Therefore, the field capacity of the above soil is 24.8 per cent. It means that in this type of soil the field capacity reaches after 72 hours of saturation.

Determination of wilting point by sunflower method

Materials

Five 600 g capacity cans with lids, sunflower seeds, glass tubing (5cm x 0.5 cm), sealing wax, moisture cans, physical balance, drying oven, bell jars or cabinet 25cm x 50 cm with a polythene cover, water trays and soil sampler.

Fill uniformly five cans having a drain hole at the bottom with about 500 g of air dry soil in each. It is necessary to have many replications in this trial as the permanent wilting point is a range of moisture. Sow about four seeds of sunflower in each and allow them to germinate.

After emergence, thin the plants to two, allow them to pass through the two holes in the lid and place the lid. Avoid heating of the cans due to insulation, by placing them in moist saw dust. Grow them for about six weeks, watering them as and when necessary. By this stage plants would have developed at least about three pairs of leaves.

Insert a glass tubing in the soil for aeration and plug it with cotton wool. Seal the soil surface with wax. Also close the drainage hole and seal it.

At this stage, water the plants for the last time and plug all the space between the soil surface and the holes in the lid of the can be plugged with cotton wool to control evaporation. Allow the plants to wilt.

As soon as both the plants show signs of loss of turgor, transfer them to a dark humid chamber. The cans with plants can be kept in a small water tray and covered with a bell jar or a wire cabinet to create a high humidity chamber. The bell or the cabinet should be covered with a black polythene piece. The aim is to close stomata and reduce transpiration.

Leave the plants overnight to gain favourable water balance by allowing them to extract moisture from the soil. If they gain turgidity, expose them to the atmosphere for a couple of hours and transfer them back to the humid chamber. Repeat the process till the plants do not recover in dark humid chamber.

At this stage, remove the lid and cut the plants. Take a duplicate soil sample. Remove the roots. Determine the moisture content of the soil samples which will represent the value of the wilting point of the soil.

Pressure plate apparatus for measuring soil moisture

Laboratory measurements of soil moisture potential are usually made with pressure membrane and pressure plate equipment and are discussed in later chapters.

Exercise

1. The weight of the moisture of soil sample taken at field capacity level was 30g and at PWP was 12g of a soil sample which weighed 150 g on drying. The root zone depth was 60cm. the bulk density of the soil is 1.4 g/cc. Find the available water holding capacity of the soil.

2. Calculate the available soil water holding capacity of a soil in millimeters in the 60 cm soil profile from the following data.

Soil depth (cm)	Fieldcapacity (%)	PWP (%)	Bulk density (g/cc)
0-15	25.1	10.8	1.51
15-30	24.8	11.1	1.52
30-45	24.4	11.4	1.54
45-60	23.9	11.3	1.55

3. Find out the volume of water required to saturate the soil of a border of 150 m long and 10 m wide with the following data available.

The irrigation is applied at 50 per cent soil water availability. The depth of root zone is 75 cm and bulk density of the soil is 1.52 g/cm^3. Available water holding capacity of the soil is 18 per cent.

Ex. No. 10

Estimation of water and irrigation requirement for horticultural crops

Consumptive use of water or water requirement of crop may be estimated from the pan evaporation data. The observations made indicated the existence of a close relationship between consumptive use by the crops and the rate of evaporation from a well located pan. Evaporimeters incorporate the effect of all climatic factors and hence are more accurate in estimating short term fluctuations in ET.

Estimation of water requirement

The standard USWB Class A pan evaporimeter is widely used. It is made of 20 gauge galvanized iron sheet, 120 cm in diameter by 25 cm in depth and is painted white and exposed on a wooden frame in order that air may circulate beneath the pan. It is filled with water to a depth of about 20 cm. The water surface is daily measured by means of a hook gauge in a stilling well, and evaporation is computed as the difference between observed levels adjusted for any precipitation measured in a standard rain gauge. Water is added each day to bring the level to a fixed point in the stilling well.

Pan co-efficient

The pans have higher rate of evaporation than large free water surface, and a factor of about 0.7 is usually recommended for converting the observed evaporation rate to those of large water surface areas. This factor is called pan co-efficient.

Crop co-efficient

Evaporation is equal to pan evaporation multiplied by the crop factor. The value of crop factor for any crop depends on its foliage characteristics, stage of growth, climate and geographical location. Consumptive use values, in general, are low during the early stages of crop growth and increases as plant approach grand growth and again decline with maturity. The value for a particular crop at a location is determined experimentally. The values of crop factor determined and available may be made useful for this purpose.

Crop coefficients (Kc) for major crops (FAO)

Crop	**Crop development stage**					
	Initial	**Development**	**Mid season**	**Late season**	**Harvest**	**Total period**
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0	0.8-0.95	0.7-0.8
Onion	0.4-0.6	0.6-0.75	0.95-1.05	0.95-1.05	0.95-1.05	0.65-0.8
Tomato	0.3-0.4	0.7-0.8	1.05-1.25	0.8-0.95	0.6-0.65	0.75-0.95
Potato	0.4-0.5	0.7-0.80	1.05-1.2	0.85-0.95	0.7-0.75	0.75-0.9
Banana	0.4-0.5	0.7-0.85	1.00-1.0	0.9-1.00	0.75-0.85	0.7-0.8
Grape	0.35-0.55	0.6-0.8	0.7-0.9	0.6-0.8	0.55-0.7	0.55-0.75

Example

Calculation of ETcrop

Month	**June**	**July**	**August**	**September**
Kc(monthly mean)	0.4	0.5	0.9	0.7
ETo (mm/day)	5.0	8.0	10.0	10.0
ETcrop(mm/day)	2.0	4.0	9.0	7.0
ETcrop(per month)	60.0	124.0	279.0	210.0
Etcrop(total)	673			

Variation in crop water requirement

There is considerable variation in crop water requirements from region to region depending up on climate and management practices. The differences are largely due to the length of growing season and incoming solar radiation during crop growing season. Irrigation requirement rarely depend on soil type and rainfall during the crop period.

