



ANGRAU

**ACHARYA N G RANGA AGRICULTURAL UNIVERSITY  
LAM, GUNTUR**

**Course Title: PRINCIPLES OF AGRONOMY**  
**Course No. DA 101**  
**Credit hours: 4(3+1)**

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**TIRUPATI-517 502**

## DEPARTMENT OF AGRONOMY

**Course No. : DA 101**

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### **Theory Lecture Outlines**

1. Agriculture and agronomy-meaning and scope; National and International Agricultural Research Institutes.
2. Agro-Climatic Zones of Andhra Pradesh-North Coastal Zone, Godavari Zone and Krishna Zone
3. Agro-Climatic Zones of Andhra Pradesh-Southern Zone, Scarce Rainfall Zone and High Altitude and Tribal Area Zone
4. Research stations in Andhra Pradesh under Acharya N.G.Ranga Agricultural University and their activities.
5. Atmosphere-composition and structure
6. Weather and climate
7. Elements of weather-solar radiation-solar energy, importance to plants, light-intensity, quality and duration
8. Temperature-factors affecting air temperature, effect on crop plants, high temperature injury, low temperature injury, soil temperature
9. Atmospheric pressure and wind-effect of pressure on crop plants-wind movement-wind direction, wind velocity. Effect of wind on crop plants
10. Atmospheric humidity and evaporation-terms related to humidity, effect of relative humidity on crop plants. Evaporation-effect of evaporation on crop plants
11. Rainfall-forms of precipitation-types of rainfall
12. Monsoon-effect of precipitation on crop plants
13. Abnormal weather conditions
14. Weather forecasting-types and uses
15. Tillage and tith-objectives of tillage, types of tillage-primary tillage; seed bed preparation and layout
16. Secondary tillage; intercultivation-advantages; laying of seed bed raising of nursery-advantages and conditions favorable for raising a nursery

17. Puddling and its advantages, modern concepts of tillage-minimum tillage, zero tillage and conservation tillage
18. Seeds and sowing-methods of sowing- raising of nursery-advantages and conditions favorable for raising a nursery
19. Crop plant density, factors affecting optimum plant population, effect of plant population on growth and yield-planting pattern
20. Weeds-definition, harmful and beneficial effect of weeds; classification of weeds and critical period of crop weed competition
21. Weed control methods-physical/mechanical, cultural and biological methods
22. Chemical method of weed control-classification of herbicide, integrated weed management
23. Irrigation/water management-definition, importance, objectives, factors influencing the irrigation water management in relation to nature of soil and crop and climate; critical growth stages for moisture
24. Water requirement of crops-scheduling of irrigation
25. Methods of irrigation-surface and subsurface methods of irrigation
26. Sprinkler and drip method of irrigation
27. Agricultural drainage-definition, types, importance and relative merits
28. Harvesting of crops -methods of harvesting
29. Maturity symptoms of important crops
30. Threshing, winnowing, drying, storage of food grains and oil seed crops
31. Dryland agriculture-definition and history and classification of climate
32. Dryland classification and importance of dryland agriculture
33. Problems of crop production in drylands
34. Moisture conservation practices in drylands-agronomic, mechanical methods, forestry and agrostological measures
35. Contingent crop planning for aberrant weather conditions
36. Cropping systems-I-cropping pattern, monocropping, intercropping and relay intercropping,
37. Cropping systems-II-sequence cropping, multiple cropping, mixed cropping, multistoried cropping and crop rotation

38. Integrated farming systems-definition, advantages and characteristics, IFS for different situations
39. Sustainable Agriculture-definition, concept, goals and elements
40. Organic agriculture-definition, concepts, principles and organic product certification
41. Forestry-definition, history of Indian forestry and branches of forestry
42. Forests-influence of forest on climate, soils, flood and human health
43. Principles of silviculture-stages of development of tree and parts of tree
44. Afforestation on different sites-tending operations
45. Social forestry-definition, objectives and scope
46. Vanamahotsavam-objectives and management of social forestry
47. Farm forestry-definition, objectives, principles for success; wind breaks, shelter belts-definition and advantages
48. Agroforestry-definition, types of agroforestry and advantages

### **Practicals**

1. Visit to research station/college farm and identification of major crops
2. Identification of instruments used to measure weather parameters and knowing the procedure of using the same
3. Study of instruments in meteorological observatory-measurement of solar radiation, temperature, wind velocity, evaporation and rainfall
4. Identification and practice of primary tillage implements
5. Study of seeding equipment, practice of different methods of sowing and calculation of seed rate
6. Study of plant population and calculation of plant population per unit area
7. Identification of manures and fertilizers and practice of methods of fertilizer application and fertilizer calculations
8. Calculation of fertilizer requirement
9. Identification and collection of weeds in field crops and other habitats (for herbarium)
10. Identification of herbicides and practice of herbicide application
11. Identification and practice of intercultivation implements

12. Demonstrations of irrigation methods
13. Identification of harvesting machineries
14. Identification of trees for planting along roadsides and for fodder purpose
15. Visit to forestry nurseries
16. Participation in vanamahotsavam and planting of trees

## Lecture 1:

### AGRICULTURE AND AGRONOMY

The term agriculture is derived from the two Latin words “*ager*” or “*agri*” meaning “*soil*” and ‘*cultra*’ meaning ‘*cultivation*’

Agriculture is a very broad term encompassing all aspects of crop production, livestock farming, fisheries, forestry etc.

Agriculture may be defined as the art, the science and the business of producing crops and livestock for man’s use and employment.

Agriculture is the cultivation of lands for production of crops for regular supply of food and other needs for progress of the nation.

Agriculture is influenced by a large number of factors, some of which can be controlled by man (soil and irrigation) and some which others are beyond the control (climate)

The term “*Agronomy*” is derived from two Greek words “*Agros*” meaning “*field*” and “*nomos*” meaning “*to manage*”.

Agronomy is a branch of agricultural science which deals with principles and practices of soil, water and crop management.

Agronomy deals with methods which provide favourable environment to the crop for higher productivity.

#### Scope of Agronomy

Agronomy is a dynamic discipline with the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified and new practices were developed for high productivity. For example, availability of chemical fertilizer has necessitated the generation of knowledge on the method, quantity and time of application of fertilizers. Similarly, availability of herbicides for the control of weeds has led to development of knowledge about selectivity, time and method of application of herbicides. To overcome the problems different management practices are developed.

Population pressure is increasing but area under cultivation is static, therefore more number of crops have to be grown on the same piece of land to increase the yield. As a result, intensive cropping has come into practice.

New technology has to be developed to overcome the effect of moisture stress under dryland conditions. As new varieties of crops with high yield potential become available, package of practices have to be developed to exploit their full potential.

Restoration of soil fertility, preparation of good seed bed, use of proper seed rates, correct dates of sowing for each improved variety, proper conservation and management of soil moisture and proper control of weeds are agronomic practices to make our limited land and water resources more productive.

## **Relation of Agronomy to other sciences**

Agronomy is a synthesis of several disciplines like soil science, agricultural chemistry, crop physiology, plant ecology, biochemistry and economics. Soil physical, chemical and biological properties have to be understood thoroughly to effect modification of soil environment. Similarly, it is necessary to understand the physiology of crops to meet their requirements. Advances in economic analysis helped in production of crops economically.

Agronomist aims to obtain maximum production at minimum cost. He exploits the knowledge developed by basic and applied science for higher crop production. Whatever may be the research findings of other scientists, agronomist has to test their suitability in the field and accept them finally and also judge the reactions of farming community. He is a key person with working knowledge of all agricultural disciplines and coordinator of different subject matter specialists.

## NATIONAL AND INTERNATIONAL RESEARCH INSTITUTES IN INDIA

### NATIONAL RESEARCH INSTITUTES

- CAZRI** : Central Arid Zone Research Institute, Jodhpur, Rajasthan
- CFTRI** : Central Food Technological Research Institute, Mysore, Karnataka
- CICR** : Central Institute for Cotton Research, Nagpur, Maharashtra
- CPRI** : Central Potato Research Institute, Simla, H.P.
- CRIJAF** : Central Research Institute for Jute and Allied Fibers, Barrackpore, W.B.
- CIAE** : Central Institute of Agricultural Engineering, Bhopal, M.P.
- CPCRI** : Central Plantation Crops Research Institute, Kasaragod, Kerala
- CRIDA** : Central Research Institute for Dryland Agriculture, Hyderabad, Telanagana
- CRRI** : Central Rice Research Institute, Cuttack, Odisha
- CSWCRTI** : Central Soil and Water Conservation Research and Training Institute, Dehradun, U.P.
- CTCRI** : Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala
- CSSRI** : Central Soil Salinity Research Institute, Karnal, Haryana
- CTRI** : Central Tobacco Research Institute, Rajahmundry, A.P.
- IIR** : Indian Institute of Oilseeds Research, Hyderabad, Telanagana
- IIRR** : Indian Institute of Rice Research, Hyderabad, Telanagana
- DWR** : Directorate of Wheat Research, Karnal, Haryana
- DWMRI** : Directorate of Water Management Research Institute, Jhansi, U.P.
- FRI** : Forest Research Institute, Dehradun, U.P.
- IARI** : Indian Agriculture Research Institute, Pusa, New Delhi
- IGFARI** : Indian Grassland and Fodder Research Institute, Jhansi, U. P.
- IISR** : Indian Institute of Sugarcane Research, Lucknow, U.P.
- IISS** : Indian Institute of Soil Science, Bhopal, M.P.
- IIPR** : Indian Institute of Pulse Research, Kanpur, U.P.
- IIHR** : Indian Institute of Horticultural Research, Bangalore, Karnataka.

- ILRI** : Indian Lac Research Institute, Ranchi, Bihar
- JTRL** : Jute Technological Research Laboratory, Kolkata, W.B.
- DMR** : Directorate of Mushroom Research, Solan, H.P.
- DGR** : Directorate of Groundnut Research, Junagadh, Gujarat
- IIMR** : Indian Institute of Millets Research, Hyderabad, Telanagana
- IISR** : Indian Institute of Soybean Research, Indore, M.P.
- IISR** : Indian Institute of Spices Research, Calicut, Kerala
- DCR** : Directorate of Cashew Research, Pattur, Karnataka
- CCRI** : Central Citrus Research Institute, Nagpur, Maharashtra
- DRMR** : Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan
- IIOPR** : Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh.
- DWR** : Directorate of Weed Research, Jabalpur, M.P.
- NBPGR** : National Bureau of Plant Genetic Resources, New Delhi
- NAARM** : National Academy of Agricultural Research Management, Hyderabad
- NBSSLUP** : National Bureau of Soil Survey and Land Use Planning, Nagpur, Maharashtra
- NIPHM** : National Institute of Plant Health Management, Hyderabad, Telanagana
- PDCSR** : Project Directorate for Cropping Systems Research, Meerut, U.P.
- SBI** : Sugarcane Breeding Institute, Coimbatore, Tamil Nadu

#### **INTERNATIONAL INSTITUTES**

- CGIAR** : Consultative Group on International Agricultural Research, Washington, D.C.
- CIFOR** : Centre for International Forestry Research, Bogor, Indonesia
- CIAT** : International Center for Tropical Agriculture, Cali, Columbia
- CIMMYT** : International Maize and Wheat Improvement Center, Mexico
- CIP** : International Potato Centre, Lima, Peru
- IBPGR** : International Board for Plant Genetic Resources, Rome, Italy

- ICARDA** : International Center for Agricultural Research in the Dry Areas, Aleppo, Syria
- ICRAF** : International Centre for Research in Agro-Forestry, Nairobi, Kenya
- ICRISAT** : International Crops Research Institute for Semi-Arid Tropics, Hyderabad, India
- IFPRI** : International Food Policy Research Institute, Washington, U.S.A
- IITA** : International Institute for Tropical Agriculture, Ibadan, Nigeria
- IIMI** : International Irrigation Management Institute, Colombo, Sri Lanka
- ILRI** : International Livestock Research Institute, Nairobi, Kenya
- IRRI** : International Rice Research Institute, Manila, Philippines
- ISNAR** : International Service for National Agricultural Research, The Hague, The Netherlands
- WARDA** : West Africa Rice Development Association, Ivory Coast, West Africa

## Lecture 2 & 3:

### AGRO CLIMATIC ZONES OF ANDHRA PRADESH

Andhra Pradesh is one of the 29 states of India. Andhra Pradesh is the seventh-largest state by area covering an area of 162,975 km<sup>2</sup> (62,925 sq miles). The state has a total of 13 districts, the Anantapuramu district is the largest and Srikakulam district is the smallest district. The districts are divided into two regions of the state, i.e., Coastal Andhra and Rayalaseema. Coastal Andhra comprises of nine districts: East Godavari, West Godavari, Krishna, Guntur, Prakasam, Sri Potti Sri Ramulu Nellore, Srikakulam, Vizianagaram, and Visakhapatnam. The Rayalaseema zone comprises of four districts: Kurnool, Chittoor, Kadapa and Anantapuramu.

Based on the type of climate and soils Andhra Pradesh is divided into 6 agro-climatic zones

1. North coastal zone
2. Godavari zone
3. Krishna zone
4. Southern zone
5. Scarce rainfall zone
6. High altitude tribal zone

#### 1. North Coastal Zone

Districts	Srikakulam, Vizianagaram and Vishakhapatnam
Rainfall and temperatures	Rainfall : 1020- 1220 mm Temperature : Max (°C): 30.3-35.6 : Min (°C) : 20.6- 26.0
Soils	Red soils and Acid soils
Major crops	Rice, Sugarcane, Bajra, Fingermillet, Green gram, Black gram, Jute, Gingelly, Groundnut, Mango and Cashew
Source of Irrigation water	Nagavali, Vamsadara, Sarada rivers, Tanks and wells
Special constraints	Low fertile soils, unassured water supply
Major research stations	Regional Agricultural Research Station, Anakapalle, Visakhapatnam district

## 2. Godavari zone

Districts	East and West Godavari
Rainfall and temperatures	Rainfall : 830- 1120 mm Temperature : Max (°C): 30 - 35 : Min (°C) : 18- 23
Soils	Red soils , Loamy soils and costal sandy soils
Major crops	Rice, Sugarcane, Cotton, Chillies, Groundnut, Coconut, Fruits and Flower crops
Source of Irrigation water	Godavari river, Canals
Special constraints	Low pressure depression during September- November, Heavy rains – cloudiness – pest and diseases, Poor drainage, Waterlogging and Saline soils
Major research stations	Andhra Pradesh Rice Research Institute (APPRI), Maruteru, West Godavari district

## 3. Krishna zone

Districts	Krishna, Guntur & Prakasam
Rainfall and temperatures	Rainfall : 1020- 1220 mm Temperature : Max (°C): 30 - 35 : Min (°C) : 21- 26
Soils	Red soils , Loamy soils, Acid soils and costal sandy soils
Major crops	Rice, Jowar, Maize, Sugarcane, Bajra, Fingermillet, Green gram, Black gram, Bengal gram, Cotton, Chillies, Tobacco, Jute, Gingelly, Groundnut, Fruits and Flower crops
Source of Irrigation water	Krishna river, Canals
Special constraints	Low pressure depression during September- November, Heavy rains – cloudiness – pest and diseases, Poor drainage, Waterlogging and Saline soils
Major research stations	Regional Agricultural Research Station, Lam farm, Guntur

#### 4. Southern Zone

Districts	Chittoor, SPSR Nellore and YSR Kadapa
Rainfall and temperatures	Rainfall : 650- 1150 mm Temperature : Max (°C): 31.3 – 37.3 : Min (°C) : 17.0 – 25.6
Soils	Red soils and shallow deep black cotton soils
Major crops	Rice, Jowar, Finger millet, Groundnut, Bajra, Sugarcane, Cotton and Tobacco
Source of Irrigation water	Penna river, tanks and wells
Special constraints	Unexpected rainfall, Soil erosion, Light soils (low water holding capacity)
Major research stations	Regional Agricultural Research Station, Tirupati, Chittoor district

