Dryland Horticulture

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Lesson Number	Lesson Name
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	Pitting/Planting, Canopy Management
Lesson 12	Characters and Special Adaptation of Crops: Ber, Aonla, Annona, Jamun, Wood Apple, Bael, Pomegranate, Carissa, Date Palm, Fig, West Indian Cherry, and Tamarind

Understanding a farmer's life is crucial because he puts all his hopes into his fields.

Course Name	Dryland Horticulture
Lesson 1	Definition, Importance and Limitation Of Dry Land Horticulture
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Objectives of the lecture:

- Definition, importance and limitation of dry land horticulture, present status and future scope.
- Constraints encounter in dry lands

Glossary of terms

1.	Dryland	-	The area where annual rainfall or precipitation counter-balance the evapotranspiration and provides limited length of growth period for growing crops
2.	Dryland Agriculture	-	The practice of farming in drylands
3.	Dryland Horticulture	-	Practice of Horticulture in drylands which could be helped by harvested rainwater also
4.	Rainfed horticulture	-	Describes horticultural practices that rely on rainfall water
5.	Evaporation	-	Process of a substance in a liquid state changing to gaseous state due to increase in temperature and pressure.

Dryland agriculture occupies 68% of India's cultivated area and supports 40% of the human and 60% of the livestock population. It produces 44% of food requirements, thus has and will continue to play a critical role in India's food security. However, aberrant behavior of monsoon rainfall results in frequent droughts that impact resource poor farmers. Eroded and degraded soils with low water-holding capacity and multiple nutrient deficiencies, declining groundwater table, etc. contribute to low crop yields that lead to further land degradation.

Growing of crops entirely under rainfed conditions is known as dryland agriculture.
Depending on the amount of rainfall received, dryland agriculture can be grouped into three categories;

1. **Dry Farming**

Dry farming is cultivation of crops in regions with annual rainfall less than 750 mm. Crop failure is most common due to prolonged dry spells during the crop period. These are arid regions with a growing season (period of adequate soil moisture) less than 75 days. Moisture conservation practices are necessary for crop production.

2. **Dryland Farming**

Dryland farming is cultivation of crops in regions with annual rainfall more than 750 mm. In spite of prolonged dry spells crop failure is relatively less frequent. These are semiarid tracts with a growing period between 75 and 120 days. Moisture conservation practices are necessary for crop production. However, adequate drainage is required especially for Vertisols.

3. **Rainfed Farming**

Rainfed farming is crop production in regions with annual rainfall more than 1150 mm. Crops are not subjected to soil moisture stress during the crop period. Emphasis is often on disposal of excess water. These are humid regions with growing period more than 120 days.

4. **Dryland horticulture**

Growing horticultural crops which needs less water in drylands with the use of rainfall is called dryland horticulture. Certain crops such as ber, custard apple, amla and mango require less water and can be grown as rainfed crops. With supplemental irrigation pomegranate and mango can be used for alternate land use systems. These orchards can be intercropped up to 3 years to generate more biomass.

4.1. Importance Of Dry Land Horticulture

The nature-dependent lands are rich in horticultural diversity, resistance against biotic and abiotic stresses, and have the potential for quality production of fruits, vegetables, flowers, and spices. Indian dryland is characterized by high temperature, erratic rainfall, poor soil, and water quality, limiting productivity. However, these conditions can favorably enhance productivity through advanced horticultural technological interventions resulting better income by utilizing solar and wind energy, human workforce, and developing infrastructure, greatly favoring the farming community's income. It is now realized that there is plenty of scope for a quantum jump in fruit and vegetable production in dryland areas. Several fruit crops such as ber, aonla, bael, pomegranate, tamarind, jamun, chironji, custard apple, wood apple, karonda, lasoda, fig, and in vegetables such as cucurbits, legumes, and solanaceous vegetable crops, spices, flower crops, medicinal and aromatic plants can be grown in semi- arid dryland areas for higher economic return. The existing low productivity could be doubled by following improved new sustainable technologies and inputs without irrigation.

1. Rainfed semi-arid horticulture supports the dwellers' livelihood and plays a significant role in nutritional and income security and environmental security.
2. The implication of untapped potential of natural resources and application of new production technologies suits to dry climate can double the farm income of arid tracts of the country.
3. Production of seeds and quality planting material of dryland horticultural crops on a large scale, the horticultural basket can provide food, nutrition, and livelihood security to the farmers of semi-arid regions with doubling farm income.
4. To a farming system in low productive land use, growing of fruit plants in drylands like arid and semiarid zones as rainfed crop. This concept is gaining importance as several fruit crops have been identified for cultivation in arid and semi-arid regions. Eg: Ber, Aonla, Date palm, Tamarind, Fig, Phalsa etc. With the advancement of irrigation technology and efficient water harvesting and conservation some of high value fruit crops are also being grown in arid and semiarid/rainfed regions. Eg: Mango, Grape, Pomegranate etc.

5. Being important component of dryland flora, they provide greater scope for wider adaptability through extensive root system, adaptability mechanism and synchronization of growth phase with rainfall. Besides, being of perennial nature and deep root system, fruit trees are able to utilize the moisture commonly stored in deeper layers of the soil. They also easily adapt to the marginal agro-ecological conditions such as undulating uplands, gullied and ravine lands, mining and industrial wastelands and poor sandy plains.
6. It is a better land use option as it provides wider opportunities on better land use, reduced pressure on natural resources, improved productivity, risk minimization, agro-industries opportunities, better economic return and nutritional security.
7. Visualizing the pattern of growth of this component it can provide support to targeted growth of agriculture.

Horticulture is therefore, important for diversification in rainfed area for nutritional and livelihood security and environmental protection on long term basis.

5. Present Status and Future Scope

Rainfed agriculture accounts for 60% of total cropped area, 48% of the food crops and 68% of non-food crops and in terms of crop groups 77% of pulses, 60% of oil seeds, 45% of cereals are grown under rainfed conditions. The additional food and nutrition have to come from the rainfed areas. Therefore, a breakthrough in rainfed farming is imperative for poverty alleviation, livelihood promotion and nutritional security in the country. It is a well-known fact that the perennial fruit trees form an important component of the flora of rainfed area. The extent, distribution and composition are however, not recorded being informal, it is estimated that out of 313 million tons of horticultural produce in the country (2019-20) 166.8 million tones is vegetables and 90 million tons of fruits. Whereas 70-80% of vegetable crops have access and irrigation, 60% of fruit crops is coming from rainfed conditions in varied proportions depending on the areas. About 80% of apples, stone and other temperate fruits in Himalayas are generally rainfed. Mangoes, wild bananas, pineapple and other plantation crops in north-east regions are thriving without committed irrigation. Konkan region is known for the production of cashew and mangoes. Similarly cashew nut another hardy crop is coming up in large proportion under rainfed conditions in western coast. About 80% of mangoes in the plains of north, central and southern plateau of Karnataka are rainfed except the initial 4-5 years during establishment. It is estimated that bulk of fruits (60%) produced in India come from rainfed regions receiving more than 700 mm annual precipitation (rainfall). The fruits common in these areas are mango, cashew, pomegranate, custard apple, ber, aonla, jamun, rayan, kokum, palmyrah palm, tamarind, plum, khejri, ker, pilu. Exact statistics is not available for their area and production because presently they are grown in sideline, scarcely mixed as a component of mixed cropping, product of nontraditional areas like hills, non-cultivable lands, common corner forests, neglected corners, around water source, forests. Nevertheless, all these fruits entirely come from rainfed conditions. However, looking to their sustainability attributed for rainfed areas regular inclusion is becoming popular especially in the form of agroforestry.

Looking to their potential usefulness, sustainability, fruit crop-based farming systems are being emphasized region wise like:

5.2.1 **Arid ecosystem** - Ber, Khejri, ker, khajoor, bael, anonla with arid legumes, grasses (Stylosanthus, and Cencrus) and seed spices.

5.2.2 **Cold arid ecosystem** – Chilgoza, chuli, almond, walnut, pecan, pistachio, Chinese jujube with local vegetation.

5.2.3. **Sub-humid ecosystem** – Mango, litchi, aonla, Jackfruit, custard apple, guava. Cashew and pomegranate can be major component with ragi, black gram, groundnut, niger, sesamum, and grasses like Stylosanthus and Dinath.

5.2.4. **Humid ecosystem** – Mango, coconut, areca nut, with tuber crops, turmeric, ginger, black pepper, cardamom such eco-friendly crops are being integrated. However, exact statistics is not available for lack of such delineation like rainfed and irrigated.

6. Limitations of dryland horticulture

Dryland is areas where annual rainfall or precipitation counter balance the evapotranspiration and provide a limited length of growth period for growing crops. The areas with rainfall less than 750 mm per annum come under this category and dryland horticulture means the practice of horticulture in dry lands which could be helped by harvested rainwater also. The climate of such areas is characterized by complex climatic deficiencies, manifested as water deficiency for rainfed/ dryland crop productions.

Indian semi-arid zone occupies nearly 37 percent of the total geographical area (131m ha) of the total 329 m ha of the country's geographical location and spread over in Maharashtra (19%), Karnataka (15%), Andhra Pradesh (15%), Rajasthan (13%), Gujarat (9.5%), Tamil Nadu (10%), Uttar Pradesh (7%) and Madhya Pradesh (6%) over 38.7 million ha (cold and hot zone) in various states of the country.

7. The important limitations of dryland horticulture are as under

1. The semi-arid region is characterized by moisture stress and poor soil and water quality.
2. Soil Quality interior of structure, texture, maturity, depth and fertility due to poor rainfall and consequent vegetation is poor.
3. They are thirsty and hungry, poor, degraded and marginal. They are shallow, marginal in fertility, low in water holding capacity and associated with severe plant nutrient deficiency with undulating physiographic and shallow depth.
4. The annual average rainfall in the semi-arid areas ranges between 200-500 mm, which is 2 to3 times less than the potential evapotranspiration. Therefore, the crop selected for the region must be abiotic stress-tolerant and should have the reproduction phase synchronized to the maximum moisture availability period.

5. The prevailing stress conditions necessitate special technologies relating to the use of suitable cultivars, propagation technologies and cultural practices, plant- protection measures, and utilization methods to realize maximum value.
6. In the semi-arid region, the large number of farming community have small land holdings and poor resources, and cannot afford the burden of credit with available resources, but they can generate income by using scientific dryland horticultural technologies.
7. A biotic stress due to extremes of temperature, atmospheric humidity, soil salinity, impermeable subsoil layers etc.
8. Biotic stress due to wild animals, rodents, birds, insects and diseases.
9. Variable resource base or lack of uniformity in resource base.
10. Small holdings and upcoming challenges of climate change.
11. Poor access to irrigation.
12. Frequent occurrence of droughts of 1 to3 weeks consecutive duration during the main cropping season happens to be dominant reason for crop failure and low yields.

8. Dry farming and Dryland farming Vs Rainfed agriculture

United Nations Economic and Social Commission for Asia and the Pacific distinguished dry land agriculture mainly into two categories: dryland and rainfed farming. The distinguishing features of these two types of farming are given below.

8.1. Dry farming and Dryland farming Vs Rainfed agriculture

Dry farming and dryland farming	Rainfed agriculture
Emphasis is on soil and water conservation; sustainable crop yields and limited fertilizer use according to soil moisture availability	Emphasis is on disposal of excess water, maximum crop yield, high levels of inputs and control of water erosion

8.2. Dryland Vs. Rainfed farming

Constituent	Dryland farming	Rainfed farming
Rainfall (mm)	<750mm	>750mm
Moisture availability to the crop	Shortage	Enough
Growing season (days)	<200 days	>200 days
Growing regions	Arid and semiarid as well as uplands of sub-humid and humid region	Humid and sub-humid region
Cropping system	Single crop or intercropping	Intercropping or double cropping
Constraints	Wind and water erosion	Water erosion

Growing of fruit plants in drylands like arid and semiarid zones as rainfed crop. This concept is gaining importance as several fruit crops have been identified for cultivation in arid and semi-arid regions. Eg: Ber, Aonla, Date palm, Tamarind, Fig, Phalsa etc. With the advancement of irrigation technology and efficient water harvesting and conservation some of high value fruit crops are also being grown in arid and semiarid/rainfed regions. Eg: Mango, Grape, Pomegranate etc.

8.3 Ber

Can be grown on any type of soil. Proper manuring and irrigation during fruit development checks the dropping of berries. Regular pruning is necessary. Spacing may be kept as 6 to 9m.

8.4. Guava

Can be grown in all types of soil where rainfall is more than 750mm having pH ranging from 4.5 to 8.2. Regular irrigation throughout the year is necessary. Light pruning of trees assists in heavy fruiting. The usual spacing is kept as 5.5 to 6m.

8.5. Amla

Can be grown even on slightly alkaline soils. Plants need light irrigation till they are well established. Fruiting starts at the age of 8 years. The trees should be planted at a spacing of 7.5 to 9m.

8.6. Mango

Though it is a dryland crop, it requires irrigations only in summer season from March to May at an interval of 15 to 20 days for fruit retention and maturity Mango requires slightly deep soils with good drainage and pH at 6.5 to 7.6. It needs 10m x 10m spacing in well deep soils and 9m x 9m in medium deep soils.

- Along with horticultural crops, plantations for timber and fibre can be developed on soils, which are not suitable for grain crops. The trees include neem / Lucerne and agave in paired rows. *Stylosanthes hamata* can be grown in the interspace.
- Silvipastural systems: Involve lopping trees and grazing under storey grasses and bushes in forests and plantations. This system is applicable to vast areas of cultivable wasteland.

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Course Name	Dryland Horticulture
Lesson 2	Constraints Encounter in Dry Lands
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Objectives of the lecture:

- Constraints encounter in Dry Lands
- Drought: definition, types- occurrence of drought and effects of drought on crop production –Management strategies for drought

Glossary of terms

1.	Vagaries of monsoon	-	The subnormal and abnormal activities of the Monsoon affect the seasonal pattern of rainfall
2.	Drought	-	Is a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall.
3.	Constraints	-	something that limits or restricts
4.	Pre-monsoon	-	Before a monsoon
5.	Post - monsoon	-	After a monsoon

Constraints Encounter in Drylands

I. Factors affecting crop production in dry farming regions:

Dryland is the area where annual rainfall/precipitation counters balance the evapo-transpiration and provide a limited length of growing period for raising crops. The areas with rainfall less than 750 mm per annum come under this category. These areas are characterized by deficiency of rainfall/ precipitation, prolonged period of heat, low relative humidity and high rates of evaporation resulting in situations for constraints in dryland making intensive agriculture difficult and risk free. In other words dryland ecosystem, limited by moisture is characterized by extreme rainfall variability. Recurrent but unpredictable droughts, high temperatures, low soil fertility leading to various categories of constraints to well planned or intensive agriculture. These characters influence resources for agriculture, technological input and socio-economic status leading to various constraints. It is for these reasons that these areas are inhabited by world's most poor people. To help these areas, the constraints need to be understood so that strategic plan for their development/ management could be worked out to raise the happiness index of people living there. Accordingly, these constraints have been basically classed into three categories: (i) Resource constraints (ii) Technological constraints and (iii) Socio-economical constraints.

I. RESOURCE CONSTRAINTS

(a) Agro-climatic conditions:

In dryland areas, the environment is often more yield limiting than even the genetic potential of the crops. The dominant features of rainfall in dryland regions are its limited quantum, temporal and spatial variability and unpredictability. There are more years below the mean than above the mean with the degree of skewers inversely relented to amount of rainfall. Rainfall distribution is also very irregular. Rainfall intensity is extremely variable and high intensity events even when the quantum is relatively low, can result in substantial run- off and soil erosion, so a crop management system must protect the soil resource. The temperature extremes also limit productivity in many dryland areas.

(b) Wind erosion:

Wind erosion is one of the geomorphologic processes that affects the process in semi-arid region and influences the very future of civilization. Soil is essential to sustain mankind, but soil can be rendered infertile by the complete removal of top soil or selected removal of soil fines by wind. As soil erosion becomes increasingly severe, alternative methods of control compatible with farming practices must be employed.

(c) Water erosion:

Water erosion at some level is inevitable. Accelerated erosion reflects the activity of man. It occurs because of cultivation of sloppy lands or lands or vegetation alteration caused by a concentrate of domesticated animals. Genetically accelerated erosion is detrimental. It results in movement of top soil from hill slopes to valley bottoms or to streams and reservoirs. Subsoil is usually less hospitable to plant growth than top soil because of lack of nutrients and lower available water holding capacity. To water erosion reduced tillage or no till systems were developed.

(d) Soil characteristics:

Soils in the dryland regions of world range from sandy, shallow, low-fertility soils to highly productive, medium to fine textured, deep soils, but the majority of dryland soils have serious problems. Soils characteristics are strongly influenced by the climate in which soils develop, and the interactions of these characteristics with current climatic conditions are a major consideration in understanding the productivity of dryland soils. Other soil problems such as surface soil hardening, compaction by tillage implements, susceptibility to water and wind erosion, low fertility, shallowness, hardening, restricted drainage and Salinization also affect crop production.

i.Physical:

Many of the upland soils in the tropical dryland areas are sandy, often gravelly, and generally shallow. These factors contribute to a low water holding capacity which makes it more difficult to deal with the detrimental effects of erratic and limited precipitation. Erosion, both wind and water intensify these constraints. Soil hardening and crusting are very common in dryland soils and result in large amounts of run-off. When water runs off, there is less water available for producing biomass and less input of organic material into the soil, which makes maintenance of good soil physical conditions even more difficult.

ii.Chemical:

Soil chemical problems include low inherent fertility, acidity, toxic levels of aluminum or other elements and low-nutrient holding capacity. Essential plant nutrients can be lost through surface run-off, erosion, leaching and removal of plant nutrients. Soil acidity resulting in aluminum toxicity is a common chemical problem in dryland soils.

iii.Biological:

Restricted biological activities resulting from a sub-optimum soil environment would greatly affect the cycling and transformation of nutrients present in organic from. Biological activity in soils is generally much lower in dryland than in more humid zones. The reasons are apparent lower organic matter levels and periods of extreme dryness. There is also evidence that the organic matter present in dryland soils is chemically and biologically less stable, because there is less biological turnover of organic matter.

. TECHNOLOGICAL CONSTRAINTS

a) Soil fertility:

Low native fertility is a widespread problem on sandy soils and on lateritic ferruginous, medium textured soils. The lack of micronutrients is apparent in specific areas, and these deficiencies will intensify and spread as cropping systems intensify. The interactions between nutrients and water are very pronounced, resulting in inadequate response to additional water at low fertility levels and poor response to nutrient additions if water is not available for plant growth.

b) Crop germplasm:

Attention for long-term plant breeding programmes for improved drought resistance is warranted, but this effort should be relatively small part of the overall effort, particularly for developing near-term strategies. Improving germplasm for disease and insect resistance is another matter of concern and this activity and the development of cultivars that are tolerant to aluminum toxicity resulting from soil acidity are extremely important in dryland regions.

c) Production practices:

Low crop and animal production in dryland farming is not necessarily the result of lack of scientific knowledge. The principles of dryland farming are fairly well established and proven practices have been developed for some areas only.

d) Horticultural practices:

A farmer with limited resources will find it difficult and risky to simultaneously adopt several new techniques that require a shifting of household

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resources. Moreover, learning a new practice thoroughly may extend over several seasons and have an uncertain future payoff. For these reasons technology adoption often proceeds slowly despite the potential benefits demonstrated at a research level. Choosing the optimum plant population and width of row spacing continues to be one of the most difficult challenges for dryland producers. High or too low plant densities can reduce grain yields because high densities use too much of the available soil water early in the season and low densities does not fully exploit the available soil water of the complete season. The constraints include contour ridging tied ridges, water harvesting, organic and chemical fertilizers, green manuring, weed control, erosion control practices, agro-forestry etc.

e) Mechanization and Power:

The lack of adequate animal and mechanical traction constrains crop production in many dryland regions. The size and complexity of equipment are not economically and socially acceptable to the farmers.

f) Institutional credit and infrastructural constraints:

A move towards more intensive farming systems significantly raises the cost of production and dryland areas where moisture supplies are not assured, greatly elevate the risk level of making a profit. Better institutions in rural areas are needed to ensure that all segments of the communities have access to credit at affordable terms. Affordable credit must be available to the poor farmer.

g) Marketing and Distribution:

The inability to effectively market the produce limits a farmer’s ability to dispose of surplus output and reduces their income earning potential. Transportation systems also improve access to production inputs.

h) Research and Technology transfer:

In dryland regions research institutions are woefully inadequate. Too often, the resources allocated to drylands have been minimal, because primary attention has been focused on irrigated agriculture. Data are often inadequate for analyzing the agro-climatology and soil resources and management practices. Good databases are essential for the development of dryland regions.

i) Fertilizers and pesticides:

The productivity of many dryland soils cannot be increased without raising the fertility level and controlling pests. Soil fertility can quickly become the limiting factor in crop production and infrastructure is inadequate in many dryland regions to assure the availability of fertilizers and pesticides. Unwise or misguided use of chemical inputs can be very costly and can lead to low efficiency and disenchanted farmers.

j) Farm level knowledge base:

If dryland farmers are to fulfil their role in the development process, they must become better informed about technical and economic matters that affect them. In the past, though the traditional practices were adequate for producing the food and fibre requirements of that population. They cannot serve the current and future needs to support increased numbers of population. Hence, dryland farmers must have a better base of technical knowledge and an understanding of the interactions between their farming practices and current and future physical resources.

III. SOCIO-ECONOMIC CONSTRAINTS

a) Population growth:

Population pressure affects the resource base extensively and intensively. Extensive pressure leads to conversion of grasslands and forests to cropland, with expansion normally progressing into less and less favorable areas.

b) Land tenure and Fragmentation:

Land ownership patterns in many parts of the world are based on the cultural inheritance traditions and often provide for equal division of agricultural land among heirs. This often results in dividing land into small blocks. With small land parcels, use of modern machinery is much more difficult to use sound soil and water conservation practices such as terracing, contouring and other methods of cross- slope farming.

The constraints raised in general are now totally different under present circumstance due to policies on liberalization, privatization and globalization/ world trade, etc. Nevertheless, the major constraints under present context also fall in following categories.

- Moisture conservation
- Soil and moisture conservation methods
- Availability of labour
- Market
- Technological development and
- Credit facilities

In the changing scenario life styles, living standards may also change, but the fate of population living in dryland farming regions may face many problems. Thus the constraints of farmers differ from time to time or over years under dynamic progress in India as well as in the world.

There are a number of limitations in arid region which hinder successful cultivation of fruit crops. These problems also relate to soil and its types and moisture and its quality.

- **Land use capability classes:** Soil types available in arid regions are of very low capability. Most of the soils are of class VI, IV and II, in that order, are of marginal type where cultivation of annual crops is very risky and fit only for pastures. With meticulous management, they can be advantageously used for high value fruit crops.

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- **Saline soil and saline irrigation water:** The arid soils are largely saline with pH ranging from 8 to 9. The underground water is scarce and highly saline, this limits the fruit culture to only salinity tolerant fruit crops.
- **Low and erratic rainfall:** The rainfall in arid zone is very low and it's confined to the period from July to September with 9-21 rainy days out of 12 to 30 rainy days in the whole year, resulting in both soil and atmospheric water stress after rainy season. In summers the vapour pressure deficit is very high reaching 24 to 30 mb during May and June. At the same time the water holding capacity of arid zone soil is very poor with very high infiltration rate.
- **Intense radiation:** In arid zone the radiation is very intense ranging between 500 to 650 cal/cm^2/day during summer months and at times it may adversely affect photosynthesis due to limitation of co_2. At the same time, rate of transpiration both through stomatal opening and cuticle and leaf temperature aggravating the problem of limited moisture. This also creates the problem of sun burning in developing fruits.

Besides these limitations, dusty winds are common in summer months which would hinder fruit setting and fruit development and increase transpiration and cause mechanical injury to trees. Therefore, choice of the fruit crops for arid areas is very important demanding careful selection for successful cultivation. This is a logical approach.

IV. Drought: Definition, types- occurrence of drought and effects of drought on crop production –Management strategies for drought

Definition of drought

There is no universally accepted definition for drought.

a. Early workers defined drought as a prolonged period without rainfall.

b. According to Ramdas (1960) drought is a situation when the actual seasonal rainfall is deficient by more than twice the mean deviation.

c. American Meteorological Society defined drought as a period of abnormally dry weather sufficiently prolonged for lack of water to cause a severe hydrological imbalance in the area affected.

d. Prolonged deficiencies of soil moisture adversely affect crop growth indicating incidence of agricultural drought. It is the result of an imbalance between soil moisture and evapotranspiration needs of an area over a fairly long period as to cause damage to standing crops and to reduce the yields.

e. The irrigation commission of India defines drought as a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall.

IV.1.Classification of drought

Drought can be classified based on duration, nature of users, time of occurrence, and using some specific terms. The demarcation between the classifications is not well defined and many a time overlapping of the cause and effect of one on the rest is seen.

1. Based on the duration

a. **Permanent drought**: This is characteristic of the dessert climate where sparse vegetation growing is adapted to drought and agriculture is possible only by irrigation during the entire crop season.

b. **Seasonal drought**: This is found in climates with well-defined rainy and dry seasons. Most of the arid and semiarid zones fall in this category. The duration of the crop varieties and planting dates should be such that the growing season should fall within the rainy season.

c. **Contingent drought**: This involves an abnormal failure of rainfall. It may occur almost anywhere, especially in most parts of humid or sub-humid climates. It is usually, brief, irregular and generally affects only a small area.

d. **Invisible drought**: This can occur even when there is frequent rain in an area. When rainfall is inadequate to meet the evapotranspiration losses, the result is borderline water deficiency in soil resulting in less than optimum yield. This occurs usually in humid regions.