Crop water requirements (mm)

Crop	**Water requirement**	**Crop**	**Water requirement**
Tomato	600-800	Cabbage	380-500
Potato	500-700	Banana	1200-2200
Pea	350-500	Citrus	900-1200
Onion	350-550	Grape	500-1200
Bean	300-500	pineapple	700-1000

Irrigation requirement

The field irrigation requirement of crop refers to water requirement of crops, exclusive of effective rainfall and contribution from soil profile, and it may be given as follows

$$IR = WR - (ER + S)$$

Where, IR = Irrigation requirement

WR =Water requirement

ER =Effective rainfall

S =Contribution from soil profile

The water requirement and irrigation requirements are usually expressed in terms of water depth per unit of land area in ha.cm or unit of depth in cm.

Irrigation requirement depends upon the irrigation need of individual crop, area of crop and losses in the farm water distribution system.

Net irrigation requirement

Net irrigation requirement is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity.

It is the difference between field capacity and the soil moisture content in the root zone before starting irrigation.

$$NIR = \frac{Mfc - Mbi}{100} \times D_b \times D$$

NIR = Net irrigation requirement (cm)

Mf_c = Moisture content at field capacity (%)

Mb_i = Moisture content before irrigation

D_b = Bulk density of the soil (g/cc)

D = Depth of soil (cm)

Gross irrigation requirement

The total amount of water applied through irrigation is termed as gross irrigation requirement.

It is the net irrigation requirement plus losses in water application and other losses.

The gross irrigation requirement can be determined for a field, for a farm, for an outlet command area and for an irrigation project depending on the need, by considering the approximate losses at various stages of crops.

$$\text{Gross irrigation requirement} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of system}}$$

For example, if the net amount of irrigation is 8 cm and the field efficiency is 75 per cent, the gross amount of water to be applied to the field is

$$8 / 0.75 \quad \text{or} \quad 8x100 / 75 = 10.66 \text{ cm}$$

Irrigation frequency

Irrigation frequency or irrigation interval is the number of days between irrigations during crop periods without rainfall.

It is the interval between two consecutive irrigations during crop periods.

It depends upon the consumptive use rate of the crop and amount of available moisture from the effective root zone.

It is a function of crop, soil and climate.

Normally irrigation is to be given at 50 or 60 per cent depletion of available moisture from the effective root zone.

In designing irrigation system, the irrigation frequency to be used is, the time (days) between two irrigations in the period of peak consumptive use of crops.

$$\text{Design frequency (days)} = \frac{\text{Field capacity - moisture content of the root zone prior to starting irrigation}}{\text{Peak period consumptive use rate of crop}}$$

Irrigation period

Irrigation period is the number of days that can be allowed for applying one irrigation to a given design area during peak consumptive use period of the crop

$$\text{Irrigation Period} = \frac{\text{Net amount of moisture in soil at start of irrigation (FC - PWP)}}{\text{Peak period consumptive use rate of crop}}$$

The irrigation system must be so designed that the irrigation period is not greater than the irrigation frequency.

Effective rainfall

Effective rainfall means useful or utilizable rainfall

The useful portions of rainfall, which is stored and supplied to the crop for its consumptive use is called effective rainfall.

Measurement of rainfall is made by a standard rain gauge. Data are usually available from a local weather station. Different components of effective and ineffective rainfall may be measured by weighing type lysimeters described earlier. Soil water content in the root zone before and after the rainfall is estimated for knowing the effective rainfall. The increment of soil water that occurs due to rain together with the crop ET during the period between the two soils samplings done before and after rainfall constitutes the effective rainfall.

All the rainfall received is not used by crops due to erratic nature in occurrence, intensity and quantity. Part of the rain which moves out of the field by surface runoff and deep percolation beyond the root zone are ineffective rainfall.

The factors influencing effective rainfall are the rainfall characteristics, land slope, soil properties, groundwater characteristics, management practices, crop characteristics and carry over soil moisture.

Exercise

1. A weighing type lysimeter lost 6.25 Kg weight in a day of 24 h through evapo transpiration showing an evapo transpiration value of 5.0 mm /day. Calculate the surface area of lysimeter.
2. After how many days the water has to be applied to a vegetable crop, with the following particulars.

   Soil moisture content at FC = 30%

Soil moisture content at PWP = 12%

Bulk density of the soil = 1.25 g/cc

Effective root zone depth of the soil = 60 cm

Daily consumptive use of the crop = 12.5 mm

Level of ASM for scheduling irrigation (20% DASM) = 80%

3. With the following information available find out the net depth of irrigation water application and irrigation period.

Soil moisture content at FC = 30%

Soil moisture content at PWP = 15%

Soil bulk density = 1.5 g / cc

Effective root zone depth = 75%

DASM level for irrigation = 75%

Irrigation efficiency = 80%

Ex.No. 11

Scheduling of irrigation – preparation of schedule by different approaches for annuals, perennials under different methods of irrigation and climate -soil type

Horticultural crops include annuals and perennials. Most of the vegetable crops come under the annual crops. Annual crops have varying duration extending for one season or more than a season but complete life span within a year.

Frequency of irrigation and amount of water to be applied depend on a number of factors like depth of root system, water use efficiency, stages of growth, soil type, prevailing weather condition and actual consumptive use of crop. Rooting depth vary greatly among vegetable crops from 30 to 180 cm.

Approaches in irrigation scheduling

Several approaches in scheduling irrigation have been used by scientists and farmers throughout the world, each one having its own advantages and disadvantages.

Soil moisture depletion approach

The available soil moisture in the effective root zone is a good criterion in scheduling irrigation. When the soil moisture in the specified root zone depth is depleted to a pre determined level, may be 50% depletion of available soil moisture, it is to be replenished by irrigation. For most field crops, 50% depletion of available soil moisture is found to be most appropriate in scheduling irrigation.

The degree of depletion can be assessed by available soil moisture estimation through gravimetric, tensiometer, resistance block and neutron probe methods.

These approaches are reliable, but cannot be recommended to farmers since the means to measure soil water content or soil moisture tension is not easily available.