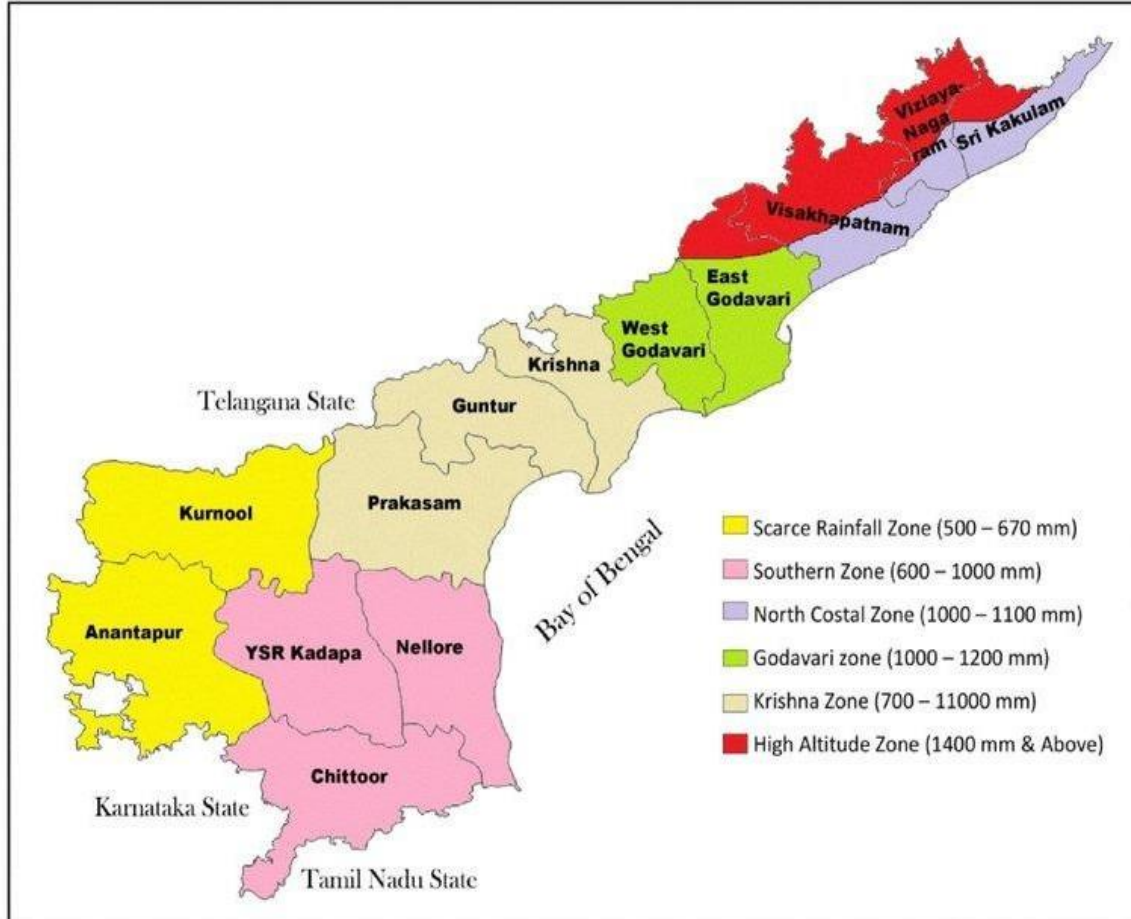
#### 5. Scarce Rainfall Zone

Districts	Kurnool and Anantapuramu
Rainfall and temperatures	Rainfall : 515- 754 mm Temperature : Max (°C): 31.3 – 34.0 : Min (°C) : 18.0 – 26.3
Soils	Red soils, red sandy soils and shallow deep black soils and very shallow deep black cotton soils
Major crops	Jowar, Pearl millet, Finger millet, Korra, Groundnut, Cotton, Rice, Redgram and Tobacco
Source of Irrigation water	Tunga Bhadra river (K.C canal ), Canals, tanks and wells
Special constraints	Very low fertile soils in Anantapuramu. Low water holding capacity, frequent droughts with lowest rainfall in the state, uncertain and erratic distribution of rainfall.
Major research stations	Regional Agricultural Research Station, Nandyal, Kurnool district

## 6. High altitude and tribal area zone

Districts	Srikakulam, Visakhapatnam and East Godavari,
Rainfall and temperatures	Rainfall : 1195 mm Temperature : Max (°C): 31.3 – 34.0 : Min (°C) : 18.0 – 26.3
Soils	Red soils, Sandy soils and forest lands
Major crops	Millets, redgram, Cotton, Rice, Banana, coffee, tea, cocoa, blackpepper, cashew, different kinds of root vegetables, honey, soapnut, rajmah, gum, sericulture and sheep rearing.
Source of Irrigation water	Podu cultivation
Special constraints	Majority of the people belong to scheduled tribes, forest and mountains are more. Highest rainfall on average 1400 mm height of the zone is 1000m MSL
Major research stations	Regional Agricultural Research Station, Chintapalle. Visakhapatnam district.

## Agro-Climatic zones of Andhra Pradesh



**Lecture 4:****RESEARCH STATIONS IN A.P UNDER ACHARYA NG RANGA  
AGRICULTURAL UNIVERSITY, LAM, GUNTUR**

<b>S. No.</b>	<b>Name of the research station/ zone</b>	<b>Main research on following crops</b>
<b>I</b>	<b>North Coastal Zone</b>	
1	Regional Agricultural Research Station, Anakapalli-531 001 Visakhapatnam District	Sugarcane. Sugarcane - based cropping systems and value added products
2	Agricultural Research Station, Kokkirapalli, Yelamanchili-531 005 Srikakulam District	Gingelly and Gingelly based value added products
3	Agricultural Research Station, Amudalavalasa-532 185 Srikakulam District	Jute, Jute based cropping systems, pulses and post- harvest technology
4	Agricultural Research Station, Ragolu-532 484 Srikakulam District	Rice, Rice -based cropping system, Rice fallow Pulse crops
5	Agricultural Research Station, Viziayanagaram-535 001 Viziayanagaram District	Finger millet, Finger millet based cropping system, Millets (Variga, Aurikalu, Udalu & Korra)
<b>II</b>	<b>Godavari Zone</b>	
6	Regional Agricultural Research Station Maruteru-534 122 West Godavari District	Rice, Summer pulses, Water and soil management, Integrated farming system, Post- harvest crop management
7	Maize Research Centre, Agricultural Research Station, Vijayarai-534 475 West Godavari District	Honey bees, Maize based cropping system
8	Agricultural Research Station, Peddapuram-533 437 East Godavari District	Finger millet, Pulses, Oilseeds (Groundnut, Gingelly) and Maize.
<b>III</b>	<b>Krishna Zone</b>	
9	Regional Agricultural Research Station, Lam-522 034, Guntur District	Pulses, Cotton, Millets and Oilseeds

<b>S. No.</b>	<b>Name of the research station/ zone</b>	<b>Main research on following crops</b>
10	Agricultural Research Station, Agricultural College Farm Campus, Bapatla 522 101 Guntur District	Rice
11	Post Harvest Technology Centre Agricultural College Campus, Bapatla-522 101, Guntur District	Post harvest techniques for horticultural crops and paddy
12	Saline Water Scheme Agricultural College Farm Campus, Bapatla-522 101, Guntur District	Salt water utilization
13	AICRP on Farm Implements & Machinery, College of Agricultural Engineering Campus, Bapatla-522 101, Guntur District	Farm machinery implements
14	Agricultural Research Station, Amaravathi-522 020, Guntur District	Biofertilisers
15	Agricultural Research Station, Jangamaheswarapuram-522 415 (J.M.Puram), Gurazala Mandal, Guntur District	Rice seed production
16	Sugarcane Research Station, Vuyyuru-521 165, Krishna District	Sugarcane
17	Agricultural Research Station, Machilipatnam-521 002, Krishna District	Rice cultivation in saline soils
18	Agricultural Research Station, Garikapadu-521 175, Krishna District	Water management
19	Agricultural Research Station, Ghantasala-521 133, Krishna District	Rice fallow pulses
20	Agricultural Research Station, Darsi-523 427, Prakasam District	Small millets, Agroforestry, Water management, Rainfed .crops
<b>IV</b>	<b>Southern Zone</b>	
21	Regional Agricultural Research Station, Tirupati-517 502 Chittoor District	Groundnut, Water management, Pulses, Farm machinery and implements.
22	Agricultural Research Station, Perumallapalle-517 505, Chittoor District	Sugarcane, Maize, Jowar and Small millets

<b>S. No.</b>	<b>Name of the research station/ zone</b>	<b>Main research on following crops</b>
23	Agricultural Research Station, Nellore-524 00333, SPSR Nellore District	Rice
24	Agricultural Research Station, Podalakur-524 345, SPSR Nellore District	Pulses and Jowar
25	Agricultural Research Station, Kavali-524 202, SPSR Nellore District	Agroforestry
26	Agricultural Research Station, Utukur-516 003, YSR Kadapa District	Rice, Rice based cropping pattern & Water management
<b>V</b>	<b>Scarce Rainfall Zone</b>	
27	Regional Agricultural Research Station, Nandyal-518 503 Kurnool District	Rice, Cotton, Jowar, Sunflower, Bengal gram & Tobacco
28	Agricultural Research Station, Rekulakunta-515 001 Anantapuramu District	Dryland agriculture, Groundnut, Bajra and Castor as well as weather forecast
29	Agricultural Research Station, Reddipalli-515 701, Anantapuramu District	Oilseed-based cropping pattern
30	Agricultural Research Station, Kadiri-515 591, Anantapuramu District	Groundnut
<b>VI</b>	<b>High Altitude and Tribal Zone</b>	
31	Regional Agricultural Research Station, Chintapalli-531 111 Visakhapatnam District	Improving the livelihood of tribal farmers and identification of different crops and hybrids based on watersheds
32	Agricultural Research Station, Seethampet-532 443 Srikakulam District	Identification of varieties and hybrids for socio economic development of tribal people

## **Lecture 5:**

# **ATMOSPHERE**

## **Atmosphere**

The earth is elliptical in shape. It has three spheres. They are

- 1 Hydrosphere: the water portion.
- 2 Lithosphere: the solid portion.
- 3 Atmosphere: the gaseous portion.

The atmosphere is defined as “the colourless, odourless and tasteless physical mixture of gases which surrounds the earth on all sides”. It is mobile, compressible and expansible.

## **Meteorology**

Meteorology is defined as "the science of atmosphere" or “A branch of physics of the earth dealing with physical processes in the atmosphere that produce weather”.

## **Climatology**

It is defined as “The science dealing with the factors which determine and control the distribution of climate over the earth's surface”. Different factors affecting the climate of a region are:

1. Latitude
2. Altitude
3. Land and water
4. Wind and air masses
5. Low and high pressure belts
6. Mountain barriers
7. Ocean currents
8. Extent of forests, etc.

The above factors are also known as “climatic elements”

## **Agricultural Meteorology**

Agriculture is defined as “the art and science of production and processing of plant and animal life for the use of human beings”. It is also defined as “A system for harnessing or exploiting the solar radiation”.

Agriculture deals with three most complex entities viz., soil, plant and atmosphere and their interactions. Among these three, atmosphere is the most complex entity over the other two. It is defined as

- "The study of those aspects of meteorology that have direct relevance to agriculture".
- It is also defined as “A branch of applied meteorology which investigates the response of crops to the physical conditions of the environment”.

- “An applied science which deals with the relationship between weather/ climatic conditions and agricultural production”.
- “A science concerned with the application of meteorology to the measurement and analysis of the physical environment in agricultural systems”.
- The word ‘Agrometeorology’ is the abbreviated form of agricultural meteorology.

### **Composition of the atmosphere**

There is no definite upper layer to the atmosphere. The decrease of air (density) with altitude (height) is so rapid that half of the atmosphere lies within 3.5 miles (5.5 kms) from the surface and nearly 3/4th of the atmosphere lies upto 7 miles (11 km).

The atmosphere is a mixture of many gases. In addition, it contains large quantities of solid and liquid particles collectively called "aerosols". The lower part of the atmosphere contains water vapour from 0.02 to 4 per cent by volume. Nitrogen and oxygen make up approximately to 99 per cent and the remaining 1 per cent by other gases (Table 5.1). Innumerable dust particles are also present in the lower layers of the atmosphere. They are microscopic and play an important role in absorption and scattering of insolation.

**Table 5.1. Principal gases comprising dry air in the lower atmosphere**

<b>S. No.</b>	<b>Constituent</b>	<b>Per cent by volume</b>	<b>Per cent by weight</b>
1	Nitrogen	78.08	75.51
2	Oxygen	20.94	23.15
3	Argon	0.93	1.28
4	Carbon-dioxide	0.03	0.046

### **Physical structure of the atmosphere**

On the basis of vertical temperature variation, the atmosphere is divided into different spheres or layers as detailed below:

#### **I. Troposphere**

1. The word “Tropo” means mixing or turbulence and “Sphere” means region.
2. The average height of this lower most layer of the atmosphere is about 14 kilometers above the mean sea level; at the equator it is 16 kilometers; and 7- 8 kilometers at the poles.
3. Under normal conditions the height of the troposphere changes from place to place and season to season.

4. Various types of clouds, thunderstorms, cyclones and anti cyclones occur in this sphere because of the concentration of almost all the water vapour and aerosols in it. So, this layer is called as “Seat of weather phenomena”.
5. The wind velocities increase with height and attain the maximum at the top of this layer.
6. Another striking feature of troposphere is that there is a decrease of temperature with increasing elevation at a mean lapse rate of about  $6.5^{\circ}\text{C}$  per kilometer or  $3.6^{\circ}\text{F}$  per 1,000 feet.
7. Most of the radiation received from the sun is absorbed by the earth's surface. So the troposphere is heated from below.
8. In this layer, about 75 per cent of total gases and most of the moisture and dust particles present.
9. At the top of the troposphere there is a shallow layer separating it from stratosphere which is known as “Tropopause”.
10. The tropopause layer is thin and its height changes according to the latitudes and infact this is a transitional zone and distinctly characterised by no major movement of air.

## **II. Stratosphere**

1. This layer exists above the tropopause (around 20 km onwards) and extends to altitudes of about 50-55 kilometers.
2. This layer is called as "Seat of photochemical reactions".
3. In any particular locality, the temperature remains practically constant at around 20 kilometers and is characterised as Isothermal because the air is thin, clear, cold and dry.
4. The temperature of this layer increases with height and also depends upon troposphere because troposphere is higher at equator than at poles.
5. In the upper parts of the stratosphere the temperatures are almost as higher as those near the earth's surface, which is due to the fact that the ultra violet radiation from the sun is absorbed by ozone in this region.
6. Less convection takes place in the stratosphere because it is warm at the top and cold at the bottom.
7. There is also persistence of circulation patterns and high wind speeds.
8. The upper boundary of the stratosphere is called stratopause and above this level there is a steep rise in temperature.

### **III. Mesosphere / Ozonosphere**

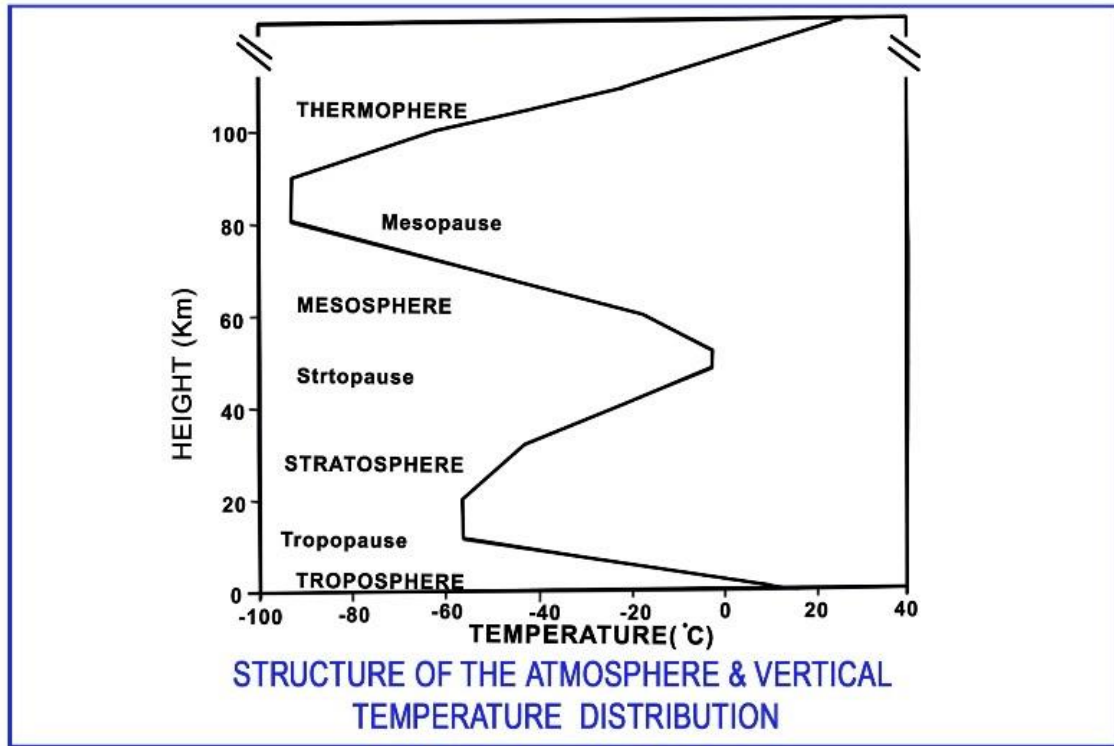
1. There is a maximum concentration of ozone between 30 and 60 km above the surface of the earth and this layer is known as ozonosphere.
2. A property of ozone is that it absorbs ultra violet rays. Had there been no layer of ozone in the atmosphere, the ultra violet rays would have reached the surface of the earth and no life on it.
3. The temperature of the ozonosphere is high (warm) due to selective absorption of ultra violet radiation by ozone.
4. Because of the preponderance of chemical process this sphere is called as "Chemosphere".
5. In this layer the temperature increases with height at the rate of 5°C per each kilometer.
6. According to some leading scientists the ionosphere is supposed to start at a height of 80 kilometers above the earth's surface. The layer between 50 and 80 kilometer is called Mesosphere. In this layer the temperature decreases with height. The upper boundary of this layer is called the mesopause.