2. Based on their relevance to the users (National Commission on Agriculture, 1976)

a. **Meteorological drought:** It is defined as a condition, where the annual precipitation is less than the normal over an area for a prolonged period (month, season or year).

b. **Atmospheric drought**: It is due to low air humidity, frequently accompanied by hot dry winds. It may occur even under conditions of adequate available soil moisture. It refers to a condition when plants show wilting symptoms during the hot part of the day when transpiration exceeds absorption temporarily for a short period. When decreases absorption keeps pace with transpiration and plants revive. (Mid day wilt).

c. **Hydrological drought**: Meteorological drought, when prolonged results in hydrological drought with depletion of surface water and consequent drying of reservoirs, tanks etc. It results in a deficiency of water for all sectors using water. This is based on water balance and how it affects irrigation as a whole for bringing crops to maturity.

d. **Agricultural drought:** It is the result of soil moisture stress due to an imbalance between available soil moisture and evapotranspiration of a crop. It is usually gradual and progressive. Plants can, therefore, adjust at least partly, to the increased soil moisture stress. This situation arises as a consequence of scanty precipitation or its uneven distribution both in space and time. It is also usually referred to as soil drought.

The relevant definition of agricultural drought appears to be a period of dryness during the crop season, sufficiently prolonged to adversely affect the yield. The extent of yield loss depends on the crop growth stage and the degree of stress. It does not begin when the rain ceases but actually commences only when the plant roots are not able to obtain the soil moisture rapidly enough to replace evapotranspiration losses. Important causes of agricultural drought are

- Inadequate precipitation
- Erratic distribution
- Long dry spells in the monsoon

- Late onset of monsoon
- Early withdrawal of monsoon
- Lack of proper soil and crop management

3. Based on the time of occurrence

a. Early season drought: It occurs due to a delay in the onset of monsoon or due to long dry spells after early sowing

b. Mid season drought: Occurs due to long gaps between two successive showers of rain and stored moisture becoming insufficient during this long dry spell.

c. Late season drought: Occurs due to early cessation of rainfall and crop water stress at maturity stage.

4. Other terms to describe drought

a. Apparent drought: What is drought for one crop may not be a drought for another crop; what is drought in red soil may not be a drought in black soil.

b. Physiological drought: Refers to a condition where crops are unable to absorb water from the soil even when water is available, due to the high osmotic pressure of soil solution due to increased soil concentration, as in saline and alkaline soils. It is not due to a deficit in the water supply.

Periodicity of drought

The Indian Meteorological Department examined the incidence of drought for the period from 1871 to 1967, utilizing the monthly rainfall of 306 stations in the country. It was seen that during 1877, 1899, 1918 and 1972 more than 40 per cent of the total area experienced drought. General observation on the periodicity of drought in respect of different meteorological subdivisions of India is given below.

Meteorological subdivisions	Period of recurrence of drought
Assam	Very rare, once in 15 years
West Bengal, MP, Konkan, Coastal AP, Kerala, Bihar, Orissa	Once in 5 years

South interior Karnataka, Eastern UP, Gujarat, Vidharbha, Rajasthan, Western UP, TN, Kashmir, Rayalaseema and Telangana	Once in 3 years
Western Rajasthan	Once in 2.5 years

Usual Drought period in different parts of India

Beginning of drought

- Droughts do not occur in Assam, South Kerala and the eastern part of West Bengal.
- Severe drought begins on 1 October in the northwest arid zone and even much earlier in the western part.
- In the southern arid zone and adjoining interior portion of Maharashtra State, the severe drought begins by the end of November.
- In most of the central portion of the country to the east of the line joining Delhi, Udaipur and Baroda, the commencement is only in the month of February or later. This is due to the high water holding capacity of the black soil region.
- In the western coastal region of Maharashtra and Karnataka states, the rainfall is very high. In spite of this, severe drought begins by December-January, probably because of the lower water holding capacity of the soil.
- Severe drought commences only after April in Gwalior, Guna, Jabalpur, Pendra, and the Satna region of Madhya Pradesh.

Closure of drought

a. On average, the severe drought ends outside the regions of east Bihar, Tamil Nadu, Karnataka, and southern Andhra Pradesh only by 1 May. In most of these regions, it ends mainly after 15 May.

b. In the arid zone of northwest India, the severe drought ends normally during the second fortnight of June, except in the Jaisalmer and Bikaner regions where normally cessation of severe drought is only by the first week of July.

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V. Effect of drought on crop production

Water relations – Alters the water status by its influence on absorption, translocation and transpiration. The lag in absorption behind transpiration results in loss of turgor as a result of an increase in the atmospheric dryness.

a. Photosynthesis – Photosynthesis is reduced by moisture stress due to a reduction in Photosynthetic rate, chlorophyll content, leaf area, and increase in assimilates saturation in leaves (due to lack of translocation).
b. Respiration – Increase with mild drought but more serve drought lowers water content and respiration.
c. Anatomical changes – Decrease in size of the cells and intercellular spaces, thicker cell wall,greater development of mechanical tissue, stomata per unit leaf tend to increase.
d. Metabolic reaction – Most all metabolic reactions are affected by water deficits.
e. Hormonal Relationships altered – The activity of growth-promoting hormones like cytokinin, gibberellic acid and indole acetic acid decreases and growth-regulating hormone-like abscisic acid, ethylene, betain etc. increases.
f. Nutrition – The fixation, uptake and assimilation of nitrogen is affected. Since dry matter production is considerably reduced the uptake of NPK is reduced.
g. Growth and Development – Decrease in the growth of leaves, stems and fruits. Maturity is delayed if drought occurs before flowering while it advances if drought occurs after flowering.
h. Reproduction and grain growth – Drought at flowering and grain development determines the number of fruits and individual grain weight, respectively. Panicle initiation in cereals is critical while drought at anthesis may lead to drying of pollen. Drought at grain development reduces yield while vegetative and grain filling stages are less sensitive to moisture stress.
i. Yield – The effect on yield depends hugely on what proportion of the total dry matter is considered as useful material to be harvested. If it is aerial and underground parts effect of drought is as sensitive as total growth. When the yield consists of seeds as in cereals, moisture stress at flowering is detrimental. When the yield is fiber or chemicals where the economic product is a small

fraction of total dry matter moderate stress on growth does not have an adverse effect on yields.

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Course Name	**Dryland Horticulture**
Lesson 3	**Agro-climatic features in rain shadow areas, scarce water resources, high temperature, soil erosion, run-off losses etc.**
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Objectives of the lecture:

- Agro-climatic features in rain shadow areas, scarce water resources, high temperature, soil erosion, run-off losses etc.

Glossary of terms

1. Rain Shadow -It is a patch of land that has been forced to become a desert because all plant-growing, rainy weather has been blocked by mountain ranges
2. Drought -It is a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall.
3. Constraints - something that limits or restricts
4. Pre-monsoon -Before a monsoon
5. Post - monsoon -After a monsoon

I. Agro-climatic features in rain shadow areas

A rain shadow is a patch of land that has been forced to become a desert because all plant-growing, rainy weather has been blocked by mountain ranges. Wet weather systems will drop rain and snow on one side of the mountain. All the precipitation is blocked on the other side of the mountain-the rain shadow side. An area with relatively little precipitation due to the effect of a topographic barrier, especially a mountain range, which causes the prevailing winds to lose their moisture on the windward side, causing dryness on the leeward side. In India, along the eastern side of Sahyadri on the Deccan plateau, the rain shadow zone is present, e.g. The Northern Karnataka & Solapur Plateau of India, Beed, Osmanabad, and Vidarbha.

Rain-bearing winds that cause rain on the western slopes are blocked by the Western Ghats. The Western Ghats are located in the rain-fed zone of the south-western monsoon branch of the Arabian Sea, while the Eastern Ghats are located in the rain-shadow area of the south-western monsoon branch of the Arabian Sea. Orographic means the mountains are connected to it. They have lost much of their moisture by the time the winds make it across the Western Ghats and very little falls on the Deccan Plateau to the east of the Ghats. This decreased rainfall is called a Rain shadow effect on the leeward side of the mountains (away from the wind) (Fig.1).

Fig.1. Rain Shadow effect

The way that mountains shape climate is known as the orographic effect, which describes how air masses change as they ascend and descend the sides of mountains. The leeward side of a mountain is often associated with warm, dry air. Rain shadows are created on the leeward slopes of mountain ranges, resulting in deserts or other climates characterized by low precipitation. This impacts the condensation water cycle step and the precipitation water cycle step as well.

A. Factors responsible for rain shadow areas

a. Temperature and Humidity

To understand what happens to leeward slope air, it is necessary to get a sense of what happens to air when it cools and warms. Relative humidity (RH) measures the amount of water vapor, or moisture, in the air in relation to how much moisture the air could hold at a given temperature. Thus, an RH of 40 percent means that the air contains 40 percent of the moisture that it could hold at its current temperature. When the RH reaches 100 percent, the air is said to have reached its saturation, or dew, point, and condensation will happen in the form of dew, fog, rain, or other precipitation. Because cool air cannot hold as much moisture as warm air, the dew point is reached more quickly when warm air cools.

b. Windward and Leeward

Mountains have two sides: windward and leeward. The windward side faces the wind and typically receives warm, moist air, often from an ocean. As wind hits a mountain, it is forced upward and begins to cool. Cool air reaches its dew point more quickly, and the result is rain and snow. As the air crests the mountain and goes down the leeward slope, however, it has lost much of its moisture on the windward side. The leeward side air also warms as it descends, lowering humidity even more. An example of this effect is Death Valley National Monument in California. Death Valley is located on the leeward side of the Sierra Nevada mountains, and it is one of the driest and warmest places on Earth.

c. Chinook winds

The orographic effect creates cooler air moving up the windward side of mountains and warmer air moving down the leeward side. Often, as the leeward air plunges down the slope, it warms quite dramatically and rapidly. Such rapid warming and drying of air can produce very high winds known as Chinook or Foehn winds. They occur when mountain ranges are at right angles to prevailing winds, such as in the Sierra Nevadas of North America or the Alps in Europe. The leeward slope winds can raise temperature as much as 1 degree Celsius for every 100-meter drop in elevation (5.5 degrees Fahrenheit per 1,000 feet). In Canada, the Chinook, or "snow eater" winter winds bring quickly rising temperatures that rapidly melt snow.

d. Rain Shadows

Another aspect of the orographic effect is the creation of rain shadows on the leeward side of mountains. Rain shadows are more prevalent when the windward side of a mountain is steep, and thus warm air cools more rapidly over a shorter distance creating more windward-side precipitation. Thus, the leeward-side air is even drier since the saturated air lost its moisture more quickly on the windward side. An example of this effect is seen in the Appalachians of the eastern United States. Moist air cools at a normal lapse rate of 6 degrees Celsius for every 1,000-meter rise in elevation (3 degrees Fahrenheit per 1,000 feet). In the Appalachians, however, the moist lapse rate is 40 percent greater, and thus the western, or leeward, side of the mountains receives much less precipitation.

e. Rain shadow areas in Indian subcontinents

Eastern Side of Sahyadri ranges on Deccan e.g. Northern Karnataka & Solapur, Beed, Osmanabad and Vidharba Plateau of India. Answer: The Thar desert is bounded and rain shadowed by the Aravalli ranges to the south-east, the Himalaya to the northeast, and the Kirthar and Sulaiman ranges to the west. Rain-bearing winds that cause rain on the western slopes are blocked by the Western Ghats. The Western Ghats are located in the rain-fed zone of the south-western monsoon branch of the Arabian Sea, while the Eastern Ghats are located in the rain-shadow area of the south-western monsoon branch of the Arabian Sea.

f. Agro climatic features in rain shadow areas

- Higher evaporation
- Low precipitation and humidity
- Rainfall in the range of 40 – 75 cm with poor cloud cover with rain burst
- Soils are prone to desertification
- Scanty vegetation and poor nutritional status of soil
- Subsoil moisture is poor and shorter length of growing period
- High wind speed

Orographic means the mountains are connected to it. They have lost much of their moisture by the time the winds make it across the Western Ghats and very little falls on the Deccan Plateau to the east of the Ghats. This decreased rainfall is called a RAIN SHADOW EFFECT on the leeward side of the mountains (away from the wind).

g. Rain shadow regions in the Indian subcontinent

1. Ladakh Plateau cold, hyper arid eco sub-region: The mean annual precipitation ranges from 100 to 115 mm covering 15 % of PET demand. They receive erratic and scanty precipitation from westerly depression mainly as snow, during winter months. The sub -region constitutes the leeward flanks of Western Himalaya facing Tibetan Plateau. It is eastern aspect of Ladakh Plateau includes Leh and its surroundings. The length of growing period is 60 – 90 days between August and November.

2. Deccan Plateau, hot arid eco-region: This constitutes the part of the Deccan plateau that include Karnataka and Andhra Pradesh state situated in the rain shadow of south west monsoon along the leeward side

of Sahyadaris. It is characterised by hot type arid with dry summers and mild winters. The rainfall is erratic and varies from year to year to a great extent. The mean annual precipitation is between 400 to 500mm. The length of growing period is less than 60 days.

3. South Western Maharashtra and North Karnataka Plateau, hot, dry semi-arid eco-region:

Being on the Leeward side of Sahyadris, the area receives the southwest monsoon in late June with erratic and scanty rainfall. The monsoon season extends till the first week of October in most the years. The mean annual precipitation ranging from 600 -750mm covers 40 -42 percent of the mean annual PET demand of 1500 – 1800 mm with a large deficit in the area.

4. Central and Western Maharashtra Plateau and N.Karnataka Plateau and North Western Telangana Plateau, hot humid, moist semi-arid eco-sub-region:

a. Being this region also lies on the leeward side of Sahyadris comprising rain shadow areas of South Western monsoon. Hence erratic summer monsoon sets in last week of June and extends till the second week of October. The main annual rainfall ranging from 700 -1000 mm covers 44 - 53 percent of the mean annual PET demands ranging between 1700 – 1900 mm. The beginning of rainy season is stormy clouds burst and ending in an abrupt with moderately high PET. The LGP of the region is 120 – 150 days with distinct moist and humid period.

b. Tamil Nadu Uplands and Leeward Flanks of South Sahyadris, hot dry semi-arid eco-sub-region. The agro eco sub- region constitutes the southern part of the Deccan Plateau situated on Leeward side Sahyadris and Nilgiris range. The area constitutes the rain shadow part of southwest monsoon, receiving the mean annual rainfall ranging from 600 – 900mm that covers 38 – 47 per cent of mean annual PET demands between 1600 and 1900 mm. The length of growing period in the area ranges 90 – 120 days beginning with October and ending with January.

II. Scarce Water Resources

Scarcity has many negative impacts on the environment, including lakes, rivers, wetlands, and other freshwater resources. Additionally, water overuse can cause water shortage, often occurs in areas of irrigation agriculture, and harms the environment in several ways including increased salinity, nutrient pollution, and the degradation and loss of flood plains and wetlands. Furthermore, water shortage makes flow management in the rehabilitation of urban streams problematic. Owing to a poor water resource management system and climate change India faces a persistent water shortage. As per OECD (Organisation for Economic Co-operation and Development) environmental outlook 2050, India would face severe water constraints by 2050. Indian agriculture accounts for 90% of water use due to fast-track groundwater depletion and poor irrigation systems.

II.a. Water available for Agricultural Production

The states of Maharashtra, Gujarat, Karnataka, Jharkhand, Andhra Pradesh and Rajasthan have been facing serious water crisis since 2017-2018. According to the Union Ministry of Agriculture, the groundwater level has fallen alarmingly over the years. Available water India is not a water-rich country and is further challenged due to the negative impact of climate change; enormous wastage owing partly to poor management and distorted water pricing policies. The Northern Ganga River Basin has abundant water resources, whereas the Southern River Basin has few, but with high levels of pollution in groundwater and surface water. An increase in population and changing lifestyles have increased the demand for water (largely for irrigation) in both urban and rural areas. India has 18% of the world's population, having 4% of the world's fresh water, out of which 80% is used in agriculture. India receives an average of 4,000 billion cubic meters of precipitation every year. However, only 48% of it is used in India's surface and groundwater bodies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. India's annual rainfall is around 1183 mm, out of which 75% is received in a short span of four months during monsoon (July to September). This results in runoffs during the monsoon and calls for irrigation investments for the rest of the year. The population of India is likely to be 1.6 billion by 2050, resulting in increased demand for water, food and energy. This calls for infrastructure expansion and improved resource utilization.

III. High temperature

Plant life exists between temperatures of -89℃ to +58℃. However, most plants are adapted to a limited range of temperatures. If the temperature drops below 15℃ plants experience low-temperature stress and if it is above 45℃, plants are subjected to high-temperature stress. An increase of 15 – 20ºC above normal temperature causes deeper modification of growth without being necessarily lethal viz., protein denaturation, enzyme inactivation, and reduction in chloroplast's photosynthetic activity.

III. 1. Heat stress on growth and development

- Seedling establishment is hampered
- Pollen development is affected
- Grain and fruit development and quality is affected

Fig. 2 Effect of High Temperature

III.1.i.HIGH-TEMPERATURE INJURIES

High temperature adversely affects mineral nutrition, shoot growth and pollen development resulting in low yield (Fig.2).

1. The critical temperature above which plants gets killed is called thermal 'death point'.
2. The temperature above 50°C may kill many annual crops.
3. The limit varies with plants; shade loving plants are killed at lower temperature.

Mineral Nutrition

1. High temperature stress causes reduction in absorption and subsequent assimilation of nutrients.
2. Absorption of calcium is reduced at temperature of 28º C in Maize.

3. Nutrient uptake is affected by both soil and air temperature in rice.

4. Nitrate reductase activity decrease under high temperature.

Shoot growth

1. High temperature, even for short period, affects crop growth especially in temperate crops like wheat.

2. High air temperature reduces the growth of shoots and in turn reduces root growth.

3. High soil temperature is more crucial as damage to the roots is severe resulting in substantial reduction in shoot growth.

4. High temperature at 38º C in rice reduced plant height, root elongation and smaller roots.

Pollen development

1. High temperature during booting stage results in pollen abortion.

2. In wheat, temperature higher than 27º C caused under-development of anthers and loss of viability of pollen.

Scorching : High-temperature lead to dehydration and leaves are scorched

Physiological activities: High temperature disturbs photosynthesis and respiration.

Injury due to scorching sun: High temperature causes injury to the exposed area of the plant/fruits (eg) Tomato, Brinjal, and Cucumber. It is known as 'Sun scald'

Burning off: The symptoms are noticed on young seedlings due to high soil temperature. The seedlings are killed.

Stem gridle: High soil temperature causes stem scorches at the ground level (eg) cotton.

Management Techniques for High-Temperature Stress in Crops

Cowpea: Foliar spray of CCC @ 50 ppm or GA3 @ 50 ppm at flowering to increase yield

Tomato:

1. Foliar spray of Triacontanol @ 1.25 ppm (625 ml in 500 liters of water) 15 days after transplanting and at the full bloom stage to control flower drop and improve fruit set.

2. Foliar spray of 0.5% $ZnSO_4$ thrice at 10 days interval from 40 days after planting to control flower drop and improve fruit set

Bhendi:

1. Foliar spray of 1 % Urea + 1 % MOP at 30 and 45 days after planting to improve yield.

2. For hybrids, foliar spray of 0.5% NPK (19:19:19) at 10 days interval from 30 days after planting to improve yield

Brinjal

1. Foliar spray of Triacontanol @ 2 ppm plus Sodium Borate or Borax (35 mg/l of water) at 15 days after transplanting and at the time of full bloom to increase flower and fruit set.

2. Mulch with black LDPE sheets of 25-micron thickness and burry both the ends into the soil to a depth of 10 cm to conserve soil moisture.

Chillies

1. Foliar spray of 1% Potassium Sulphate to boost up the flowering and fruit set.

2. Foliar spray of NAA @ 10 ppm on 60 and 90 days after planting to increase fruit set.

3. Foliar spray of Triacontanol @ 1.25 ml/l on 20, 40, 60 and 80th day of planting to enhance flower and fruit set

Tapioca

1. Foliar spray of water (500 lit/ha) at weekly twice during evening hours to rejuvenate the crop.

2. Foliar application of 0.5% NPK (19:19:19) + 0.5% $FeSO_4$ + 0.25% $ZnSO_4$ twice at 15 days interval to rejuvenate the crop

Mango

1. Foliar spray of water when it is hot and dry to prevent heat stress effects.

2. Use of wind-breaks for protecting the orchard from warm air during February to May.

3. Foliar spray of 0.5% NPK(19:19:19) + 0.5% $FeSO_4$ + 0.25% $ZnSO_4$ + 0.3% Borax twice

at 15 days interval to rejuvenate the crop

4. Foliar spray of 2% KNO_3 at mustard size will increase the fruit set and retention of fruits

5. Foliar spray of 0.5% Urea or 1% Potassium Nitrate to induce flowering during February (if

trees do not flower by that time)

6. Foliar spray of NAA @ 20 ppm at flowering stage to increase the fruit retention.

7. A shelterbelt in the southwest of the orchard block can control sunscald in mango by decreasing direct sunlight and protect the fruit from overexposure to heat

8. Use of shade nets or shade-frames to decrease strong sunlight in hot, dry seasons can also reduce sun-scald. Shading should be 25-50% as heavier shading will reduce fruit set the following season

Banana

1. Foliar spray of GA_3 @ 50 ppm on 35 or 55 days old banana bunches three times on alternate days increases the weight and volume of fingers in both young and old bunches

2. Foliar spray of micronutrients viz., 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ + 0.2% $CuSO_4$ + 0.1% H_3BO_3 at 3, 5 and 7 MAP to increase yield and quality of banana

Custard apple

1. Irrigation and mulching during summer season helps to prevent fruit drop

2. Foliar spray of NAA @ 20 ppm four times at weekly interval during flowering to enhance the fruit set

3. Dipping of freshly opened flower in GA_3 @ 50 ppm to enhance fruit set, retention, size, weight with less seeded

4. Use black polythene mulch or organic mulch around the tree to conserve moisture and reduced the formation of stone fruits

5. Application of superphosphate and bone meal improves crop yield and reduce the formation of stone fruits

Tuberose

1. Dipping of bulbs in CCC @ 5000 ppm to enhance flower yield

2. Foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ + 0.1% Boric acid.

3. Foliar application of GA_3 @ 50-100 ppm thrice at 40, 55 and 60 days after planting

Jasmine

Foliar spray of CCC @ 1000 ppm to enhance early flower production

Note:

1% - 10 gram dissolved in 1 litre (made up to 1 litre)

1ppm - 1 mg dissolved in 1 litre (made up to 1 litre)

IV. Soil Erosion

Soil erosion is defined as the detachment and transportation of soil mass from one place to another through the action of wind, water in motion or by the beating action of rain drops. Erosion extensively occurs in poorly aggregated soils (low humus) and in a higher percentage of silt and very fine sand. Erosion increases when soil remains bare or without vegetation. In India, about 86.9% of soil erosion is caused by water and 17.7% of soil erosion is caused by wind. Out of the total 173.6 M ha of total degraded land in India, soil erosion by wind and water accounts for 144.1 M ha (Govt. of India, 1990). The surface soil is taken away by the runoff causing loss of valuable topsoil along with nutrients, both native and applied. In India, about 5334 million tonnes (16.35 tonnes/ha/year) of soil is being eroded annually due to agriculture and associated activities.

Soil erosion is the process of detachment of soil particles from the top soil and transportation of the detached soil particles by wind and / or water. The agents causing erosion are wind and water. The detaching agents are falling raindrop, channel flow and wind. The transporting agents are flowing water, rain splash and wind.

a.Nature and extent of erosion

The problem of soil erosion exists all over the country. Out of the 329 m. ha of India's geographical area about 175 m. ha (53.3%) is subjected to soil erosion and some kind of land degradation (Druvanarayana, 1993). About 150 m. ha is subjected to wind and water erosion. It is estimated that about 5333 Mt of soil is detached annually. Out of this 29 % is carried away by rivers to seas and about 10% is deposited in reservoirs resulting in 1-2 % of loss of storage capacity annually. The estimated annual soil loss is 16.35 tones /ha/year.

b. Losses due to erosion

i	Loss of fertile top soil	vi	Reduction in soil depth
ii	Loss of rain water	Vii	Floods
iii	Loss of nutrients	Viii	Adverse effect on public health
iv	Silting up of reservoirs	ix	Loss of fertile land
v	Damage to forests	x	Economic losses

c. Types of erosion:

There are two major types of soil erosion

1. Geological erosion (Natural or normal erosion): is said to be in equilibrium with the soil-forming process. It takes place under the natural vegetative cover completely undisturbed by biotic factors. This is a very slow process.

2. Accelerated erosion: is due to disturbance in natural equilibrium by the activities of man and animals through land mismanagement, destructing of forests overgrazing etc., Soil loss through erosion is more than the soil formed due to the soil-forming process.

3. Based on the agent causing erosion, erosion is divided into

a. Water erosion b. Wind erosion c. Wave erosion

a. Water erosion

Loss of soil from the land surface by water including runoff from melted snow and ice is usually referred to as water erosion. Major erosive agents in water erosion are impacting/ falling raindrops and runoff water flowing over the soil surface.

Process of water erosion

Detachment of soil particles is by either raindrop impact or flowing water. Individual raindrops strike the soil surface at velocities up to 9 m/s creating very intensive hydrodynamic force at the point of impact leading to soil particle detachment. Overland flow detaches soil particles when their erosive hydrodynamic force exceeds the resistance of soil to erosion. Detached soil particles are transported by raindrop splash and runoff. The amount of soil transported by runoff is more than due to raindrop splash. Thus the falling raindrops break the soil aggregates and detach soil particles from each other. The finer particles (silt and clay) block the soil pores and increase the rate of runoff and hence the loss of water and soil.