Actual measurement of soil moisture and subsequent calculation of available soil moisture.

The gravimetric method is the basic and standard determination of soil moisture content to which all other methods are referred. Soil samples are dried at 105^0 C until a constant weight is reached. The difference in weight before and after drying divided by the weight of the dry soil gives the water content by weight. The other way of expression is water content by volume.

$$Dm = Ww- Dw/Dw * 100 * Db * DS$$

Where

Dm _ Soil moisture deficit at different layers

Ww – Wet weight of soil

Dw – Dry weight of soil

Db – Bulk density

Ds – Depth of soil layer

The soil moisture for different depths may be calculated and added for total quantity or the mean values of soil moisture content and apparent density may be taken and worked out for the deficit moisture level for replenishment.

Use of Tensiometers for soil moisture estimation

Irrigation can be scheduled based on soil moisture tension with the use of tensiometers. Tensiometers are installed at required depth in the root zone. When the soil moisture tension reaches a specified value (0.50, 0.75 or 1.0 bar etc) irrigation is scheduled. Tensiometers are generally used for irrigating orchards especially in coarse textured soils.

Simple techniques in irrigation scheduling

Other simple techniques are in practice for scheduling irrigation to crops are described below

a) Indicator plant technique

Some crops like sunflower and tomato are highly sensitive to water stress which will show stress symptoms earlier than other stress tolerating crops. Hence to know the stress symptoms earlier, such sensitive crops are planted in random in the field and based on the stress symptoms noticed in such plants, scheduling of irrigation can be made. This approach is called as indicator plant technique in scheduling irrigation.

b) Micro plot technique

In this method, one cubic metre pit is dug in the middle of the field. About five percent sand by volume is added to the dugout soil, mixed well and the pit is filled up in the natural order to have more infiltration and less water holding capacity than the actual main field. Crops are grown as usual in the entire area of the field including the micro plot area. The plants in the micro plot show wilting symptoms earlier than the other plants in the remaining area. Irrigation can be scheduled as soon as wilting symptoms appear on the plants in the micro plot.

c) Plant indices

Any plant character, related directly or indirectly to plant water deficit which responds readily to integrated influence of soil, water, plant and evaporative demand of the atmosphere may serve as a criterion for timing of irrigation to crop.

Visual symptoms of plant wilting can be used to schedule irrigation to crops. Farmers usually use drooping, curling or rolling of leaves and changes in foliage colour as an indication for irrigation scheduling.

Relative leaf water content and leaf water potential

Some crops such as sugarcane show strong correlation between the water content of leaf or leaf sheath and the available soil water. The relative leaf water content (RLWC) and leaf water potential change with variations in soil water availability or owing to lag between water absorption by plants and evaporative demand of the atmosphere. The relative leaf water content and plant water potential have been suggested for scheduling irrigation. However sophisticated equipment, intricate measuring devices, high cost and lack of proper standardization of instruments deter the use of this technique on large scale.

Plant temperature

Solar radiation reaching on the earth not only causes evapotranspiration but also heats up leaf tissues. With water deficit in plant the temperature of leaf tissues rises. Many investigations have shown that leaf temperature is a sensitive index of plant water status. The difference between stressed and unstressed leaf or canopy temperatures was a better index of water deficit than the difference between plant canopy and air temperatures.

Orchard crop irrigation management

The depth of root penetration varies from 1 to 9 m depending up on the fruit species. However as much as 80 – 85% of the available soil moisture is drawn from 0-90 cm layer by most of the tree fruit species and thus for all practical purposes the amount of water applied should replenish the water deficit of this layer (0 – 90 cm). During warm period or summer the 90 – 120 cm layer need to be replenished. Irrigation is most effective if applied before soil moisture becomes limiting to fruit trees.

As a thumb rule, water should be applied when 50 % of the available water in the root zone has been depleted. If further depletion is allowed, the plants may be subjected to a level of stress that might cause an appreciable reduction in yield. The available water refers to total soil moisture held with a water potential between -0.33 bars and -15 bars. Perennial fruit trees, by virtue of a deep root system, absorb water from deeper soil layers even if water potential soil layers of the upper layers drops below -15 bars the trees may not show wilting symptoms. But such a condition adversely affects subsequent growth and fruiting of the trees.

Papaya

Papaya is a crop of humid tropics. The crop is irrigated at 12 days interval in winter and at 6- 8 days in summer. The crop can not tolerate water stagnation and well drained condition is important for good papaya growth. In monsoon drains are necessary to be provided for removal of excess water and the same is used as irrigation channel during summer. Soil moisture potential of 0.5 to 0.8 bar seems ideal for papaya crop. The crop needs 120 cm water in 9 months.

Pine apple

Pine apple is mostly grown as a rainfed crop, but supplementary irrigation helps in production. Irrigation at 75% depletion of available soil moisture is sufficient. Therefore 4-6 irrigations in hot months at 20-25 days ensure good crop.

Guava

Guava hardly requires any irrigation during rainy season. In the early stage, plants require 8-10 irrigations a year, while fully grown bearing trees require watering from April to June at 15 days interval to get higher fruit set. Irrigation at early fruit set was also found to be effective in reducing fruit drop and improving fruit size of winter crop.

Scheduling tuber crops

Sugarbeet

The crop can be suitably irrigated by furrow and sprinkler method of irrigation. Consumptive use of sugarbeet varies from 800-1000 mm. frequent irrigation at IW/CPE ratio of 0.85 is more conducive for sugarbeet yield.

Potato

For land preparation about 4-5 cm water is required. After planting sprinkling helps in quick germination. After 20 days when the stolons start forming the crop needs irrigation. Irrigation at 0.3 to 0.4 bar (soil water potential) in 0-15 cm layer is good for potato.

In sandy soils of Bhubaneswar, the crop needs irrigation of 2.5 cm at 4 days interval till 25th day. After hoeing, topdressing and earthingup 3cm irrigation at 4 days interval till harvest produced maximum yield

Vegetable crops

Tomato

Tomato an important fruit bearing vegetable crop. Under Delhi conditions optimum moisture regime was found to be from 100- 60% availability of soil moisture in 0 -120 cm root zone.