### **IV. Ionosphere/Thermosphere**

1. Ionosphere layer lies beyond ozonosphere (mesosphere) at a height of about 80 km above the earth's surface and extends upto 400 kilometers.
2. The atmosphere in ionosphere is partly ionised. Enriched ion zones exist in the form of distinct ionised layers. So, this layer is called as ionosphere.
3. Above the ozonosphere the temperature falls again. According to some climatologists, the layer between 80 and 140 kilometers is known as "Thermosphere".
4. The ionosphere reflects radio waves because of one or multiple reflections of short wave radio beams from the ionised shells. So, long distance radio communication is possible due to this layer.

### **V. Exosphere**

1. The outer most layer of the earth's atmosphere is named as exosphere and this layer lies between 400 and 1,000 km.
2. At such a greater height the density of atoms in the atmosphere is extremely low.
3. Hydrogen and helium gases predominate in this outer most region.
4. At an altitude of about 500 to 600 km the density of the atmosphere becomes so low that collisions between neutral particles become extremely rare.



**Fig. 5.1. Structure of atmosphere**

## Lecture 6:

# WEATHER AND CLIMATE

## Weather

It is defined as “a state or condition of the atmosphere at a given place and at a given instant of time”.

- ◆ The daily or short term variations of different conditions of lower air in terms of temperature, pressure, wind, rainfall, etc”.
- ◆ The aspects involved in weather include small areas and duration, expressed in numerical values etc. The different weather elements are solar radiation, temperature, pressure, wind, humidity, rainfall, evaporation etc. Weather is highly variable. It changes constantly sometimes from hour to hour and at other times from day to day.

Example: The air temperature of Tirupati on 20.01-2021 at 2.30 p.m. is 30.8°C.

## Climate

It is defined as

- ◆ “The generalised weather or summation of weather conditions over a given region during comparatively longer period”.
- ◆ “The sum of all statistical information of weather in a particular area during a specified interval of time usually a season or year or even a decade”. The aspects involved are larger areas like a zone, a state; a country is described by normals etc.

Example: The climatic elements are latitude, longitude, altitude etc. In Andhra Pradesh the winter temperatures range from 15 to 29<sup>o</sup> C.

**Table 6.1. Differences between Weather and Climate**

S. No.	Weather	Climate
1	A typical physical condition of the atmosphere	Generalized condition of the atmosphere which represents and describes the characteristics of a region
2	Changes from place to place even in a small locality	Different in different large regions
3	Changes according to time (every moment)	Change requires longer (years) time

S. No.	Weather	Climate
4	Similar numerical values of weather of different places usually have same weather	Similar numerical values of climate of different places usually have different climates
5	Crop growth, development and yield are decided by weather in a given season	Selection of crops suitable for a place is decided based on climate of the region
6	Under aberrant weather conditions planners can adopt a short-term contingent planning	Helps in long-term agricultural planning

### Factors affecting climate:

i) **Latitude:** The distance from the equator, either south or north, largely creates variations in the climate. Based on the latitude, the climate has been classified as

- i) Tropical
- ii) Sub-tropical
- iii) Temperate &
- iv) Polar.

ii) **Altitude (elevation):** The height from the MSL creates variation in climate. Even in the tropical regions, the high mountains have temperate climate. The temperature decreases by 6.5 °C/Km from the sea level. Generally, there is also a decrease in pressure and increase in precipitation and wind velocity. The above factors alter the kind of vegetation, soil types and the crop production.

iii) **Precipitation:** The quantity and distribution of rainfall decides the nature of vegetation and the nature of the cultivated crops. The crop regions are classified on the basis of average rainfall which is as follow.

Rainfall(mm)	Name of the climatic region
Less than 500	Arid
500-750	Semi-arid
750-1000	Sub-arid
More than 1000	Humid

iv) **Soil type:** Soil is a product of climatic action on rocks as modified by landscape and vegetation over a long period of time. The colour of the soil surface affects the absorption, storage and re- radiation of heat. White colour reflects while black absorbs more radiation. Due to differential absorption of heat energy, variations in temperature are created at different places. In black soil areas, the climate is hot while in red soil areas, it is comparatively cooler due to lesser heat absorption.

v) **Nearness to large water bodies:** The presence of large water bodies like lakes and sea including its current affect the climate of the surrounding areas, eg. Islands and coastal areas. The movement of air from earth's surface and from water bodies to earth modify the climate. The extreme variation in temperature during summer and winter is minimized in coastal areas and island.

vi) **Topography:** The surface of landscape (leveled or uneven surface areas) produces marked change in the climate. This involves the altitude of the place, steepness of the slope and exposure of the slope to light and wind.

vii) **Vegetation:** Kinds of vegetation characterize the nature of climate. Thick vegetation is found in tropical regions where temperature and precipitation are high. General types of vegetations present in a region indicate the nature of the climate of that region.

## Lecture 7:

### ELEMENTS OF WEATHER

#### Solar radiation

Solar radiation is radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. The spectrum of solar radiation is close to that of a black body with a temperature of about 5800° K. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. The units of measurements are Watts per square meter.

The energy emitted by the sun is known as solar radiation. The incoming solar radiation to the earth is known as **insolation**. Radiation from the earth is called terrestrial radiation.

Solar radiation can be measured using sunshine recorder also known as Campbell Stokes recorder. Pyranometer is used for measuring global radiation and pyrheliometer is used for measuring direct radiation.

**The Earth** absorbs most of the energy reaching its surface, a small fraction is reflected. In total approximately 70% of incoming radiation is absorbed by the atmosphere and the earth's surface while around 30% is reflected back to space and does not heat the surface.

Solar energy provides light as well as heat energy. Light and heat are essential for plants.

Light and heat energy are essentially required for germination of seeds, plant growth and flowering cum fruiting.

Most of the enzymatic reactions work essentially using heat energy.

Photosynthesis is the process through which green plants use water, solar energy from sun and carbon dioxide to create their food, grow and release excess oxygen into the air. Photosynthesis uses sunlight, carbon dioxide and water to produce oxygen, glucose and water.

#### Characteristics of light energy and influence on plant growth

Of the solar radiation or electromagnetic spectrum, light is the visible portion. It is a form of kinetic energy that comes from the sun in tiny particles called quanta or photons, travelling in waves. Three properties of this climatic factor that affect plant growth and development are **light quality**, **light intensity** and **day length** or **photoperiod**.

1. Light quality refers to the specific wavelengths of light;
2. Light intensity is the degree of brightness that a plant receives; and
3. Day length is the duration of the day with respect to the night period.

### **Light:**

Light is a climatic factor that is essential in the production of chlorophyll and in photosynthesis, the process by which plants manufacture food in the form of sugar (carbohydrate).

Any impedance or reduction on the availability of light will affect plant.

- ❖ Light is the visible portion of the solar spectrum with wavelength range is from 0.39 to 0.76 $\mu$ .
- ❖ Light is one of the important climatic factors for many vital functions of the plant.
- ❖ It is essential for the synthesis of the most important pigment i.e. chlorophyll, chlorophyll absorbs the radiant energy and converts it into potential energy of carbohydrate.
- ❖ The carbohydrate thus formed is the connecting link between solar energy and living world.
- ❖ In addition, it regulates the important physiological functions.
- ❖ The characteristics of light viz. intensity, quality, duration and direction are important for crops.

### **1. Light quality**

When a beam of white light is passed through a prism, it is dispersed into wavelengths of different colours. This is called the visible part of the solar spectrum. The different colours and their wave lengths are as follows viz., 400- 750 m  $\mu$  wave lengths are the principal wavelength absorbed and used in photosynthesis. Red, orange and violet lights useful for photosynthesis. Among this, short rays beyond violet (<400 m  $\mu$ ) such as X rays, gamma rays and larger rays beyond red(>750 m  $\mu$ ) such as infrared, are detrimental to plant growth. Red light is the most favourable light for growth followed by violet – blue. Ultra – violet and shorter wave lengths kill bacteria and many fungi.

### **2. Light intensity**

- About one percent of the light energy is converted into biochemical energy.
- Very low light intensity reduces the rate of photosynthesis resulting in reduced growth.

- Similarly, very high intensity is detrimental to plant in many ways as below.
  - It increases the rate of respiration.
  - It also causes rapid loss of water (ie) increases the transpiration rate of water from the plants.
  - The most harmful effect of high intensity light is that it oxidises the cell contents which is termed as ‘Solarisation’. This oxidation is different from respiration and is called as photo- oxidation.
- Under field conditions the light is not spread evenly over the crop canopy but commonly passed by reflection and transmission through several layers of leaves.
- The intensity of light falls at exponential rate with path length through absorbing layers according to Beer’s law. ie the relative radiation intensity decreases exponentially with increasing leaf area.
- At ground level the light intensity is below the light compensation point (The light intensity at which the gas exchange resulting from photosynthesis is equal to that resulting from respiration)

Based on the response to light intensities the plants are classified as follows.

- (i) **Sciophytes (shade loving plants):** The plants grow better under partially shaded conditions. (eg.) Betel vine, buck wheat, sunflower, pineapple, coffee and ginger.
- (ii) **Heliophytes (Sun loving):** Many species of plants produce maximum dry matter under high light intensities when the moisture is available at the optimum level. (eg.) Maize, sorghum, rice etc.

### 3. Duration of light:

- The duration of light has greater influence than the intensity for canopy development and final yield.
- It has a considerable importance in the selection of crop varieties.
- The response of plants to the relative length of the day and night is known as photoperiodism. The plants are classified based on the extent of response to day length which is as follows.

(i) **Long day plants:** The plants which develop and produce normally when the photoperiod is greater than the critical minimum (greater than 12 hours). ex. Potato, Sugarbeet, Wheat, Barley, etc.

(ii) **Short day plants:** The plants which develop normally when the photoperiod is less than the critical maximum (less than 12 hours). Ex. Maize, Soybean, Small millets, Rice, Sorghum, Cotton, Sunflower, etc.

**(iii) Day neutral plants / Indeterminate:** Those plants which are not affected by photoperiod. Ex. Tomato, Maize, etc.

The photoperiodism influences the plant character such as floral initiation or development, bulb and rhizome production etc. In long day plant, during periods of short days, the growth of internodes are shortened and flowering is delayed till the long days come in the season. Similarly, when short day plants are subjected to long day periods, there will be abnormal vegetative growth and there may not be any floral initiation.

### **Direction of light**

- The direction of sunlight has a greater effect on the orientation of roots and leaves.
- In temperate regions, the southern slopes plants produce better growth than the northern slopes due to higher contribution of sunlight in the southern side.
- The change of position or orientation of organs of plants caused by light is usually called as phototropism ie the leaves are oriented at right angles to incidence of light to receive maximum light radiation.

## Lecture 8:

# TEMPERATURE

### Factors affecting air temperature

1. Latitude
2. Altitude
3. Distribution of land and water
4. Ocean currents
5. Prevailing winds
6. Cloudiness
7. Mountain barriers Nature of surface
8. Relief
9. Convection and turbulence etc.

#### 1. Latitude:

The distance from the equator, either south or north, largely creates variations in the climate. Based on the latitude, the climate has been classified as

- i) Tropical
- ii) Sub-tropical
- iii) Temperate &
- iv) Polar.

The latitude is a geographic coordinate that indicates the North-South position of a particular point on the surface of the earth. Latitudes are angles that range from zero degrees at the equator to 90 degrees North or 90 degrees South at the poles. All latitude lines are parallel, and they run from East to West as circles, which are parallel to the equator. Together with the longitudes, latitudes are used to indicate a precise location of any feature on the earth's surface.

**Temperature is inversely proportional to latitude.** Temperature is inversely related to latitude. As latitude increases, the temperature falls, and vice versa. Generally, around the world, it gets warmer towards the equator and cooler towards the poles. However, other factors could influence the temperature in different locations such as altitude, precipitation, and **ocean currents**. The time of occurrence of maximum monthly mean temperature and minimum monthly mean temperature also depends on latitude of a place. The coldest month is January in northern regions of India while December in the south. Similarly, the warmest month is May in the south while June in the north across the country.

## **2. Altitude:**

Temperature decreases with height in troposphere. As we go up or our altitude increases, temperature falls. The rate of decrease of temperature is 6.5 degrees C for each 1 km altitude change. This can also be written as 3.6° F for every 1000 ft increase in altitude. In general, as we go higher, the temperature falls. As you climb a mountain, you can expect the air temperature to decrease by 6.5° C for every 1000 meters you gain. This is called the standard (average) lapse rate.

Adiabatic lapse rate : the rate at which atmospheric temperature decreases with increasing altitude in conditions of thermal equilibrium. Adiabatic lapse rate for every one kilo metre is 5.5°F.

The surface air temperature decreases with increasing altitude from the mean sea level as the density of air decreases. Since the density of air is less at higher altitudes, the absorbing capacity of air is relatively less with reference to earth's longwave radiation.

## **3. Distribution of land and water:**

Land and water surfaces react differently to the insolation. Because of the great contrasts between land and water surfaces their capacity for heating the atmosphere varies. Variations in air temperature are much greater over the land than over the water. The differential heating process between land and sea surfaces are due to their properties. It is one of the reasons for Indian monsoon.

## **4. Ocean currents and reservoirs:**

The energy received over the ocean surface carried away by the ocean currents from the warm areas to cool areas. This results in temperature contrast between the equator and poles. The occurrence of El-Nino is due to change in sea surface temperature between two oceanic regions over the globe. Whenever abundant water supply is available near reservoirs, oceans, water easily evaporates into air. Thus, air contain more water due to which the air temperature decreases. When the wind blows from the ocean to land, it is known as sea breeze which occurs in the spring and summer. During sea breeze the temperatures on land will be decreased.

## **5. Prevailing winds:**

Various types of wind affect temperature. Moisture laden air influence the air temperature with the change in direction of wind. When air contain less moisture (dry air) increases the air temperature along with fast blowing wind. Air temperature varies between day and night and from season to season due to changes in the heating earth's atmosphere. Because of the sun's warming effect, there are more winds during the day. Warm air is less dense than cold air, so warm air rises up and over the cold air, causing winds. Winds can moderate the surface temperature of the continents and oceans. In the absence of winds, we feel warm in hot climates. At the same time, the weather is pleasant if wind blows.

## 6. Cloudiness and rains

The amount of cloudiness affects the temperature of the earth's surface and the atmosphere. A thick cloud reduces the amount of insolation received at a particular place and thus the day time temperature is low. At the same time, the lower layers in the atmosphere absorb earth's radiation. This results in increasing atmospheric temperature during night. That is why, cloudy nights are warmer. This is common in the humid tropical climates. When clouds are more or receiving heavy rainfall, the soil will not be heated up due to incoming solar radiation. Thus, air temperature will be low.

## 7. Slope, color of the soil and mountain barriers:

The temperature of the soil is usually higher on south-facing slopes than on north-facing slopes. When the land slope is more, solar radiation received by the land is less. Presence of mountains with lush green forest plants will always be cooler. Black color of soils absorbs more radiations and other types reflect them. Air at the top of the mountain makes little contact with the ground and is therefore cold while in the valley at the foothills makes a great deal of contact and is therefore warm. That is, the lower region of the earth's atmosphere is relatively warmer when compared to hillocks.

1. **Topography: (Relief):** The surface of landscape (leveled or uneven surface areas) produces marked changes in the climate. This involves the altitude of the place, steepness of the slope and exposure of the slope to light and wind.
2. **Vegetation:** Kind of vegetation characterizes the nature of climate. Thick vegetation is found in tropical regions where temperature and precipitation are high. General types of vegetations present in a region indicate the nature of climate of that region.
3. **Other factors of atmosphere:** More carbon dioxide will be observed in the air near the factories, thereby the air temperatures will be more (due to greenhouse effect).

## Importance of air temperature on crop plants

1. Temperature influences distribution of crop plants and vegetation (In Western Himalayas the temperature falls as altitude increases and this change is responsible for the change of vegetation at different altitudes).
2. The growth and development of crop plants are chiefly influenced by air temperature.
3. Affects leaf production, expansion and flowering.
4. Physical and chemical processes within the plants are governed by air temperature

5. The diffusion rate of gases and liquids changes with temperature
6. Solubility of different substances is dependent on temperature
7. Influences biochemical reactions in crops (double or triple with each 10°C rise)
8. Equilibrium of various systems and compounds in a function of temperature
9. Temperature effects the stability of enzymatic systems in the plants.

### **Air temperature and plant injury**

**Low air temperature and plant injury:** On exposure of crop plants to low temperature the following effects are observed. The primary effect of low air temperature below their optimum temperature is the reduction of rates of growth and metabolic processes.

#### **1. Suffocation**

- a. Small plants may suffer from deficient oxygen when covered with densely packed snow.
- b. Certain toxic substances accumulate in roots and crowns because of low diffusion of carbon dioxide

#### **2. Physiological drought**

- a. In middle latitudes drought occurs under cool temperature conditions. This is due to excessive transpiration and absence of absorption of moisture from the soil, when the soil is in extremely low temperature conditions.
- b. The internal water content of crop plants is depleted which may result in death of leaves.

#### **3. Heaving**

- a. The injury to a plant is caused by lifting upward from the normal position causing the root to stretch or break at a time when the plant is growing.
- b. Sometimes the roots are pushed completely above the soil surface.
- c. It is difficult for the roots to become firmly established again and the plants may die because of this mechanical damage and desiccation.