Forms/Types of water erosion

Water erosion occurs in stages identified as sheet erosion, rills, gullies, ravines, landslides and stream bank erosion.

a) Sheet erosion: It is the uniform removal of surface soil in thin layers by rainfall and runoff water. The breaking action of raindrops combined with the surface flow is the major cause of sheet erosion. It is the first stage of erosion and is the least conspicuous, but the most expensive.

b) Rill erosion: When runoff starts, channelization begins and erosion is no longer uniform. Raindrop impact does not directly detach any particles below the flow line in rills but increases the detachment and transportation capacity of the flow. Rill erosion starts when the runoff exceeds 0.3 to 0.7 mm/s. Incisions are formed on the ground due to runoff and erosion is more apparent than sheet erosion. This is the second stage of erosion. Rills are small channels, which can be removed by timely normal tillage operations.

c) Gully erosion: It is the advanced stage of water erosion. Size of the unchecked rills increases due to runoff. Gullies are formed when channelized runoff from vast sloping land is sufficient in volume and velocity to cut deep and wide channels. Gullies are the spectacular symptoms of erosion. If unchecked in time no scope for arable crop production.

d) Ravines: They are the manifestations of a prolonged process of gully erosion. They are typically found in deep alluvial soils. They are deep and wide gullies indicating an advanced stage of gully erosion.

e) Landslides: Landslides occur in mountain slopes when the slope exceeds 20% and width is 6 m. Generally, landslides cause blockage of traffic in ghat roads.

f) Stream bank erosion: Small streams, rivulets, and torrents (hill streams) are subjected to stream bank erosion due to obstruction of their flow. Vegetation sprouts when streams dry up and obstruct the flow causing cutting of bank or changing of flow course.

g) Factors affecting water erosion

i.Climate: Water erosion is directly a function of rainfall and runoff. Amount, duration and distribution of rainfall influence runoff and erosion. High-intensity rains of a longer duration cause severe erosion. Greater the intensity, the larger the size of the raindrop. Rainfall intensity of more than 5 cm/hr is considered as severe. The total energy of raindrops falling over a hectare land with rainfall intensity of 5 cm /hr is equal to 625 H.P. This energy can lift 89 times the surface of 17.5 cm of soil from one ha to a height of 3 ft. Two-thirds of the above energy is used for sealing soil pores. Runoff may occur without erosion but there is no water erosion without a runoff. The raindrop thus breaks down soil aggregates, detaches soil particles and leads the rainwater with the fine particles. These fine particles seal the pores of the surface soil and increase runoff causing erosion.

ii.Topography: The degree, length and curvature of slope determine the amount of runoff and extent of erosion. Water flows slowly over a gentle slope whereas at a faster rate over a steeper one. As water flows down the slope, it accelerates under the forces of gravity. When runoff attains a velocity of about 1 m/s it is capable of eroding the soil. If the percent of the slope is increased by 4 times the velocity of water flowing down is doubled. Doubling the velocity quadruples the erosive power and increases the quantity of soil that can be transported by about 32 times and size of the particles that can be transported by about 64 times.

iii. Vegetation: Vegetation intercepts the rainfall and reduces the impact of raindrops. It also decreases the velocity of runoff by obstructing the flow of water. The fibrous roots are also effective in forming stable soil aggregates, which increases infiltration and reduces erosion.

iv. Soil Properties: Soil properties that influence soil erodability by water may be grouped into two types.

Those properties that influence the infiltration rate and permeability

Those properties that resist the dispersion, splashing, abrasion and transporting forces of rainfall and runoff.

The structure, texture, organic matter and moisture content of upper layers determine the extent of erosion. Sandy soils are readily detachable but not readily transportable. Soils of medium to high clay content have low infiltration capacities and they are readily transported by water after they are dispersed, but their detachability is generally low.

a.Man and beast

Man and beast accelerates erosion by extensive farming and excessive grazing. Faulty practices like cultivation on steep slopes, cultivation up and down the slope, felling and burning of forests etc., leads to heavy erosion. Excessive grazing destroys all vegetation and increases the erosion.

b.Estimation of soil loss by water erosion

Based on the mechanism and factors influencing soil erosion, a universal soil loss equation (USLE) developed by Wischmeier (1959) is most useful for predicting soil loss due to water erosion. It is an empirical equation and estimates average annual soil loss per unit area as a function of major factors affecting sheet and rill erosion. It enables determination of land management erosion rate relationships for a wide range of rainfall, soil slope and crop and management conditions and to select alternative cropping and management combinations that limit erosion rates to acceptable limits.

A= R x K x L x S x C x P

A= predicted soil loss in t/ha/year

R= rainfall erosivity factor or index K= soil erodibility factor

L= length of slope factor

S= slope steepness factor

C= soil cover and management factor and P= erosion control factor

c.Wind erosion

Erosion of soil by the action of wind is known as wind erosion. It is a serious problem on lands devoid of vegetation. It is more common in arid and semi-arid regions. It is essentially a dry weather phenomenon stimulated by the soil moisture deficiency. The process of wind erosion consists of three phases:

a. initiation of movement b. transportation and c. deposition.

About 33 m.ha in India is affected by wind erosion. This includes 23.49 m.ha of desert and about 6.5 m.ha of coastal sands. The Thar Desert is formed mainly by blow in sand.

d.Mechanism of wind erosion

Lifting and abrasive action of wind results in detachment of tiny soil particles from the granules or clods. The impact of these rapidly moving particles dislodge other particles from clods and aggregates. These dislodged particles are ready for movement. Movement of soil particles in wind erosion is initiated when the pressure by the wind against the surface soil grains overcomes the force of gravity on the grains. Minimum wind velocity necessary for initiating the movement of most erodable soil particles (about 0.1 mm diameter) is about 16 km /hr at a height of 30.5 cm. Most practical limit under field conditions, where a mixture of sizes of single grained material present is about 21 km/hr at a height of 30.5 cm.

In general movement of soil particles by wind takes place in three stages: saltation, surface creep and suspension.

i.Saltation:

It is the first stage of movement of soil particles in a short series of bounces or jumps along the ground surface. After being rolled by the wind, soil particles suddenly leap almost vertically to form the initial stage of movement in saltation. The size of soil particles moved by saltation is between 0.1 to 0.5 mm in diameter. This process may account for 50 to 70% of the total movement by wind erosion.

ii.Surface creep:

The rolling and sliding of soil particles along the ground surface due to the impact of particles descending and hitting during saltation is called surface creep. The movement of particles by surface creep causes an abrasive action of the soil surface leading to the breakdown of non-erodable soil aggregates. Coarse particles longer than 0.5 to 2.0 mm diameter are moved by surface creep. This process may account for 5 to 25% of the total movement.

iii.Suspension:

The movement of fine dust particles smaller than 0.1 mm in diameter by floating in the air is known as suspension. Soil particles carried in suspension are deposited when the sedimentation force is greater than the force holding the particles in suspension. This occurs with decrease in wind velocity. Suspension usually may not account for more than 15% of total movement.

V. Runoff losses:

Runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil which is a measure of the ability of the soil to absorb and transmit rainwater. Runoff is limited on soils with a high infiltration capacity.

High surface runoff and accelerated soil erosion are major degradative problems on newly cleared land. Immediately implementing appropriate erosion management techniques is therefore, essential. Accelerated erosion can be most severe in the very first season after land clearing. Soil erosion is caused by raindrop impact surface sealing, and crust formation leading to high runoff rate and amount, high runoff velocity on long and undulating slopes, and low soil strength of structurally weak soils with high moisture content due to frequent rains. Effective erosion management lies in:

(a) preventing or minimizing the raindrop impact, through mulching and canopy cover;

(b) maintaining favorable soil structure for reducing crusting; (c) managing soil surface to enhance infiltration rate;

(d) reducing slope length to minimize runoff build-up; and

(e) disposing of excess runoff safely through protected waterways and graded channels.

Based on these principles, erosion control measures are grouped into two broad categories: erosion preventive techniques and erosion control measures .

Fig. 3 Technological options for erosion management on newly cleared land

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Course Name	Dryland Horticulture
Lesson 4	Techniques and management of dry land horticulture
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Course Reviewer	SANGRAM SAHEBRAO DHUMAL
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Objectives of the lecture:

- To learn about the dryland farming techniques, Selection of trees, flowering and fruiting period of dryland horticulture

Glossary of terms

1.	Run-off		The portion of the precipitation or other water that could not be absorbed by the soil finds its way out of the location of its occurrence to the lower areas and streams.
2.	Water losses	-	The difference between the gross and net application
3.	Water logging	-	The saturation of soil with water, causing the water table of soil to rise high enough to expel normal soil gases and interfere with plant growth or cultivation. It causes soil degradation.
4.	Evapotranspiration	-	The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as evapotranspiration (ET)
5.	Water conservation	-	As in-situ rain water harvesting

TECHNIQUES AND MANAGEMENT OF DRYLAND HORTICULTURE

I. DRYLAND FARMING TECHNIQUES

Dryland farming is the profitable production of crops, without irrigation, of land with a low average or highly variable rainfall. Appropriate techniques developed to minimize the effects of constraints need to be followed.

1. **Water conservation:** Water conservation methods, often referred to as in-situ rain water harvesting; include activities such as mulching deep tillage,

contour farming and ridging, the purpose behind these methods is to ensure that the rainwater is helped long enough on the cropped area to ensure infiltration. These techniques are best suited to areas to ensure infiltration. These techniques are best suited to areas where rainfall and water holding capacity are sufficient to meet the crop water holding capacity to meet the crop water requirement. But the amount of water infiltration is not adequate to reach the required moisture level.

2. **Increase water absorption:**

a. **Prevent a crust at the soil surface:** Probably the greatest deterrent to a high rate of water absorption is the tendency for soils to puddle at the surface and room a seal or crust against water intake. The beating action of raindrops tends to break down clods and disperse the soil.

By tillage, create a rough, cloddy surface which lengthens the time necessary for the rain to break down the clods and seal the surface. For seedbed preparation in general, small seeds should have a finer, mellower bed than large seeds. After harvest, create stubble mulch on the surface. Such material not only prevents raindrops from impinging directly on the soil, but impedes the flow of water down the slope, increasing absorption time.

b. **Reduce the run-off of water:** To the extent that water logging is not a problem, the runoff of water and its attendant erosion must be stopped. Croplands should be as leveled as possible. All planting and tillage must run across (or perpendicular to) the slope of the land. Such ridges will impede the downward movement of water.

3. **Reducing the loss of soil moisture**

a. **Reducing soil evaporation:** Water in the soil exists as a continuous film surrounding each grain. As water near the surface evaporates, water is drawn up from below to replace it, thinning the film. When it becomes too thin for plant roots to absorb, wilting occurs. Shelterbelts of trees or shrubs reduce wind speeds and cast shadows which can reduce evaporation 10 to 30 per cent by itself and also reduce wind erosion. Mulching reduces the surface speeds of wind and reduces soil temperatures. Tillage must be repeated after each rain to restore the discontinuity. This is most workable where rainfall occurs in a few major rainfalls with relatively long intervals in between.

b. **Reducing transpiration:** All growing plants extract water from the soil and evaporate it from their leaf and stem surface in a process known as transpiration. About 99 percent of water absorbed by the roots is lost in the atmosphere as transpiration. Plants with reduced transpiration (xeric) mechanism like small leaves, succulent stem and loss of leaves in hot season should be preferred for plantation. Anti- transpirant are used to conserve water that otherwise is lost through transpiration. They can be effective in two ways.

- Through films that coat the leaf surface and
- Chemicals that close the stomata

Antitranspirant is any material applied to transpiring plant surfaces for reducing water loss from the plant. These are of four types:

i) Stomatal Closing
ii) Film forming
iii) Reflective
iv) Growth retardant

i) Stomatal closing type

Most of the transpiration occurs through the stomata on the leaf surface.

1. Fungicides like Phenyl Mercuric Acetate (PMA) and herbicides like atrazine in low concentrations serve as antitranspirants by inducing stomatal closing.

These might reduce the photosynthesis also simultaneously. PMA was found to decrease transpiration to a greater degree than photosynthesis in a number of plants.

ii) Film Forming Type

Plastic and waxy materials which form a thin film on the leaf surface retard the escape of water due to formation of physical barrier. Mobileaf, hexadeconol, silicone are some of the film forming type of antitranspirants. The success of these chemicals is limited since they also reduces photosynthesis.

The desirable characteristics of film forming type of antitranspirants are:

1. They should form a thin layer,
2. They should be more resistant to the passage of water vapour than carbon dioxide and the film should maintain continuity and should not break

iii) Reflectant Type

These are white materials which form a coating on the leaves and increase the leaf reflectance (albedo). By reflecting the radiation, they reduce leaf temperatures and vapour pressure gradient from leaf to atmosphere and thus reduce transpiration.

1. Application of 5 per cent kaolin spray reduces transpiration losses.
2. A diatomaceous earth product (celite) also increases reflection of solar radiation from crop canopy

iv) Growth Retardant

These chemicals reduce shoot growth and increase root growth and thus enable the plants to resist drought. They may also, induce stomatal closure.

1. Cycocel is one such chemical useful for improving water status of the plant

Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from death under severe moisture stress. If crop survives, it can utilise the rainfall that is received subsequently. Antitranspirants are also useful for reducing the transplantation shock of nursery plants. They have some practical use in nurseries and horticultural crops.

c. Weeds compete for soil nutrients & water

a. Selection of crop is significant as well. Dwarf varieties have less surface and so lose less water. Some plants close their stomata when it is hot, reducing their leaves during hot afternoon and open them at night, effectively changing their surface area in response to conditions.
b. Where rainfall is frequently marginal to insufficient, drought "insurance" can be obtained by clear fallowing a sufficient area.
c. Post harvest tillage will create stubble and dirt mulches and destroy weeds before the onset of the dry season.

4. Budding and Terracing:

It is one of the important methods to conserve soil and moisture by creating earthen barriers in watersheds. The shape and size of the bund will depend upon soil type, and rainfall. Amount of water to be stored, infiltration rate and tolerance of crop to be grown. Buds in clayey soils may develop cracks, so one should be careful while planning for earthen bunds in black cotton soils.

5.Contour bunding:

In this, earthen bunds are constructed on contours in gentle slopes ranging from 0.5 to 6% with average annual rainfall not exceeding 750 to 1000 mm. It is adopted on all types of relatively permeable soils except clayey or deep black cotton soils, where it may cause water stagnation and reduction of yields on upstream side. Contour bunded treatment records a low soil loss per ha (0.3t/ha) compared to control plot being around 18t/ha.

6. Ridge and furrow with mulch

It consists of forming furrows and beds across the slope before sowing. This is beneficial for moisture storage in soil profile while draining of excess run-off safely. This technique mostly used in soil moisture conservation in black cotton soil.

7. Mulching

Mulching is spread of any material on soil surface. It is an important agronomic practice that not only dissipates the kinetic energy of the rain drops and prevents soil erosion, but also facilitates infiltration and reduces runoff and evaporation losses. The water which is held in capillary, it helps in maintaining its thickness and prevents or slows down the effect of sun, wind and dry air and help in equalizing the distribution of water. It should be practiced as per needs stubble mulching aims at disrupting the soil drying process by protection the soil surface all the times, either with a growing crop or with crop residues left on the surface during fallow. To be effective, at least one tone per hectare must cover the surface, and the maximum benefit per unit residue is obtained at about two tonnes per hectare. The benefit may still be obtained at 8 tonnes per hectare. It reduces the wind speed and loss through evaporation. In addition, crop and weed residues can improve water penetration and decrease water runoff losses.

There are two limitations to the advantages offered by stubble mulching (i) Dead surface vegetative matter can provide a breeding ground for pests rodents and diseases and (ii) for decomposition, the ideal carbon to nitrogen ratio (C/N) being 25 to 30 is raise to 50 to 100, adversely affection the availability of nitrogen by depleting its level. This may have to be substituted.

Dirt mulching aims at disrupting the soil drying process with tillage techniques that separate the upper layer of the soil from the lower layers making the soil moisture film discontinuous. In addition, the soil surface is made more receptive to water intake.

For drylands with a rainy growing season and a hot, windy, dry season, dirt mulching should only be performed during the rainy season and with a growing crop to slow the wind and water and hold the soil.

7.1.Types of mulches

a. **Soil mulch or dust mulch:**

If the surface of the soil is loosened, it acts as a mulch for reducing evaporation. This loose surface soil is called soil mulch or dust mulch. Intercultivation creates soil mulch in a growing crop.

b. Stubble mulch

Crop residues like wheat straw or cotton stalks etc., are left on the soil surface as a stubble mulch. The advantages of stubble mulch farming are protection of soil from erosion and reduction of evaporation losses.

c. Straw mulch

If straw is used as mulch, it is called as straw mulch.

d. Plastic mulch

Plastic materials like polyethylene, polyvinyl chloride are also used as mulching materials.

 

e. Vertical mulching

To improve infiltration and storage of rainwater in these soils, vertical mulches are formed. It consists of digging narrow trenches across the slope at intervals and placing the straw or crop residues in these trenches. The pruned plant material is placed in contour trenches formed between rows or in trenches around the plants in concentric circles each year in one circle.

8. **Intercropping**
   Intercropping should be a routine practice under dryland conditions for the purpose of making best use of the soil and inter row moisture harvesting. It is significant between the rows of trees during juvenile phase. It can also concentrate on crop diversification based on region.
9. **Precision horticulture**
   Precision horticulture methods focus on information technology using site specific soil, crop and other environmental data to determine specific inputs required for certain sections of a field. Many of these methods involve the use of technologies such as geographic information system (GIS), satellites and remote sensing. Precision horticulture can directly increase crop yields, and also improve water availability through greater relative infiltration of rainfall. In developing countries, the smaller farm sizes could allow for management

on a field basis. Precision horticulture may hold significant promise in the future for horticulture in developing countries nutrient levels can vary greatly from field to field.

10. **Use of drip irrigation facilities**

Under dryland conditions, water is the most important component and water harvested should be meticulously recycled. Drip irrigation is the most efficient irrigation method for horticultural crops where it saves 30-70 per cent irrigation water and enhances productivity by adding fertilizer into irrigation water (Fertigation).

11. **Crop and variety selection**

Crops with synchrony of reproductive phase with moisture availability and xeric characters are best suited for dry lands and they should form the choice of crops. The varieties chosen should fulfill following attributes.

a. Short-stemmed varieties with limited leaf surface minimize transpiration.
b. Deep, prolific root systems enhance moisture utilization.
c. Quick maturing varieties are important in order that the crop may develop prior to the hottest and driest part of the year and mature before moisture supplies are completely exhausted.

12. **Growth regulators and chemicals**

Exogenous application of natural plant hormones as well as synthetic plant regulators are known to modify growth and development and modify vegetative growth, flowering, fruit set, and yield and accelerate uniform ripening for easy and early harvest in rainfed conditions. Mepiquat chloride is a bio regulator which promotes the reproductive phase in vegetable crops. It imparts dark green color to the leaves and shortens intermodal length. Under moisture stress, potassium protects the plant by involving in the exchange of cytoplasmic potassium for stomatal hydrogen ions thus raising stomatal pH and facilitating photosynthesis. This spray significantly reduces transpiration rate, this may be due to increased stomatal resistance, which leads to conservation of moisture in the cells by maintaining high relative water content. Proline accumulation was also higher in potassium chloride, which helps to channel the diversion of protein metabolism for withstanding drought.

Therefore, effort should be initiated on war footing, to bring together all the best that is available and horticulture into an organized unit to give farmers the maximum benefit and rainfed horticulture a success story. Within horticulture perennial fruit tree crops are better suited for stressed conditions of dryland and these need consideration on the following technologies.

13. Selection of fruit trees under dryland conditions

Selection of trees is necessary and care should be taken while establishing dryland orchards. The criteria for selection should consider the following points.

The trees selected should have the ability to withstand or tolerate drought and their water requirement is given in table-1.

Table 1: Water requirement of fruit trees.

S.N.	Fruit trees	Water requirement 1 /Week
1.	Mango	140
2.	Sapota	140
3.	Guava	91
4.	Pomegranate	91
5.	Ber	63
6.	Tamarind	63
7.	Jamun	35
8.	Custard apple	7

a. In areas of very low rainfall, while establishing orchards it is desirable to raise seedling rootstock in long tubes and in-situ grafting should be employed especially softwood grafting e.g. mango, jamun, guava, ber.

b. Selection of trees should be based on prevailing soil and climatic conditions. Rainfall plays a major role in deciding the crop growth. The period of high intensity rainfall should not coincide with flowering or fruiting season as it may cause flower and fruit to drop. The flowering and harvesting periods of different fruit trees suited for dryland orchards are detailed in Table-2.

Table .2: Flowering and harvesting periods of important fruit trees.

S.N.	Fruit	Flowering period	Harvesting period
1.	Mango	December-February	March- may
2.	Sapota	August -September	December-February
3.	Tamarind	May-June	February - March
4.	Guava	June- July	December- January
5.	Pomegranate	December- January	February - March
6.	Ber	June- July	October- January
7.	Custard apple	July -August	October- January
8.	Cashew	November - December	October- January
9.	Aonla	February - March	December- January

c. Temperature exceeding 45°C coupled with desiccating winds during summer is highly injurious to crop growth and may lead to fruit drop in crops like mango, citrus etc. Under these conditions, windbreaks should be provided to avert the situation.

d. Prevalence of humid weather during flowering and fruiting may attract diseases and pests diversely affection pollination and colour development. Precautionary measures against pests and diseases during adverse weather conditions are necessary as per standards schedules available then.

e. Dryland soils are poor in structure, texture and nutrient status. Plant tolerant to abiotic stress should be chosen and need-based chemical amendments like gypsum, organic matter recommended should be incorporated.

f. The dryland regions of the country have huge potential to produce horticultural crops. This region may work as a huge potential to produce several kind of horticultural crops in bulk to meet the increasing demand of fast-growing population of the country. This dream and targets may be achieved by the adoption relevant scientific approaches; technologies and knowledge by the farmers like to protect their crops in harsh and hot climatic conditions of the region.

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Course Name	Dryland Horticulture
Lesson 5	Watershed development, soil and water conservation methods – terraces, contour bunds etc.
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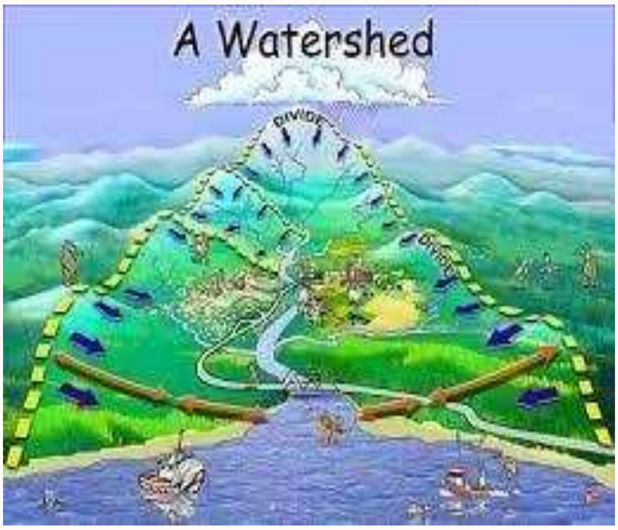
Glossary of terms

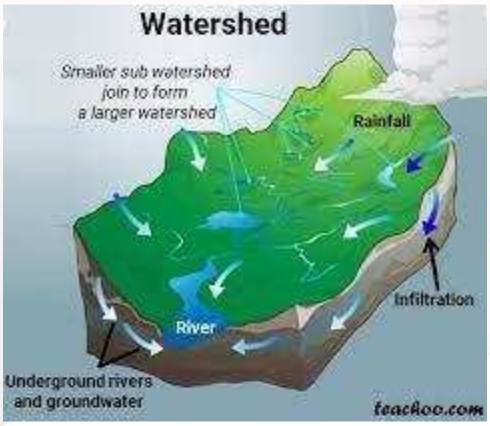
1.	Watershed	-	A watershed is **the area of land where all of the water that drains off of it goes into the same place—a river, stream or lake**.
2.	Insitu conservation	-	Storage of rainfall in soil at the place where it falls is termed as "insitu" soil moisture conservation
3.	Exsitu conservation	-	The runoff is diverted and stored in a natural or artificial reservoir for later use.
4.	Agrostological method	-	Grasses are grown to check the soil erosion.
5.	Strip cropping	-	Strip cropping is a practice of growing field crops in narrow strips either at right angles to the direction of the prevailing wind , or following the natural contours of the terrain to prevent wind and water erosion of the soil.

a.Watershed definition:

Watershed is an area of land and water bounded by a drainage divide with in which, the surface runoff collects and flows out of the area through single outlet into a river or other body of water. It is referred as catchment or drainage basin.

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





Depending upon the operational feasibility they are classified major watershed or basin micro-watershed. Major watershed is more than 1000 ha. Micro-watershed is between 100-1000 ha. Presently it is 500 ha ± 10%.

- ✓ Micro – watershed: 500 ha ± 10%
- ✓ Major – watershed: **> 1000 ha**

b.TYPES OF WATERSHED

Watersheds is classified depending upon the size, drainage, shape and land use pattern.