Radish

This is a rapid growing crop and has limited root system and respond readily to irrigation.Radish matures in 4- 6 weeks. Irrigation at frequent intervals

Cauliflower

Adequate moisture is necessary in the top 40 cm of soil all through the growth period. Shortage of water in the early seedling stage or just after planting or when curds are growing rapidly leads to physiological disorders. Depletion of more than 25% available soil moisture is deleterious. However, irrigation at 50% depletion of available soil moisture at 30 cm soil depth is optimum on sandy loam soil at Delhi. Two to four irrigations are required depending on the rainfall.

Spices and condiments

Important crops in this group are turmeric, ginger, chillies, coriander,etc. Turmeric and ginger respond to irrigation at 40% depletion of available soil moisture in the 50 cm soil depth. The optimal moisture regime for chillies is 50-100% available soil moisture in the top 60 cm of soil depth. Flowering and fruit development are critical periods. Coriander and cumin are winter crops and irrigation is given at 10-12 days interval on light soils and 15-20 days interval on heavy soils.

Example

1. Calculate the total water presently contained in the top 120cm soil layer of a mango orchard spreading in an area of one hectare and the quantity of water required to wet the soil to field capacity level. The soil measurements are as follows.

- Present water content(W/W) 18 percent
- Water content at FC (W/W) 21 percent
- Permanent Wilting Point(W/W) 9 per cent
- bulk density of the profile on an average 1.35 g/cm^3

2. Given the following information, find out the irrigation interval.

- Field capacity of the soil = 30%
- Permanent wilting point = 11%
- Bulk density of the soil = 1.3 g/ cm^3
- Effective root zone depth = 700 mm
- Level of DASM for irrigation = 25%

3. With the following information find out the allowable depletion depth between irrigations, frequency of irrigation, net depth of water application and volume of water required.

- Available soil moisture = 140 mm/m depth
- Effective root zone depth of the crop = 30 cm
- Allowable soil moisture depletion = 35 %
- Daily water use rate = 5 mm /m depth
- Area to be irrigated = 6 ha
- Irrigation efficiency = 40%

Ex. No. 12

Working out Irrigation scheduling based on soil type and climatic requirements

It is the decision making process indicating when irrigation water is to be applied and the quantity of water to be applied each time.

Soil as a factor influencing on scheduling of irrigation

Water retentive capacity of the soil is considered as the most important soil factor deciding the frequency and interval of irrigation. Texture, structure, aggregates and organic matter influence the water retentive capacity of the soils.

A soil with greater water retentive capacity serves as a bigger water reservoir for crops and can supply water for longer duration. Consequently, frequency of irrigation is lower and interval of irrigation is longer in heavier soils and in soils with crumb structure, good organic matter content and low content of soluble salts.

On the other hand, the frequency is more in porous sandy soils with coarse texture, poor structure and low organic matter content. Retention of greater amount of available water is considered more important than total quantity of water retained by a soil.

Depth of soil is another factor that influences the frequency of irrigation. A shallow soil can not hold enough water to meet the crop demand for a longer period. Necessarily, frequent irrigations are required with smaller depth of water each time. Irrigation at long interval is applied to deep soil that has a greater storage capacity. Such soil can supply water for longer duration particularly when the root system is quite deep and extensive.

Soil texture	**F.C.(% by weight)**	**P.W.P (% by weight)**	**Available soil water(cm/m depth)**
Sandy	5-10	2-6	5-10
Sandy loam	10-18	4-10	9-16
Loam	18-25	8 -14	14-22
Clay loam	25-32	11-16	17-25
Clay	32-40	15-22	20-28

Approaches in irrigation scheduling

Several approaches in scheduling irrigation have been used by scientists and farmers throughout the world, each one having its own advantages and disadvantages.

1. Soil moisture depletion

The degree of depletion can be assessed by available soil moisture estimation through gravimetric, tensiometer, and resistance block and neutron probe methods.

These approaches are reliable, but cannot be recommended to farmers since the means to measure soil water content or soil moisture tension is not easily available.

2. Climatological approach

The amount of water lost through evapotranspiration (ET) is estimated from Climatological data and when ET reaches a particular level, irrigation is scheduled.

The most widely used approach for scheduling irrigation based on Climatological data is termed as IW/CPE ratio method.

In IW/CPE ratio approach, a known amount of irrigation water (IW) is applied when the Cumulative Pan Evaporation (CPE) from an USWB open pan evaporimeter reaches a pre-determined level.

The ratio can be expressed as

$$\frac{IW}{CPE} = \frac{\text{Depth of irrigation water}}{\text{Cumulative pan evaporation}}$$

The irrigation depth (IW) for different crops are fixed based on soil, climate and root zone depth and it ranges from 4 to 6 cm, the most common being 5 cm of irrigation

For fixing the ratio of IW/CPE for each crop, experiments are conducted by irrigating the crop at different ratios and the ratio, which gives the maximum yield, is taken as the optimum IW/CPE ratio. The ratio ranges from 0.4 to 1.0 for different crops.

For arriving the cumulative pan evaporation value, the daily pan evaporation data are added till it is equal to the ratio of the amount of water applied as irrigation

Scheduling irrigation at IW / CPE ratio of 1.0 with 5 cm of irrigation water means, 5 cm of irrigation is to be applied when the cumulative pan evaporation reaches 5cm.

The irrigation depth (IW) divided by the ratio (R) will give the cumulative pan evaporation value at which irrigation is to be made

For example, if the irrigation depth needed is 50 mm and the optimum ratio is 0.5, the cumulative pan evaporation value needed to irrigate the field is

$$CPE = \frac{IW}{R} = \frac{50}{0.5} = 100 \text{ mm}$$

If the 100 mm CPE is attained in 10 days @ 10 mm per day of pan evaporation, irrigation is to be scheduled at 10 days interval.