#### **4. Chilling**

- a. Due to this injury some crop plants are killed and others recover under favourable conditions later on.
- b. This injury is common in temperate climates where delayed growth and sterility are common symptoms.

- c. Moderate wind speeds when the air temperature ranges from 0 to 10°C, tends to cause very rapid fall in the activity of metabolic processes, especially respiration in crop plants. Which is known as “chilling injury”. This results in severe damage and death within a few hours or days.
- d. Chilling in the affected plants causes a phase change (“liquid” to “solid”) in membrane lipids resulting in inactivation of membrane bound enzymes.
- e. Sometimes chilling results yellowing of plants.

## **5. Freezing**

1. Freezing damage is caused by the formation of ice crystals in the intracellular spaces and extracellular spaces.
2. Ice within the cells cause injury by mechanical damage and plant parts or entire plant may be killed or damaged.
3. If extracellular ice persists, the gradient of water vapour pressure between the apoplast and the cells causes water to migrate out of the cells and into the apoplast, where it freezes, thereby increasing the amount of ice, in the plant tissue.
4. This results not only in mechanical damage to the tissue, but also brings about dehydration of cell contents and lead to death of the cell.

## **II. High air temperature and plant injury**

1. High air temperature results in the desiccation of the crop plants also.
2. The injury caused because of short period fluctuation (within a day highest in noon and lowest at early morning) in air temperature is known as sunclad.
3. The scorching of stem near the soil surface known as stem girdle is another injury at high air temperatures.
4. Plant tissues escape from high heat by emission of long wave radiation, convection of heat and transpiration.
5. However, transpiration is the most effective process in many natural situations.
6. High plant temperatures (> 40°C) are almost invariably due to the cessation of transpirational cooling caused by stomatal closure.
7. Exposure of crop plants to temperatures over 45°C for just 30 minutes can cause severe damage to the leaves of plants.
8. The effect of high temperature are the disruption of cell metabolism (possibly by protein denaturation), production of toxic substances, and damage to cellular membranes.

## **Soil temperature**

The soil temperature is one of the most important factors that influence the crop growth. Under the low soil temperature conditions intake of water by root is reduced.

In a similar way extreme soil temperatures (45°C) affect the seed germination, injures plant and its growth. Metabolic reactions will be normally high when the soil temperature is ranged from 20-30°C. if the soil temperature is <20°C resulted in very low water uptake by the roots resulting in reduced plant growth. The sown seeds, plant roots and micro organisms live in the soil. The physio-chemical as well as life processes are directly affected by the temperature of the soil. Soil temperature regulates the growth of microbes as well as nutrient availability. Nitrification will be stopped if the soil temperature exceeds beyond 50°C. Eg. On the sunny side, plants are likely to develop faster near a wall that stores and radiates heat. If shaded by the wall, however, the same variety may mature later. In such cases soil temperature is an important factor.

### **Importance of soil temperature on crop plants:**

The soil temperature influences many processes.

1. Governs uptake of water, nutrients etc needed for photosynthesis.
2. Controls soil microbial activities and the optimum range is 18-30°C.
3. Influences the germination of seeds and development of roots.
4. Plays a vital role in mineralization of organic forms of nitrogen.
5. Influences the presence of organic matter in the soil. (more under low soil temperature)
6. Affects the speed of reactions and consequently weathering of minerals.
7. Influences the soil structure (types of clay formed, the exchangeable ions present, etc.)

## Lecture 9:

### ATMOSPHERIC PRESSURE AND WIND

**Pressure:** Technically pressure is defined as “Force per unit area”.

**Atmospheric pressure:** The pressure exerted by a column of air with a cross sectional area of a given unit i.e., a square inch or a square centimeter extending from the earth surface to the upper most boundary of the atmosphere.

**Standard atmospheric pressure:** The atmospheric pressure varies continuously over a relatively small range and the average of these fluctuations is very close to a value adopted for certain standard conditions defined as “Standard atmosphere”. At a temperature of 15°C and at 45° latitude the standard normal pressure is 1013.2 millibars which is equivalent to 29.92 inches (or) 760 mm of mercury at the sea level, which is considered as standard atmospheric pressure.

#### Importance of pressure on crop plants

The effect of changes in atmospheric pressure on crop plants are normally studied in controlled environmental conditions, because, the temperature and other environmental elements also change markedly with changing altitude. The lower pressures experienced as altitude increases have important consequences for high altitude plant life. At high altitudes and low atmospheric pressures the solubilities of carbon-di-oxide and oxygen in water are reduced. This has important consequences for respiration, which relies on the transport of these gases in solution.

- The plants show stunted growth at higher altitudes as concentrations of oxygen and carbon di oxide reaches low
- At higher altitudes increase ultraviolet rays makes environment less favourable for plant growth
- The plant with strong root system and tough stems can live under increased wind speeds at low pressure in high altitude areas

#### WIND

Air in horizontal motion is known as “Wind”. Winds are named by the direction they come from. Windward refers to the direction a wind comes from and leeward is the direction towards which it flows. The wind which flows more frequently from one direction than any other is called as “Prevailing wind”. The speed with which the wind is blowing is called wind velocity and is measured in  $\text{km h}^{-1}$ .

#### Importance of wind crop plants

1. Transports heat in either sensible or latent form, from lower to higher latitudes,
2. Provides the moisture (to the land masses) which is necessary for precipitation

3. Moderate turbulence promotes the consumption of carbon – dioxide by photosynthesis.
4. Wind prevents frost by disrupting a temperature inversion
5. Wind dispersal of pollen and seeds is natural and necessary for certain agricultural crops, natural vegetation, etc.
6. Action of wind on soil

Wind causes soil erosion in two ways

- a. Strong wind flows loose and coarse soil particles (sand) and dust for long distances. In some areas all the soil is blown by this way, and no cultivation is possible in such areas.
- b. In dry countries and sea shores, strong wind is seen to eat up a cliff or a hard rock. When strong wind armed with millions of small particles of sand flows against a cliff or a hard rock, it gradually eats it up. The action is strongest near the ground so that the rock is undercut and eventually falls over.

## Lecture 10:

### ATMOSPHERIC HUMIDITY AND EVAPORATION

#### Atmospheric Humidity

Water is present in the atmosphere in the form of invisible water vapor, normally known as humidity. It will not be same on different places of earth. It will be higher in the regions of coastal areas and lower in distant places like deserts. It depends upon altitude. Water vapor content will decrease in the air after troposphere layer.

**Humidity:** The terminology related to humidity and concerned with gaseous form of water i.e., water vapor, several expression of the amount of water vapor in the air are used.

Humidity will be expressed in three types.

#### Absolute humidity

The actual mass of water vapor present in a given volume of moist air. It is expressed as grams of water vapor per cubic meter or cubic feet.

$$\text{Absolute humidity} = \frac{\text{Weight of water vapor (g)}}{\text{Specific volume of air (cubic meter / cubic feet)}}$$

#### Specific humidity

Weight of water vapor per unit weight of moist air. It is expressed as grams of water vapor per kilogram of air ( $\text{g kg}^{-1}$ ).

$$\text{Specific humidity} = \frac{\text{Weight of water vapor (g)}}{\text{Specific weight of air (kg / pounds)}}$$

Eg: If an air contains 250g of water vapor then its specific humidity=250g/kg

#### Relative Humidity

The ratio between the amount of water vapor present in a given volume of air and the amount of water vapor required for saturation under fixed temperature and pressure. There are no units and this is expressed as percentage.

Eg: At a specific environment, temperature and pressure air contains 6 g of water vapor. It requires 150 g of water vapor to reach saturation. Then relative humidity

$$= 60 / 150 \times 100 = 40 \%$$

$$\text{R.H.} = \frac{\text{Amount of water vapor in the air (g)}}{\text{Amount of water vapor needed for saturation of air (g)}} \times 100$$

## **Effects of humidity on crops**

Humidity is an important factor in crop production and it is not an independent factor but closely related to rainfall and temperature. It plays significant role in weather and climate. The dampness of air is called humidity.

- a. Humidity is the invisible vapour content of the air and is of great importance in determining the vegetation of a region.
- b. It affects the internal water potential of plants.
- c. Humidity is a major determinant of potential evapotranspiration. So, it determines the water requirement of crops.
- d. It influences certain physiological phenomena including transpiration.
- e. Change in relative humidity can produce various morphological and anatomical changes in the plants. For example, orchids grow abundantly in humid forests as epiphytes depend for their moisture supply on the atmosphere by developing certain morphological and anatomical characteristics that are not found in other plants (hygroscopic aerial roots).
- f. Xerophytes in desert region where relative humidity is low show certain adaptations to conserve water.
- g. High relative humidity can prolong the survival of crops under moisture stress.
- h. Relative humidity plays a significant role in the outbreak of disease and pest epidemics. High humidity promotes the growth of some saprophytic and parasitic fungi and bacteria which cause various plant diseases.
- i. Very high or very low relative humidity is not conducive for higher yields.

## **Evaporation**

Evaporation is the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. Evaporation results in accumulation of water vapor in the atmospheric air.

Rate of evaporation depends on air pressure, temperature, wind velocity and relative humidity. Moisture enters into atmosphere due to evaporation

## **Importance of evaporation on crop plants**

- Evaporation is an important process of hydrological cycle
- The evaporation from the soil is an important factor in deciding the irrigation water requirement of a crop
- In modifying the micro-climate of a crop the evaporation from the soil is an important factor for consideration

- Evaporation is the most important of all the factors in the heat budget after radiation
- The evaporation plays a key role in water economy
- Since, a certain amount of evaporation also demands a definite amount of heat, it provides a link between water budget and heat budget

## Lecture 11:

# RAINFALL

## Precipitation

For general use the terms precipitation and rainfall are used as synonyms with each other. Precipitation is defined as "Earthward falling of water drops or ice particles that have formed by rapid condensation in the atmosphere and are too large to remain suspended in the atmosphere" or Precipitation is any form of liquid or solid water particles that fall from the atmosphere and reach the surface of the Earth.

In condensation the water vapour is suspended in the air in different forms. But, in the precipitation an appreciable deposit either in solid or liquid form takes place on the earth surface. There are some common forms and different types in precipitation.

Precipitation occurs when heated air flows to top layers of atmosphere while water vapor cools down and condenses in the higher layers of atmosphere as small droplets . Condensation is when water vapor turns to liquid water. If the droplets get heavy enough (more than 0.2mm), they fall back to the ground due to gravity.

**Table 10.1. Different forms and types of precipitation**

S. No.	Form	Type
1	Liquid	Rain, Drizzle, Shower
2	Solid	Snow, Hail
3	Mixed	Sleet, Glaze

### I. Liquid forms

- 1 Rain:** It is defined as "Precipitation of drops of liquid water". The cloud consists of minute droplets of water and when these droplets combine and form large drops and can not remain suspended in the air they fall down as rain. These droplets are formed by rapid condensation. The size of rain drop is more than 0.5 mm in diameter. The imaginary lines drawn on a map connecting the points of equal rainfall are known as "Isohytes".
- 2 Drizzle:** It is more or less uniform precipitation of very small and minute rain drops. These drops can be carried away even by light winds. The diameter of drizzle drop less than 0.5 mm. It falls from low lying nimbostratus cloud. Fog merges to form drizzle.
- 3 Shower:** It is the precipitation lasting for a short time with relatively clear intervals.

## II. Solid forms

1. **Snow:** It is defined as “Precipitation of water in solid form of small or large ice crystals”. It occurs only when the condensing medium has a temperature well below freezing ( $0^{\circ}\text{C}$ ) temperature. It is also seen in the form of flakes which are aggregates of many crystals, formed due to sublimation of water vapour at sub-freezing temperatures.
2. **Hail:** It is a precipitation of solid ice. A strong convective column on a warm sunny day may cause the formation of pellets of spherical shape with concentric layers of ice, which is known as hail. Hail falls from cumulo-nimbus clouds and is often associated with thunder and storm. The size of hail ranges from peanut to cricket ball. The rainfall associated with the hailstorms is called as "Hail storm".

## III. Mixed

1. **Sleet:** It is the simultaneous precipitation of the mixture of rain and snow. Occasionally half frozen drops also fall, as sleet forms when rain drops are frozen as they fall through a layer of cold air.
2. **Glaze:** Freezing rain is known as glaze. This is formed at sub freezing temperatures when rain falls on objects or on ground. It looks like a sheet or coat.

## Condensation

- ◆ Condensation is defined as “the process in which the water vapour is converted into its liquid form”.
- ◆ This process is inverse of evaporation process. In condensation 600 calories of heat is released by each gram of water which was taken in the evaporation process.
- ◆ Thus the evaporation of water produces cooling effect and condensation gives warming effect.
- ◆ The visible forms of condensed moisture in the atmosphere are known as “Hydrometeors”.

## Forms of condensation

1. **Dew:** The deposition of water vapour in the form of tiny droplets on the colder bodies by condensation is known as dew. The temperature at which water vapour condenses is known as dew point temperature. When the objects on the surface of the earth get cooled in the night below dew temperature the water vapour is condensed on these surfaces. Dew forms when condensation takes place above freezing point. These surfaces should be good radiators and bad conductors of heat (Plant leaves; window glasses, pieces of paper etc.)

2. **Frost:** When the temperature of atmospheric air falls below  $0^{\circ}\text{C}$  before the dew point is reached, the water vapour is directly converted into crystals of ice called as “Frost”. This is a form of sublimation, because, water vapour is directly converted into ice. Frost is injurious to agricultural and horticultural crops.
  - a. **Hoar frost:** The white and opaque deposition in the form of ice crystals having the shapes of feathers, needles etc.
  - b. **Glazed frost:** This is caused by rains which are freezed on falling to the ground. This is transparent.
3. **Fog:** “Low cloud” near the ground surface. Extremely small water droplets suspended in the atmosphere reducing the horizontal visibility is known as ‘Fog’. Fog reduces the visibility. The conditions for the formation of fog are calm wind and atleast upto 75% relative humidity.

Fog is also called as “Cloud on and near the ground”. There is no particular form, shape or structure to fog. The following are types of fog.

**a. Radiation fog**

This results from radiation, cooling of the ground and adjacent air. These are not very thick and usually occurs in winter.

**b. Inversion fog:**

This is another type of radiation fog. This results from condensation of water vapour in a mass of warm moist air lying over a layer of cold air and near the ground.

These two fogs occur during night or cold morning. They disappear due to desaturation of air with vapours after the rise of sun in the morning.

**c. Advection fog**

This fog occurs when warm moist air rides in over a cold surface of either land or water. These fogs occur at any time of the day. They are thick, persistent and occur in oceans

- 4 **Smog:** The combined effect of smoke and fog droplets which reduce visibility is called “Smog”. Some solid particles like dust, smoke from fires and industry restricts the visibility further when these are added to smog which is known as ‘Haze’. On some occasions toxic materials present in fog, smog and haze and these are harmful. All these processes cause difficulty in rail, road, aviation and shipping traffics.

- 5 **Rime:** This is “Freezing fog” and is formed when wet fog has super cooled droplets immediately freeze on striking objects having temperatures below freezing point. White ice is formed on windward freezing point (telegraph post).
- 6 **Mist:** The difference between mist and fog is that mist contains more moisture. Mist is less dense fog. The suspended water droplets in the atmosphere restrict the visibility between 1100 to 2200 yards or number 4 on the coded scale (IMD). The obscuration is known as mist. The relative humidity is 75 per cent when mist occurs. Mist disappears with rising sun.

### **Types of rainfall**

There are mainly 3 types of rainfall which are as follows:

#### **Convective rainfall:**

Rainfall occurs due to thermal convection due to heating of ground surface. When land gets warm, air starts to move upward. This causes the air to expand, rise and move upwards. As the air rises it cools (10°C per kilometer) quickly and becomes saturated, relative humidity reaches 100% and dew point is reached where condensation begins in tiny water droplets when it exceeds 0.2mm size falls back as rainfall. These rains are known as convective rains and mostly occur in the tropics.

#### **Cyclonic or frontal rainfall:**

The rains received from cyclones are known as 'cyclonic rains'. Winds with different densities and temperature were suddenly blown from higher pressure areas to lower pressure areas, the air rises at concentrated area cools down and condenses as falls back as rainfall for longer periods. Frontal rain produces a variety of clouds, which bring moderate to heavy rainfall. Normally these types of rains were observed at colder regions and rare at equatorial regions.

#### **Orographic or relief rainfall:**

When moist air coming from the sea or ocean strikes a mountain it can not move horizontally. It has to overcome the mountains. When this air rises upward, cools down, a cloud is formed and condensation reaches droplet size more than 0.2mm starts precipitation. These rains are known as orographic rains. These are also known as 'relief rains' as the rains also occur when the air from sea or ocean strikes or passes over relief barriers. Due to these processes rains with high intensity are possible on the windward side of the mountain. These types of rainfall normally occur at windward side of mountain series.