- ✓ Macro watershed (> 50,000 Hect)
- ✓ Sub-watershed (10,000 to 50,000 Hect)
- ✓ Milli-watershed (1000 to10000 Hect)
- ✓ Micro watershed (100 to 1000 Hect)

✓ Mini watershed (1-100 Hect)

c.Concept :

Development on watershed basis in hilly and mountain ecosystems is relatively more relevant where high erosion rates and wide spread land degradation are major concerns. Recently, erosion rates of the order of 600-700 t /ha per annum have been observed in the over-exploited small watershed of shiwaliks.

d. objectives

- Effective and efficient utilization of rain water for agricultural production by improving infiltration of water, reuse of drainage and runoff water and tapping the percolated water in deep tube wells for the productive use in dry farming**.**

e. Specific objectives

- Improving land productivity though SMC
- Sustaining and augmentation of the resource base
- Comprehensive development – holistic development

I.Watershed development:

Watershed development refers to the conservation; regeneration and the judicious use of all the natural resources particularly land, water, vegetation and animals and human development within the watershed. Watershed development approach is based on participatory planning following a bottom-up approach for developing a context appropriate plan for execution; empowerment and employment of people through establishment and strengthening of local level institution; conservation and appropriate management of watershed's natural resources through holistic development of the watershed; sustainability through people's participation in the process of development, voluntary contribution and formulation and adoption of a withdrawal strategy for post-project sustainability of the project.

A. Growth of watershed programmes

Harvesting of rain water from the watershed and its storage in Talabs (Tanks) of Jaisalmer, Johads of Alwar, Chaals (small reservoirs) of Himalayas, Khuls of Ghuhls (diversion channels) of Spiti, Kuis (percolation wells) dug inside the ponds, virdas made by nomadics of Gujarat are frequently mentioned in Kautilayas Arthasastra (321-297B.C.). Many ancient archaeological evidences are available about traditional systems in the excavation of old civilizations. However organized governmental development efforts were initiated in 1930s under the banner of dry farming research, which had substantial component of watershed management.

B. Watershed Development Programme

Watershed development as a means for increasing agricultural production in rainfed, semi-arid areas. There are nearly 85 million hectares of land as rainfed area in the country. These areas were bypassed by the Green Revolution and so experienced little or no growth in agricultural production for several decades. By capturing the Water Resources Management and improving the management of soil and vegetation, Watershed Development aims to create conditions conducive to higher agricultural productivity while conserving natural resources.

C. Objectives

- To mitigate the adverse effects of drought on crops and livestock.
- To control desertification.
- To encourage restoration of ecological balance and
- To promote economic development of village community.

Water shed development originally managed by national wasteland development board under Ministry of Environment and forest .It is now placed under Ministry of Rural Development and Department of Land Resources. The main objective of this programme for development of waste lands in non-forest areas, checking of land degradation, putting such waste land into sustainable use and increasing bio mass, availability of fuel wood, fodder and restoration ecology etc.Thus concept of watershed development is a integrated nurture with multi-disciplinary activities in the area. At present Ministry of Rural Development and Department of Land Resources, Government of India funding watershed development programmes under D.P.A.P., D.D.P., and Integrated Wasteland Development Plan (I.W.D.P.) etc. This programme is intended to be taken up in rain-fed and drought-prone areas especially predominated by SC/ST population and preponderance of wasteland. There are six major projects/programmes in watershed development programme namely,

- National Watershed Development Project for Rainfed Areas (NWDPRA)
- Watershed Development in Shifting Cultivation Areas (WDSCA)
- Drought Prone Areas Programme (DPAP)
- Desert Development Programme (DDP)
- Integrated Wasteland Development Project (IWDP)
- Employment Assurance Scheme (EAS)

These six projects/ programmes also account for about 70 percent of funds and area under watershed programmes in the country.

Through various watershed development programmes, about 30 million ha. of land has so far been developed at an expenditure of Rs.9343 crores, including external funding up to the end of IX Five Year Plan. During X Five Year Plan about 11.4 million ha is proposed to be developed at an outlay of Rs.7440 crore. Besides, an area of 1.24 million ha is likely to be treated under watershed programmes at a cost of Rs.1872 crore through ongoing externally aided projects.

d. Components of watershed programme

1. Soil and water conservation
2. Water harvesting
3. Crop management

e.Soil and water conservation methods :

Soil conservation refers to protection of soil against erosion or deterioration. Soil conservation is a set of management strategies for prevention of soil being eroded from the earth's surface or becoming chemically altered by overuse, acidification, salinization or other chemical soil contamination

f.Methods of conservation :

- Exsitu conservation
- Insitu conservation

g.Exsitu method

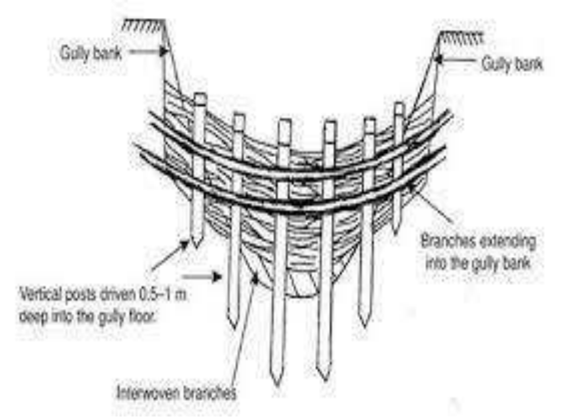
1. **Brush dams**

Brushwood check dams are constructed with the help of locally available wooden poles and brushwood. Wooden poles are driven into the ground in a single or double row and brushwood is packed on the upstream face of the check dam

It is suitable to stabilize small gullies of 1.2 to 2 m deep. Cheap and easy to construct with brush and hay. It does not require any skilled labour. Make use of materials at the location.

i) Single row post brush dam

ii) Double row post brush dam.



2. **Loose rock dams**

These types of check dams are used for checking runoff velocity in steep and broad gullies where good size of stones is available in abundance. Loose rock check dams have longer life and usually require less maintenance as compared to brushwood check dam. Loose stones of fairly good size are used. Woven wire netting provide stability to the dam.

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3. Plank or slab dams

Plank dams construction is rare with the increase in the cost of timber. North eastern region of the country plank dams are in use because there is not much scarcity of timber. Requires Less labour, More expensive. It is used for relatively large drainage areas

4. Log dams

The use of these types of check dams should be restricted only to the places where no other material such as stones, brick etc. is available and the wooden logs are available in abundance. White ants are the greatest enemy of this type of structures and accordingly the required measures should be taken before hand. Water tight construction is not possible. Construction of log dam is almost similar to that of plank dam.

5. Gabion check dams

A gabion is semi permeable barrier, made of boulders in a mesh of steel wires and anchored to the stream bank, to slow but not stop, the flow of storm water in a small watercourse so to favour water infiltration to groundwater and help prevent soil erosion. Expected velocity of water is very high. Rectangular shaped cage made of galvanized wire and filled with locally available stones. Stones-shapes and sizes - unsuitable for loose stone dams. Just after construction, they are permeable reducing the velocity of water, deposition of soil particles and finally complete filling up behind the gabion check dams.

I. INSITU MOISTURE CONSERVATION METHODS

a.Definition of insitu

Storage of rainfall in soil at the place where it falls is termed as "insitu" soil moisture conservation. It aims at increasing infiltration of rainfall into the soil and reducing runoff loss of rainwater.

Insitu soil moisture conservation can be accomplished through.

- Cultural /agronomic methods
- Mechanical methods
- Agrostological / biological methods

The extent of soil moisture storage from rainfall is influenced quantity and intensity of rainfall, slope, soil properties such as texture, structure, depth, surface characters, presence of sub soil hard pans, rate of infiltration and permeability, water holding capacity, vegetative cover etc

b.Insitu Moisture Conservation

Cultural/agronomical	Mechanical	Agrostological
1.Addition of organic matter 2.Summer ploughing, 3.Contour farming, cover crops mulching, strip cropping, cropping systems, Tillage practices	Basin listing, Subsoiling, Compartmental Bunding, Ridges and furrows, Broad bed furrow, Contour bunding, graded bunding, Bench terracing	Pasture, Strip cropping with grasses, Ley farming, Vegetative barriers

C.Methods of soil conservation

- Biological measures or Agronomic measures – Through crops or vegetation and agronomical practices for lands with slope less than 2%
- Engineering measures- for land slopes greater than 2%
- Agronomic measures are also adopted in conjunction with engineering measures

1. Cultural /Agronomical methods

i) Addition of organic matter:

By improving soil physical properties and water holding capacity.

ii) Off season/summer tillage:

Plough furrows can hold water in the depressions and thereby increase the infiltration. When done across the slope, the plough furrows check runoff, reduce the velocity of runoff water and improve storage. Summer tillage is a traditional practice helps in the storage of pre-sowing rainfall. When ploughing is done along contour, it is termed as contour ploughing and is more helpful for in situ moisture conservation. Summer ploughing also helps in control of perennial weeds, pest control and enables early sowing with onset of rains.

iii) Contour farming:

Ploughing along the contour and sowing reduce soil erosion and reduce runoff. For e.g., Jowar sown in the black soils on contour line restricts the run off to 13.7% of the total rainfall and soil loss to 2.4 t/ha/year. The soil conservation method proves efficient in slope territories and suggests planting species along the contour. Rows up and down the slope provoke soil erosion due to water currents while rows along the contour restrain it. An impact of terracing is similar, it also helps to conserve soil and reduce its degradation processes. Contour cultivation reduces the velocity of overland flow and retards soil erosion. Ridge and furrow system on contour offers greater resistance to surface runoff. Crops like maize, sorghum and pearl millet grown in row are ideally suited for contour cultivation.

iv) Cover crops:

A cover crop is any crop grown to provide soil cover, regardless of whether it is later incorporated. Cover crops are grown primarily to prevent soil erosion by wind and water. Cover crops can be annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year. In addition to providing ground cover and, in the case of a legume, fixing nitrogen, they also help suppress weeds and reduce insect pests and diseases. When cover crops are planted to reduce nutrient leaching following a main crop, they are often termed "catch crops."Rice - Rice – Blackgram in Cauvery Delta Zone of Tamil Nadu

Erosion will be reduced if the land surface is fully covered with foliage. e.g., black gram, green gram, groundnut and fodder grasses like *Cenchrus ciliaris, Cenchrus glaucus,* dinanath grass, marvel grass. Both contour cropping and cover cropping can be practiced when the slope is less than 2 per cent.

Advantages of cover crops :

1. By reducing soil erosion, cover crops often reduce both the rate and quantity of water that drains off the field, which would normally pose environmental risks to waterways and ecosystems downstream.
2. Cover crop biomass acts as a physical barrier between rainfall and the soil surface, allowing raindrops to steadily trickle down through the soil profile.
3. Root growth results in the formation of soil pores, which in addition to enhancing soil macro fauna habitat provides pathways for water to filter through the soil profile rather than draining off the field as surface flow. With increased water infiltration, the potential for soil water storage and the recharging of aquifers can be improved.

v) Mixed cropping :

Mixed cropping, including intercropping, is the oldest form of systemized agricultural production and involves the growing of two or more species or cultivars of the same species simultaneously in the same field

vi) Inter cropping :

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

vii) Mulching :

Mulching is a soil and water conserving and weed management practice through soil solarisation also in which any suitable material is used to spread over the ground between rows of crops or around the tree trunks. This practice helps to retain soil moisture, prevents weed growth and enhances soil structure. Types of mulching includes

A. Surface mulching

Organic mulching, Chemical mulching, Soil mulching / Dust mulching, Pebble mulching

B. Vertical mulching

c. Vegetative barrier

viii) Strip cropping:

Strip intercropping involves erosion resistant crops and erosion permitting crops in alternate strips of 2–3 m width across slope and along the contour. Erosion resistant crops include grasses and legumes with rapid canopy development. For example, *Cenchrus glaucus* + *Stylosanthes hamata*. In this case, farmers combine high-growing crops with low-growing ones for the sake of wind protection, like when corn grows in strips with forage crops. The strip cropping practice works even better when high-growing crops are intensified in the sides where winds blow most frequently. An extra benefit is the organic matter material from the low crops.

Types of strip cropping

- Contour strip cropping
- Field strip cropping
- Buffer strip cropping
- Wind strip cropping

(a) Buffer strip cropping (b) Contour strip cropping

(c) Field strip cropping

Table 11.3. Recommended strip widths for wind-strip cropping (FAO 1965)

Soil Types	*Strip width (m)*
Sandy soil	6.0
Loamy sand	7.0
Sandy loam	30.0
Loam	75.0
Silt loam	85.0
Clay loam	105.0

1. Contour strip cropping

In contour strip cropping, the crops are planted in strips along the contour at right angles to the direction of natural land slope. The growing of crops in strips are in a definite rotational sequence. Although, it is not strictly essential that all the crops must be in the rotation in the same field and in the same year, but as far as possible it should be maintained to keep the soil in proper order. Contour strip cropping is adopted on the level land across the slope instead of up and down hill, for checking the flow of surface water. From field studies, it has been observed that the strip cropping on the contour plays a key role in conserving the soil and water, when combined with terracing. The width of strips depends on the topographical features of the area.

2. Field Strip Cropping:

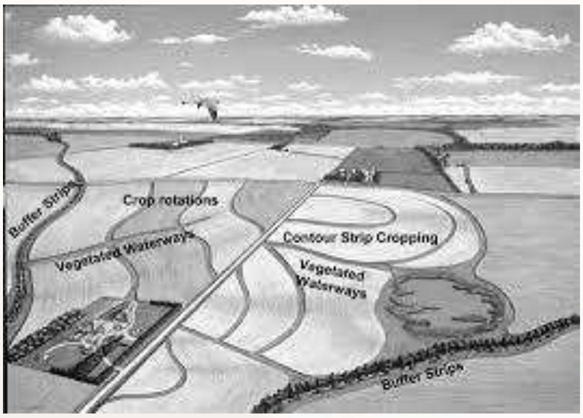
It is modified form of contour strip cropping, in which crop strips are laid parallel, across the land slope, but not always exactly on the contour; may be changed depending on the land situation. This type of strip cropping is suitably used where the topography is either too irregular or undulating, as they make accurate layout of contour strip cropping, impractical. The depressed areas should be avoided for field strip cropping; they can be left for establishing the grassed waterways.

3. Buffer Strip Cropping:

In buffer strip cropping, the strips of grasses or legume crops are laid between contour strip crops in regular rotation. The width of these strips may or may not be uniform. The buffer strips are usually 2 to 4 m wide, and are placed at 10 to 20 m intervals. They can also be placed on critical slopes of the field. The main purpose of buffer strip cropping is to provide protection to the land from soil erosion.

4. **Wind Strip Cropping:**

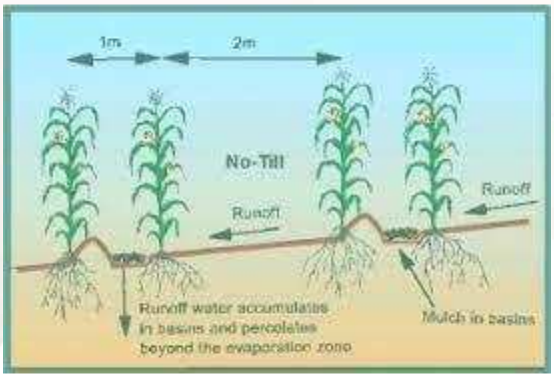
In wind strip cropping system, the strip crops of uniform width are laid at right angles to the direction of prevailing winds, without regard of the contour. The main objective of this system is to control the wind erosion rather water erosion. This cropping is recommended for level or nearly level topography, where wind erosion is more effective.



(ix) Conservation Tillage

The conservation tillage aims at addressing wind and water erosion by covering the earth with vegetation (either crops or their residues) and limiting the number of tilling operations. Another significant aspect is to choose the proper time for field operations, depending on the soil types. For example, clay ones are better to till after harvesting while other types are better to plough before seeding. Also, handling wet soils leads to their compaction. Minimum tillage – preparation of seed bed with minimum soil disturbance. The practice consists of opening the land just to plant the seed and use of chemical herbicides to control the weeds. Strip or zone tillage- seed bed is prepared by cultivating the soil in a narrow strip. The area in between the rows is either left untilled or tilled in a different manner.

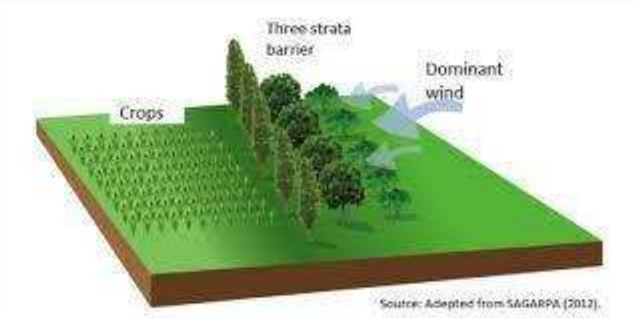
MULCH TILLAGE - A tillage operation that will leave a substantial part of the residual vegetative materials of the previous crop on or near the surface as a protective cover is known as mulch tillage. This is also called as stubble mulching.



No-till farming assists in soil conservation as well since it implies no or minimum disturbance and planting seeds into the crop residue. The basic idea is not to leave soil bare, as bare areas are highly prone to erosion, and plants keep it in place with their root systems. Additionally, vegetation accumulates moisture for future crops.

(x) Windbreaks

As the name suggests, this soil conservation practice is used to reduce the power of winds and its disruptive effect on soil. These are trees or bushes to shelter crops from snow and winds planted in several rows. Depending on the number of rows, we can distinguish windbreaks properly (up to five rows) and shelterbelts (six and more). Windbreak vegetation also provides a living environment for wildlife and eliminates soil abrasion on crops due to strong wind blows.



(xi) Crop Rotation

Crop rotation vs. monocropping farming suggests changing agro species instead of planting one and the same for many subsequent seasons. Crop rotation helps them improve the earth structure with diverse root systems, to mitigate pest establishments, and to add nitrogen to the land with legumes known as nitrogen-fixing plants.

(xii) Cropping Systems

Cropping system refers to a sequence of crops grown on a given area over a period of time for prevention or control of soil erosion, building up of soil fertility, building up of organic matter and control of weeds. Crop rotation is chosen in such a way that during rainy periods there is a vegetative cover over the soil surface. Vegetative cover controls splash erosion by intercepting the rain drops, and absorbing their energy. It also helps in maintaining the infiltration rate of the soil as on a bare soil beating action of rainfall breaks down the clods and forms a tight layer

Mechanical methods

The basic principle are:

(i) Shaping the land surface manually or with implements in such a way as to reduce the velocity of runoff

(ii) To allow more time for rainfall to stand on soil surface, and

(iii) To facilitate more infiltration of rainfall into soil layers.

Choice of any particular method under a given situation is influenced by rainfall characters, soil type, crops, sowing methods and slope of land.

(i) Basin listing:

Formation of small depressions (basins) of 10–15 cm depth and 10–15 cm width at regular intervals using an implement called basin lister. The small basins collect rainfall and improve its storage. It is usually done before sowing. It is suitable for all soil types and crops.

(ii) Bunding:

Formation of narrow based or broad based bunds across slope at suitable intervals depending on slope of field. The bunds check the free flow of runoff water, impound the rainwater in the inter-bund space, increase its infiltration and improve soil moisture storage. Leveling of inter-bund space is essential to ensure uniform spread of water and avoid water stagnation in patches.

Contour Ploughing

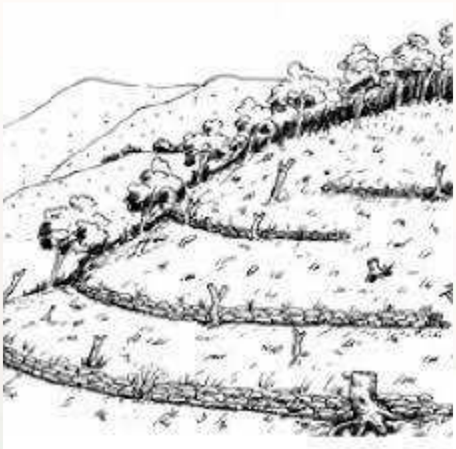

Terrace Farming


Contour Bunding

It can be classified into three types:

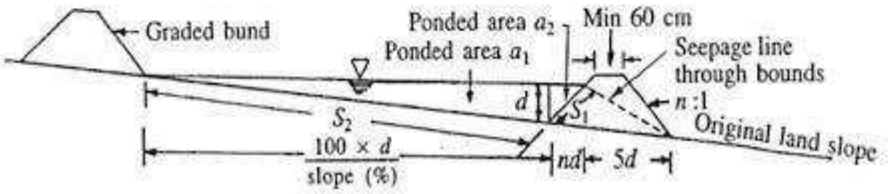
(a) Contour bunding:

Bunds of 1 m basal width, 0.5 m top width and 0.5 m height are formed along the contour. The distance between two contour bunds depends on slope. The interbund surface is leveled and used for cropping. It is suitable for deep red soils with slope less than 1%. It is not suitable for heavy black soils with low infiltration where bunds tend to develop cracks on drying. Contour bunds are permanent structures and require technical assistance and heavy investment.



(b) Graded/field bunding:

Bunds of 30-45 cm basal width, and 15-20 cm height are formed across slope at suitable intervals of 20-30 m depending on slope. The inter-bund area is leveled and cropped. It is suitable for medium deep-to-deep red soils with slopes up to 1%. It is not suitable for black soils due to susceptibility to cracking and breaching. Bunds can be maintained for 2-3 seasons with reshaping as and when required.

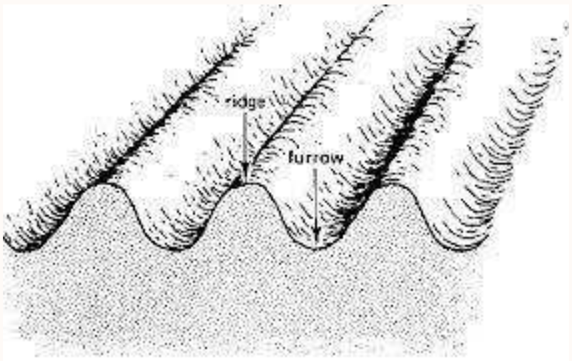


(c) Compartmental bunding:

Small bunds of 15 cm width and 15 cm height are formed in both directions (along and across slope) to divide the field into small basins or compartments of 40 sq. m. size (8 × 5 m). It is suitable for red soils and black soils with a slope of 0.5-1%. The bunds can be formed before sowing or immediately after sowing with local wooden plough. It is highly suitable for broadcast sown crops. CRIDA has recommended this method as the best in situ soil moisture conservation measure for Kovilpatti region of Tamil Nadu. Maize, sunflower, sorghum performs well in this type of bunding.

(d) Ridges and furrows:

Furrows of 30-45 cm width and 15-20 cm height are formed across slope. The furrows guide runoff water safely when rainfall intensity is high and avoid water stagnation. They collect and store water when rainfall intensity is less. It is suitable for medium deep-todeep black soils and deep red soils. It can be practiced in wide row spaced crops like cotton, maize, chillies, tomato etc. It is not suitable for shallow red soils, shallow black soils and sandy/ gravelly soils. It is not suitable for broadcast sown crops and for crops sown at closer row spacing less than 30 cm. Since furrows are formed usually before sowing, sowing by dibbling or planting alone is possible. Tie ridging is a modification of the above system of ridges and furrows where in the ridges are connected or tied by a small bund at 2–3 m interval along the furrows. Random tie ridging is another modification where discontinuous furrows of 20–25 cm width, 45–60 cm length and 15 cm depth are formed between clumps or hills of crops at the time of weeding. Yet another modification of ridges and furrows method is the practice of sowing in lines on flat beds and formation of furrows between crop rows at 25–30 DAS. This enables sowing behind plough or through seed drill.



(e) Broad Bed Furrow (BBF):

Here beds of 1.5 m width, 15 cm height and convenient length are formed, separated by furrows of 30 cm width and 15 cm depth. Crops are sown on the beds at required intervals. It is suitable for heavy black soils and deep red soils. The furrows have a gradient of 0.6%. Broad bed furrow has many advantages over other methods.

• It can accommodate a wide range of crop geometry i.e., close as well as wide row spacing.

• It is suitable for both sole cropping and intercropping systems.

• Furrows serve to safely guide runoff water in the early part of rainy season and store rainwater in the later stages.

• Sowing can be done with seed drills.

• It can be formed by bullock drawn or tractor drawn implements. Bed former cum seed drill enables BBF formation and sowing simultaneously, thus reducing the delay between rainfall receipts and sowing.

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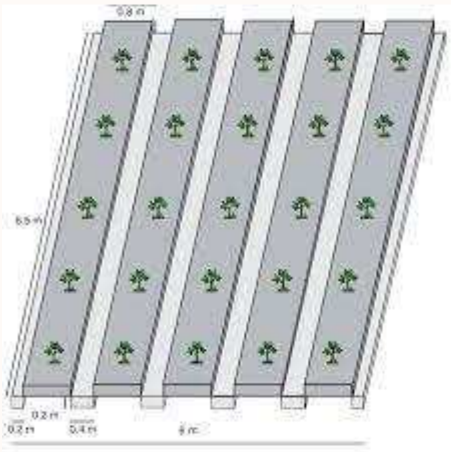


(f) Dead furrow

At the time of sowing or immediately after sowing, deep furrows of 20 cm depth are formed at intervals of 6–8 rows of crops. No crop is raised in the furrow. Sowing and furrowing are done across slope. It can be done with wooden plough in both black and red soils.

(g) Bench terracing/ terrace bunding

It consist of step-like or benches along contours by cut and fill method to reduce length and degree of slope. It helps in promoting uniform distribution of soil moisture, irrigation water and controlling soil erosion. It is recommended for 16 to 33 % slope

(h) Subsoiling

This method consists in breaking with a sub soiler the hard and impermeable subsoil to conserve more rain-water by improving the physical conditions of a soil. This operation, which does not involve soil inversion and promotes greater moisture penetration into the soil, reduces both run-off and soil erosion. The sub soiler is worked through the soil at a depth of 30-60 cm at a spacing of 90-180 cm.