In the same way, if the CPE and ratio (R) are known, the amount of irrigation water to be scheduled at 10 days interval is

$$IW = CPE \text{ X } R = 100 \times 0.5 = 50\text{mm}$$

Problem

Calculate the cumulative pan evaporation value at which irrigation is to be scheduled for tomato, if the IW/CPE ratio recommended is 0.6 and irrigation water to be

$$CPE = \frac{IW}{R} = \frac{50}{0.6} = 83.3 \text{ or } 83 \text{ mm}$$

applied is 50 mm.

This approach provides best correlation since climatic and soil parameters are considered.

For use by farmers, the values are to be translated in terms of irrigation interval in days between two consecutive irrigations.

Depth of irrigation

Depth of irrigation is a function of the water retentive capacity of the root zone soil and the extent of soil water depletion at the time of irrigation. It refers to the depth to which the applied water would cover an area. As for example, a 10 cm depth of irrigation to a hectare denotes the volume of water which when allowed to stand without any loss or infiltration into the soil would stand over one hectare area to a depth of 10 cm. The net depth of irrigation is decided by the amount of water required to bring the soil water content just before an irrigation to field capacity in the root zone soil.

Pan evaporation for scheduling irrigation

As the rate of evaporation from pan evaporimeter is higher than that over a large free water surface, the pan evaporation value is multiplied by 0.7 to obtain the evaporation rate over the large free water surface (E_o). The relationship between actual evaporation and pan evaporation rates may be presented as,

$$E_o = K_p . E_{pan} \text{ or, } \quad Kp=Eo/Epan$$

Where,

K_p = pan evaporimeter coefficient (a commonly used value of 0.7)

E_{pan} = evaporation value from pan evaporimeter

$$ET_{crop} = K_c.ET_o$$

$$K_c=ET_{crop} / ET_o$$

Where K_c is the crop co-efficient.

Irrigation schedule for Spices

Pepper

In India irrigation during summer is beneficial. Irrigation at IW/ CPE ratio of 0.25 or summer irrigation of pepper vines @ 10 litres /vine/week by basin method from December to march increases the yield.

Garlic

1. First irrigation is given just after sowing and then the field is irrigated after every 10-15 days till the season warms.
2. Irrigation at 60 mm CPE for higher yield. Frequency of irrigation should be decreased towards maturity.

Vegetable crops

Tomato

Tomato is a deep rooted plant with high water requirement. Adequate water supply is necessary from the start of fruit set. Irrigations are necessary at flowering, fruit development and fruit ripening stages. The plant is sensitive to excessive moisture in seedling stage. The optimum moisture regime is at 70 to 100% soil moisture availability. Irrigation scheduling of IW/CPE ratio of 0.75 during vegetative period and 0.9 thereafter give higher yield.

Exercise

1. A crop is irrigated to a depth of 5 cm using IW/CPE approach. The ratio is taken as 1.0. Then what should be the cumulative pan value for irrigating the crop?
2. It is proposed to irrigate a tomato crop at IW/CPE ratio of 0.75 during vegetative period and 0.9 thereafter to 6cm depth of water. What should be the CPE for the schedule during vegetative and reproductive stage?
3. A young orchard is to be irrigated when half of the available water in the top 90 cm soil is used up. How often must the orchard be irrigated during May when the class A pan evaporation is 5.6 cm of water per week? The orchard soil is a loamy soil holds 5.0 cm of plant available water in top 30 cm and 10.6 cm of plant available water in the rest 60 cm sub-soil. The crop coefficient (Kc) for the month is 0.8 and pan coefficient is 0.7.

Ex. No. 13

Practicing the use of instruments in irrigation practices

Tensiometer

Matric potential can be measured *in situ* with tensiometers in the tension range upto about 0.8 bars. Tensiometer consists of a ceramic porous cup and a mercury manometer attached to the water filled cup through a water reservoir tube. The porous cup has high conductance, low response time and air entry pressure of about 1.0 bar. When a porous cup is placed in a soil and equilibrated, water tends to move out of the cup under the suction exerted by soil. As a result, vacuum pressure develops in the cup and to make up this, mercury rises in the manometer tube attached to water reservoir tube. Vacuum in porous cup is actually is the matric potential of soil water. Tensiometer indicates the tension with which water is held by the soil but not the actual water content. Relationship between soil moisture tension and available soil moisture has to be prepared for reading soil moisture percentage.

Useful limit of most tensiometers is about -0.8 bar of maximum potential. Hence, they are more accurate in wet range of soil. Tensiometers are ideal for sandy soils as -0.8 bars may occur at about 80 per cent of available soil moisture. Matric potential can be measured in situ with tensiometers in the tension range of up to 0.8 bars.

Electrical resistance blocks

Installation

Materials

Block units and a post hole augur, a wooden rod

Procedure

Sink a bore with a post hole auger to the depth of installation of blocks. Place the blocks inside and fill back the bore in small depths by tamping the soil with a wooden rod. After placement ensure that there is an intimate contact of the block with the soil. There should not any root pieces, pebbles, etc., near the blocks. Fill back the whole bore with the soil in its natural order.

Do not place two blocks at a vertical interval less than 30 cm. Normally four to five blocks can be placed in one bore. When more than one block is to be installed in a bore, label them near their terminals carefully with their depths before installation.

Heap the soil to a height of about 3 cm near the surface at the bore spot to prevent any water stagnation. Irrigate the field and note the readings. Check the resistance reading at field capacity.

While installing in a crop, ensure that these are placed in the root zone. The convenient spot for installation is in a row and in between two plants, which avoids any disturbance during intercultivation, etc.

Pressure plate method

The method is used to determine the soil water potential curve or soil water release curve up to two atmospheric pressure. It consists of a closed air tight chamber in which soil sample is placed on a ceramic plate permeable to water. The chamber is connected at the top to a compressor to create the desired pressure and at the bottom, to an outlet for water. The portion of the chamber below the plate is kept at atmospheric pressure and the plate remains in contact with water. Constant pressure at desired level is applied to the upper side of the plate and water flows out from the saturated soil sample through the outlet. When soil water comes in equilibrium at the pressure applied, the soil sample is taken out and water content is estimated gravimetrically. Soil water contents at different pressures are determined to construct the soil water potential curve which is referred to estimate the water content of a soil at a particular pressure whenever wanted.