## Lecture 12:

### MONSOON

The term monsoon is derived from an Arabic word “Mausim” means “Season”. There are different concepts to explain Indian monsoons. Of them the “Thermal concept” proposed by Halley in 1636 is of more practical relevance than other concepts like aerological, Flohins etc. The two types of distinguished monsoons over India are

1. South-West monsoon (SW),
2. North-East monsoon (NE)

#### 1. South-West monsoon (SW)

1. In summer the land mass of India heats quickly and develops a strong low pressure centre, particularly over north-west India during April and it exists upto September. The low pressure areas near the equator are called “Doldrums”.
2. As the pressure over the adjacent oceans is high, a sea to land pressure gradient is established.
3. Therefore, the surface air flow is from the high pressure areas over the oceans towards the low pressure areas over the heated land.
4. Even though India should have North east monsoon winds throughout the year due to its position in NE trade wind zone, the SW winds predominate because of the low pressure through lesing along Ganges and upper India.
5. The air that is attracted into the centres of low pressure from over the oceans is “Warm and moist”.
6. This monsoon is active from June to September.
7. The rainfall received is 80 to 90 per cent of the total annual rainfall of India covering all parts.
8. This monsoon enters Kerala on June and by 15 July reaches the northern most parts of the country
9. There are two branches of the South West Monsoon.
  - a. The Arabian Sea branch: This branch crosses Western ghats reaches kerala.
  - b. The Bay of Bengal branch: This branch crosses Gangetic plains

## **North-East monsoon**

1. A complete reversal of the South west monsoon winds takes place during winter.
2. In this season the land mass over India cools more rapidly than the surrounding oceans.
3. So, a strong high pressure centre develops over the continent.
4. On the other hand, the pressure over the adjacent oceans is relatively lower.
5. As a consequence, the pressure gradient is directed from land to sea and winds flow in North-East direction.
6. Therefore, there is an outflow of air from the continental land mass to the adjacent oceans.
7. The air flow brings “Cold dry” air towards low latitudes.
8. This monsoon is active from October to mid December.
9. The rainfall received is 10 to 20 per cent of the total annual rainfall of India covering parts of Andhra Pradesh (Nellore, Chittoor) and Tamil Nadu.
10. The driving mechanisms of monsoon
  - a) Differential heating of land and ocean masses causes a pressure gradient and wind is driven accordingly.
  - b) Twist to wind by rotation of earth.
  - c) Moist process determines strength, vigour, location etc.
11. The path of monsoon air is distributed by diverse features like Earth’s rotation

## **Mountain barriers**

The retarding effect of friction as winds blow over land.

## **Effect of rainfall (water) on crop plants**

- Moisture is essential for germination of seed and growth of the plant which is obtained from the rainfall.
- The source of water for the major irrigation projects (Nagarjuna and Bhakranangal etc), ponds, lakes and the underground water is rainfall. Only when these are filled up the water is diverted for irrigation to the crops. So, the water needed for crop plants, day to day activities of human beings, for industries is met from the rain water.

- For optimum yield, the crops should not be subjected to moisture stress or drought. Optimum soil moisture is essential. Distribution of rainfall is more important than the intensity of rainfall. For example in a place, 10 cm rainfall received in 3-4 spells in a week or 10 days is better than the 10 cm of rainfall received in 1 hour.
- In low rainfall areas the crops are subjected to drought, hence the crops suitable for drought conditions are grown. For example in low rainfall areas of Telangana on light soils castor is mostly grown. In a similar way on light soils of Anantapuramu district, groundnut is mostly grown. In heavy soils, sorghum, bengalgram are grown during *rabi* season.
- If high amount of rainfall is received during harvest of the crop then lodging of the plants occur and harvesting becomes difficult. In crops like paddy if high amount of rainfall is received at harvest, then quality of the grain is lost and even the germination of the seed occurs.

#### **Influence of heavy rainfall**

- Due to heavy rainfall, the soil gets saturated quickly, infiltration is reduced and waterlogging occurs on the surface of the soil resulting in anerobic conditions.

#### **Influence of low rainfall**

- Low rainfall with improper distribution results in drought conditions hence, the nutrient uptake by the plants is reduced which results in poor growth of plants and yield.
- Under stress conditions soil moisture is less due to high evaporation losses

## Lecture 13:

### ABNORMAL WEATHER CONDITIONS

Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy.

The following are the adverse weather conditions and the possible management strategies.

#### 1. Rainfall

Rainfall is the major source of water which is essential for plant growth and development. However, rainfall is considered under it is a. Excess rainfall b. Scanty rainfall and c. Untimely rainfall. The total amount of rainfall in a season is not the criteria. But, its well distribution over a large area is desirable. Heavy rains with short frequencies will result in floods. If 125 mm of rain is received in two and half hours it is called as heavy rain.

##### a) Excess rainfall

- 1 Even though water in all its forms plays a fundamental role in the growth and production of all crops, excessive amounts of water in the soil alter various chemical and biophysical processes.
- 2 Free movement of oxygen is blocked and compounds toxic to the roots are formed, due to drainage problem.
- 3 Soils with high rate of percolation are unsuitable for cultivation as plant nutrients can be removed rapidly.
- 4 Heavy rains directly damage plants on impact or interfere with flowering and pollination.
- 5 Top soil layers are packed or hardened which delays or prevents emergence of tender seedlings.
- 6 Snow and freezing rain are threats to winter plants. The sheer weight of ice and snow may be sufficient to break limbs on trees and shrubs.
- 7 A thick ice cover on the ground tends to produce suffocation of crop plants such as winter wheat.
- 8 Under excess rainfall conditions floods occur in areas drained by large river systems.
- 9 Floods submerge crops; silt up fields; tank bunds and river embankments are washed off.

### **Management of excess rainfall (floods)**

- 1 By constructing multipurpose projects such as irrigation and electric systems.
- 2 Planned afforestation.
- 3 Keeping the field drains open
- 4 By growing flood obstructing crop

### **b) Scanty rainfall**

This is a synonym with "Inadequate rainfall" or 'Drought'. The influence of drought can be observed not only on phenology but also on phenophases of crop plants.

- 1 Water limitation from seedling emergence to maturity in all the cereals is very damaging.
- 2 Water stress/drought during flowering reduces the size of inflorescence, affect fertilization, grain filling and reduce final yield.
- 3 Plants show wilting symptoms
- 4 Cell division and enlargement are very sensitive to drought stress, which results in stunted growth.
- 5 Drought effect nutrient absorption, carbohydrate and protein metabolism and translocation of ions and metabolites.
- 6 Abscission of leaves, fruits and seeds can be induced by plant water deficit during droughts.
- 7 Plant respiration is drastically reduced.

### **Management of drought / scanty rain**

- 1 Application of sufficient irrigation water negates the condition of insufficient or scanty rain.
- 2 Discover amount of water needed at various stages and adjust the sowing dates.
- 3 Conserve water by suitable management of fallow and cropped field's viz., breaking up the surface to reduce runoff, removal of weeds, digging pits of small size which collects runoff water, etc.

### **c) Untimely rains**

This refers to rainfall received too early or too late in the season with the result that normal agricultural operations are upset.

- 1 Too early rains do not permit proper preparation of seedbed due to heavy rains.

- 2 Too late rains delay sowings and pest attack cause colossal losses.
- 3 Wet spells during flowering and harvesting results in poor fertilization and subsequent loss in yield.

#### **Management of untimely rains**

- 1 Farmers shall be advised to follow the weather forecasting by IMD for proper management of their crops through crop-weather advisories.
- 2 Contingency crop plans shall be made available to the needy farmers.

#### **d) Tropical cyclone**

Tropical cyclone, also called typhoon or hurricane, an intense circular storm that originates over warm tropical oceans and is characterized by low atmospheric pressure, high winds and heavy rain. Drawing energy from the sea surface and maintaining its strength as long as it remains over warm water, a tropical cyclone generates winds that exceed 119 km (74 miles) per hour. In extreme cases winds may exceed 240 km (150 miles) per hour, and gusts may surpass 320 km (200 miles) per hour.

#### **e) Thunderstorms, dust storms and hail storms**

Thunderstorms, which kill more people than hurricanes and tornadoes, produce thunder, lightning and sometimes hail. Violent storms such as tornadoes and hurricanes are equally destructive. These storms are known as local severe storms. As many as 44,000 thunder storms occur daily on earth.

- 1 These are formed in a situation where a great deal of the energy for their genesis and development comes from the release of the latent heat of condensation in rising humid air.
- 2 These local storms cause severe damage to the standing crop by causing mechanical injury to the plants.
- 3 In dust storms, the dust is rised by the wind covers small plants, which may cause stomata closure and suffocation.
- 4 Hails cause direct damage to crops by lodging, shattering of seeds etc., depending on their intensity.

#### **Management of storms**

- 1 Prevention of hails by hail suppression techniques.
- 2 Following forecasts of weather and protecting crops.
- 3 Spraying of salt on harvested paddy, to prevent the germination / sprouting of harvested produce.

## **f. Flood**

Years in which actual rainfall is 'above' the normal by twice the mean deviation or more is defined as years of floods or excessive rainfall.

(a) *Climatic causes* - The predisposition of a climate to storms producing excessive precipitation is the fundamental basis of the flood. In some cases, storms occur irregularly; in others they follow a seasonal pattern. Two types storms causing flood are:

- Violent thunder showers, which is of short duration and produces a flash flood.
- Prolonged wide spread rain creates extensive flooding over entire watersheds.

(b) *Damages* - The damages due to flood are:

- Loss of human life, cattle wealth and properties.
- Loss of field crops, soil-may vary according to the duration and intensity of flooding.

Not all floods are "bad" for agricultural areas in the lower-Nile flood plain and Mesopotamia depend on annual river flooding and the accompanying deposits of fertile silt.

(c) *Management of flood* - For managing flood, the following measures may be taken.

- Conserve water in the soil where it falls by increasing porosity of the soil and growing vegetations to reduce runoff.
- Increase the capacity of channels (rivers) to carry excess water direct to the ocean or to the water bodies for storage.
- Avoid silting of water courses to conserve soil by adopting soil conservation techniques such as by vegetative barriers, contour bunding, contour cultivation, allowing grassy water ways etc.

The most injurious aspects of flooding or too much of water are lack of aeration and reduction in oxygen supply. In wet soil, nitrification suffers which causes yellowing and sickly appearance of plants. The following measures may be taken for the crops affected by flood.

- Drain away excess water as early as possible.
- Give a foliar spray of nutrients especially N for immediate relief Ex. rice: 1.0 % urea + 0.5 %  $ZnSO_4$  .
- Spray fungicides to protect the crop from fungal diseases, which are common under high moisture condition.

## 2. Temperature

Temperature is essential for all plant physiological processes, gaseous exchange between plant and environment, stability of plant enzymatic reactions etc (chapter 3). However, both cold and heat waves and abnormal soil temperatures are adverse to crop growth and development.

### (a) Cold waves

During winter (December - February), temperature decreases generally over the Indian subcontinent. It is lower in northern-India and higher in southern- India. This fall in temperature may cause damage to the crops. If the temperature drops on freezing or below, a frost may occur which causes severe damage to the crops/crop plants. Threat of frost is danger to crops.

1. Frost is a form of condensation that forms on cold objects when the dew point is below freezing.
2. Frosts are of two types.
  - a. Advection or air mass frost: Which results when the temperature at the surface in an airmass is below freezing.
  - b. Radiation frost: Which occurs on clear nights with a temperature inversion.
3. There is a special case of frost caused by loss of heat by evaporation. This occurs when cold rain showers wet the leaves and are then followed by dry wind.

### Advection frost

The usual effects of advection frost are:

- 1 The injury and death caused by frost is due to the formation of ice crystals in and outside the plant cells.
- 2 During dormancy, plants can withstand lower temperatures upto  $-20^{\circ}\text{C}$ .
- 3 Once growth has commenced temperatures of few degrees below freezing point may be fatal.
- 4 The cell sap gets frozen below  $0^{\circ}\text{C}$ , as also between cells.
- 5 Extra cellular ice formation occurs followed by withdrawal of water from the cell.
- 6 The protoplasm may become dehydrated and brittle, resulting in mechanical damage, or the cell may contract and damage the protoplasm.

## **Management of advection frost**

For production of most field crops, the only satisfactory solution to the problem of advection freezing is to avoid it as far as possible by planting after the damage is past and by selecting varieties which will mature before the beginning of the hazard.

## **Radiation frost**

The damage due to radiation frost differs from the above freeze damage in degree and its spotly occurrence.

- 1 This radiation frost damage is critical during critical stages of growth.
- 2 Young seedlings may be killed.
- 3 Flowering stage is most prone.
- 4 Crops like potato, tomato and melons are vulnerable right upto maturity.
- 5 For most field crops and orchard crops flowering stage is most critical for frost damage.
- 6 Frosty nights followed by warm sunny days produce a sun clad on orchard fruits, considerably reducing their production.

## **Management of radiation frost**

The management of radiation frost can be grouped into a) Passive and b) Active

### **a) Passive methods**

- Clean cultivation.
- Maintenance of soil moisture.
- Wrapping plants with insulating material and enclosing the basal part of the plant.
- Proper site selection.
- Choice of growing season.
- Breeding of cold resistant varieties.

The above methods can be followed even for advection frost also. These passive methods do not involve any modification of environment.

### **b) Active methods**

The active methods of frost protection are many, like use of

- Heaters.
- Wind machines.
- Sprinkling water.
- Following weather forecast for better management of crops.

### **c) Heat Waves**

These are very harmful during summer. These are experienced over Deccan and Central parts of India during March to May. The harmful effects include shedding of fruits, plants drying of water resources.

- 1 Loss of water by evaporation from irrigation channels.
- 2 Transpiration increases from plants beyond recouping levels
- 3 Plants tend to wilt and die owing to rapid desiccation.
- 4 Hot winds cause shriveling effect at milk stage of all agricultural crops.

### **Management of heat waves**

Adoption of specific agronomic practices like, shelterbelts, choice of heat tolerant varieties etc.

### **d) Cold wave**

A cold wave is a rapid fall in temperature within a 24-hour period requiring substantially increased protection to agriculture, industry, commerce, and social activities. The precise criterion for a cold wave is determined by the rate at which the temperature falls, and the minimum to which it falls. This minimum temperature is dependent on the geographical region and time of year.

## **3. Drought**

The term drought can be defined by several ways.

1. The condition under which crops fail to mature because of insufficient supply of water through rains.
2. The situation in which the amount of water required for transpiration and evaporation by crop plants in a defined area exceeds the amount of available moisture in the soil.
3. A situation of no precipitation in a rainy season for more than 15 days continuously. Such length of non-rainy days can also be called as dry spells.

## **4. Excessive or defective insolation**

Excessive solar radiation results in rise of soil and air temperatures. Defective insolation with consistently cloudy weather on one hand and consistently bright and high intensity sunshine on the other hand causes enormous damage to crop plants.

- 1 Cloudy weather retard growth, affect pollination and cause disease and pest incidence.
2. High solar radiation intensity cause pollen burst or flower drop.

## **Management**

Since, these are very rare, the location specific solutions like

- 1 Proper site selection.
- 2 Allowing air drainage.
- 3 Adequate water supply.
- 4 Pruning of orchard trees.
- 5 Spray of chemicals and plant hormones.
- 6 Covering plants with "hot caps" (covering plants with some standard and recommended material) may prove beneficial.

## **5. Wind**

Wind has its most important effects on crop production indirectly through the transport of moisture and heat. Vegetative growth at 'Zero' wind, as experienced in glass houses or under low glass cover is luxuriant. But, there is typically a reduction in vegetative growth as the wind increases to small values, viz., 1 or 2 metres per second.

### **Beneficial effects of winds**

- 1 Moderate turbulence promotes the consumption of carbon-dioxide by photosynthesis.
- 2 Prevent frost by disrupting a temperature inversion.
- 3 Wind dispersal of pollen and seeds is natural and necessary for certain agricultural crops and natural vegetation also.

### **Harmful effects of winds**

- 1 At sustained high speeds (12-15 metres per second) at plant height, plants assume a low, dwarf like form, whilst the intermittent high wind speeds experienced in gales, hurricanes etc., results in gross physical damage to bushes and trees.
- 2 At higher wind speeds, the shape of the orchard tree alters giving rise to the characteristic wind shaping of trees in exposed positions.
- 3 Leaves become smaller and thicker.
- 4 Breakage occurs and bushes and trees subjected to natural (seasonal) pruning.
- 5 Direct mechanical effects are the breaking of plant structures, lodging of cereal crops, or shattering of seed from panicles.

## **Management of high winds**

It can be done by using wind breaks and shelter belts.

- 1 The effects of wind on evaporation can be avoided by using proper method of irrigation.
- 2 The damaging effect of wind can be reduced over a limited area by the use of shelter belts (rows of trees planted for wind protection) and wind breaks (any structure that reduce the wind speed).

## **Tornado**

This is a violent, destructive storm of small horizontal dimensions. A cumulonimbus cloud forms into a funnel shape with an vortex extending from the base of the storm to the surface. The whirl-wind encircles a small dimension of about 500 metres. These are capable of causing severe structural and other damages. The violent winds associated with this abnormality are strong upward air currents. The tornados occurring on water are known as “Water spouts”.

## **Management**

- 1 Warning in advance
- 2 Precautions to protect the agricultural produce like transportation to safety places etc.
- 3 Quick removal of debris immediately after damage.

## Lecture 14:

### WEATHER FORECASTING

Weather is the major factor which influences agricultural operations and farm production. A substantial portion of crop is lost due to aberrant weather. The pre-harvest loss may range between 10 and 100 per cent in various crops.

The main ways we can forecast the weather include looking at current weather conditions, tracking the motion of air and clouds in the sky, finding previous weather patterns that resemble current ones, examining changes in air pressure, and running computer models.