Mechanical structures	Soil type	Rainfall (mm)	Slope %
Contour bund	High soil	<600	>1.5
Graded bund	All soil	>600	1.5-6.0
Bench terraces	Deep soil	>1000	6 - 30
Graded border strips	Deep Alfisols and related red soils	>800	>1.5

Agrostological methods

The use of grasses to control soil erosion, reduce run off and improve soil moisture storage constitutes the agrostological method. Grasses with their close canopy cover over soil surface and profuse root system, which binds soil particles, provide excellent protection against runoff and erosion. The following are the various agrostological methods of in situ moisture conservation.

(i) Pastures/grass lands:

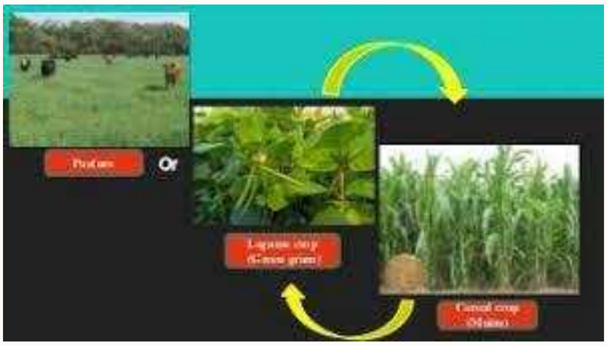
Raising perennial grasses to establish pastures or grass lands is recommended for shallow gravelly, eroded, degraded soils. Grass canopy intercepts rainfall, reduces splash erosion, checks runoff and improves soil moisture storage from rainfall.

(ii) Strip cropping with grasses:

Alternate strips of grasses and annual field crops arranged across slope check runoff and erosion and help in increasing moisture storage in soil.

(iii) Ley farming:

It is the practice of growing fodder grasses and legumes and annual crops in rotation. Grasses and legumes like Cenchrus, stylo are grown for 3–5 years and followed by annual crops like sorghum for 2 year. When the field is under grasses or legumes, soil moisture conservation is improved.



(iv) Vegetative barriers:

Vegetative barrier consists of one or two rows of perennial grasses established at suitable interval across the slope and along the contour. It serves as a block to free runoff and soil transport. Vetiver, Cenchrus etc., are suitable grasses. Vetiver can be planted in rows at intervals of 40 m in 0.5% slope. Plough furrows are opened with disc plough first before commencement of monsoon. 5–8 cm deep holes are formed at 20 cm interval and two slips per hole are planted in the beginning of rainy season. The soil around the roots is compacted. Vetiver barriers check runoff and prevent soil erosion. While they retain the soil, they allow excess runoff to flow through their canopy without soil loss. It is adapted to drought and requires less care for maintenance. It does not exhibit any border effect on crops in adjacent rows. It allows uniform spread of water to lower area in the field resulting in uniform plant stand thus increasing yield of a crop by 10–15%. It facilitates better storage of soil moisture. If fodder grasses like Cenchrus glaucus or marvel grass are used, fodder can also be harvested and given to the animal. Vegetative barriers are best suited for black soil. Unlike contour bunding, which gives way due to development of crack in summer in black soils, vegetative barriers do not allow such phenomenon in black soil. Hence, the vegetative barriers can be effectively maintained in black soil for 4–5 years. After 4–5 years, replanting material can also be had from the old barrier by ‘quartering’.

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Course Name	Dryland Horticulture
Lesson 6	Methods Of Control And Impounding Of Run-Off Water –Farm Ponds, Trenches, Macro Catch Pit.
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Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture:

- Agro-climatic features in rain shadow areas, scarse water resources, high temperature, soil erosion, run-off losses etc.
-

Glossary of terms

1.	Rain Shadow	-	It is a patch of land that has been forced to become a desert because all plant-growing, rainy weather has been blocked by mountain ranges
2.	Drought	-	Is a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall.
3.	Constraints	-	something that limits or restricts
4.	Pre-monsoon	-	Before a monsoon
5.	Post - monsoon	-	After a monsoon

Methods Of Control And Impounding Of Run-Off Water – Farm Ponds, Trenches, Macro Catch Pit

I. Methods Of Controlling Runoff

A. Mechanical Methods:

1. Contour bunding
2. Graded bunding
3. Biological Bunding or live Bunds or vegetative bunding; or Vegetative barriers
4. Watershed management- inter bund management
5. Broad bed furrow
6. Vertical mulching

B. Agronomical practices

1. Strip cropping
2. Mulching
3. Contour cultivation
4. Planting of grasses for stabilizing bunds.
5. Intercropping
6. Sequence cropping
7. Relay cropping

i.Vertical mulching

This is the practice followed in dry farming areas for moisture conservation. The infiltration rate to black soils of dry lands is very low. In the event of high intensity rainfall much more water is lost as runoff instead of infiltrating into the soil profile. This process still accelerated under sloppy lands. Under these conditions the technique of vertical mulch has been found useful in Dryland farming.

This technique consists of digging suitable trenches across the slope and thus making more surface area available for absorption. The open trenches are filled with organic farm wastes like straw stubbles the stalks etc. which is called as filter. The filter should be resistant to decomposition and provide service for 3 – 4 years. The upper portion of filter should be 15 – 20 cm above the soil surface.

The trenches should be of 20 cm width in between two crop rows. The trench depth of 60 to 90 cm is optimum. The interval between trenches should be 4 m. the runoff water is trapped by the filter and allowed to percolate in the trenches the stored water in the trenches recharge the soil profile by lateral movement of water.

ii.Vegetative or Biological bunding

The bushes like *Subabul shevri* of the grasses like vetiver i.e. thus grass are planted in between the bunds in the fields across the slope or along the average contours. The system is called as vegetative bunding or biological bunding. The grasses or the bushes are cut close to the ground periodically leaving 20 to 30 cm top portion above the ground. This above ground portion helps to arrest the surface flow of excess water. The water halts temporarily along the vegetative bunds and helps in silting of soil particles. During this time water gets some time to infiltrate into the soil. Then partially clear excess water goes up to the field bunds with non-erosive velocity which is further drained into field drains. The interval between two vegetative bunds will depend on the slope of the field. However, 10 – 12 m interval between two bunds is convenient for carrying out field operations.

The bushes like Subabul or shevri can also be planted at 15 – 20 m intervals across the wind direction in the fields which acts as wind breaks and useful for checking soil erosion and moisture conservation.

Iii.Effective rainfall

From crop production point of view, it is the portion of rainfall which contributes to the crop water needs is the effective rainfall. In other wounds the and of in tall watch becomes the part of consumptive use of water of a crop. An actual farmer considers that the effective rainfall which's that total rainfall which is useful in raising crops planted on his soil. Water which moves out of his field by surface runoff is the portion of total rainfall which is ineffective. Also, the water that moves below root zone as deep percolation is ineffective. Any rainfall received after the soil has attained the field capacity up to root zone depth is ineffective.

iv.Farm Ponds

Farm ponds are small tank or reservoir like constructions, are constructed for the purpose of storing the surface runoff, generated from the catchment area. The farm ponds are the water harvesting structures, solve several purposes of farm needs such as supply of water for irrigation, cattle feed, fish production etc.
Farm ponds also play a key role in flood control by constructing them in large numbers in the area. In addition, the farm ponds are also used for storing the monsoon water, which is used for irrigation of crops, and several other purposes, according to the need. A farm pond also has significant role in rainfed farming.

iv.a.Types of Farm Pond

In broad sense, the farm ponds are divided in following two general categories:

1. Embankment type, and
2. Excavated or dug out type

1. Embankment Type:

Embankment type farm ponds are generally constructed across the stream or water course. Such ponds consist of an earthen embankment, which dimensions are fixed on the basis of volume of water to be stored, mainly. These farm ponds are usually constructed in that area where land slope ranges from gentle to moderately steep; and also, where stream valleys are sufficiently depressed to permit a maximum storage volume with least amount of earthwork.

2. Excavated or Dug Out Type:

Dug out type farm ponds are constructed by excavating the soil from the ground, relatively in flat areas. The depth of pond is decided on the basis of its desired capacity, which is obtained almost by excavation. The use of this type of pond is suitable, particularly where a small supply of water is required.

Apart from above two types, the farm ponds are also of two more types, i.e., the spring or crack fed and off-stream storage pond, depending on the sources of water available for feeding them.

The spring or crack fed ponds are generally found is hilly areas, where natural cracks or springs are available to supply the water. Since, the source of water supply to these ponds is the crack or spring, therefore, they are named as spring or crack fed pond.

Off-stream storage ponds are constructed on the side of ephemeral streams, in which water flows seasonally. This seasonal water is stored in these ponds. This type of ponds are provided with a suitable arrangement for safe conveyance of flow into the pond and supply of water to channels.

'Seepage' is counted as one of the main factors for pond design, e.g., in the areas of high gypsum the seepage loss is much more, causing construction of farm pond impractical. Although, everywhere there is seepage due to ponding of water but it should be under favourable limit.

Normally, it is advised to allow the seepage loss at the rate of 1m depth of water per year, when estimating minimum storage. The depth of farm pond also varies as per climatic condition.

Typical values of average pond depth are given in Table 17.1.

Table 17.1. Typical average pond depth based on climatic condition

Climate	*Average depth (m)*
Wet	2.0 (5 ft.)
Humid	2.4 — 2.8 (6 —7)*
Most sub humid	2.8 — 3.15 (7 — 8)
Dry sub humid	3.15 — 4.00 (8 — 10)
Semi-arid	4.00 — 4.80 (10 — 12)
Arid	4.80 — 5.50 (12 — 14)

* Values given in parenthesis are the average depth in the unit of 'feet'.

iv.a.Components of Farm Pond:

A farm pond essentially consists of following components:

1. Pondage or storage area
2. Earthen embankment
3. Mechanical and emergency spillways.

The mechanical spillway is used for letting out the stored water from the pond. In other words, mechanical spillway acts as an outlet for safe disposal of water from the storage area of the pond. On the other hand, the emergency spillway is used as safeguard for earthen dam against overtopping, when volume of inflow becomes greater than the pondage capacity of the farm pond.

V.Macro catchment pits

Macro catchment Water Harvesting (Macro WH) systems usually consist of four components: the catchment area, the runoff conveyance system, the storage system and the application area. In the catchment area, rainwater runoff is collected from compacted surfaces, including hillsides, roads, rocky areas, open range lands, cultivated and uncultivated land and natural slopes. Most Macro WH practices have a catchment area of less than 2 ha, in some cases however runoff is collected from catchments as large as 200 ha. The runoff is conveyed through overland, rill, gully or channel flow and either diverted onto cultivated fields (where water is stored in the soil) or into specifically designed storage facilities. Where concentrated runoff is directly diverted to fields, the application area is identical with the storage area, as plants can directly use the accumulated soil water. The application or cropping area is either terraced or located in flat terrain. The ratio of the catchment to the application area (usually cultivated) varies between 10:1 and 100:1. In the second case, a great variety of designed storage systems keep the water until it is used either adjacent to the *storage* facilities or further away (involving a conveyance system). The classification of technologies into Flood WH or Macro WH is not always straightforward. It depends on the catchment size (Flood WH > Macro WH), the size of rainfall event (Flood WH > Macro WH) and concentration/size of runoff which is tapped (Flood WH harvest from the channel flow, Macro WH collects sheet and rill flow and short-distance channel flow). The harvested water is mainly used for crop and livestock production but also for domestic use, depending on the quantity and quality.

vi.Trench with recharge well

- In areas where the surface soil is impervious and large quantities of roof water or surface runoff is available within a very short period of heavy rainfall, the use of trench/ pits is made to store the water in a filter media and subsequently recharge to ground water through specially constructed recharge wells.
- This technique is ideally suited for area where permeable horizon is within 3m below ground level.
- Recharge well of 100-300 diameter is constructed to a depth of at least 3 to 5 m below the water level. Based on the lithology of the area, well assembly is designed with slotted pipe against the shallow and deeper aquifer.
- A lateral trench of 1.5 to 3m width and 10 to 30 m length, depending upon the availability of water is constructed with the recharge well in the centre.
- The number of recharge wells in the trench can be decided on the basis of water availability and local vertical permeability of the rocks.
- The trench is backfilled with boulders, gravels and coarse sand to act as a filter media for the recharge wells.

If the aquifer is available at greater depth say more than 20 m, a shallow shaft of 2 to 5 m diameter and 3-5 metres deep may be constructed depending upon availability of runoff. Inside the shaft a recharge well of 100-300 mm dia is constructed for recharging the available water to the deeper aquifers. At the bottom of the shaft a filter media is provided to avoid choking of recharge well.

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Course Name	**Dryland Horticulture**
Lesson 7	**In-situ water harvesting methods, micro-catchment, different types of tree basins, etc.,**
Content Creator	**V.P.SANTHI**
University Name	**Tamil Nadu Agricultural University, Coimbatore**
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Objectives of the lecture:

To learn about the in-situ water harvesting methods , micro-catchment,different types of tree basins, etc.,

Glossary of terms

1.	In-situ water harvesting	-	Conserve the rain water where it falls for increasing soil water storage or reducing run off and soil loss and enhancing the crop productivity.
2.	Corrugation	-	In a closely planted crop, the small v-shaped furrows, are drawn, are referred as corrugations
3.	*Terrace farming*	-	A method of farming whereby “steps” known as terraces are built onto the slopes of hills and mountains.
4.	*Trench*	-	*Trench* is a long cut in the ground
5.	*Micro-catchment*	-	It is one of the direct water harvesting system where small structures are constructed across land slopes which captures surface runoff water.

IN SITU WATER HARVESTING METHODS

Technologically all rainfall harvesting systems have three components: a collection area, a conveyance system, and a storage area. In this application, collection and storage is provided within the landscape. Topographic depressions represent ideal collection and storage areas. In many situations such areas are impermeable, being uncertain by clay soils that minimize infiltration. The in situ water harvesting methods are those which conserve the rain water where it falls for increasing soil water storage or reducing run off and soil loss and enhancing the crop productivity. These techniques include the following:

1. Land treatment
2. Engineering measures
3. Cropping system and cultivation

1. LAND TREATMENT TECHNIQUES

(i) General smoothening of land

In this case, prior to bunding, small gullies are formed all over the land to spread the flow of water. At the time of bunding these are flattened for better conservation of water over the land surface. The gullies which are not suitable for grass waterways are also smoothened and leveled. This will help in conservation of water in situ.

(ii) Zigzage Terracing:

Under contour bunding the runoff water is not well distributed and gets concentrated near the bunds leading to stagnation and damage to crops. To avoid this hazard, a practice of leveling the lower one third portion of the land between contour bunds is leveled to help spreading of runoff water in the larger area of interbunded area and ensure availability of more water to crop.

(iii)Compartmental Bunding:

It means the entire field is divided into small compartments with predetermined size to retain the rain water where it falls and arrest soil erosion. The size of the bunds depends upon slope of the land. Compartmental bunds provide more opportunity time for water to infiltrate into the soil and help in conserving soil moisture.

SALIENT FEATURES

- Compartmental bunding is an effective moisture conservation measure in dryland.
- It is suitable for lesser rainfall areas and the slope is less than 1 percent.
- The lands are divided into small compartments with the dimension of $8x5m^2$

- It increases the water holding capacity of the soil.
- It can be formed while ploughing itself or before early sowing.
- Reduces the formation of cracks.
- It will overcome the disadvantages of contour bunding.

It is commonly followed practice in deep black soils. A rain received during monsoon is collected and help in compartments to percolate down for surface storage and raising crop production.

Tied ridging:

In this case well harrowed field is converted into ridges and furrows and tied separately to make the rain water collect in the furrows for water conservation. Important features are:

- The ridges are vertically tied at shorter interval to create rectangular water harvesting structures. During heavy rainy season it facilitates to infiltrate water to the soil.
- The slight sloppiness in the tied ridges facilitates drainage of excess water infiltrate into the soil.
- Summer ploughing, broad bed and furrows ridges and furrows, random tie ridging, compartmental bunding etc. are the various in situ water harvesting method for black and red soils cause an increase of up to 15 percent in crop yields.
- It conserves soil and moisture in red soils.

Another variable in the tied contour ridging system, contour ridges are small earthen ridges 15-20 cm high, with an upslope furrow which accommodates run off from a catchment strip between the ridges. The ridges may be 1.5 to 10.0 m apart, but, as this is a micro-catchment system and catchment is a function of distance between ridges, the precise distance should be calculated for the expected rainfall. The tied contour ridging system is used for tree planting (with a wider distance between ridges) and crop production. Crops are planted on ridges as well as furrows. It is also referred as basin listing. It is more successful when carefully designed and constructed. . It is suitable on level ground and when the amount of water which can be stored in basin plus the quantity infiltrating during the storm is more than the worst storm likely to occur. It is more successful on permeable than shallow soils. To prevent failure, tied ridges are constructed on grade with ties lower than the ridges so that the failure and run off will be along each ridge and not down the slope.

Scooping:

In addition to explanation provided elsewhere, scooping is another method of improving in situ water harvesting in dryland areas. It is quite similar to range pitting method practiced in grasslands. It provides more time for water to infiltrate into the soil that would otherwise be lost as runoff. It helps in increasing the crop yield also up to the range of 20 per cent.

Ridge and Furrow system:

Ridge and furrow is an archeological pattern of ridges and thoughts created by a system of ploughing, typical of the open field system. It is also known as Rig (or Rigg) and Furrow mostly created to increase the surface area to help drainage as well as conservation of water. Cultivation of crops under ridge and furrow systems across the land slope with a gradient of 0.2 to 0.4 percent and inland having 2-4 percent slope will greatly help in *in situ* moisture conservation. A length of 60-90 m is optimum. Under this method, depending upon soil and climate conditions variations have been suggested.

(i) Interrow water harvesting:

In this case crop is sown in narrow strips between wide intervals that are ridged as artificial miniature watersheds. Later on these are compacted to increase run off to the crop rows. It is more practical as no land is sacrificed for harvesting water. It is practiced in arid areas with light soil where annual rainfall does not exceed 400-500 mm.

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(ii) Inter-plot or micro plot water harvesting system:

In this case water is harvested in furrows between the plots when rainfall is comparatively more. Runoff from sloping area supplements rainfall for raising crop on level land.

(iii) Raised-sunken bed:

It is a combination of raised and sunken beds alternatively where soil dugout from area makes sunken bed and place where it is spread makes the raised bed for raising crop. The sunken bed is mainly for drainage and water harvesting. It is commonly adopted in arid and semi arid region. This technology has proved useful for both kharif and Rabi crops. In this case 6m wide and 30-35 cm high beds are made which provide drainage to the upland crops, keeps the part of runoff water stored in sunken beds which facilitates the profile recharge and tends to stabilize root zone moisture during the periods of long dry spells.

Broad bed and Furrow system (BBF):

In this system broad beds are separated by sunken furrows. It is a raised land configuration, helps the soil to preserve the water level for a longer period by holding moisture intact. The bed stimulates crops growth. This system would not only help in water conservation for better crop yield but also help adapt to the ever changing climate. The crops will respond better to fickle rain duration and survive longer.

The system consists of broad beds about 100 cm wide separated by sunken furrows about 50 cm wide. The preferred slope along the furrow is between 0.4 and 0.8 percent on vertisols. Thus, three or four rows of crops can be raised on the broad bed, and the bed width and cop geometry can be varied to suit the cultivation and planting equipment. This system is commonly used on vertisols (heavy black soils)

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THE BASIC OBJECTIVES OF THIS SYSTEM ARE

- To encourage moisture storage in soil profile
- To dispose safely of surplus surface runoff without causing erosion.
- To provide a better drained and more easily cultivated soil in the bed.
- The possibility of the re-use of runoff stored in small tanks.

Once formed, they should be retained for some seasons for use by working on beds only.

Bedding system:

In this system of land configuration, a furrow is drawn after a few rows of crops across the slope on a grade of 0.2 to 0.4 percent. The bed width could be 3 to 6m and can vary based on crop and type of equipments for field preparation. This is suitable for narrow spaced row crops. In this method there is no water stagnation near the bund and therefore, the system acts both as disposal and conservation method. It provides better rainwater management at the times of low as well as high intensity of rain. This system provides both in situ moisture conservation during lower rainfall periods and safe disposal of excess run off during higher rainfall periods.

Ridge and Furrow and bedding system:

It is a combination of ridge and furrow and bedding system where the field is prepared in ridge and furrows for the plantation of crop on ridges and then furrows are drawn at a specified interval to conserve the water and reduce the run off generally after two seed drill width (i.e.3m interval). This system is useful for widely spaced crops at 60 to 90 cm between rows on a gradient of 0.3 to 0.4 percent.

A comparative evaluation of different land configuration viz. Flat bed system, broad bed and furrow bed and furrow (BBF), narrow bed and furrow

(NBF) and raised and sunken bed system (BSB). BBF is better followed by RSB and FB in black soil region (vertisol).

Corrugation:

In a closely planted crop, the small v-shaped furrows, are drawn, are referred as corrugations. Here the water gets soaked in the corrugation and spreads outside ways into the areas between them. Corrugations are generally smaller than furrows used in irrigating cultivated row crops. They also become site for in situ conservation of water. This can be done by the use of ridger.

2.ENGINEERING MEASURES

Terracing:

Terrace is an earthen embankment, ridge or ridge-and-channel built across a slope to intercept runoff water and reduce erosion. They are usually built in a series parallel to one another with each terrace collecting excess of water from the area above. Terraces can be designed to channel excess water into grass water ways or direct it underground to drainage tile and a stable outlet. There are three main types of terraces: Broad-based terraces, grassed back-slope terraces and narrow based terraces.

They are created for following usefulness

(i) Reduce soil erosion by breaking slope
(ii) Protect water quality by intercepting agricultural runoff.
(iii) Help prevent gully formation by directing run off to stable outlets.
(iv) Make it easier to form steep slope
(v) Improve soil quality and productivity by improving moisture retention and reducing soil erosion.

Conservation terraces:

Conservation terracing is mainly done to establish the vegetation and thereby reduce surface run off from these areas and improve conservation of soil moisture and reduce soil erosion.

Bench Terracing:

Bench terraces are a soil and water conservation measure used on sloping land with relatively deep soils to retain water and control erosion. They are normally constructed by cutting and filling to produce a series of level steps or benches along contours cut into hill/slope in a step like fashion. These platforms are separated at regular intervals by vertical drops or by steep sides and protected by vegetation and sometimes by packed stone retaining walls. Thus bench terraces convert the long un-intercepted slope into several small strops and make protected platform available for crop cultivation.

In hilly areas bench terracing has been employed for the purpose of converting hill slopes to suit agriculture. Depending on the climatic condition and resource availability they can be put to use for potato, coffee etc. There areas are also used for converting sloping lands to irrigated fields or for orchard plantations. Generally bench terracing is recommended for 16 to 30 percent slope range.

Types of Bench terraces

Based on the purpose for which to be utilized, bench terraces have been classified into the following types:

(i) Hill type bench terraces: It is used for hilly areas with a reverse grade towards the hill.

(ii) Irrigated bench terraces: Level benches are adopted under irrigated conditions.

(iii) Orchard bench terraces: Narrow width terrace (about 1 m) for individual terrains.

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Bench terraces have also been typed based on the type of surface slope as

(i) bench terraces sloping outward
(ii) bench terraces slopping inward, and
(iii) Bench terraces with level top.

I. Bench terraces slopping outward:

They are used in low rainfall areas with permeable soils. These terraces require a shoulder bund. The shoulder bund helps to conserve the rainfall coming over the area as it provides more time for moisture soaking into the soil. Bench terraces with narrow width are sometimes constructed for orchards and also referred as orchard bench terraces. These terraces are recommended to reduce existing steep slope to mild slope (say from 8 to 4%).

II. Bench terraces slopping inwards:

These terraces are recommended for heavy rainfall areas where a major portion of the rainfall is to be drained as surface run off. Thus, each of these terraces is provided a drain for runoff and therefore, they are made slopping inwards. Hey require a suitable outlet to drain out runoff safely. These are also referred as hill type bench terraces.

III. Bench terraces with level tops:

Suitable for areas with medium rainfall, evenly distributed well drained permeable soils. Due to this reason no slope is provided to the benches with the expectations that most of the rainfall coming over the area is absorbed and very little water will go out as runoff. These types of terraces are also made in areas with provision of irrigation facilities as referred to be as irrigated bench terraces. These terraces are recommended for slopes steeper than 6 to7 percent.

IV. Contour terracing:

In this, physical barriers (store bunds) are created along the contours to retain rain water and make it infiltrate into the soil and to minimize soil erosion.

Fairly flat strips of land develop between barriers which are made into terraces where crops are grown.

V. Contour trenching:

Contour trenching means excavating trenches along the contour or along the contour or along the uniform level or construction of trenches on slope contours to detain water and sediment transported by water or gravity down slope generally constructed with light equipments. These are also known as contour terraces or contour furrowing, lined with geotextiles and filled with rock stacked to placed to form an erosion resistant structure.

Purpose:

Contour trenches are used to break up the slope surface, to slow runoff and allow infiltration and to trap sediments. Rills are stopped by the trenches. Trenches or terraces are often used in conjunction with seeding. Width and depth varies with design storm, spacing, soil type and slope. Threshes trap sediment and interrupt water flow, slowing runoff velocity. They work best on coarse granitic soils.

Types of Trenches: They may be classified as follows:

(i) Continuous trenches
(ii) Interrupted viz., staggered and in line

I. Continuous trenches:

As the name implies they are continuous along the contour, used for moisture conservation in low rainfall areas and require careful layout.

II. Interrupted trenches:

These are constructed in series in a staggered manner. They are adopted in high rainfall areas so that excess of water form top can move downwards and help accumulation and conservation of water.

The optimal distance between two trenches depends upon the slope of the field, where steeper grounds require less distance shown in table below:

Hill slope	Distance between trenches
0-4%	10-12 m
4-8%	8m
8-15 %	6m
15-33%	4m

Field trenches suit most soil and rainfall conditions. Their design may be adapted to different rainfall conditions. While continuous trenches are good for dry regions, interrupted bunds can be helpful for water harvesting in regions with higher rainfall.