Pressure membrane method

It is a pressure plate apparatus. It is particularly used when soil water potential curves from low to more than 15 atm are required. Because of high pressure used, the construction of apparatus is robust and a cellulose membrane is used in place of porous ceramic plate. The cellulose membrane rests on a fine screen mesh and / or blotting paper and water drains through a small outlet in to burette.

Exercise

Gather information of the following instruments and observe the working where ever available.

a) Infrared thermometer

b) Steady state porometer

c) Neutron probe meter

Ex. No. 14

Irrigation planning and scheduling for the water resources available

Irrigation water drawn from different sources *viz,* river, canal, tank, open well or tube well always contain some soluble salts dissolved in it. Water being a universal solvent, several salts are dissolved in irrigation water. The quality and quantity of salt present in the water depend on the nature of water sources, and the soils and underground strata over which the water flows. The main soluble salts in water are Ca, Mg, Na and K as cations and chloride, sulphate, carbonate and bicarbonate as anions. The amount and kind of salts present determines the suitability of water for irrigation.

Classification and suitability of irrigation water

Classification and suitability of irrigation water to crops are based on the following criteria.

1. Total salt concentration
2. Relative proportion of sodium to other cations
3. Carbonate and bicarbonate concentration and
4. Boron concentration

1. Total salt concentration in irrigation water

Total concentration of soluble salts is the most important single criterion of irrigation water quality. The harmful effects increase with increase in total salt concentration.

Water salinity is the amount of salt contained in the water. It is also called the salt concentration and may be expressed in grams of salt per litre of water (grams/litre or g/l) or milligrams per litre (which is same as the ppm). However, the salinity of both water and soil is easily measured by means of an electrical device. It is then expressed in terms of electrical conductivity i.e. millimhos/cm. A salt concentration of of about 1 g/l is about 1.5 millimhos/cm. Thus a concentration of 3 g per litre will be about the same as 4.5 millimhos/cm.

Soil salinity

The salt concentration extracted from a saturated soil defines the salinity of the soil.

Salt concentration of the soil water salinity

In g/l	In millimhos/cm or dS/m	Category
0-3	0-4.5	Non saline
3-6	4.5 – 9.0	Slightly saline
6 – 12	9 – 18	Medium saline
>12	>18	Highly saline

Irrigation water quality

Salt concentration of the irrigation water in g/l

Salt in g/l	Soil salinization risk	Restriction on use
Less than 0.5 g/l	No risk	No restriction on use
0.5 – 2.0 g/l	Slight to moderate risk	Should be used with appropriate water management practices
>2.0 g/ l	High risk	Not generally advised for use

The type of salt present in the irrigation water will influence the risk of developing sodicity. The higher the concentration of sodium present in the irrigation water the higher the risk.

Management of saline water for irrigation

In areas where there is no alternate source of good quality water for irrigation, it is inevitable to use the available water of poor quality. The yield potential of crops under these conditions can be increased by adopting the following management practices.

1. Application of greater amounts of organic matter such as farmyard manure, compost , green manuring etc., to improve soil permeability and structure.
2. Application of gypsum to the irrigation water to increase the proportion of calcium.
3. Combined use of poor quality water with good quality water in proper proportion so that both the sources are effectively used for maximum advantage.
4. Scheduling irrigation with small quantity of water at more frequent intervals to avoid shortage of available water to plants.
5. Optimum use of manures and fertilizers to encourage favourable growth of crops and application of acid forming fertilizers like ammonium sulphate, di-ammonium phosphate and super phosphate.
6. Providing better drainage facilities.
7. Adopting ridges and furrow and drip methods of irrigation.
8. Deep ploughing to break the impervious layer.
9. Mulching with locally available plant materials to reduce evaporation and increasing infiltration.
10. All soil management practices that improve the infiltration rate and maintain favourable soil structure reduce salinity hazard.
11. Selection of salt tolerant crops. The tolerance of crops for salinity is listed below.

Degree of salt tolerance		
Good	***Moderate***	***Poor***
Turnips	Lettuce ,Tomato,Asparagus,Carrot	Peas, Celery, Cabbage, Egg plant
Beet root	Spinach,Onion, Pepper, Clove	Sweet potato ,Potato,Green beans, Plum , Pear, Apple, Orange
Date palm	Fig, Grape, Olive	

Irrigation management under limited water supply

Integrated use of all the available water resources namely surface, ground water and waste water is most essential to obtain maximum productivity per unit of water used to meet the growing demand. Due to uncertainty in occurrence and distribution of rainfall, the availability of water for crop production becomes limited. Under this condition, new management techniques are to be adopted in irrigation management and crop production activities to mitigate water scarcity due to limited supply of irrigation water.

Management strategy under limited water supply

1. Assessing resource potential

Optimizing the irrigation water

2. Improvement in conveyance structure

It is estimated that 30 – 40 % of water is lost in conveyance and the losses can be minimized by proper maintenance and lining of channels.

3. **Conjunctive use of water**

Optimum use of water from different sources is the main aim of conjunctive use. In canal irrigation system, optimum utilization of rainfall and well water is essential to protect the crop from scarcity of water.

Management technique under limited water supply

1. Summer ploughing is to be practiced to conserve moisture, check weed growth and to facilitate dry sowing and Strengthening bunds
2. Adoption of drip and sprinkler methods of irrigation and on farm management to reduce water loss
3. Introduction of new cropping pattern for efficient utilization of water
4. Adoption of watershed and water conservation methods
5. Turn and rotational system of water supply can be adopted

Other techniques are

Irrigation at critical periods, in situ moisture conservation, mulching, selection of drought resistant varieties, growing deep rooted crops, weed control with herbicides, adopting alternate and skip furrow methods of irrigation

Exercise

1. An irrigation water contains 2000 ppm of salt. Find the salt in terms of g / l or millimhos/cm or dS/m.

Ex. No. 15

Working out area irrigable with available source of water

Horticultural crops are grown in an ecosystem which is in between the wet and dry systems. In certain regions it is termed as irrigated dry condition. They are called as garden lands. The cropping activities are taken up with the onset of rain and the crops are supplemented with water through irrigations. The crop production is assured in that situation.