The India Meteorological Department (IMD) is an agency of the Ministry of Earth Sciences of the Government of India. It is the principal agency responsible for meteorological observations, weather forecasting and seismology.

India Meteorological Department (IMD) was established in Pune in 1875. It collects met data from all the centers and coordinates the weather-related issues all over the country. There are about 500 meteorological observatories of different types, distributed all over India, for the purpose of forecasting.

The prime object of Agricultural Meteorology Division, India Meteorological Department (IMD), Pune is to minimize the impact of adverse weather on crops and to make use of crop-weather relationships to boost agricultural production. Presently, 130 Agromet Field Units (AMFU) are working in India. ICAR has sanctioned 52 Agromet research centers in 21 Agricultural research stations of 21 Agricultural Universities.

There are 6 Regional Meteorological Centre's, each under a Deputy Director General with headquarters at Mumbai, Chennai, New Delhi, Calcutta, Nagpur and Guwahati. Weather bulletins will be broadcasted through Akash Vani (radio) in local languages.

#### **Types of weather forecasting**

There are three types of weather forecasting for agriculture.

1. **Short range weather forecast:** It is valid for 12-48 hours with 70-80% accuracy. Low pressure changes in the weather can be notified before 48-72 hours.

Short range forecast gives emphasis on temperature, wind velocity and directions, duration of sunshine, time and amount of precipitation, R.H, heat, cold wave conditions and thunder storms etc.,.

Uses (Applicability):

- i. Scheduling of irrigation
- ii. Adjusting of time of agricultural operations
- iii. Protection of plants from frost
- iv. Useful for irrigation engineers, mariners, aviation engineers and farmers

**Medium range weather forecast:** It is valid from 3 days to 2-4 weeks.

It gives emphasis on type of weather, sequence of rainy days, normal weather, sequence of rainy days, normal weather hazards in farming such as strong winds, extended dry or wet spells.

Uses:

- i. Useful to determine sowing time
- ii. Useful to determine depth of sowing
- iii. Planning of irrigation
- v. Decision on harvesting
- vi. Decision on time of spraying to get higher efficiency
- vii. Management of labour and equipment

2. **Long range weather forecast:** It is valid for four weeks to months, season and year. It has emphasis in abnormality of temperature and precipitation.

Uses:

- i. To decide on soil moisture management
- ii. To decide on irrigation scheduling
- iii. Decision on selection of crops
- iv. Decision to manage irrigation with limited water supply
- v. Decide on cropping pattern and
- vi. To determine crop yield

	<b>Types of forecast</b>	<b>Validity period</b>	<b>Main Users</b>	<b>Predictions</b>
1	Short Range a) Now casting	Up to 72 hours 0-2 hours	Farmers, marine agencies and general public	Rainfall distribution, heavy rainfall, heat and cold wave conditions, thunder storms etc.,
	b) Very short range	0-12 hours		

	<b>Types of forecast</b>	<b>Validity period</b>	<b>Main Users</b>	<b>Predictions</b>
2	Medium Range	Beyond 3 days and up to 10 days	Farmers	Occurrence of rainfall, temperature
3	Long Range	Beyond 10 days to a month and a season	Planners	This forecasting is provided for Indian monsoon rainfall. The outlooks are usually expressed in the form of expected deviations from normal rainfall.

**Synoptic report** Observed weather conditions are marked in brief coded form as a synopsis of the conditions. Such a brief report on weather conditions is known as “Synoptic report”.

### **Synoptic charts**

A synoptic chart is any map that summarizes atmospheric **conditions** (temperature, precipitation, wind speed and direction, atmospheric pressure and cloud coverage) over a wide area at a given time. They display an overview of the weather conditions observed from many different weather stations, aeroplanes, balloons and satellites.

### **Weather Forecasting**

The weather elements which influence the agricultural operations and crop production can be forecast upto different spans of time. Weather forecast is defined as “prediction of weather for the next few days to follow”.

### **Weather data used in forecasting**

The following weather elements are measured routinely.

1. Pressure, temperature, wind (speed and direction) humidity.
2. Rainfall, cloud (type and amount), visibility pressure change, present and past weather, maximum and minimum temperatures etc.

**Table 14.1 Important symbols for synoptic representation of precipitation:**

			<b>Rain (light, moderate, heavy)</b>
			<b>Snow (light, moderate, heavy)</b>
			<b>Thunder (with rain, snow, no precipitation)</b>
			<b>Shower (rain, snow)</b>
			<b>Drizzle</b>
			<b>Freezing rain, Freezing drizzle</b>
			<b>Ice pellets/Sleet</b>
			<b>Fog (shallow, deep)</b>
			<b>Haze</b>

### Utility of weather forecasting

In India the total annual pre harvest losses of various crops range from 10 to 100 per cent. Similarly, the post harvest losses average upto 10 per cent. When an accurate weather forecast is given for the needs of agriculture it contributes immensely to the monetary benefits of the farmers.

There are various uses of weather forecasting in day-to-day life, it can be as simple as deciding whether to take an umbrella with you on your work or to deciding your outfit. Following are some of the places where weather forecasting plays a major role:

1. The forecast of the weather events helps for suitable planning of farm.
2. It helps in to undertake or withheld the sowing operation
3. It helps in following farm operation:
  - a. To irrigate the crop or not
  - b. When to apply fertilizer or not.
  - c. Whether to start complete harvesting or to withhold it.

4. It also helps in to take measures to fight frost.
5. It helps in transportation and storage of food grains.
6. Helps in management of cultural operations like ploughing, harrowing, hoeing, etc.
7. It helps in measures to protect livestock. Short term adjustments in daily and weekly agricultural operations is possible.
8. If heavy rain occurs immediately after sowing of seeds, the seeds are washed away. If a hail storm occurs during harvesting it causes shedding of grains and fruits. If warned in time the farmer would hurry up some of the operations or postpone them suitably adjusting the cropping operations to weather conditions.
9. The critical periods for normal growth of the crop can be adjusted for healthy growth and development of crop.
10. Markedly improve the yields of crops both qualitatively and quantitatively.
11. If farmer knows when the monsoon rains are likely to commence and how the rainfall could be from time to time in the season he would be able to plan his agricultural operations like preparation of seed bed, manuring, intercultivation including drying and threshing of the produce.
12. The weather forecasts also provide guidelines for long range seasonal planning and selection of crops suited to the anticipated climatic condition.

## Lecture 15:

### TILLAGE

**Tillage:** The mechanical manipulation of soil with tools and implements for obtaining good tilth for better seed germination, seedling establishment and growth of crops is known as tillage.

**Tilth:** It is the physical condition of soil resulting from tillage.

#### Objectives of Tillage:

1. To produce a satisfactory seed bed for good germination and good crop growth.
2. To make the soil loose and porous.
3. To aerate the soil
4. To control weeds
5. To remove the stubbles. (that may harbour pests)
6. To expose the soil inhabiting pathogens and insect pests to sun and kill them.
7. To break hard pans in the soil
8. For deep tillage and inversion of soil
9. For incorporating bulky organic manures
10. To warm up the soil
11. To increase infiltration rate.

#### Types of tillage

Tillage operations are grouped into two types based on the time at which they are carried out.

##### 1. **Preparatory cultivation** – which is carried out before sowing the crop

i) Primary tillage – Ploughing

ii) Secondary tillage – harrowing

iii) Layout of seed bed – country plough can be used.

##### 2. **After cultivation** – That is practiced after sowing the crop.

**Primary tillage or ploughing:** It is the operation done with a plough to open the hard and compact soil and to uproot the weeds and stubbles. But with this operation the soil will not come to fine tilth because of the presence of clods and stubbles. Therefore, sowing cannot be taken up with primary tillage. In order to make the soil suitable for sowing i.e. seed bed secondary tillage is to be done. Ex. Mould board plough, Disc plough, country plough, etc.

### **Factors influencing preparatory tillage:**

1. **The previous crop grown:** Stubble of previous crop influence the tillage (Redgram, cotton stubbles are very deep rooted and require deep tillage to remove them)
2. **The crop to be grown:** Crops like sorghum can be grown with rough tilth. For very small seeded crops like tobacco, Mustard, chillies and small millets etc., fine tilth is required. Deep tillage is required for crops like tuber crops and sugarcane.
3. **Types of soil:** Clay soil can be ploughed only within a narrow range of soil moisture and the power or drought required is high. Light textured soils can be ploughed under a wide range of soil moisture and require less drought.
4. **Climate:** Deep tillage is not permitted in shallow soils in low rainfall areas as it leads to rapid drying and loss of stored soil moisture. Use six tyned gorru and guntaka for sowing and intercultural operations so that loss of moisture can be minimized. Deep cultivation is possible in high rainfall areas.
5. **Type of farming:** Intensive cropping requires intensive tillage. Depending up on number of crops grown in a year, the number of ploughings will be increased or decreased.

### **Primary Tillage Implements**

Primary tillage is the deepest operations/performed during the period between two crops. The following are the implements used for primary tillage.

1. Country/wooden/Desi plough
2. Improved iron plough
3. Mould board plough
5. Turn wrest plough
6. Disc plough

## Lecture 16:

### SECONDARY TILLAGE, INTERCULTIVATION AND LAYOUT OF SEED BED PREPARATION

#### Secondary tillage

Lighter or finer operations performed on the soil after primary tillage are known as secondary tillage. After ploughing, the fields are left with large clods with some weeds and stubbles partially uprooted.

Harrowing is done to a shallow depth to crush the clods and to uproot the remaining weeds and stubbles. Disc harrows, cultivators, blade harrows etc., are used for this purpose. Planking is done to crush the hard clods to smoothen the soil surface and to compact the soil lightly. Thus the field is made ready for sowing after ploughing by harrowing and planking. Generally sowing operations are also included in secondary tillage.

#### After Cultivation

It begins with the germination of the seed and continue till the harvest of the crop. After tillage is any operation done in a standing crop either to the crop or to the field. The main objective is to promote the growth of the crop to get higher yield. After cultivation operations include

**Gap filling:** It is the process of filling the gaps by the same seed. It is done 10 days after sowing to maximum optimum population so as to realize the higher yields.

**Thinning:** Process of removal of excess plants from the fields with the objective of maintaining optimum plant population.

**Weeding:** It is the removal of unwanted plants.

**Intercultivation:** It is any operation done only to the field in a standing crop.

**Fertilizer application:** Process of application of fertilizers to the crops at appropriate time as per the recommendations.

**Irrigation:** Application of water artificially for the purpose of supplying moisture essential for plant growth.

**Plant protection:** Whenever pest and diseases are observed, plant protection measures are taken up to control them.

All these operations are required in general for all the crops but some crops require special after cultural operations.

## **Special operations:**

**Earthing up:** This operation is done to provide anchorage to the crops and to facilitate drainage during the rainy period. Soil is loosened and the loose soil is mounted on both sides of the crop. Practiced for crops like maize, sugarcane, banana, tuber crops, etc.

**Wrapping:** Process of twisting the bottom leaves round the cane stem and the cane is completely covered giving protection from direct sunlight and rats. It also prevents the attack of shoot borer.

**Propping:** This is practiced in banana and sugarcane. It is the operation of tying the canes together using the dry leaves and bottom leaves twisted to prevent the plant from lodging. In banana, bamboo propping is done.

**Topping (cotton):** Process of removal of the apical or terminal portion of the main stem alone or with monopodial branches is called topping. It is done to promote sympodial branching.

**Topping and desuckering (tobacco):** Process of removal of terminal bud or inflorescence with or without some of small top leaves just before or after the emergence of a flower bud is called topping in tobacco. It is done to promote the quality of leaf.

The process of removal of shoots that arise from the auxillary buds known as suckers as a result of topping in tobacco is called desuckering. Coconut oil is used for desuckering. The main objective is to divert the energy and nutrients from the flower heads to the leaves i.e. economic part.

**Nipping (castor):** Process of removal of axillary buds on the main stem when the primary spike emerges in 40-45 days after sowing to allow a single spike to develop is called nipping.

**Roguing:** Process of removal of off type plants in the crop field is known as roguing. It is an unwanted plant belonging to the same species but of a different variety. It is mainly done in seed production plots.

**Hand pollination:** Hand pollination can be done by gentle rubbing of the sunflower head with palm or muslin cloth during flowering period between 7-11 am on alternated days for two weeks.

## **Intercultivation:**

Any operation done only to the field in a standing crop preferably between the crop rows is called intercultivation.

## **Advantages:**

1. Soil becomes loose, porous and well aerated
2. Water holding capacity of the soil is improved

3. Controls weeds effectively
4. Earthing up of soil towards the base of the crop
5. Application of fertilizers to crops
6. Cracks developed in the field is completely closed, thereby arresting the water loss from soil

### **Laying of seed bed:**

Majority of the crops can be sown after secondary tillage. But certain crops under certain situations require a special seed bed. Laying of seed bed differs with the crop and situation. Some of the special types of seed beds are

**Ridge and furrow:** Crops like maize, sugarcane, solanaceous vegetables or any other crop which cannot tolerate water stagnation, the seed bed is to be laid out in the form of ridges and furrows because during heavy rainfall, water will be collected in the furrows and there by water stagnation is avoided. Usually the crop will be sown on ridges.

**Broad bed and furrows (BBF):** This method is exclusively adopted in (black soils) clayey soils or vertisols and was developed by ICRISAT. Since clayey soils are ill drained, a furrow will be made at regular intervals and the crop is raised on beds and the furrows act as drainage channel.

**Check basin method :** Some of the vegetable crops and crops grown in small areas under well irrigation with limited water availability, this method is used. Field will be divided into small plots with bunds on all the four sides and such plot is known as check basin.

**Marker type:** Marker is an implement with small teeth located at equal distances on the implement. For crops like tobacco and chillies the marker will be drawn on the fields in both the direction and crop is sown or planted at the intersection points so as to create uniform spacing throughout the field. Intercultivation can be done with the help of implements in both the directions.

**Secondary tillage implements:** Cultivators, disc harrow, blade harrows or guntaka

**Intercultural Implements:** Blade harrow, metla guntaka, meesala guntaka, rekkala guntaka, danti, Japanese rotary weeder, cono weeder, star weeder

**Land leveling implements:** Buck scraper, levelling board, wooden float

**Land shaping implements:** Ridge plough, bund former, rollers

The rollers are used for breaking clods and compacting the soil. There are different types of rollers in use.

(i) Iron rollers

(ii) Stone rollers

## **Lecture 17:**

### **PUDDLING AND MODERN CONCEPTS OF TILLAGE**

#### **Nursery bed preparation for paddy**

##### **Puddling:**

Rice growth and yield are higher when grown under submerged conditions. Maintaining standing water throughout the crop period is not possible without puddling. Puddling is ploughing the land with standing water so as to create an impervious layer below the surface to reduce deep percolation losses of water and to provide soft seedbed for planting rice. Puddling operation consists of ploughing repeatedly in standing water until the soil becomes soft and muddy. Initially, 5 cm to 10 cm of water is applied depending on the water status of the soil to bring it to saturation and above and the first ploughing is carried out.

After 3 to 4 days, another 5 cm of water is applied and later after 2 to 3 days second ploughing is carried out. By this operation, most of the clods are crushed and majority of the weeds are incorporated. Within 3 to 4 days, another 5 cm of water is given and third ploughing is done in both the directions. The third ploughing can be done either with a wetland plough or with a wetland puddler. Planking or levelling board is run to level the field. To know whether puddling is thorough or not, a handful of mud is taken into the hand and pressed. If it flows freely through fingers and if there are no hard lumps, puddling is considered to be thorough. Unlike in other tillage operations, puddling aims at destroying soil structure. The individual soil particles viz., sand, silt and clay are separated during puddling operation. The soil layer with high moisture below the plough sole is compacted due to the weight of the plough. The soil particles separated during puddling settle later. The sand particles reach the bottom, over which silt particles settle and finally clay particles fill the pores thus making impervious layer over the compacted soil.

Puddling is done with several implements depending on the availability of equipment and nature of the land. Soils with bulk density less than 1.0 are considered as problem soils as puddling with animal-drawn implements is difficult. The feet of the animals sink very deep during puddling. Under such a situation, puddling is done with spades by manual labour. Most of the farmers use wetland plough or worn out dryland plough or mouldboard plough. Wetland puddler consists of a series of blades attached to a beam at an angle. When it is worked, the soil is churned and puddling operation is completed quickly compared to the country plough. Generally green manure is applied to rice field which is incorporated by green manure trampler. Tractor drawn implements can be used for puddling by attaching cage wheels to prevent sinking.

**Advantages:**

- It obtains a soft seed bed for the seedlings to establish themselves faster
- It control weeds
- It facilitates easy transplantation
- It will mix organic matter with the soil
- It creates an impervious sub soil layer for reducing deep percolation and leaching losses
- It minimizes leaching losses of nutrients particularly nitrogen and thus increase the availability of plant nutrient through reduced soil conditions.

**Modern concepts of tillage****1. Minimum tillage:**

It is defined as the method aimed at reducing tillage to the minimum necessary for ensuring a good seed bed, rapid germination, a satisfactory crop stand and favourable growing conditions. Tillage can be reduced in two ways i.e. by omitting operations which do not give much benefit when compared to the cost and combining agricultural operations like seeding and fertilizer application.