Advantages

- Applicable to all soil and rainfall conditions.
- Prevent soil degradation and erosion.
- Enhance surface water infiltration and soil moisture.
- Help to reduce flood hazards.
- Comparably simple construction, requiring only basic construction material.

Disadvantages

- Intense labour is needed for maintenance.
- Less land is available for cultivation.
- May create temporary water logging in dense soil.

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Stone terracing:

In agriculture, a terrace is a piece of slopped plane that has been cut into a series of successively receding flat surfaces or platforms, which resemble steps, for the purpose of more effective farming. Graduated terrace steps are commonly used to form on hilly and mountain terrain. In stone terracing small embankments constructed with stones across the hill sloped. These are recommended on any slope where stones are available in plenty at the spot. These stone terraces help in retarding the soil loss and conserving soil and moisture. By intercepting the surface runoff, the stone terraces also help in removing the stones that lie scattered on the field and otherwise hinder agricultural operation like ploughing, inter-culturing etc.

Contour Bunding:

Contour bunding or contour farming or contour ploughing is the farming practice of ploughing and/or planting across a slope following its contour lines. These contour lines create a water break which reduces the formation of rills and gullies during times of heavy water runoff, which is a major cause of soil erosion. The water break also allows more time for the water to settle into the soil. In contour ploughing, the ruts made by the plough run perpendicular rather than parallel to sloped, generally resulting in furrows that curve around the land and are level. This method is also known for preventing tillage erosion. Tillage erosion is the soil movement and erosion by tilling a given plot of land. In the similar practice of contour bunding, stones are placed around the contours of slopes. So it is the practice of construction earthen embankment on contour, which arrest the runoff from the field, thereby store profile is increased and resulting into higher productivity and water productivity.

Soil erosion prevention practices such as this can drastically decrease negative effects associated with soil erosion such as reduced crop productivity, worsened water quality, lower effective reservoir farming is considered an active form of sustainable agriculture.

Contour bunding is a proven sustainable land management practice for marginal, sloping and hilly land where the soil productivity is very low.

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Course Name	**Dryland Horticulture**
Lesson 8	**Methods of reducing evapotranspiration, use of shelter belts, mulches, antitranspirant, growth regulators etc.**
Content Creator	**V.P.SANTHI**
University Name	**Tamil Nadu Agricultural University, Coimbatore**
Course Reviewer	**SANGRAM SAHEBRAO DHUMAL**
University Name	**Mahatma Phule Krishi Vidyapeeth,Rahuri**

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Objectives of the lecture:

To learn about the different methods of reducing evapotranspiration, uses of shelterbelts, mulching, PGRs, antitranspirants,etc.,

Glossary of terms

1.	Evapotranspiration	-	The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration
2.	*Antitranspirants*	-	*Antitranspirants* are compounds applied to the leaves of plants to reduce transpiration.
3.	Mulch	-	A layer of material applied to the surface of soil to check evaporation and improve soil water.
4.	Rainfed horticulture	-	Describes horticultural practices that rely on rainfall water
5.	Evaporation	-	Process of a substance in a liquid state changing to gaseous state due to increase in temperature and pressure.

I. REDUCING EVAPORATION LOSSES:

Soil moisture is the most limiting factor in dryland agriculture. It is lost as evaporation from the soil surface and as transpiration from the plant surfaces. Evaporation has to be arrested as it is not directly related to productivity whereas transpiration can be reduced to some extent without affecting productivity of plants. The evaporation losses can be reduced by:

1. Mulches
2. Antitranspirants
3. Wind breaks
4. Weed control

1. Mulches

About 60 to 75 per cent of the rainfall is lost through evaporation. These evaporation losses can be reduced by applying mulches. Mulch is any material applied on the soil surface to check evaporation and improve soil water. Application of mulches results in additional benefits like soil conservation, moderation of temperature, reduction in soil salinity, weed control and improvement of soil structure.

Types of mulches
i)**Soil mulch or dust mulch:**

If the surface of the soil is loosened, it acts as a mulch for reducing evaporation. This loose surface soil is called soil mulch or dust mulch. Intercultivation creates soil mulch in a growing crop.

ii)Stubble mulch

Crop residues like wheat straw or cotton stalks etc., are left on the soil surface as a stubble mulch. The advantages of stubble mulch farming are protection of soil from erosion and reduction of evaporation losses.

iii)Straw mulch

If straw is used as mulch, it is called as straw mulch.

iv)Plastic mulch

Plastic materials like polyethylene, polyvinyl chloride are also used as mulching materials

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v)Vertical mulching

To improve infiltration and storage of rainwater in these soils, vertical mulches are formed. It consists of digging narrow trenches across the slope at intervals and placing the straw or crop residues in these trenches. The pruned plant material is placed in contour trenches formed between rows or in trenches around the plants in concentric circles each year in one circle.

2.Antitranspirants

About 99 per cent of the water absorbed by the plants is lost in transpiration. If transpiration is controlled, it may help in maintenance of favourable water balance.

Antitranspirant is any material applied to transpiring plant surfaces for reducing water loss from the plant. These are of four types:

1. Stomatal Closing
2. Film forming
3. Reflective
4. Growth retardant

Stomatal Closing type

Most of the transpiration occurs through the stomata on the leaf surface.

1. Fungicides like phenyl mercuric acetate (PMA) and herbicides like atrazine in low concentrations serve as antitranspirants by inducing stomatal closing.

These might reduce the photosynthesis also simultaneously. PMA was found to decrease transpiration to a greater degree than photosynthesis in a number of plants.

Film Forming Type

Plastic and waxy materials which form a thin film on the leaf surface retard the escape of water due to formation of physical barrier. Mobileaf, hexadeconol, silicone are some of the film forming type of antitranspirants. The success of these chemicals is limited since they also reduce photosynthesis.

1. The desirable characteristics of film forming type of antitranspirants are:
2. They should form a thin layer,
3. They should be more resistant to the passage of water vapour than carbon dioxide and the film should maintain continuity and should not break

Reflectant Type

These are white materials which form a coating on the leaves and increase the leaf reflectance (albedo). By reflecting the radiation, they reduce leaf temperatures and vapour pressure gradient from leaf to atmosphere and thus reduce transpiration.

1. Application of 5 per cent kaolin spray reduces transpiration losses.
2. A diatomaceous earth product (celite) also increases reflection of solar radiation from crop canopy

Growth Retardant

These chemicals reduce shoot growth and increase root growth and thus enable the plants to resist drought. They may also, induce stomatal closure.

1. Cycocel is one such chemical useful for improving water status of the plant

Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from death under severe moisture stress. If crop survives, it can utilise the rainfall that is received subsequently. Antitranspirants are also useful for reducing the transplantation shock of nursery plants. They have some practical use in nurseries and horticultural crops.

3.WIND BREAKS AND SHELTERBELTS

Wind breaks are any structures that obstruct wind flow and reduce wind speed while shelterbelts are rows of trees planted for protection of crops against wind. The direction from which wind is blowing is called windward side and direction to which wind is blowing is called leeward side.

Shelterbelts are planted across the direction of wind. They do not obstruct the wind flow completely. Depending upon their porosity, certain amount of wind passes through the shelterbelts while the rest deflects and crosses over the shelterbelts. It thus reduces wind speed without causing turbulence. The protection offered by the shelterbelts is dependent on the height of central tree row in the shelterbelts. Generally, shelterbelts give protection from desiccating winds to the extent of 5 to 10 times their height on windward side and up to 30 times on leeward side. Due to reduction in wind speed, evaporation losses are reduced and more water is available for plants. The beneficial effect of shelterbelts is seen more clearly in drought years. In addition, shelterbelts reduce wind erosion.

4.WEED CONTROL

1. Promptweed control eliminates the competition of weeds with crops for limited soil moisture.
2. Transpiration rate from weeds is more compared to crops.
3. Effective weed control in dryland agriculture leads to increasing availability of soil moisture to crops.

This is the most useful measure to reduce transpiration losses.

Spraying nutrient solution

Nutrient solution spray is recommended in the event of revival of rain and release of moisture stress.

Urea or DAP spray (2% solution) is useful for quicker regeneration of crops like legumes and castor after rain

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Course Name	Dryland Horticulture
Lesson 9	Water use efficiency – need based , economic & conjunctive use of water , micro system of irrigation
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Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives of the lecture:

To learn about the WUE, need based ,micro system of irrigation like drip,sprinkler ,etc

Glossary of terms

1.	Water use efficiency	-	The ratio of water used in plant metabolism to water lost by the plant through transpiration.
2.	Sub surface system	-	It is a system in which water is applied slowly below the land surface through emitters
3.	Conjunctive use of water	-	Coordinated use of surface water and groundwater
4.	Conveyance loss	-	The loss of water from a pipe or canal that is caused by leakage, seepage, evaporation, or evapotranspiration
5.	Evaporation	-	Process of a substance in a liquid state changing to gaseous state due to increase in temperature and pressure.

1.WATER USE EFFICIENCY – NEED BASED

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 mid day 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 under laid 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 wateruse 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

2. ECONOMIC & CONJUNCTIVE USE OF WATER:

Any approach to water resources management that takes the linkages within the water cycle systematically into account may be called 'Conjunctive Water Management'.

Conjunctive Water Management is an approach to water resources management in which surface water, groundwater and other components of the water cycle are considered as one single resource, and therefore are managed in closest possible coordination, in order to maximize overall benefits from water at the short and at the long term

The new concept of "Conjunctive Use of Water" is a wise use of water resources in an integrated manner. New water resource development is increasingly costly and often environmentally prohibited. Two types of conjunctive use of water will be discussed: conjunctive use of surface water and groundwater; and wastewater reclamation/reuse.

It is obvious; however, that wastewater contains pathogenic microorganisms and toxic substance. Therefore, once the contaminated water is reclaimed and used for several purposes such as irrigation, non-potable urban use, industrial use, or groundwater recharge, it may cause the outbreak of waterborne diseases. The health protection from the use of reclaimed water is one of the most critical objectives in any water reuse project. The potential health risks associate with wastewater reclamation and reuse are related to the extent of direct exposure to pathogenic organisms and chemicals in reclaimed water. The procedures for protecting public health is summarized in the Guidelines for Water Reuse by United States Environmental Protection Agency as follows; (1) reducing concentrations of pathogenic bacteria, parasites, and enteric viruses in the reclaimed water, (2) controlling chemical constituents in reclaimed water, and/or (3) limiting public exposure (contact, inhalation, ingestion) to the reclaimed water

Conjunctive Use of Surface Water and Groundwater

Groundwater and Surface Water, and Their Interaction

- The hydrologic cycle has three basic parts: the atmosphere, the surface water, and the groundwater.

- To understand the hydrologic cycle, the concept of flow and stock of water is important. It is said that the amount of water stored in the atmosphere is 5.6 percent of the total surface water and is 0.0009 percent of the sum of global water in the global water budged.
- Water flows through the atmosphere are the precipitation and evaporation.
- The balance between these two flows controls the water resource in a region.
- The variation of precipitation and evaporation is significant and seasonal.
- The fluctuation of precipitation results in variation of flow in surface water network. In order to withdraw constant amount of water from surface water flow, it is essential to compensate variation of flow rate in surface water.
- This operation is storing water in reservoir.
- The groundwater moves much more slowly than the surface water, and flow rate often measured in meters per year.
- The residence times for a groundwater system may range from months to hundred years. Notably, the movement of groundwater is dependent on the media of aquifer.There is an interaction between surface water and groundwater.
- If the water table stands higher than the river stage, groundwater may enter the stream as base-flow. Normally, groundwater discharge can make up most of the stream flow during dry months.
- Many perennial streams recharge the subsurface formation in some portion upstream of their reach, while groundwater discharge appears in the streams farther downstream

Conjunctive Use of Surface Water and Groundwater

Most conjunctive use of surface and groundwater systems has developed for one of those two reasons: (1) Water resource of either surface water or groundwater could not meet the water demand or (2) the quality of groundwater was poor and mixing of groundwater with surface water was required to improve the water quality.

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In the viewpoint of the watershed, there are two parallel stocks and flows: one is the surface watershed and the other is the underlying groundwater watershed. The surface watershed has quick-response characteristics (surface runoff).

The groundwater system response slowly (groundwater movement), but it has large storage capacity. The capacity of underground aquifer as a reservoir and the difference in response characteristics are utilized for wise use of water resource.

Supposing the following watershed;

• In this region, there are two seasons; dry and wet season.

• Unfortunately, this watershed does not have enough capacity for surface water storage.

• In dry season, stored water in the reservoir cannot meet the water demand.

• Due to the slow response character of groundwater system, enough water cannot penetrate into groundwater system in wet season. In dry season, groundwater system cannot support surface water well. The introduction of the conjunctive concept to the watershed;

• Use excess water for recharging groundwater in the wet season.

• Use the large storage capacity of groundwater system,

• Withdraw water stored in the groundwater system in dry season. This concept is applicable also to the yearly variation of precipitation. The basin is directly or indirectly recharged in years of above-average precipitation so that groundwater could be extracted in years of below-average precipitation when surface water supplies are below normal.

3. MICRO SYSTEM OF IRRIGATION:

The micro irrigation system can be classified in respect to variety of parameters. The micro irrigation system can be classified in respect to variety of parameters. The micro irrigation encompasses several ways of water application to plants: Drip, spray, subsurface and bubbler irrigation.

Drip Irrigation

Drip or trickle irrigation is the newest of all commercial methods of water application. It is described as the frequent, slow application of water to soils through mechanical devices called emitters or applicators located at selected points along the delivery lines. The emitters dissipate the pressure from the distribution system by means of orifices, vortexes and tortuous or long flow paths, thus allowing a limited volume of water to discharge. Most emitters are placed on the ground, bu they can also be buried. The emitted water moves within the soil system largely by unsaturated flow. The wet soil area for widely spaced emitters will be normally elliptical in shape. Since the area wetted by each emitter is a function of the soil hydraulic properties, one or more emission points per plant may be necessary.

Spray Irrigation

Spray irrigation is a form of irrigation in which pressurized water is sprayed over plants to provide them with water. This type of irrigation is also sometimes called sprinkler irrigation, and it is very widely used all over the world. The spray irrigation sizes can be designed for all size of farms, ranging from a home sprinkler to keep a lawn green to industrial sized sprinklers used to irrigate crops.

The application of water by a small spray or mist to the soil surface, water travel through the air becomes instrumental in the distribution of water. In this category two types of equipment are in use viz., micro-sprayers and micro-sprinklers. Micro-sprayers and static micro jets are non-rotating type with flow rates ranging from 20 to 150 litre/hour, where as, micro-sprinklers are rotating type with flow rates ranging from 100 to 300 litre/ Hour.

This system is similar to the way one may water lawn at home- stand there with a hose and spray the water in all directions. The system can simply bel long hoses with sprinklers along the length or a center-pivot system that transverses a circle in the fields. With a spray irrigation system, the irrigation sprinklers may be fixed in place, or located on movable frames. Some sprinkler heads will only spray in one direction, requiring careful placement, while others will rotate as they spray, and delivering water across a broader area. Rotating heads are often preferred because it allows for the installation of single sprinkler array to cover a big area.

The center-pivot system have a number of metal frames (on rolling wheels) that hold the water tube out into the fields. Electric motors move each frame in a big circle around the fields (the tube is fixed at the water source at the center of circle), squirting water. The depth of water applied determined by the rate of travel of the system. Single units are ordinarily about 1,250 to 1300 feet long and irrigate about a 130 - acre circular area. In high-pressure systems, there can be very big water guns along the tube.

A more " modern" alternative to the high-pressure water guns is the low - pressure sprinkler system. Here, water is gently sprayed downward onto plants instead of being shot high in the air. Low pressure systems are more efficient in that much less water evaporates or is blown off the fields, if there is a strong wind present.

Sources of water for spray irrigation vary. The utilization of treated wastewater should be encouraged. This is an environmentally friendly choice which reduces the demand for fresh water, nourishes the plants, and reduces wastewater runoff into waterways. Treated wastewater can be used on ornamental crops and landscaping, but it may be banned for use on crops. The source of water can be from wells, reservoirs, rivers, lakes and streams.

Sub - Surface System

It is a system in which water is applied slowly below the land surface through emitters. Such systems are generally preferred in semi permanent/ permanent installations.

Subsurface drip irrigation (SDI) is a low - pressure high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. SDI technologies have been a part of irrigated agriculture since the 1960s; with the technology advancing rapidly in the last two decades. A SDI system is a flexible and can provide frequent light irrigation. This is especially suitable for arid, semi-arid, hot, and windy areas with limited water supply. Farm operations also become free of impediments that normally exist above ground with any other pressurized irrigation system. Since the water is applied below the soil surface, the effect of surface infiltration characteristics, such as crusting, saturated condition of pounding water, and potential surface runoff (including soil erosion) are eliminated during irrigation. With an appropriately sized and well-maintained SDI system, water application is highly uniform and efficient. Wetting occurs around the tube and water moves out in all directions. Subsurface irrigation saves water and improves yields by eliminating surface water evaporation and reducing the incidence of disease and weeds. Water is applied directly to the root zone of the crop and not to the soil surface where most weed weeds winter over. As a result, germination of annual weed seed is greatly reduced, and lowers weed pressure on beneficial crops. In addition, some crops may benefit from the additional heat provided by dry surface conditions , producing more crop biomass, provided water is sufficient in the root zone. When managed properly, water and fertilizer application efficiencies are enhanced, and labor needs are reduced. Field operations are also possible, even when irrigation is applied.

Bubbler System

In this system the water is applied to the soil surface in a small stream or fountain. The discharge rate for point source bubbler emitters is greater than the drip or subsurface emitters but generally less than 225 litre/ hour. Since the emitter discharge rate generally exceeds the infiltration rate of the soil, a small basin in usually required to contain or control the water. Bubbler systems do not require elaborate filtration systems. These are suitable in situations where large amount of water need to be applied in a short period of time and suitable for irrigating trees with wide root zones and high water requirements.

Course Name	**Dryland Horticulture**
Lesson 10	**Selection Of Plants Having Drought Resistance**
Content Creator	**V.P.SANTHI**
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Objectives of the lecture:

- To learn about the plant selection having drought resistance

Glossary of terms

1.	Dryland	-	The area where annual rainfall or precipitation counter-balance the evapotranspiration and provides limited length of growth period for growing crops
2.	Drought	-	A prolonged dry period in the natural climate cycle that can occur anywhere in the world
3.	Soil salinity	-	The amount of dissolved salts in the soil solution
4.	Micro catchments	-	A micro catchment is a specially contoured area with slopes and berms designed to increase runoff from rain and concentrate it in a planting basin where it infiltrates and is effectively “stored” in the soil profile.
5.	*Antitranspirants*	-	*Antitranspirants* are compounds applied to the leaves of plants to reduce transpiration.

The flora of a locality is the result of matching of its climate with climatic requirement of the plants and plants come up in places where their heat unit and humidity requirements are met. Therefore, the flora of a climatic zone is characteristic to the climate of that place. Thus the distribution of horticultural crops is determined almost entirely by climatic factors, the most important of which is temperature. In the hot arid zone of India, temperature and humidity conditions are ideally suited for growing of fruits of high quality like date, ber, grave, fig, olive, pomegranate, citrus, papaya, grapes etc. However, there are hardly any orchards in this region in spite of great potential. It is therefore, necessary to analyze the limitations and look for crops which can stand these limitations and provide sustained income to prospective growers.

1.LIMITATIONS OF DRYLANDS

There are a number of limitations in dry land conditions which hinder successful cultivation of horticultural crops. These problems relate to soil and its types and moisture and its quality.

I. **Land use capability classes:**
Soil types available in dry land situations are of very low capability. Most of the soils are of class VI, IV, II in that order.

II. Cultivation of annual crops is very risky and fit only for pastures. With meticulous management they can be advantageously utilized for high value fruit crops.

III. **Saline soil and saline irrigation water:**

The dryland soils are largely saline with pH ranging from 8 to 9. The underground water is scarce and highly saline. This limits the fruit culture to only salinity tolerant fruit crops.

IV. **Intense radiation:**
In dry lands, radiation is very intense ranging between 500 to 600 cal/cm^2 days during summer. At times it may adversely affect photosynthesis due to limitation of CO_2. At the same time transpiration both stomatal and cuticular and leaf temperature aggravating the problem of limited moisture. This also creates problem of sun burning in developing fruits.

Besides these limitations, dusty winds are common in summer months which would hinder fruit setting and development and increase transpiration and cause mechanical injury to trees. Therefore, choice of the fruit crops for drylands is very important demanding careful selection for successful cultivation.

2.SELECTION OF TREE CROPS FOR DRYLANDS

In the strategy of development of horticulture in dry lands of India, correct selection of fruit crops is of prime significance. The crops should have following attributes.

1. In dry land areas the crop selected must be such that its maximum growth period synchronizes with the period of maximum water availability and low vapours pressure deficit in the atmosphere. Ideally the period from flowering to fruiting, it must also fall during this period and fruit ripening must be completed well before the onset of summers. In brief the crop should be able to complete maximum vegetative growth and reproductive phase during the period of maximum water availability. During the monsoon up to September starting from May in South India and from July in North India the soil and atmospheric moisture stress is low. The fruits such as ber, custard apple, phalsa, Cordia myxa (Gonda / Lehsua) conform to this condition. Otherwise the crops selected should be such that their reproductive cycle can be monitored to synchronize with maximum moisture availability periods e.g. the crops like guava, pomegranate, acid lime which bear fruits in distinct bahars and the bahar (flush) which coincides with rainy season (Mrig bahar) can only be encouraged.
2. Since the water is a limiting factor in dryland areas, the crops selected for such areas should have drought tolerance mechanism like (a) deep root system to draw water from deeper soil profile like ber, mango, walnut etc. (b) leaf shedding in summer to conserve moisture like ber and gonad (*Cordia myxa*), (c) water binding mechanism as in fig and (d) other xeric characters like wax coating, hairiness, sunken and covered stomata on leaves to minimize the loss of water through transpiration as in fig, phalsa, ber and gonad (*Cordia myxa*) and reduced leaf area (as in aonla).
3. Crops for dry lands should have tolerance to salinity and saline water and alkalinity which are common features of these areas. Fruits like aonla, grape and ber have great tolerance to pH and can row in the range of 9.2 to 10.5 and their tolerance limit to salt is being depicted in Table below.

Plants	**Salt tolerance limit**	
	ECe	**pH/ESP**
Aonla	15	40ESP
Ber	14	30ESP
Grape	7	9.0pH

Guava	8	9.0pH
Karonda	-	10.0pH
Mulberry	-	9.5pH

4. Dry atmosphere and high heat accumulation is the hall mark of majority of Indian drylands. The crops requiring these type of climates or adaptable to these climates may be chosen like date palm, grapes and papaya. Similarly intense radiation is another important feature of climate in drylands. The crops with good canopy to shade fruits and protect them from sun burning could be chosen like 'Kinnow" mandarin which has tolerance against drought as well as bears fruits inside well formed canopy.
5. Dry lands are characterized by shallow, rocky, gravelly and undulating wasteland soils and the crops adaptable to such conditions like aonla, pomegranate, cashew could be chosen. In high rainfall areas crop selection is based on the resistance to diseases and pests owing to high humidity conditions and adaptability to water stagnation e.g. mango, jackfruit, tamarind, mahua, persimmon, avocado, Kokum, palmyra palm etc.
6. Variety selected or evolved for dryland conditions should be short duration i.e. early varieties, so that they can complete their fruiting period in shortest possible time to evade drought conditions. Varietal requirements for dry farming:

- Short stemmed varieties with limited leaf surface minimize transpiration.
- Deep, prolific root system enhances moisture utilization.
- Quick maturing varieties are important in order that the crop may develop prior to the hottest and driest part of the year and mature before moisture supplies are completely exhausted.

3.Special Techniques for orchard management in dry farming areas

While analyzing the special features of crops suitable for dry farming situations, it has been visualized that the potential of fruit culture in such areas is immense. To make this venture more successful and economically viable, it is desirable to overcome some of the impediments which are inherent in dry land region through management skills and use of common sense. It is known that availability of water and quality of underground water are the most important impediments in the cultivation of horticultural crops in this area. Similarly adverse weather, soil salinity and shallow, rocky-and gravelly soils are other limitations. To modify or remove these limitations a number of special techniques have been developed through experimentation and experience.

3.a.SOME OF THESE TECHNIQUES ARE AS UNDER

1. For water use efficiency

a) Provision of micro catchments around the trees:

In dryland areas, average annual precipitation is very low which makes horticulture difficult. Since dryland soils have high infiltration rate as well as runoff losses due to concentrated rains, the idea here is to develop catchment areas for each tree, the size of which is determined by the slope of the land, water requirement for optimum production, runoff coefficient and the canopy of the fruit tree (feeding zone). A fruit like fig, almond, peach, grapes etc are being successfully grown in such micro catchments in Israel. Fruits like grape, fig, and pistachio are being raised similarly in the USA. In grapes ,10 units of catchment for every one unit of cultivated area has been found optimum; similarly the linear catchment area determined for fig, pistachio and olive are respectively 3:1, 4:1 and 5:1 which are estimated to provide 80 percent of water requirements.

b) Crescent bunding and opening of catch pits:

Crescent shaped or semi circular bunds with a diameter of 6 to 13 meters (depending on the space requirements of individual fruit trees) are prepared and catch pits are also dug at the same time on the upper side of the slope. The trees are planted at the center of the crescent. While the crescent bunds help collect rainwater, the catch pits conserve the same. New pits are opened as the old ones get filled with silt or organic matter.

c) Planting on terraces:

In hilly areas depending on the spacing requirement and slope of the land broad terraces are recommended to be prepared with the slope towards the higher elevation and trees be planted. Such terraces help in conservation of moisture and support plant growth.