The following information are required for efficient utilization of the water available.

- ✓ Area of the Garden
- ✓ Crops grown and to be raised during the year
- ✓ Water requirement of the crops
- ✓ Duration of the crops
- ✓ Water sources and period of water availability
- ✓ Energy requirement for irrigation- By gravity or by pumping
- ✓ Discharge available through the water sources

Area of the Garden

It is a fixed one for the gardener. Based on the size it may be categorized into marginal, small, medium and large one as in the case of farms raising field crops. The soil type, climatic conditions, topography, water and organic matter availability play a role in the irrigation planning.

Crops grown and to be raised during the year

The crop selection is influenced by many factors. They are grouped into physical, chemical, biological, social and economic factors. In a garden setting aside of the socio-economic factors the physical factors climate, soil , water availability , biological factors such as crops grown in other farms ,competing in the cropping programme, pest problems play a role in the selection.

The crops that have the suitability to the physical and biological factors is listed and the one fetching more profit to the farmer is selected. Taking in to consideration of the soil fertility and productivity crop diversification is included in the crop planning.

Water requirement of the crops

Water requirement of the crop to be grown has influence on the selection. It determines on the area of the crop grown. Water requirement based on the estimation or by experimentation is taken for the individual crop and for the crops in the cropping programme.

Duration of the crops

Duration of the crop is essential information on the extent of the period of irrigation and the number of times the crop is irrigated and helps in planning the irrigation.

Water sources and period of water availability

Water availability to the farm may be from different sources i.e. Canal, tank and well. The water availability period during the year in total and for the seasons is information for raising seasonal crops.

Energy requirement for irrigation- By gravity or by pumping

Discharge available through the water sources

Whether the water is made available by gravity flow or by pumping and the discharge from these sources. How much water is available for a given time.

Problem

1. How much area of a brinjal crop may be irrigated with the water discharge available at the rate of 5 litres per second from a pump set of an open well? The crop is irrigated to a depth of 50 mm for each irrigation. The pump is operated for 8 hrs in a day. The irrigation efficiency is 70 %.Assume that the water is available for 6 months.

Solution

Total quantity of water discharged in a day in m3 = Discharge in litres/Second x60 x 60 x8 /1000 m^3

$=5x60x60x8/1000\ m^3=144\ m^3$

Water required for one square metre for irrigating to a depth of 50 mm = 1x50/1000 $m^3=0.05m_3$

The area irrigable with the water discharged = total water dischargeable in a day/ water required for irrigating 1 Sq.m x irrigation efficiency, which is 0.70

=144/0.05 x 0.7 = 2016 m^2 approximately 1/5 of a hectare.

Number of days required for irrigating one hectare = 10000 m^2/ area irrigated by the source in a day

=10000/2016 = 4.96 days or 5 days.

Problem

2. How much time is required to irrigate an area of 10 m x 5 m to a depth of 5cm if the flow rate is 2.5 lit/sec.

Solution

Flow rate =2.5 lit/sec

Area = 10x5 = 50 sq.m.

Depth = 5 cm = 0.05 m

Volume of water required = 50x 0.05= 2.5 m^3= 2500 litres

1000 lit = 1 cumec

T = Volume/ discharge = 2500/2.5= 1000 sec

=16 min 12 sec

Problem

3. How much depth can 1 cumec of water for 10 minutes wet over an area of 2 ha?

Solution

Area = 2x10000 = 20000 sq.m

Discharge = 1 cumec x 10 x 60 = 600 cumecs

Depth = Volume/ area= 600/2000 = 0.03 m

=3cm.

Problem

4. A tube well having a capacity of 4000 lit per hour operates for 10 hrs each day during the crop season. How much area it can command if the irrigation interval is 20 days and depth of irrigation is 7 cm?

Solution

Tube well capacity = 4000 x10=40000 lit/day

= 40 cumec / day.

Depth = 0.07 m

Irrigation interval = 20 days

Volume of water required to cover 1 ha is 10000x0.07 = 700m^3

700 m^3 of water covers 1ha of land

40 m^3 of water will cover = (40/700)*1= 0.057 ha

Water management for horticultural cropping system

Assured irrigation water is the real potential for multiple cropping. Major irrigated areas receive irrigation water only for a part of the year. A horticultural farm differs from a farm engaged in field crop production. The crops have differing habits and duration and their requirement on water with respect to quantum, quality and the way in which it is applied. The soil and climate also considerably vary. A grower may not restrict only to the horticultural crops. He may be growing a combination of field and vegetable crops or fruit crops. He may also be raising more than one vegetable or fruit crops.

Example

A farmer owns a farm of 2 hectares. He plans to raise 0.4 ha each of mango, sapota, guava and lime. The annual water requirements of these crops under drip irrigation are 70.3, 42.4, 9.9 and 12.4 lit/day respectively. The spacing recommended is 10x10m for mango, 8x8 m for sapota, 5x5m for guava and 4.5x4.5m for lime. Besides he desires to raise vegetable in 0.4 ha which will have an average consumptive use of 5 mm per day. The farmer has a tube well with a discharge of 10 lit/sec. Find out how much area the farmer can take up cultivation? How much water is in excess or deficient? Suppose the farmer does not want to spent more money on drip irrigation and prefers to select surface method a water requirement of 166% is required.

Ex. No. 16

Soil moisture conservation practices for increasing WUE

Water use efficiency

i) Field water use efficiency:

It may be defined as the ratio of the amount of economic crop yield to the amount of water required for crop growing. It is obtained as follows.

$$Eu = \frac{Y}{WR}$$

Where

Eu = Field water use efficiency expressed in kilogram of economic yield per hectare – cm or ha-mm of water.