**Advantages:**

- Improved soil condition (soil fertility) due to decomposition of plant residues in situ
- Improved soil aeration
- Increased water infiltration
- Reduction of soil compaction and less resistance to root growth
- Conserving soil moisture and reduce erosion
- Energy requirement is less
- Cost of production is less because of less number of tillage operations and labour requirement

**Disadvantages:**

- Reduced seed germination
- Root nodulation is adversely affected in some leguminous crops
- More nitrogen is required to enhance mineralization process
- Requires specially designed equipment since it is difficult to take up sowing with ordinary equipment

Minimum tillage can be practiced by different methods. They are

**Row zone tillage:** After primary tillage, secondary tillage operations are reduced to only crop row zone.

**Plough plant tillage:** After primary tillage, a special planter is used for pulverizing the soil, sowing the seed and covering the seed in the row zone.

**Wheel track planting:** After primary tillage, the tractor is used for sowing and the wheels of the tractor pulverize the row zone.

## **2. Zero tillage:**

It is an extreme form of tillage. It is a tillage system in which mechanical soil manipulation is reduced to traffic and seeding only, where weed control must be achieved by chemical means. The primary tillage is completely avoided and secondary tillage is restricted to seed bed preparation in the row zone only. Herbicides are used to destroy the vegetation for taking up sowing. The machinery should have attachment for four tasks in one operation namely clearing the narrow strip over the crop row, open the soil for seed inversion, placing the seed and covering the seed properly.

### **Advantages:**

- Saving in energy, labour and time
- Biological activity in the soil increases
- The soil organic matter content increases due to decomposition of crop residues
- Reduces the soil compaction and surface runoff

### **Disadvantages:**

- Seed germination is poor and hence, difficult to establish optimum crop stand.
- Higher dose of nitrogen is required as mineralization of organic matter is slow
- Pest and disease incidence more
- Some perennial and voluntary plants or weeds predominate

## **3. Strip tillage:**

It is a system combining the benefits of no tillage and full width tillage. It is confined to narrow strips where seeds will be placed. Rows are united and covered with undisturbed crop residue.

### **Advantages:**

- Soil conservation due to undisturbed residue between the rows
- Improved soil condition
- Early planting or sowing
- Fertilizer rates can be reduced due to band placement

**Disadvantages:**

- Special equipment is required for sowing
- Crop residues on soil surface interfere with cultural operations
- Pest and disease incidence more
- Build up of herbicide residue

**4. Conservation or stubble mulch tillage:**

The main objective is to conserve the soil and water conservation. It is a new approach developed for keeping soil protected at all times whether by growing a crop or by crop residues left on the surface during fallow period. It is a year round system of managing plant residue with implements that undercut residue, loosen the soil and kill weeds.

**Advantages:**

- Improves soil properties that affect plant growth
- Increases the organic matter content in the soil
- Reduces soil erosion there by water runoff from fields
- Mulched soil is cooler and the soil surface under the residue is moist

**Disadvantages:**

- The residues left on the surface interfere with seed bed preparation and sowing operation
- The traditional tillage and sowing equipment is not suitable

Modern tillage methods are practiced in western countries especially in USA. Most of these practices are not suitable for Indian conditions due to various reasons. In USA, straw and stubbles are left over in the field. In India, it is a valuable fodder for the cattle and fuel for the home. Use of heavy machinery in India is limited and hence, no problem of soil compaction.

The age old practice of relay cropping i.e. broadcasting of pulse crop seed in lowland rice crop 10 days before rice crop harvest in coastal areas in AP and Tamil Nadu is one of the best example of zero tillage system in India. Minimum tillage can be practiced under Indian conditions by reducing the number of ploughings to the minimum necessary. A single tillage operation over a hectare with a country plough requires 40 km walk on rough land.

## Lecture 18:

### SEEDS AND SOWING

Grains that are used for further multiplication are called as seeds. Fertilized ovule consisting of intact embryo, stored food and seed coat which is viable and has the capacity to germinate. Those plants which do not produce seeds are multiplied with vegetative parts. Ex. Stem cuttings in sugarcane, rooted slips in forage crops, tubers for potato, rhizomes for turmeric, etc. Vegetative propagation needs large quantities of seed material.

Sowing is the process of placing the seeds in seed bed to have good germination in the field or the process of placing of specified quantity of seeds in the soil in the optimum conditions for germination and grow as crop plant. Sowing is an important agricultural operation that is done after land preparation. Method, time and depth of sowing are important aspects for establishing a good plant stand.

#### **Characteristics of a good quality seed:**

- The seeds should be of adaptable crop variety or hybrid and their duration should be according to the agroclimate and cropping system of the locality
- The seeds should be pure (true to type)
- The seeds should have high germination percentage
- The seeds should be free from dormancy
- The seeds should be free from rogues (off types)
- The seeds should be free from seed borne diseases (red rot in sugarcane and tikka leaf spot in groundnut)
- The seeds should be free from other crop seeds and weed seed
- The seeds should be free from inert material
- The seeds should be free from insects, insect eggs, disease spores in or on the seeds
- The seeds should be clean, large, plump, bold, uniform in size, shape, colour, texture, development and of proper test weight
- The seeds should be fully matured and well developed
- The seed should have evenness in growth pattern and maturity
- The seed should contain a required amount of moisture
- The seed should be as fresh as possible
- The seed should be whole, not broken, crushed, peeled off, half filled, half rotten or affected with damp

### **Methods of sowing:**

Seeds can be sown by two methods i.e. direct sowing and transplanting

**Direct sowing:** It is the process of sowing of seeds directly in the main field and it is done in two ways i.e. broadcasting and line sowing.

### **Broadcasting:**

It is the most primitive method of sowing crops. In this method, seeds are spread uniformly and evenly over the entire field which is covered by ploughing or planking. To ensure uniformity of sowing, the field is divided into 2-3 parts and the required quantity of seed for each part is taken in container and spread uniformly and evenly on the field by hand. This operation is repeated with the remaining quantity of seed in other parts of the field also. Immediately after sowing the seeds are covered with thin layer of soil either by working with harrow or guntaka or plank to prevent the birds from eating the seed. This method is generally recommended for sowing green manure crops and fodder crops. Small seeded crops like sesamum and mustard are also broadcasted by mixing with sand.

### **Advantages:**

- Easy, quick, cheap method of sowing and implement is not required
- Skilled labour is not a compulsory
- Large area can be covered in a short time

### **Disadvantages:**

- The seed rate required is higher than all other methods
- Uniform plant population/unit area cannot be maintained
- Seeds may fall at different depths and germinate at different times resulting in non synchronous maturity
- Intercultivation with implements is not possible to control weeds
- Only skilled person is required for broadcasting
- Hand weeding is expensive, time consuming and laborious

### **Line sowing:**

It is the method of sowing of seeds in rows or lines and it is of two types i.e. drilling and dibbling. The problems of broadcasting can be overcome by this method.

- The seed rate required is less
- It facilitates uniform depth of sowing resulting in uniform crop stand
- Rapid and uniform germination with good seedling vigour
- Weeds can be controlled economically by inter-cultural operations

**Drilling:** Method of sowing of the seed in lines with the help of an implement called seed drill or gorru is called drilling and then the seeds are covered by working with wooden plank or harrow to have contact between the soil and seed. Gorru and mechanical seed drill are used for sowing seed by this method in crops like groundnut, sunflower, jowar, millets, etc.

**Dibbling:**

**Dibbling behind the country plough:** In this method furrows are opened with the help of a country plough and the seed will be dropped in the furrow by a person walking behind the plough. The seed in the furrows will be covered by the same plough while opening the adjacent furrow or by harrowing or planking. Ex. groundnut.

**Dibbling with a dibbler:** A wooden stick with a sharpened end called dibbler is used for making small holes in the soil at required distance and the seeds are dropped in the hole and covered with the soil. This method is recommended for wide spaced crops like cotton, castor, etc. particularly hybrids.

**Hand dibbling:** In this method, the soil is scooped with the help of hand hoe/sickle/finger to a shallow depth and the seed is placed and covered with soil. This is done in small areas for crops like bhendi, onion, etc.

**Planking:** Placing of vegetative parts of crops which are vegetatively propagated in the laid out field. Ex. Sugarcane, potato, turmeric, etc.

**Transplanting:** It is the process of removal of an actively growing seedling from one place (usually nursery bed) and planting it in the main field for further growth till harvest. This method is mostly practiced in rice, ragi, tobacco, chilli, brinjal, tomato, etc.

**Advantages:**

- Seed rate can be reduced
- Uniform and good crop establishment
- Optimum plant population maintained
- Synchronous maturity will be maintained
- Special care of nursery seedling in nursery can be possible
- Some crops like rice will give higher yields under transplanting

**Disadvantages:**

- Labour requirement is higher
- Relatively costly compared to other methods
- Sometimes seedlings may get damaged while pulling from nursery or during transport to main field or wrong handling by human labour

### **Importance of time of sowing:**

Sowing the crop at optimum time invariably increases the yield due to suitable and favourable climatic conditions at all the growth stages of the crop, flowering is induced after sufficient vegetative growth and crop will not be subjected to moisture stress i.e. dry spell particularly during critical stages.

The optimum time of sowing for most of the crops i.e. tropical crops during *kharif* / rainy season is immediately after the onset of monsoon i.e. II Fortnight of June to I Fortnight of July while for temperate crops like wheat/barley during *rabi* or post rainy season is II FN of Oct to II FN of Nov and for summer crops it is I FN of Jan. Any crop should not be sown either too early or too late.

If the crop is sown early, yield reduces invariably and it is attributed to

- The crop may face high rainfall in the beginning
- Failure or scarcity of rainfall at reproductive stage
- Critical stages may coincide with dry spells
- Harvesting may coincide with rains

If the crop sowing is delayed, yield reduces invariably and it is attributed to

- Unfavourable temperature and rainfall
- Very little time for vegetative growth
- Early induction of flowering
- Pest and disease incidence more ex. Rainfed sorghum yields are reduced due to delay in sowings beyond June because the crop will be subjected to severe attack of shoot borer and at Tirupati, rainfed groundnut sowing beyond July reduced the yields of all varieties

### **Importance of depth of sowing:**

Uneven depth of sowing results in uneven crop stand. Optimum depth of sowing is another important aspect for obtaining a good crop stand and it depends on size of seed and soil moisture.

**Seed size:** Size of the seed indicates the food reserves of the seed which indirectly decides the length of the plumule. As a rule, depth of sowing of any seed should be lesser than the length of the plumule. The other rule is to sow seeds to a depth approximately 3-4 times their diameter. The optimum depth of sowing for most of the field crops is 3-5 cm. The depth of sowing of crops with bigger sized seeds like groundnut, castor, bengalgram is 5-7 cm. Small sized seeds like sesamum, ragi, mustard, etc. are sown at a shallow depth of 2-3 cm. Very small sized seeds like tobacco are planted at a depth of 1.0 cm

**Soil moisture:** If the seeds are sown too shallow, the surface soil dries up quickly and germination may not occur due to lack of moisture. If the seeds are sown too deep, they may not be able to get sufficient soil and besides moisture resulting in poor germination. Also the emergence of seedling from the soil will be a problem. Seed food reserves may be insufficient to put forth long coleoptile for emergence.

## **Raising of nursery**

Conditions favourable for raising nursery

1. Nursery bed should be leveled and have gentle slope for draining excess water
2. Nursery bed should have fine tilth
3. Nursery bed should be nearer to irrigation source
4. Nursery bed should be sterilized by burning the rice bran to protect the nursery from soil borne insects and diseases
5. Nursery bed should be drenched with suitable fungicides to prevent seed borne disease in the nursery
6. Seed should be sown uniformly avoiding thick and thin population
7. Weeds should be controlled as and when required
8. Seedling should be uprooted from nursery at right time and transplanted in the main field immediately
9. Main field should be ready by the time the nursery is ready for pulling from the nursery bed
10. While transplanting, spacing and number of seedlings per hill should be followed based on the crop
11. Nursery bed should be protected by fencing

## **Advantages**

1. Optimum plant population can be maintained in the main field
2. Nursery is in small area. Hence, plant protection measures can be taken up effectively resulting in better growth of the crop in the main field
3. Duration of the crop in the main field decreases because crop is in nursery for some period
4. Crops like rice, finger millet and many of the vegetables give higher yields when transplanted in the main field
5. Nursery can be raised even when there is a crop in the main field

## Lecture 19:

### CROP PLANT DENSITY

**Plant population:** Number of plants per unit area is called plant population

**Spacing:** The distance between the crop rows (inter row spacing) and between the plants within the row (intra row spacing) is called spacing.

**Crop geometry:** The way in which the crop plants are arranged in the field is called crop geometry

If we know the spacing we can tell the number of plants but on the basis of number of plants we can't say the planting pattern i.e. spacing.

#### **Competition:**

It is a physical process when the growth resources fall below the combined demand of plants, the competition starts or It is the struggle between individuals within a population for available resources, when the level of resources is below the combined need of the members of the population. Plants that are growing together do not compete with each other as long as resources are in excess of combined demand of both the plants.

**Interspecific competition:** Competition occurring between the plants of two different species is called interspecific competition. The competition is between crops two or between crop and weeds or species and species.

**Intraspecific competition:** Competition occurring between the plants of same species in the absence of weeds is called intraspecific competition.

#### **How does competition occurs in plants:**

Crop plants are not grown in isolation but in closely spaced population. In the early phase of growth, individual plants are small and widely spaced and do not interfere with each other. At some point, as the plants grow they start to interfere with their neighbours and competition begins. Two plants no matter how close do not compete with each other so long as the growth resources are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demand of the two plants, competition begins.

**Competition for nutrients:** Nutrient uptake increases with increase in plant population. Higher population under low fertility conditions leads to development of nutrient deficiency symptoms because of completion.

**Competition for light:** Competition for light may occur whenever one plant casts a shadow on another or within a plant when one leaf shades another leaf. In early plant growth stages, there will be little mutual shading and even at relatively low light intensities, the plant will be able to photosynthesize with full efficiency. As the plant develop, mutual shading increases and light becomes a limiting factor.

**Competition for water:** The success of any plant in competition for water depends on the rate and competitiveness with which it can make use of soil water supply.

**Factors influencing optimum plant population:**

The optimum plant population differs with the crop, variety, season, type of farming and soil fertility status

**Crop:** Optimum plant population is 75,000 plants, 10,000 plants and 10.0 lakh plant/ha in case of maize, cotton hybrid and short duration rice crop, respectively.

**Variety:** Within the same crop, optimum plant population varies with the variety. Generally, traditional varieties will have lesser plant population per unit area while modern dwarf or high yielding varieties will have more plant population.

**Season:** For the same crop and variety, the optimum plant population varies with the season. As a rule for any crop variety, optimum plant population will be lesser during *kharif* season than *rabi* season. Ex. In groundnut, the optimum plant population during *kharif* is 3.33 lakhs while during *rabi*, it is 4.44 lakhs ha<sup>-1</sup>.

During *kharif*, more number of rainy days/cloudy days result in more vegetative growth and to avoid mutual shading wider spacing is recommended. Hence, less plant population. During *rabi*, more sunny days/low temperature results in less vegetative growth, so closer spacing and hence more population.

**Type of farming:** As a rule, the optimum plant population for rainfed farming is lesser than irrigated farming because of limited supply of moisture and hence, lesser the optimum plant population.

**Soil fertility status:** As a rule, the optimum plant population is higher for highly fertile soils compared to low fertility soils where the plant population is less.

**Effect of plant population on growth and yield:**

The growth and yield of crops depend upon the plant population in the field. If the plant population per unit area is either lesser or more than optimum plant population, the yield will be reduced because of different types of competition that occurs. The competition that occurs at low plant population differs from the competition that occurs with high plant population.

Optimum plant population is the plant population where the yield is maximum because competition of any type does not occur at any stage of the crop growth. Optimum plant population for any crop varies considerably due to environment under which it is grown. It is not possible to recommend generalized plant population since the crop is grown in different seasons with different management practices. Ex. Redgram plants sown as winter crop will have half the size of those grown in monsoon (*kharif*) season. Optimum plant population for *kharif* is 55,000 plants ha<sup>-1</sup> and it is increased to 3.3 lakh ha<sup>-1</sup> for *rabi* season as low temperature retards the rate of growth.

### **Low plant population (wider spacing):**

If the spacing is wider and plant population is lesser there will not be any competition during early stages of crop growth for any resource. Because of this the plant grow luxuriantly and put forth excessive vegetative growth and exhaust all the resources quickly. By the time the crop reaches reproductive stage, the competition starts and continues to become more and more severe. As a result, the yield is reduced.

### **High plant population (close spacing):**

When spacing is closer and plant population is higher, competition starts from the seedling stage and continues throughout the crop growing period. With the result, the competition become severe by the time the reaches reproductive stage due to which the yield will be reduced. High plant population brings out certain modifications in the growth of plants.

Plant height increases with increase in plant population due to competition of light. Sometimes, it may happen that moderate increase in plant population may not increase but decrease plant height due to competition for water and nutrients but not for light. Leaf orientation is also altered due to population pressure. The leaves are erect, narrow and are arranged at longer vertical intervals under high plant densities. This is a desirable character to intercept more light.