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d) Trench planting:

Deep trenches (0.5 to 1.0 m) are dug across the contours and fruit spp. such as ber, aonla, anonas and custard apple are planted. The trenches collect rain water along with silt and organic matter and thus promote tree growth. Planting of pineapple in trenches is common under dry conditions.

e) Windbreak and shelterbelts:

Under dry lands fruit crops undergo heavy damage by frequent winds in the form of water loss through evapotranspiration and dust deposition, mechanical damage to plants and soil erosion. S single row of plantation of *Acacia tortillas* for arid tract in North India has been found useful. Along with these wind-breaks an inward row of any fruit crop can also be planted like *Cordia myxa*, tamarind, jamun, jackfruit etc., depending upon the location. These will effectively reduce the wind velocity and maintain humidity, thus ensure water saving and provide micro-climate favorable for good growth.

f) Mulching:

Mulch is a loose layer of extraneous material, such as hay, straw, cut grass, dry leaves, plastic etc., on soil surface to minimize the evaporation of water from soil especially in dry lands. Besides conserving moisture, it also suppresses weed growth, prevents soil erosion and adds organic matter to the soil.

g) Use of antitranspirants:

Antitranspirants are chemicals, which when sprayed on plants form a film which increases the diffusion resistance of water from stomata and thus reduces transpiration losses of water. Several antitranspirants have been successfully utilized on fruit trees like Acropyl in grape vines, polycot (Tag) in banana, Kaolinite (3-8%) in several fruit species. Their uses can be extended to dryland fruit species to overcome water stress.

h) Use of drip irrigation:

Drip irrigation is a method of watering plants at a rate equivalent to its consumptive use so that plants would not suffer any moisture stress throughout their life cycle. It is not only an efficient mode of water use but also important in management of soils irrigated by saline water for irrigation without allowing accumulation of salts in root zone. In long run it is economical and efficient but boon for dry lands for high value crops like fruit cops.

2. Fruit crops for shallow soils:

Usually dry land soils are shallow and have hardpan in subsoil which cannot subsist perennial crops. However, for such situations the fruit species selected should be able to thrive like pomegranate and custard apple. On the other hand crop's roots of which can penetrate through hard pan should be selected e.g. ber (*zyazyphus mauritiana*) kair (*Capparis decidua*) and Lehsua (*Cordia myxa*).

3. Salinity problem:

Wide occurrence of salinity and saline underground water are common features of dry farming areas of India. They affect plants by changing osmotic potential and specific ion effect. Such problems could be tackled by following approach.

a) Use of salinity tolerant crops:

There is wide variation in salt tolerance of fruit crops. If potential salinity problem is indicated, suitable crops can be chosen. Datepalm, ber, aonla, pomegranate, fig, guava, kair, pilu have great tolerance to such conditions. However, most of the crops are relatively sensitive during early stage of growth. When the plants are well established they can tolerate high concentration of salt.

Table: Relative tolerance of fruit crops to salinity.

Tolerant	Moderately tolerant	Sensitive
(8mmhos)	**(6 to 3mmhos)**	**(3 to 1.5mmhos)**
Date palm	Fig	Peach
Ber	Orange	Apricot
Pomegranate	Lemon	Avocado
Phalsa	Mango	Almond
Aonla	Grapefruit	Plum
Custard apple	Grape	
Kair		

Pilu		
Guava		

b) Planting techniques:

Soil working techniques should be such that the rain water is utilized to the maximum extent possible and the salt concentration in root zone is kept to the minimum level through leaching. Micro catchment of 4 to 6 percent additional runoff water in root zone and help in leaching of accumulated salts.

Pits prepared for planting could either be located in better patches or the pits can be filled with imported soils and separated from original soils by providing a polythene lining in between so that young plants can establish well. Thereafter, the tolerant plant species may not be injured. In 'alkali soils, deep pits with the addition of gypsum @ 5kg and FYM@ 20 kg give better results.

c) Irrigation management:

Schedule irrigation with saline water 4 to5 days prior to normal irrigation schedule and provide additional depth of irrigation water to meet the leaching requirement (0.3 leaching fraction), maintains adequate water supply to the plant and low salinity in soil. Use of drip method is still a better option to manage saline irrigation water and salinity problem.

d) Use of salt tolerant root stock:

To extend the scope of fruit cultivation in saline situations of drylands, salt tolerant root stock can be utilized like bordi (*Ziziphus mauritiana var. rotundifolia*) for ber, ramphal (*Annona reticulate*) for custard apple and Rangpur lime, Cleopetra mandarin, Tryer and Jallandhri Khatti for various citrus species such as sweet orange and mandarins.

4. Selection of suitable cultivars for dry farming situations:

Since water is a limiting factor in dry land areas, selection of early cultivars provide distinct advantage over late cultivars in this region in escaping drought.

Suitable cultivars have been identified Fruits, Vegetables, Medical and Aromatic, Spices.

To epitomize, it can be brought out that by selecting suitable fruit species and their cultivars and adopting modern techniques of soil and water management, fruit cultivation in dry land can become a reality. It will not only help develop dry wastelands but also add to quality of life of people living in this region of the country.

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Course Name	Dryland Horticulture
Lesson 11	Special techniques, planting & after care use of seedling races.
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Objectives of the lecture:

To learn about the Special techniques, planting & after care use of seedling races, rootstocks , insitu grafting , deep pitting / planting, Canopy management.

Glossary of terms

1.	Evapotranspiration	-	The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration
2.	*Antitranspirants*	-	*Antitranspirants* are compounds applied to the leaves of plants to reduce transpiration.
3.	Mulch	-	A layer of material applied to the surface of soil
4.	Rainfed horticulture	-	Describes horticultural practices that rely on rainfall water
5.	Evaporation	-	Process of a substance in a liquid state changing to gaseous state due to increase in temperature and pressure.

DRYLAND TECHNOLOGIES

A..TECHNIQUES TO REDUCE EVAPORATION AND TRANSPIRATION LOSS

A.a.REDUCING EVAPORATION LOSSES

Soil moisture is the most limiting factor in dryland agriculture. It is lost as evaporation from the soil surface and as transpiration from the plant surfaces. Evaporation has to be arrested as it is not directly related to productivity whereas transpiration can be reduced to some extent without affecting productivity of plants. The evaporation losses can be reduced by:

1. Mulches
2. Antitranspirants
3. Wind breaks
4. Weed control

1.Mulches

About 60 to 75 per cent of the rainfall is lost through evaporation. These evaporation losses can be reduced by applying mulches. Mulch is any material applied on the soil surface to check evaporation and improve soil water. Application of mulches results in additional benefits like soil conservation, moderation of temperature, reduction in soil salinity, weed control and improvement of soil structure.

Types of mulches

i.**Soil mulch or dust mulch:**

If the surface of the soil is loosened, it acts as a mulch for reducing evaporation. This loose surface soil is called soil mulch or dust mulch. Intercultivation creates soil mulch in a growing crop.

ii.Stubble mulch

Crop residues like wheat straw or cotton stalks etc., are left on the soil surface as a stubble mulch. The advantages of stubble mulch farming are protection of soil from erosion and reduction of evaporation losses.

iii.Straw mulch

If straw is used as mulch, it is called as straw mulch.

iv.Plastic mulch

Plastic materials like polyethylene, polyvinyl chloride are also used as mulching materials.

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v.Vertical mulching

To improve infiltration and storage of rainwater in these soils, vertical mulches are formed. It consists of digging narrow trenches across the slope at intervals and placing the straw or crop residues in these trenches. The pruned plant material is placed in contour trenches formed between rows or in trenches around the plants in concentric circles each year in one circle.

A.b.REDUCING TRANSPIRATION LOSSES

A.b.1.**Antitranspirants**

About 99 per cent of the water absorbed by the plants is lost in transpiration. If transpiration is controlled, it may help in maintenance of favourable water balance.

Antitranspirant is any material applied to transpiring plant surfaces for reducing water loss from the plant. These are of four types:

1. Stomatal Closing
2. Film forming
3. Reflective
4. Growth retardant

i.Stomatal Closing type

Most of the transpiration occurs through the stomata on the leaf surface.

1. Fungicides like Phenyl Mercuric Acetate (PMA) and herbicides like atrazine in low concentrations serve as antitranspirants by inducing stomatal closing.

These might reduce the photosynthesis also simultaneously. PMA was found to decrease transpiration to a greater degree than photosynthesis in a number of plants.

ii.Film Forming Type

Plastic and waxy materials which form a thin film on the leaf surface retard the escape of water due to formation of physical barrier. Mobileaf, hexadeconol, silicone are some of the film forming type of antitranspirants. The success of these chemicals is limited since they also reduce photosynthesis.

The desirable characteristics of film forming type of antitranspirants are:

1. They should form a thin layer,
2. They should be more resistant to the passage of water vapour than carbon dioxide and the film should maintain continuity and should not break

iii.Reflectant Type

These are white materials which form a coating on the leaves and increase the leaf reflectance (albedo). By reflecting the radiation, they reduce leaf temperatures and vapour pressure gradient from leaf to atmosphere and thus reduce transpiration.

1. Application of 5 per cent kaolin spray reduces transpiration losses.
2. A diatomaceous earth product (celite) also increases reflection of solar radiation from crop canopy

iv.Growth Retardant

These chemicals reduce shoot growth and increase root growth and thus enable the plants to resist drought. They may also, induce stomatal closure.

1. Cycocel is one such chemical useful for improving water status of the plant

Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from death under severe moisture stress. If crop survives, it can utilise the rainfall that is received subsequently. Antitranspirants are also useful for reducing the transplantation shock of nursery plants. They have some practical use in nurseries and horticultural crops.

A.b.2.WIND BREAKS AND SHELTERBELTS

Wind breaks are any structures that obstruct wind flow and reduce wind speed while shelterbelts are rows of trees planted for protection of crops against wind. The direction from which wind is blowing is called windward side and direction to which wind is blowing is called leeward side.

Shelterbelts are planted across the direction of wind. They do not obstruct the wind flow completely. Depending upon their porosity, certain amount of wind passes through the shelterbelts while the rest deflects and crosses over the shelterbelts. It thus reduces wind speed without causing turbulence. The protection offered by the shelterbelts is dependent on the height of central tree row in the shelterbelts. Generally, shelterbelts give protection from desiccating winds to the extent of 5 to 10 times their height on windward side and up to 30 times on leeward side. Due to reduction in wind speed, evaporation losses are reduced and more water is available for plants. The beneficial effect of shelterbelts is seen more clearly in drought years. In addition, shelterbelts reduce wind erosion.

A.b.3.WEED CONTROL

1. Prompt weed control eliminates the competition of weeds with crops for limited soil moisture.
2. Transpiration rate from weeds is more compared to crops.
3. Effective weed control in dryland agriculture leads to increasing availability of soil moisture to crops.

This is the most useful measure to reduce transpiration losses.

A.b.4.**Spraying nutrient solution**

Nutrient solution spray is recommended in the event of revival of rain and release of moisture stress.

- Urea or DAP spray (2% solution) is useful for quicker regeneration of crops like legumes and castor after rain.

B. Plant selection

- Select and identified the crop which is suitable for dry land farming and also which has more demand in that particular area. The main features of plants are followed below.
- Deep root characteristic features (E.g. Ber, Mango, Custard, Jamun *etc.*)
- Grease coated surface leave / wax coated leaf plants (Eg: Ber)
- Disease and pest resistance variety.
- Flowering and fruiting period should be adjusted to rainy and winter seasons receptivity (Eg: Guava, Amla and Custard)
- Adopted in less water / scarcity of water.
- Shedding of leaves when there is no fruits (Eg: Custard, Tamarind, Bur and Guava) are selected.

i.Fruits crops grown in dry land are categorized into different types and are followed below

1. Originality: Fruits growing in drought condition area: The various fruits trees are (Bow, Banana, Jamoon, Drumstick, Custard apple *etc*.) grown in these area.
2. Fruit crops should utilize available water from soil, when ever supplied

- Several fruit trees like: Fig, Pomegranate, Guava, Amla and Custard apple grows in less moisture area and all the metabolic activities initiates when moisture is available.
- More yields can be obtained if water supply is available for 3-4 times. Water conservation methods can also be adopted.
- If the availability of water is more in dry land farming then fruit crop like lemon, papaya are cultivated.
- Usually it cannot be grown in dry land. The dry land fruit crops can be cultivated if water structure like wells are constructed.

ii.Rain fed horticulture crop farming methods

- Few fruit, vegetables, medicinal and fragrance crop can be grown successfully in dry land conditions.
- Deep rooted and perennial fruit crops are ideal in dry land farming.
- Traditionally rigid and drought resistance crop like Tamarind, Rose, Mango, Chikku, Guava, Custard, Soursop, Ber, Pomegranate, Fig, Jack fruit *etc.* are grown in dry land as commercial crop.
- In Karnataka, weather and soil condition are divided into three major parts. List of area with suitable crop grown is given below.

Ground area: Mango, Chikku, Guava, Jackfruit, Cashew, Custard, Bur *etc*.

Coastal area: Rubber, early harvest variety Mango, Sapota, Soursop, Cashew, Jack fruit, Guava, Coffee *etc.*

- Irrigating the dry land fruit crop during initial / first years continuously is very essential.
- Advantage of growing fruits in dry land agriculture are, if there is loss in annual crop then small amount fruit crop yield is obtained and dry land horticultural crop are also cultivated in land where less income of food crops is generated.
-

iii.Dry land horticulture crop plantation and their management

- Cropping is adopted by considering slope of land, following soil and moisture conservation methods and then transplantation is carried out.
- The suitable pits dimension for planting is 3 feet and 2 feet depth.
- Grow asexual and healthy grafted plants for transplantation each time.

- Grafted node is selected from 4-3 feet above the ground level and plants are transplanted.
- Once the seedlings are transplanted they are tied to supporting structure to avoid wind blow damage.
- After this, the ideal irrigation is required during summer season for one year.
- Plants are protected from termites and suitable measures should be taken care.
- Remove weeds, prepare pits, covered it for moisture conservation.
- Remove the lower leaves which emerge from grafted seedling / stock.
- Maintaining plants slope, removal of branches and twigs are necessary.
- Give recommend dose of fertilizer during rainy season and adopt conservation methods.
- Alternate extra income is generated from mixed/mid farming.

iv.Water conservation methods in dry land horticulture:

1. Modification of micro water shed area: Each plant is provided with seed bed, which mainly helps in absorbing of rain water. The criteria for construction of micro water shed are selection slope area/land, water requirement by crop, flow speed and plant canopy.
2. Constructing bunds in half moon slope: About 18-45 feet diameter of half moon shape bunds are constructed to avoid water flow rate and run off. Transplant the plants in mid portion of pit.

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3. Leveled bunds (Stairs / terraces bunds): Depending up on the slop of land, terraces/ stairs like structures are built with suitable width and height. These stairs helps in water retention and absorption uniformly in all areas.
4. Depression pits: Dig open the deep canals (1.5-3 ft.) opposite to slope area and transplant fruit crop like Ber, Amla, Custard apple *etc*. which grows well by utilizing water collected in canals.
5. Farm ponds: Construct the farm pond near valley area. Initial months, the collected water are used for irrigating. Construct the rim of bund with more height than land surface.
6. Avoid wind blow: Grow tall trees in North-South direction to avoid wind blow damage. The tree species also helps in retaining moisture is the field (avoid evaporation). Best results are observed when the trees are planted in triangular shape.
7. Coverage: Dry grass, dried leaves are covered on soil to avoid water evaporation, weeds growth and soil erosion. Now a day black polythene sheets are used for coverage.
8. Use of non evaporating materials: Some chemical materials sprayed on leaves mainly slow down in evaporation process by formation thin sheet layer. Various materials are in use presently. *E.g.*:, Acropol is used in grapes, Polycarp is used in Banana crops *etc*.
9. Drip irrigation: In this irrigation system about 30-50% of water is conserved. The well developed drip irrigation system, the equal amount of water of 5-10 liters is supplied to each tree crop at same interval of time from small drips closed with cotton.

V.Plantation methods

- In dry land horticulture, farmers can grow crop depending on his requirement and circumstances. Once crop is grown the crop management is easier.
- But in case of mixed farming, the income is generated by supplement crop and also main crop.
- Pomegranate and Mango *etc* can be grown as main crop in mixed farming.

Mixed and distance farming: Mixed and distance farming methods and combination are listed below.

Groundland area

- Mango + Custard + Pomegranate / Legumes / Oil seeds / Vegetable crops
- Sapota + Guava / Oil seed / Vegetable crops
- Custard / Bow + legume / grain crops / vegetable
- Tamarind / Jack fruit + legume / oil seeds / vegetable crops

Western Ghats region

Cashew + fodder crops

Rubber + Coffee + Fodder crop

Sapota / Mango + Fodder crops

Costal area

Cashew + Black pepper + Fodder crops

Rubber + Fodder crops

Sapota / Mango + Fodder crops

vi.Soil and water management

- To make dry land cultivation of horticultural crop successful, it is very necessary to make use of natural resources available in conserved way without any wastage.
- For example, construct pounds to harvest rain water, ground coverage, establishment of side canals. In addition to this, open small ditch / trenches and streepages. With all these implied measurements in field conditions, deep rooted crops like Ber, Custard apple and Pomegranate are recommended to cultivate.

- The process of irrigating planted seedling near the roots, supply water drop wise slowly during course of water requirement from the plant, in equal interval of time, at basal rate is called as drip irrigation.
- Drip irrigation technology 40-70% of water is economically used, and available water is also supplied to 2-3% more area comparing to drainage system of irrigation. The yield obtained is approximately more than 20%. There are various methods of irrigating land.

1. **Earthen vessel burial (Picher):** porous pot vessels are placed near the root of plant and filled with water, water is supplied slowly through porous at required interval of time.
2. **Drip irrigation / trough pipes**

- More intensives are given by the government for cultivation practice in dry land to conserve water and moisture content in land.
- It effect on the initial growth of plant during 1-2 years. It is constructed in small water shed area depending upon soil type, level/sloppy land, rainfall water, water size of bund *etc*. The development of small water sheds helps in retaining water even if there is less rainfall near plants and farm land. Proper measurements should be taken care to conserve water by constructing bunds to avoid erosion losses by heavy rain fall.

A) Basin -shaped bed, B) V -shaped bed, C) Half moon -shaped bed, D) Inward slope bed, E) Two -pit method, F) Button line - lying reefs and other methods

Method	Crop	Advantages
Square	Mango, Sapota, Guava, Cashew, Tamarind *etc.*	In fertile land
Hidden design	Mango, Sapota, Rose, Tamarind *etc.*	In fertile land
Hexagonal shape	Mango, Cashew, lemon, citrus, pomegranate *etc.*	About more than 15 plants are planted
Kiwnkenial shape	Mango, Papaya, Lemon Tamarind, sapota *etc.*	About 75 plants are planted, mixed / space crops ca be adopted
Triangular design	Lemon, Citrus, Cashew etc.	About 9 plants
Compartment farming	Mango, Tamarind, Cashew crop *etc.*	Slope land area is suitable

Sl. No.	Crop name	Varieties	Spacing (ft)	No of plant (acre)
Fruit crop				
1	Mango	Badami, Raspuri, Mallika	30' x 30'	40
2	Sapota	Kalipathi, Cricket ball etc.	30' x 30'	40
3	Jack fruit	Singapoor local	30' x 30'	40
4	Bur	Umran, Sanaar-2	24' x 24'	61
5	Pomegranate	Basin seed less, Jyothi, Ganesh, Kesari, Bhagya	18' x 18'	134
6	Custard apple	Myammat, Balanagar, Cerimoya, Arkasahana	18' x 18'	134
7	Jasminum	Local varieties	30' x 30'	40
8	Amla	Banarsi, Krishna, Cakaiya, Kanchan	15' x 15'	160
9	Fig	Poona	15' x 15'	160
10	Jamoon	Arabhavi - 1, Arabhavi - 2	30' x 30'	40
11	Cashew	Ullal varieties, Chinthamani - 1	24' x 24'	76

10	Jamoon	Arabhavi - 1, Arabhavi - 2	30' x 30'	40
11	Cashew	Ullal varieties, Chinthamani - 1	24' x 24'	76
12	Gauva	Sardhar, Alhabad safed	18' x 18'	134
13	Kamarakshi	-	15' x 15'	160
14	Tamarind	GKVK-6 and 33, PKM -1, Urugam DTS – 2	30' x 30'	40
15	Butter fruit	Mexican, Gatimala	18' x 18'	110
Vegetable crop				
1	Drumstick	GKVK – 1, Dhanaraj, PKM -1,2, Bhagya	9 x 9	440
2	Curry leaves	Suhasini	9 x 12	332
Flower crops				
1	*Michelia champaca*	-	24 x 24	62
Medicinal plants.				
1	Oleander	-	1.35 x 1.2	22,200
2	Ashwagandha	-	0.9 x 0.9	44,000
2	Ashwagandha	-	0.9 x 0.9	44,000
3	Kashibadane	-	2.7 x 1.8	4920
Aromatic crops				
1	Nilgiri	-	2.7 x 1.8	7400
2	Couscous	-	1.35 x 0.9	29,600
3	Barsera	-	18 x 18	1141
Other varieties				
1	Rubber	R.R.I.M-700 R.R.I.M-600	15 x 15	160
2	Coffee	Robasta	9 x 9	435

C.AFTERCARE OPERATIONS

I.SOIL COVER

- In the dry zone soil is frequently dried up.
- Therefore you have to save water in the land by covering the land You can use paddy straw.
- Lay paddy straw 6 *away from the plant as a circle*
- If you can lay paddy straw in whole cultivation field, that can be better.
- This will reduce the weed growth and add organic matter to the soil.

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- It will alos ensure proper drainage.

II.WATERING

- Water is frequently use by the plant for their growth and production of foods.
- Therefore we have to supply water to fill their needs
- Avoid supplying excess water as well as avoid no water supply. That is we called adequate water .
- Irrigation through drains
- If you have a cannel near the field you can practice cannel irrigation through pumps or without pumps.
- You can pump water and allow to flow over the field.
- If you have drains in the field you can fill water in to the drains. Then plants get water from it.
- In the first month you should supply water once a day in afternoon.
    - After 1 month to 3 months use two days interval.
    - 3 months to 6 months 3-4 days interval.
    - 6 months to 12 months 5 days interval.

III.FERTILIZATION

i.Chemical fertilizers

- Chemical fertilizers contain chemicals , Urea, Triple super phosphate(TSP), Muriate of Potash (MOP) are the 3 components
- Fertilizer mixtures vary according to the climatic zone.

- After first month of cultivating, add the mixture 1/ away from the plant as a circle.

- After first month of cultivating, add the mixture 1/ away from the plant as a circle.

- After 3 months of cultivating , add the mixture 2/ away from the plant as a circle.
- After 3 months to 12 months, add the mixture 2/ away from the plant as a circle within two months interval.

ii.Organic fertilizers

- Organic fertilizers are prepared by natural components.
- They are compost, cow dung, poultry manure or goat manure.
- You can prepare compost by your self as mentioned earlier.
- You should apply 5Kg for one bush in 3 months intervals

IV.BUSH MANAGEMENT

- If there are large numbers of plants around the mother plant you can't get high yield, due to lack of nutrients.
- You should destroy all suckers emerge until 4 months.
- After 4 months, you can maintain one sward sucker in the direction of sunlight.
- When fruiting, you can maintain another healthy sward sucker in the direction of sunlight.
- After 7-8 months from cultivating you can see fruiting of plants.

V.BRACT REMOVING

- Banana flower is an inflorescence.That means a bunch of flower. There are rows of flower and they are covered with bract.
- In certain time bract is not opened for fertile
- Then you have to remove the bract after opening the bunch completely.

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- The bract should be removed 15 cm below from the last hand.
- You also have to remove 1st hand of the bunch.
- Then you can ensure proper growth of other hands.

VI.BUNCH COVERING

- When 1st hand appears you have to cover the bunch using 2/ wide blue color polythene bags with holes.
- You can increase bunch weight from 18%-23% by covering.
- Avoid thrips damage. Then there are not patches on the fruits.
- Tied the bag 6// above from the 1st bunch.