Y =Economic yield in kilogram per hectare

WR =water requirement of the crop in hectare-cm or ha-mm.

ii) Crop water use efficiency

This may be defined as the ratio of the amount of economic yield of a crop to the amount of water consumptively used by the crop. It is found out as follows.

$$Ecu\ (\text{or WUE}) = \frac{Y}{\text{CU or ET}}$$

Where,

Ecu = crop water use efficiency in kilogram of economic yield per hectare-cm or ha - mm of water.

Y = Economic yield of crop in kilogram per ha.

Cu =Consumptive use of water in ha-cm or ha-mm

ET = Evapotranspiration in ha-cm or ha- mm.

To maximize crop water use efficiency, it is necessary both to conserve water and to promote maximal growth.

Ways to improve water- use efficiency

Conservation practices

Increasing the moisture storage in the root zone is one of the approaches to increase yields and in turn WUE. Conservation of rain water under unirrigated conditions is possible by

1. Taking steps which are conductive to the maximum absorption in to the ground in a given area.
2. Reducing loss of stored water in evaporation, consumption by weeds and sub-surface flow.
3. Improving structure of soil by addition of organic amendments

Tillage

a) a.to produce a suitable seed bed

b) b. to destroy weeds

c) c. to conserve moisture

d) d.to maintain soil and surface conditions resistant to erosion.

Land formation

Broad Bed and Furrow is superior over flat method which increases infiltration of rain water in to sub-surface in situ. Compartment bunding, graded bunds, contour bunds, vegetative live bunds check erosion improve water storage in the soil.

Incorporation of organic amendments

Incorporation of 10 t FYM/ha or 15 t/ha of calotropis foliage at 30 cm depth increased the water holding capacity in sub-surface layer and increasing yield of bajra by 50%

Moisture conservation practices

Mulching: Checks evaporation from soil surface, increasing infiltration and thus conserve moisture in soil. Straw, husk or polythene are effective in a drought year.

Fertilizer application: A balanced nutrient supply is beneficial even under limited rainfall, as it actually enables the crop to make more efficient use of limited soil moisture available.

Weed control: Controlling weeds at the early stage of crop would conserve more moisture since weeds frequently transpire greater amounts of water per unit of dry matter produced than the plants.

Anti- transpirants: PMA, Kaoline, Diuron at low concentration reduce the transpiration. Removal of older or senescent leaf helps to reduce evapotranspiration losses.

Reducing leaf area: Removal of older or senescent leaf helps to reduce evapotranspiration losses

WUE under irrigated conditions

In irrigated conditions, efficient utilization of irrigation water and increasing productivity per unit of irrigation water depends on two factors.

1. 1.Efficient conveyance of irrigation water
2. 2.Soil and plant characteristics

Water use efficiency under irrigated conditions could be increased by selection of efficient crop, appropriate irrigation method, scientific way of scheduling irrigation, efficient fertilizer management and required plant protection methods.

Increasing the effective rainfall: Water from precipitation stored in the soil contributes to consumptive use of water. Increasing this fraction of rainfall will appreciably reduce irrigation requirement.

Enhancement of crop growth

All possible packages to provide a favourable environment for maximum growth and yield of crop like time of planting, optimum tillage, appropriate pest management, optimum nutrient management and irrigating at high frequency.

Landscape water conservation

Xeriscaping

Xeriscaping is a term used to describe landscape practices involving water conservation. The word is derived from the greek word xeros, which means dry. The practice is most common in parts of the country where rainfall is scarce. It involves designing to group plants of similar water needs, limiting turf areas, selection of drought tolerant plants, improving drainage and water holding capacity, use of efficient irrigation system, use of mulches, weeding, pruning and scheduling of irrigation by scientific methods.

Exercise

1. Observe and understand the various measures used by the gardeners in minimizing the loss of water.
2. The onion crop raised yielded 20tonnes per hectare and the water applied through irrigation was500 mm during the crop period with an efficiency of 70%. Find out the field water use efficiency and crop water use efficiency.

   FUE = 20x1000/500= 40 Kg / ha- mm of water

   CUE = 500x0.7= 350 mm =20000/350=57.1 Kg/ha-mm water
3. Given the following information work out water conveyance efficiency, water application efficiency, water storage efficiency and water distribution efficiency.

   Canal stream size = 125 lps

   Stream size delivered to the field = 100 lps

   Area irrigated = 1.6 ha in 8 hrs

   Effective root zone depth = 1.7 m

   Run off losses in field =420 m^3

   Variation in the depth of application = 1.7m at head end to 1.3 m at the tail end

   ASM holding capacity of soil = 20cm m^{-1} depth

Irrigation schedule = 50% DASM

Water conveyance efficiency (Ec) =Wf/Wr x 100

Wf = water delivered to the farm

Wr = water delivered to the reservoir

Ec= 100/125= 80%

Water application efficiency (Ea) =Ws/Wr x100

Wf = water delivered to the farm = 100x60x60x8/1000= 2880 m^3

Wr = water stored in the root zone = 2880-420= 2460 m^3

Ea = 2460/2880 x 100 = 85.4%

Water storage efficiency (Es) = Ws/Wn x 100

Ws = water stored in the root zone

Wn = water needed in the root zone

Root zone water holding capacity = 20x1.7=34cm

Moisture in the root zone at irrigation start = 50/100x34= 17 cm

Additional water required in root zone of 1.6 ha = 17/100x1.6 x10000= 2720 m^2

Es = 2460/2720x100= 90%

Water distribution efficiency (Ed) = (1-y/d) x100

y= average numerical deviations in depth of water stored from average depth stored during irrigation

d= the average depth stored during irrigation

Mean depth of water stored in root zone = (1.7+1.3)/2=1.5 m

Numerical deviation from depth of penetration

Upper end = 1.7-1.5=0.2 m

Lower end = 1.5-1.2 = 0.2m

Average numerical deviation = (0.2+0.2)/2 = 0.20

Average numerical deviation = 100(1-(0.2/1.5))= 86.7%

Ex.No.17

Final practical examination


**********Thanks**********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