D.Insitu grafting:

I**n-situ patch budding for better establishment of bael in rainfed areas:**

Bael (Aegle marmelos), is one of the very important indigenous fruit plant with several medicinal uses. Because of its multifaceted uses, it may be more popular in the time to come. Looking into the importance of this fruit, the demand for its planting material is increasing day by day. To meet out the demand of genuine planting material, the procedure of vegetative propagation was standardized for generating quality planting material. From the studies of optimization of period for in-situ patch budding, May and June (before onset of rain) is ideal time for multiplication of bael genotypes under rainfed conditions of western India. The technique of in-situ patch budding is being described in detail. BAEL is naturally grown by seed in mixed dry deciduous forests of tropics and sub - tropics of India. In the wasteland development and dryland horticulture, it assumes great significance due to its multifarious uses and capacity to withstand adverse climatic conditions. Bael exhibits a wide range of genetic diversity, yet vegetative propagation techniques are required to conserve biodiversity and reduce long juvenile phase in order to domesticate the crop at farmers' fields. Therefore in situ patch budding was attempted during 2011 and 2012 under semi-arid tropics of western India. THE TECHNIQUE Sowing of Seeds The seeds of deshi bael available at farm were extracted during April- May. They were sown in raised nursery beds at 2-3 cm depth and watered. Seedlings were directly transplanted in pits in the field at 3-5-leaf stage just after first rain. The seedlings became ready after 8-12 for in-situ patch budding in the field condition. This method not only saves time but also ensures higher success. Pits and Rootstock Planting Pits of 1 m × 1 m × 1 m size are prepared at 7m × 4 m spacing during March-April and they are left open during summer for solarization. The pits are filled with a mixture of top soil and 20-30 kg well-rotten farmyard manure. In order to ward off the seedlings from the attack of termites, pit is drenched with chlorpyriphos (3ml / liter water). With the onset of the monsoon season (midJune), the pit soil starts settling down and the seedlings grown in nursery are planted in pits in June just after first shower. Planting during drizzling rain is better for establishment of rootstocks. After planting, soil around the seedlings is firmly pressed to avoid formation of air pockets which ensures better survival of plant under rainfed conditions. Patch budding Detopping and promotion of scion wood: For getting vigorous and healthy scion shoots, the branches are detopped in April-May during leaf less condition of the tree. The multiple axillary shoots arise below the cut portion and attain the length of 50–60 cm in two months, and are vigorous and healthy in growth, can be used as scion shoot with better success and survival under rainfed conditions. Selection of bud wood: Bud wood becomes available during the active growth from May onwards. The bud stick, 1-11/2 months old having 20- 25 mm girth of current growth and recently matured buds (but still not open) are collected. Over mature (basal portion of shoot) and immature and undeveloped buds (upper part of the new shoots) are not used for bud selection. Similarly, over mature and inactive buds should not be used. The active growth period is indicated by easy and clear separation of the scion shoot from the wood of scion sticks. After collection, bud wood stored for a while as it takes some time in transportation. It has been observed that during this period, considerable loss of survivability may take place. Bud woods retain good survival when kept under ventilated shade and wrapped in moist jute cloth during storage and transportation. In situ patch budding In this method, healthy buds are selected from the axils of leaf. Leaf blade is removed with the help of a sharp knife leaving petiole intact. The upper cut is given about 1 cm above bud which goes downwards up to 1.0- 1.5 cm below the bud without wood portion and then lower cut is given about 1.0 cm below the bud. The similar rectangular incision is made on the rootstock by placing the bud on the rootstock so as to mark the exact size of the bud on them and after removing the bark of rootstock, bud is placed at the cut from where bark is removed. The bud is pressed by hand to remove airy space, if any and tied tightly with white polythene strip (200-gauge thick and 2 cm wide) leaving only the bud. In case, the cuts on rootstock are wider, it should be placed in such a way that at least one side bark of scion and stock matches with the cut surface. The rootstock is cut about 10-15 cm above the bud to facilitate bud to sprout. The polythene strips should not be removed unless it is ensured that the scion shoot has started sprouting and yielded growth. In bael, root system is very vigorous. The root system is, therefore, disturbed during the process of planting of grafts, which ultimately affects growth and establishment adversely in the field conditions particularly under rainfed condition.

Standards for patch budding in bael under semi-arid ecosystem

- Type of rootstock - Straight and active growth stage
- Age of rootstock - 8–12 month old
- Diameter of rootstock - 0.70–1.00 cm
- Age of scion shoots - 1–11/2 month old
- Diameter of scion - 0.70–1.00 cm
- Girth of scion shoots - 2.00–3.00 cm
- Size of patch - 2 cm x 1 cm
- Budding height - 20-25 cm above the ground
- Bud union - Smooth
- Plant height - 50-60 cm
- Root type/architecture - Well developed root system without coiling
- Foliage - Healthy and green foliage having 2-3 branches
- Disease/pest incidence - Plant should be from insect, pests and diseases

Precautions Avoid splitting of bark during detopping, but invariably the cut portion of the detopped branches should be pasted with copper fungicides. Scion shoots should be selected from healthy plants so as to evade the infestation of pests and diseases during the establishment of orchard Sprouts emerging from the rootstock should be removed except budded on at periodical interval to promote the growth of scion shoots. Size of bark patch containing bud should properly be matched with the cut portion of the bark on the rootstocks for perfect and quick union. Polythene strip should not be removed unless it is ensured that scion shoots has properly esatablished and started growing. Mulching of basin soil should be done regularly to avoid moisture loss through evaporation and also to fill up the cracks developed in basin. Newly emerging shoots are often damaged by leaf eating caterpillars and hence, the management of the pest should be done using sprays of Dimethoate @1.5 ml/l twice at 15 days interval.20

I.New technology (in situ grafting) for faster production of walnut

(*Juglans regia* L.):

Technology regarding grafted walnut production is very complex and expensive because it depends on a number of factors that directly influence grafting success. Due to a long production period and a smaller number of first class plants compared to other fruit species, young walnut trees are among the most expensive. New in situ production technology of young walnut trees has led to quicker production, shorter by 1 year, and increased the success of grafting, allowing for large-scale production of grafted walnut. In order to increase the production of quality planting material for walnut varieties, the possibility of walnut grafting in the open, i.e. in situ, was examined herein. Based on the average results for all of the varieties/selections, similar performance was achieved with grafting (57.14%) and the number of first class plants (55.71%) when compared to conventional grafting (54.46% and 53.39%, respectively), but it was concluded that this method shortened the process of plant production for 1 vegetation. The greatest success with the application of in situ grafting was with the Rasna selection, which had significantly the best grafting take (72.86%) in comparison with the other walnut varieties examined during the research period. By comparing the success of the indoor and in situ production methods and examining the influence of certain factors on production success, it was concluded that the in situ method proved to be a better option for a simpler, more profitable, and faster mass production of high-quality walnut planting material.

II.Standardization of Period for Soft Wood Grafting in Custard Apple (Annona squamosa) :

Custard apple is the most important dry land fruit crop. In different countries the name custard apple is given to separate species of genus Annona. In India, the custard apple is Annona squamosa, in the USA, A. reticulata or A. glabra. According to Hayes (1966) the term custard apple may be applied to all Annonas are mostly consumed as dessert fruits. Custard apple is very delicious fruit. The important features of custard apple are its wide adoptability to soil and climatic conditions and free from pest and diseases. Custard apple is mostly subtropical fruit performing in warm climate with moderate winter and humidity for high production. Custard apple is mostly consumed as table fruit. They are also used in ice – creams and others milk products on a limited scale (Rao, 1975). The immature fruits, seeds, leaves and roots are of considerable medicinal value both in Ayurveda and Yunani systems of medicine (Kirtikar and Basu, 1933). Generally the dry land fruit crops are propagated by seed. In this region attempt were made by various workers to locate superior types through the survey in custard apple. In recent year softwood grafting has become popular because of its added advantages over other methods. This has been successfully tried in mango, sapota, aonla (Amin, 1978). However, little information is available on the softwood grafting in custard apple. Therefore an investigation was planned to study the standardization of period for softwood grafting in custard apple. Materials and Methods An experiment was conducted at the Central Nursery Scheme, VNMKV, Parbhani. The experiment was laid out in Complete Randomized Design (CRD) comprising of twelve treatments which were replicated thrice. The treatment used were T1- Grafting on 1st December 2004, T2 - Grafting on 1st January 2005, T3- Grafting on 1st February 2005,T4- Grafting on 1st March 2005, T5-Grafting on 1 st April 2005, T6-Grafting on 1st May 2005,T7- Grafting on 1st June 2005, T8- Grafting on 1st July 2005, T9- Grafting on 1st August 2005, T10-Grafting on 1st September 2005, T11- Grafting on 1st October 2005 and T12-Grafting on 1st November 2005. The seedlings were selected were about 7 to 10 months old, 40-50 cm in height and 0.3 -0.6 cm in diameter above ground level at the time of grafting operation. Custard apple bud sticks were taken from current season growth of about 8-10 months, 15-25 cm in length with 8-10 buds with brownish black in colour was used. The scion bud sticks were defoliated 8- 10 days prior to grafting operation. Soft wood grafting in custard apple was done by as reported in mango by Amin (1974). The rootstock seedling was deheaded 15-20cm height above the ground level. A vertical slit of 2.5 to 3.0cm length was given on the rootstock. On scion shoot similar matching cut was prepared in slanting manner on both the surfaces in lower portion. It is inserted on rootstock and wrapped by using polythene tape. The grafts in polythene bags were watered on alternate day. The emerging shoots on the rootstocks were nipped off whenever they appeared while watering the plants care was taken that tied strips were not wetted. Five uniform grafts were selected in each treatment for recording observations. The data were recorded on various parameters for two years and pooled data was shown in Table 1 and 2. Results and Discussion Results presented in Table 1 revealed that the significantly minimum numbers of days were required for sprouting when grafted on 1 st February (16.06) and maximum days were required when grafting was carried out on 1st December (33.50). Significantly maximum initial percent success was observed when grafting was carried out on 1 st February and March (100 %). These treatments were at par with each other. Significantly final percent success (94.99 %) was obtained in case of grafting carried out on 1st February. No success was obtained when grafting on 1st May and 1st July. Results presented in Table 2 revealed that maximum height was obtained during 1st January. Significantly more diameter was produced when grafting was carried out on 1 st December 2004, 2005 and 1st January 2005 (0.43 cm). When grafting was carried out on 1st July (0.32 cm) minimum diameter of sprouted scion shoot was recorded. The maximum number of buds were recorded when grafting was carried out on 1st February (6.02) followed by 1st January, 1st December and 1st October (3.33) and at par with each other. Maximum buds were found in the month of 1 st February. As temperature and humidity are enough for sprouting of buds in the month of February. The maximum numbers of leaves (22.01) were produced when grafting was carried when grafting was carried out on 1st February followed by 1st December, 1st January (0.61) and 1st

March (0.59) were at par with each other. The minimum root: shoot ratio was observed in 1st October.

E.Planting/Deep pitting:

- Cropping is adopted by considering slope of land, following soil and moisture conservation methods and then transplantation is carried out.
- The suitable pits dimension for planting is 3 feet and 2 feet depth.
- Grow asexual and healthy grafted plants for transplantation each time.
- Grafted node is selected from 4-3 feet above the ground level and plants are transplanted.
- Once the seedlings are transplanted they are tied to supporting structure to avoid wind blow damage.
- After this, the ideal irrigation is required during summer season for one year.
- Plants are protected from termites and suitable measures should be taken care.
- Remove weeds, prepare pits, covered it for moisture conservation.
- Remove the lower leaves which emerge from grafted seedling / stock.
- Maintaining plants slope, removal of branches and twigs are necessary.
- Give recommend dose of fertilizer during rainy season and adopt conservation methods.
- Alternate extra income is generated from mixed/mid farming.
- Appropriate pit preparation: Preparation of pit is be carried out during the
- beginning of summer season. For planting main crops with bigger size canopies,

- appropriate the pit size is 3ft x 3ft x 3ft in length, width and depth whereas for filler
- crops with medium size canopies the appropriate pit size is 2ft x 2ft x 2ft in length,
- width and depth. While digging the pit, the soil of the upper half is kept separately
- from the soil from the lower half of the soil. The dug-up pits are left exposed during
- the entire summer months in order to minimize the pest load in the pit. The pit filling
- operation is carried out in the beginning of rainy season. While pit filling, 15 to 20 kg
- FYM, 1 kg karanj cake, 300g Single super phosphate is mixed with the with upper
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F.Canopy Management:

Effective canopy management from initial stage helps in a healthy framework of the canopy: In order to provide proper frame to the main crop, training of the plants is done from the first year of planting. All the branches emerging up to the height of 80 cm from the ground level are removed for formation of the main trunk. At the end of first year of the plant, heading back is done at a height of 80 cm at the beginning of rainy season. All the shoots emerging after the heading back are removed retaining three to four healthy shoots oriented towards four direction of the main branch which form the main frame of the plant. During the next year, 3 healthy shoots emerging on each of the primary branches after the heading back operation during the beginning of rainy season are retained which form the secondary branches. The operation is repeated during the third year also. Branches oriented towards the centre of the plants are removed. In case of filler crops like guava the main trunk is kept at 30-40 cm from the ground level.

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Course Name	**Dryland Horticulture**
Lesson 12	**Characters and special adaptation of crops**
Content Creator	**V.P.SANTHI**
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Objectives of the lecture:

To learn about the characters and special adaptation of different drought tolerant crops

Glossary of terms

1.	Dryland	-	The area where annual rainfall or precipitation counter-balance the evapotranspiration and provides limited length of growth period for growing crops
2.	Adaptation	-	the act of changing something for a purpose, or the result of something that has been changed.
3.	Xerophytes	-	a species of plant that has adaptations to survive in an environment with little liquid water
4.	Dormancy	-	state of reduced metabolic activity adopted by many organisms under conditions of environmental stress
5.	Astringent	-	is a chemical that shrinks or constricts body tissues.

CHARACTERS AND SPECIAL ADAPTATION OF CROPS

Adaptation of crop plants depends on many factors and is best considered in relation to a set of conditions (environmental, edaphic and biotic) rather than to a single factor. In many situations one factor (e.g. water availability in dry lands) may dominate the prevailing conditions and the nature of the plant response then largely reflects its adaptation to the existing level of that factor. More typically, adaptation to the existing level of that factor. More typical, adaptation is expressed as response to a combination. Success of a plant in a particular environment rarely, depends on possession of a single adaptive character. Rather, fitness or adaptation to an environment depends on possession of an optimum combination of characters that minimize the deleterious effects and maximize the advantageous effects.

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Adaptation may be defined as any feature of an organism which has survival value under the existing conditions of its habitat. Such a feature or features may allow the plant to make fuller use of the nutrients, water, and temperature or light, available or may give protection against adverse factors such as temperature extremes, water stress, disease or insect pressures. The concept adaptation can be difficult to define, as it is used in respect of both the evolutionary origins of a character and its contribution to the fitness of the plant to survive in its present environment. Adaptation is also heritable i.e., it is determined by the genotype of a plant. Hence the definition can be refined to the heritable modification to a plant which enable it to survive, reproduce or both in a given environment.

The majority of Indian dry lands are characterized by moisture stress, poor quality of soils, extreme temperatures and intense radiation. The features of tree crops which have survival value under these conditions and capable for providing economic production through adaptation to these conditions is valuable. They will be examined for their special attributes which make them suitable for dry lands to help in making choice of potential fruit crops based on the quality of dry lands.

Ber

Botanical name: *Ziziphus mauritiana*

Family: Rhamnaceae

Native: India

Characters:

- It is spiny evergreen shrub.
- It has wide spreading drooping branches.
- The leaves are alternate, elliptic with rounded apex.
- The flowers are orange to brown with edible white pulp surrounding two locular pyrene.

- The fruit is soft, juicy, drupe.
- The ripe fruit is sweet and sour in taste.

Adaption:

It is the most droughts hardy fruit tree known in Indian sub continent, which can stand salinity and saline water for following important features inherent in it.

Its root system is extensive, tends to go deep and can penetrate hard pan and draw moisture from deeper layers of soil. In this case flowering starts with the onset of monsoon and the crop is harvested well in advance of onset of hot and dry summer. The most interesting feature of this crop is that during hot summer it will shed its leaves completely and thus conserve moisture by getting rid of transpiration mechanism. At the same time the leaves have xerophytes characters and the buds are scaly and thus stand intense summer heat with no damage. If this crop is helped with supplementary irrigation and a development of micro catchment around the tree to collect runoff water, shall help in raising production. A large number of varieties are available in this crop and therefore, early varieties like 'Gola', 'Seb' and 'Murdia" are suitable for dry farming conditions because their bearing synchronizes with the period of maximum natural moisture availability.

Aonla

Botanical name: *Emblica officinalis*

Family: Euphorbiaceae

Native: India

Characters:

- It has its beneficial role in cancer, diabetics, liver treatment.
- It is a tree of moderate size with greenish grey bark.
- The leaves are linear, pinnate.
- The flowers are greenish yellow borne in axillary fascicles.
- The fruits are capsular berries with a fleshy exocarp.

- The ripe fruits are astringent, extremely acidic.

Adaption:

Beside the ability of tolerance of drought this crop has great ability to tolerate salinity, alkalinity and sodality prevalent in dry areas. About its ability to survive in drought it can be stated as if physiology of this plant spp is turned for drought conditions only. In aonla, flowering takes place in spring and after fruit set fruits enter quiescence/ dormancy and remain so throughout summer. Therefore, trees do not require irrigation in summer when most crops would need it. With the onset of monsoon, the fruits come out of dormancy, begin to grow and mature by December, the period when moisture stress is minimum. Therefore, this is the most ideal crop for dry land crop for dry land conditions.

Annona

Botanical name: *Annona squamosa*

Family: Annonaceae

Native: Central America

Characters:

- It is a small, semi-deciduous, much branched small tree.
- The branches are light brown bark with leaf scars.
- The leaves are simple arranged in alternate manner.
- The flowers are solitary, greenish-yellow on the hairy slender long stalk.
- Aggregate and soft fruits form from the numerous and loosely united pistils of the flower which become enlarged.

Adaption:

Custard apple is also a very hardy fruit crop, tolerant to drought, salinity and saline irrigation water to some extent. It also grows well and shallow soils, fruiting coincides with maximum moisture stress availability period with flowering in June/ July and maturity by November/ December. It enters in dormancy due to moisture stress and shed off leaves during hot and dry summer to evade moisture to evade moisture loss from plant tissues by transpiration. Growth is under the influence of temperature and moisture. In places where irrigation facilities are available fruiting period can be pre-poned or postponed to get early or late crops in tropics.

Jamun

Botanical name: *Syzygium cumini*

Family: Myrtaceae

Native: India

Characters:

- It is a rapidly growing tree with dense foliage.
- The wood is water resistant after being kiln dried.
- The leaves have an aroma similar to turpentine, pinkish when young, glossy dark green with yellow midrib when mature.
- The flowers are fragrant and the fruit is oblong, ovoid has a sweet, mildly sour and astringent flavor.

Adaption:

Once established, Jamun tree can face drought to a very great extent. This has been attributed to its extensive root system and thick plant sap. Flowering starts in spring and the final swell of fruits takes place in monsoon. Jamun fruits ripe little later than mango. The colour of the fruit and the pulp is purple and fruits are astringent even after ripening. Early and seedless varieties are being developed looking to the demand for its role in sugar metabolism (Diabetes).

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Wood apple

Botanical name: *Limonia acidissima*

Family: Rutaceae

Native: India

Characters:

- It is a slow growing tree grows in dry and warm areas. It has rough spiny bark. The spines are short, axillary on the zigzag twigs.
- The leaves are deciduous, alternate, and leathery.
- The fruit is round to oval, woody hard rind difficult to crack.
- The pulp is sticky, brown and aromatic.

Adaption :

It is a tree of family Rutacaeae and possesses great tolerance to drought and salinity. Extensive root system and synchronization of its reproductive phase with high moisture availability make it a suitable crop for dry lands. Fruits per se hardly have any table value but the pulp is extensively used for chutney preparation and being rich in pectin, it is an excellent adjunct in jelly preparation. Wood apple is an excellent tree for waste-land.

Bael

Botanical name: *Aegle marmelos*

Family: Rutaceae

Native: India

Characters:

- It is a deciduous shrub with slender drooping branches, irregular crown.
- The bark is pale brown or greyish, smooth or finely fissured and flaking.
- The leaf is trifoliate, alternate, and ovate with tapering tip.
- The flowers are pale green or yellowish, sweetly scented borne in clusters at the end of the twigs and leaf axils.

- The fruits are pear shaped with thick, hard rind and difficult to crack.

Adaption:

It is a drought and solidity tolerant plant in which flowering coincides with the onset of monsoon and the fruits mature before the onset of hot summer. It can stand swampy and alkaline soils also. It is these physiological attributes which make this species suitable for dry land farming. A grown up tree yields about 300 to 400 fruits per annum which as such hardly have any table value but it makes excellent squash or RTS beverage. Bael is considered to have many medicinal properties and is effective in treatment of dysentery.

Pomegranate

Botanical name: *Punica granatum*

Family: Lythraceae

Native: Iran

Characters:

- It is a shrub or small tree has multiple spiny branches.
- The leaves are opposite or subopposite, glossy, narrow oblong and broad.
- The flowers are bright red in color with prominent calyx.
- The fruits are red-purple in color with hard pericarp and inner spongy mesocarp in which the seeds attach.
- The edible part is juicy arils.

Adaption :

This frit crop can tolerate salinity as well as saline irrigation water and grow even in shallow soils. It can also tolerate drought as fruiting can be tailored to synchronize with the period of maximum moisture availability of natural moisture. Under normal conditions pomegranate plant flowers three times in a year: *Ambe bahar* (spring flowering), *Mrig bahar* (rainy season flowering) and Hastha bahar (post monsoon flowering). If we concentrate only on 'Mrig bahar' and keep trees under stress during rest of the period, it will adjust its growth and fruiting period of dry land situations and plants will even shed off leaves during summer to evade water loss. Ability of plant to flower in three waves and ability to evade transpiration or tolerate moisture stress by entering in dormancy and shedding of leaves during water stress are the positive considerations of this plant species for dry land conditions. However, this fruit crop is highly sensitive to soil and atmospheric moisture fluctuation which result in cracking of fruits. But under dry land conditions, extent of this problem is not so severe. Supplementary irrigation and micro catchment around the tree to harvest rain water increases productivity.

Carissa

Botanical name: *Carissa spinarum*

Family: Apocynaceae

Native: Africa

Characters:

- An erect thorny shrub with forked branches.
- The bark is very hard with thorns.
- The leaves are ovate, broad, and leathery with reticulate venation and exuding white latex when plucked from the stem.
- The flowers are short stalked, sweet scented.
- It is very hardy and drought resistant and can grow on very poor and rocky soils.

Adaption:

This plant is drought tolerant owing to its ability to synchronize reproductive phase to the period of moisture abundance. Therefore, it’s highly suitable for dry land horticulture. Fruits are small and acidic and highly prized for their pickling value and excellent jelly.

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Date palm

Botanical name: *Phoenix dactylifera*

Family: Arecaceae

Native: North Africa

Characters:

- Date tree reach up to 30m growing singly or forming a clump with several stems from a single root system.
- The leaves are pinnate and the full span of the crown ranges 6-10m.
- The palm is dioecious.
- Date fruits are oval-cylindrical bright red in color.

Adaption :

This plant can tolerate salinity and saline irrigation water to a great extent. The crop requires sufficient heat units by the end of June (before the onset of monsoon) and high vapour pressure deficit (25 mb) during fruit development. These conditions are required for faster fruit development and avoidance of damage to fruits due to cracking and splitting which takes place due to high humidity and rainfall for fruits being rich in sugar. Such climatic conditions are available only in the arid regions of India especially in Thar deserts of Rajasthan and Katcha district of Gujarat, the crop suits. Climatically the tree needs head in fire and foot in water such situations exist in oasis. Early cultivars have belter chance.

Phalsa

Botanical name: *Grewia asiatica*

Family: Malvaceae

Native: India

Characters:

- It is a small tree. It has long, slender, dropping branches.

- The leaves are heart shaped alternately arranged.
- The inflorescence is cymes borne in the leaf axils.
- The fruit is small and round in shape.

Adaption :

It is drought hardy and has very short reproductive phase. After the harvest of crop in early summer, plants tend to lose foliage to evade stress of severe hot summer. In this crop the flowering starts of severe hot summer. In this crop the flowering starts in December fruits are ready in April. Fruits hardly gave table value/ but utilized extensively for squash preparation. Short reproductive phase, ability to become quiescent tin hot summer and extensive root system lend in plants drought tolerance ability.

Fig

Botanical name: *Ficus carica*

Family: Moraceae

Native: Mediterranean region

Characters:

- It is called as poor man's food. It contains significant amount of calcium, potassium, phosphorous and iron.
- It is a bush or small tree with broad, rough, deciduous leaves.
- The leaves and stems exude white latex when broken.
- The fruits known as syconia are borne singly or in pairs above the scars of fallen leaves or in axils of leaves of the present season.
- Fig wasp is important for pollination.

Adaption:

This plant can tolerate salinity and drought. Fruiting is monitor able to synchronies with rainy season only so that crop is harvested in late winter and plants will shed off leaves during summer and overcome the drought conditions.

West Indian cherry

Botanical name: *Malpighia emarginata*

Family: Malpighiaceae

Native: West Indies

Characters:

- Rich in vitamin C
- It is a low branching, prickly, bushy shrub reaches to a height to 2-3m.
- It can be pruned to any desired shape.
- The root system is shallow and plants can be toppled by wind.
- The leaves are dark to light green, glossy with minute hairs.
- Foliage will drop during water stress.
- The flowers are sessile, pink to white in color.
- Flowering can occur throughout the year.
- The fruits are round, bright red in color, juicy, sour in taste and with a delicate flavor.

Adaption:

Also known as Acerola or Barbados cherry belongs to family Malpighiaceae. It prefers tropical and humid climate. It tends to drop foliage during water stress but recovers well with flush and flowering. Flowering can occur throughout. The year, but is typically in cycles associated with rain. The plant grows well on limestone, clay and other heavy soils as long as drains well but water logging will cause death. It tolerates drought and flowering can be regulated by water supply, this makes it suitable for rainfed horticulture.

Tamarind

Botanical name: *Tamarindus indica*

Family: Fabaceae

Native: Tropical Africa

Characters:

- It has multiple uses cultivated around the tropical and subtropical zones.
- Tamarind is a long lived, medium growth tree.
- The crown has an irregular, vase shaped outline of dense foliage.
- The evergreen leaves are alternately arranged and pinnately lobed.
- The timber consists of hard, dark, red heartwood and soft, yellow sapwood.
- The flowers are red and yellow, five petalled, borne in raceme.

Adaption:

- The tree grows well in full sun.
- It prefers clay, loam, sandy and acidic soil with a high resistance to drought and aerosol salt.
- At night, the leaflets close up.
- It is frost sensitive.
- The pinnate leaves with opposite leaflets give a billowing effect in the wind.

Besides these, there are many high value crops like grape, sweet orange, papaya, mango, 'Kinnow' mandarin and Mulberry which require dry conditions during flowering and fruiting for the development of high quality fruits. These fruit species can adjust to dry farming situations with the provision of irrigation through recycling of harvested runoff water. Nevertheless, within a fruit species it would be advisable to select early varieties with short reproductive phase for more successful and relevant horticulture.