At high plant density decrease in yield of individual plant is due to the reduction in the number of ears/panicles/pods. Ex. Redgram produces about 20 pods plant<sup>-1</sup> at 3.3 lakh plants ha<sup>-1</sup> (30 cm x 10 cm spacing) while it produces more than 100 pods plant<sup>-1</sup> at 55,000 plant ha<sup>-1</sup> (90 cm x 20 cm spacing).

**Significance of optimum plant density:** There are two types of yield in agriculture.

**Biological yield:** The total biomass produced by the crop during the crop growth period.

**Economic yield:** Of the biological yield, only a fraction is useful for economic purpose which is called economic yield or saleable yield.

The relationship between the biological yield (BY) and economic yield (EY) is expressed as harvest index (HI).

$$HI = EY / BY \times 100$$

Highest HI is with fodder/leafy vegetables followed by sugarcane, cereals, pulses, oilseeds, fibre crops, narcotics and medicinal plants.

The relationship between yield and plant population per unit area can explained by a graph which has two curves i.e. BY curve and EC. The BY curve indicates that biological yield will increase with increase in the plant population and reaches maximum. After that further increase in plant population will make the BY curve to reach a plateau. The EY curve indicates that the economic yield will increase with

increases with increase in population and reaches a maximum value. Any further increase in population the economic yield curve will tend to decline. The point at which both the BY curve and EY curve shows the maximum values and draw a perpendicular line to x-axis and the point where this line intersects the x-axis is the optimum plant population for that crop, below or above which the EY will be lesser than maximum yield.

### **Planting pattern:**

It influences the crop yield through its influence on light interception, rooting pattern and moisture extraction pattern. Different planting patterns are followed to suit different weed control practices and cropping systems. Crop geometry refers to the shape of space available for individual plants and it is altered by changing inter and intra row spacing.

### **Square planting:**

In this method, the plants will be more efficient in the utilization of light, water and nutrients available to the individual plants than in rectangular arrangement. In tobacco, intercultivation in both directions is possible in square planting and helps in effective control of weeds. In wheat, decreasing inter row spacing below the recommendation of 12-15 cm i.e. reducing rectangularity, generally increases yield slightly. However, square planting is not advantageous in all crops. Groundnut sown with a spacing of 30 cm x 10 cm (3.33 lakhs ha<sup>-1</sup>) gave higher pod yield than with same amount of population in square planting. Pod yield is reduced either by increasing rectangularity or approaching towards square planting.

### **Rectangular planting:**

Sowing the seed with seed drill is the standard practice. Wider inter row spacing and closer intra row spacing is very common for most of the crops thus attaining rectangularity. This rectangular arrangement is adopted mainly to facilitate intercultivation. Sometimes, only inter row spacing is maintained and intra row spacing is not followed strictly and seeds are sown closely as solid row.

### **Miscellaneous planting arrangement:**

- Crops are sown with seed drill in two directions to accommodate more number of plants and mainly to reduce weed population
- Crops like rice and ragi are planted @ 2-3 seedlings hill<sup>-1</sup>
- Transplanting is done either in rows or randomly
- Skipping of every alternate row of planting is known as skip row planting
- The technique of paired row planting is one way of accommodating the full population of the base crop and creating inter space wide enough to accommodate one or two rows of the inter crop. In this technique, two adjacent rows of the base crop are paired reducing the inter row space in the pair narrow enough to create inter space between pairs of base crops wider enough to minimize undue competition among the plants of the base crop.

## Lecture 20:

### WEEDS

The new cultural strategy involves growing of high yielding varieties of crop plants under conditions of optimum fertility levels and irrigation. These conditions which stimulate the crop growth are also conducive to the growth of weeds. Unless weeds are controlled properly, the purpose behind the adoption of improved agronomic practices gets defeated. Weed free environment for higher crop production is mainly to avoid competition of weeds for soil moisture, nutrients and light which affect the yield and quality.

Weeds constitute a major problem in agriculture and the losses due to them are far greater than are usually realized. Depending on the degree of weed competition, crop yield reduction is between 10-15 per cent (some times as high as 50 per cent). If weed competition is completely eliminated from the entire crop land, farm production can be increased by 10-15 per cent.

There is no reliable study of worldwide damage due to weeds. However, it is widely known that losses caused by weeds exceeds the losses from any other category or agricultural pests like insects, diseases, nematodes, rodents, etc. Of the total annual loss of agriculture produce from various pests in India, weeds account for 45, insects 30, diseases 20 and other pests 5 per cent. Very few realize the importance of weeds as the destructive work is going on in a silent and unnoticed way.

- A weed is a
- plant growing where it is not desired
  - plant growing where nothing should grow
  - plant out of place
  - unwanted plant
  - plant of negative value
  - plant whose economic value are yet to be discovered
  - plant that is extremely noxious, useless, unwanted or poisonous

Jethro Tull (1731), a great Britain farmer used the word Weed for the first time in the above meaning and is the author of "Horse Hoeing Husbandary".

The above definition does not identify a particular portion of plant kingdom as weedy. The term weed differs from person to person, engineer to farmer, place, changes in course of time. Weedy nature of the plant depends on the situation in which it occurs and the human attitude towards it. Thus, a plant could be undesirable at one place and time, and desirable or of little concern at the other.

- Bermuda grass (*Cynodon dactylon*) is a troublesome weed all over the world in all crops but it is used as a fodder grass in village pastures.
- Quack grass (*Agropyron repens*) is a serious weed in crop fields and orchards but it is good soil binding grass in erodible and non cropped land.
- Prickly pear (*Opuntia dillenii*) is a aggressive weed in range lands but in deserts it is not a weed.
- Water hyacinth (*Eichhornia crassipes*) is a problem in hydro projects, irrigation channels and fishermen but it is a plant of aesthetic value for city dweller.

Some times two persons may differ about the weedy nature of a plant at the same place and time. Self sown crop plants like groundnut, jowar, bajra growing in patches in some other crop or cotton or sugarcane, they are considered as weeds.

All weeds are unwanted plant but all unwanted plants are not weeds.

The plants are listed as weeds based on the situation in which they adversely affect man affairs. This situation may be a crop field, road side, water body, wood land, garden, orchard, industrial area, railway track, etc. About 30,000 plant species have been identified as definite weeds in the world infesting the above situation.

### Uses of weeds

Attempts are underway to convert weedy vegetation into useful manure, animal feed, paper pulp, edible protein, etc. on a commercial basis to make physical control of weeds more attractive.

1. Weeds are used as a forage. Ex Star grass, Chicory, Water hyacinth
2. Weeds as green manure. Ex *Croton sparciflorus*
3. Weeds form a source of protein. Ex *Chlorella pyrenoides*
4. Weeds used in crop breeding. Widely exploited for development of present noble canes for sugarcane varieties. Ex *Saccharum spontaneum*
5. Weeds for paper and fibre pulp. Ex Aquatic weeds
6. Weeds used in cottage and industry for making thatching and rope. Ex Cattail, *Saccharum spontaneum*
7. Weeds used as pollution indicators.
  - NO<sub>2</sub> gas is indicated by Wild mustard (*Brassica kaber*)
  - SO<sub>2</sub> gas is indicated by Chick weed (*Stellaria media*)
8. Weed used as a flavor. Chicory is cultivated by the coffee industry, the roots used for adding favour to coffee powder.

9. Weeds used as medicinal plants and aromatic plants

- Leucas aspera* - snake bite, malaria  
*Striga orobanchoides* - diabetes, chewed to strengthen gums of teeth  
*Phyllanthus niruri* - jaundice, diabetes, purifies liver  
*Cyperus rotundus* - agarabatties (incense sticks)

10. Weeds used as leafy vegetables

- Amaranthus viridis* (Chilaka thota kura)  
*Digera arvensis* (Chenchali kura)  
*Portulaca oleracea* (Payala kura)  
*Amaranthus sessile* (Ponna ganti kura)  
*Chenopodium album* (Lambsquarter)

11. Weeds used for beautification Prickly pear, Lantan, Water hyacinth, Lambsquarter

12. Weeds used to reclaim alkali soils. Ex Mexican poppy (*Argemone mexicana*)

13. Weeds form canopy over the surface and protect the soil from wind and water erosion. They bind the soil particles together. Ex Quack grass (*Agropyron repense*)

14. Certain weeds exhibit nematicidal properties. Their incorporation into the soil has been found to result in greatly reduced root knot nematode. Ex Calotropis, Parthenium, Eichhornia

15. Weeds provide pollen as food for beneficial insects and act as a alternative host to pest predators.

16. Weeds are often used as a means of irrigation scheduling i.e. indicators of soil moisture status.

17. Weed used as a organic manure and for biogas production. Ex Water hyacinth

18. Certain plants have proved useful indicators of metals in the geological substrata and the environment. Such plants concentrate in the tissue specific metals in excess of their concentration present in the environment. Now satellite imaging has become a powerful tool in locating distribution of such plants and the subject has come to be known as indicator geobotany.

*Salsola nitrata* - Boron

*Crotalaria cobalica* - Cobalt

## **Harmful effect of weeds**

### **1. Reduction in the quantity of farm produce:**

Growing with crop plants, weeds cause tremendous reduction in crop fields. Several scientists have estimated such losses in crop yields in different parts of India. On an average, the yield reduction is to the tune of 15-30 % in wheat, 30-35 % in rice, and 15-85 % in cereals and oilseeds. Reduction in crop yield has a direct correlation with weed competition. Increase in 1.0 kg of weed growth corresponds to reduction in 1.0 kg of crop growth. If the weeds are left uncontrolled, they grow taller than the crop plants and inhibit tillering and branching. In upland rice and vegetables, complete crop failure due to weeds is often observed.

### **2. Loss of quality of farm produce:**

Weeds may affect the quality of farm produce in many ways.

1. Contamination of food with weed seeds, particularly of poisonous nature, fetches low price in the market. The weedy grains produce flour with bad odour.
2. In ware houses, the weed seeds and weed fragments continue respiration and thus cause the grain to heat and rust or rot.
3. In tea, the presence of loranthus (*Dendrophthoe falcata*) leaves impair the quality.
4. In cotton, the dry weed fragments adhere to its lint and hinder the spinning process.
5. In dryland agriculture, weeds cause severe moisture stress and force the food grains to shrivel.
6. Growing with forage crops, weeds often help to fill the carts and silos but it is in the milk and meat returns, that their damage becomes more apparent i.e. odd flavored, tainted, bad quality and infected. Ex. Chicory, ambrosia, wild garlic.
7. The quality of wool is reduced when grazing animals pick up fruits of grassland weeds like prickly chafflower, cocklebur, etc.

### **3. Reduction in land value:**

Heavy infestation by perennial weeds could make the land unsuitable or less suitable for cultivation resulting in loss in its monetary value. Millions of hectares of cultivable area in rice growing regions of Asia have been abandoned or not regularly cultivated due to severe infestation with thatch grass (*Imperata cylindrica*).

#### 4. Limited choice of crops:

Crops differ in their ability to compete with weeds. In many instances, the presence of particular weeds in fields limits the choice of crops to be grown. Very heavy weed infestation render some economically important crops, particularly pulses, jute and forage crops unsuitable or less suitable for cultivation.

#### 5. Competition and yield reduction:

**Competition for water:** Water is the most costly input in agriculture. Water requirement of weeds is higher than that of the crop plants. Wild mustard transpires four times more than the cultivated oat. Transpiration coefficient of weeds (1000-1400) is higher than the crop plants (400-500). This shows that the water requirement of crops is less than that of weeds. But weeds grow faster utilizing the water available and depriving the crop plants of water. A considerable amount of water can be saved by weed free environment. According to scientists 750-1250 t of water ha<sup>-1</sup> forming one meter depth can be saved per year by maintaining a weed free environment.

**Competition for nutrients:** The weeds use more amount of nutrients than crop plants. These weeds constitute 30-50 % of the dry matter production/ha. Wild mustard takes 2 times N and P and 4 times K than the cultivated oats. Weeds with their high rate of absorption and utilization of nutrients usually invade and deplete the land. In irrigated area, the competition for nutrients will be more than for water. In irrigated agriculture, the competition between crop and weed will be more for nutrients.

**Competition for space:** Certain vigorous weeds will surpass the growth of crop plants and finally crowd the crop plants. The weeds occupy space around or near the plant. This may be achieved by one plant or group of plants with slow or rapid growth. In cultivated lands, these weeds appear in large number presenting a carpet like appearance. Ex. Abutilon, Portulaca, Trianthema, Amaranthus, Digera, etc. These weeds will smother the crop plants due to which the growth of crop plants will be stunted and finally die. Jowar infested with Celosia will have poor growth.

**Competition for light:** Coarse and broad leaved weeds restrict the photosynthetic activity of crop plants due to shading. The shading effects crop plants and grasses in grazing lands and pastures.

#### 6. Added protection costs from pest and diseases

Weeds harbor pest and diseases, rats and other pests. These require control measures which increase the cost of plant protection. Outside the field, weeds often acts as alternate host to crop pests which later migrate to the main fields.

<b>Insect pest</b>	<b>Alternate host</b>
- Cotton boll worm on cotton	wild cotton
- Sweet potato weevil on sweet potato	field bind weed

**Disease organism**

- Club root of cabbage / cauliflower
- Stem rust of barley / wheat / oats

**Alternate host**

- wild mustard
- wild oat / quack grass

**7. Increase in cost of labour and equipment:**

Because of more weeds, more time is spent for land preparation, cleaning drainage and irrigation channels and for harvesting and cleaning of final produce. About 50 per cent of cost of cultivation is towards weeding usually. These all put together increase cost of cultivation.

**8. Menace to human health:**

Health, comfort and work efficiency of men are adversely affected by weeds.

1. Numerous people are plagued year after year with hay fever and asthma aggravated by pollens of common rag weed (*Ambrosia artemissifolia*) and *Franseria bursage*.
2. *Parthenium hysterophorus* (carrot weed), *Rhus spp.* (poison ivy), *Ambrosia artemissifolia* (common rag weed) and *Helenium spp.* (sneeze weed) are responsible for different dermal allergies on humans.
3. Weeds provide food, protection and habitat for the reproduction of vectors of human diseases.
4. Aquatic weeds shelter alternate hosts and vectors of malaria, yellow fever, encephalitis, dengue fever and filariasis
  - Water lettuce - *Pistia stratiotes*
  - Water fern - *Salvinia molesta*
  - Alligator weed - *Alternanthera philoxeroides*
5. *Argemone mexicana* (Mexican poppy) seeds crushed with mustard seeds have brought death and blindness to thousands of people in India (alkaloid sanguinarine and 11-oxotriacontanoic acid).

**9. Loss of animal health:**

Several weeds of grasslands and forage crops carry high contents of alkaloids, tannins, oxalates, glucosides, prussic acid, nitrates, etc. that often prove poisonous to animals when ingested.

1. The leaves of lantana (*Lantana camara*) induce acute photosensitivity and jaundice in animals due to their toxic principle "lantra dene-A".
2. Carrot grass (*Parthenium hysterophorus*) causes contact dermatitis (skin disease) in livestock.

3. *Halogeton glomeratus* causes death of sheep because of its high oxalate content.
4. The spiny fruits of *Xanthium stumarium*, *Achyranthus aspera*, *Cirsium arvense* stick to the mouth, tail and body of animals and annoy them badly.
5. *Rhododendron spp.* causes diarrhoea in milch animals.
6. Under drought conditions weeds like chenopodium, amaranthus, cirsium and polygonum spp develop nitrate levels as high as 1000 ppm or more which cause 'asploxyia' in animals.

#### **10. Deterioration of aesthetics:**

In many advanced countries, lowering of aesthetic values is primary objection to weeds growing around houses, kitchen gardens, parks, playgrounds, roadside, etc. It is desirable that public places are kept clean of weeds. Presence of weeds around living and working places makes surroundings dull and insipid (without taste and flavor).

#### **11. Weed menace to industry and public utilities:**

1. Weeds and brush weeds on industrial sites are a potential source of fire
2. Weeds also contribute to deterioration of stores, equipment and materials and impairs man's working efficiency
3. Weeds cling to the fence causing erosion
4. Weeds mislead the people by obstructing road signs and viability at crossings and curves
5. Weeds encroachment reduces road width
6. Weeds growing around poles prevent ready accessibility to work crews
7. On railway tracks, weeds weaken the rails and reduce traction for breaking
8. On abandoned land and around farm ditches and farm houses weeds may shelter deadly snakes, rodents and other farm pests

#### **12. Weed menace to aquatic ecosystem:**

1. Not only on land, weeds are a nuisance in water bodies too
2. Aquatic weeds change the flavor, appearance and taste of drinking water and render swimming, boating and other recreations unappealing
3. Flow of canals is reduced by 50 per cent or more when submerged weeds infest them
4. Drainage and irrigation channels are clogged completely by aquatic weeds

5. Weeds like water hyacinth and cattail transpires heavily and accelerate water loss by 130 to 250 per cent of the water evaporated from weed free water surface
6. BGA supersaturate water with oxygen which proves fatal to fish
7. Changes in the quality of water due to weeds reduce production of edible fish

### **13. Loss of forest and woodland products:**

Weeds and brush shade desirable trees and nursery plants and compete with them for water and other nutrients to stunt their growth. Undesirable brush weeds and trees eventually replace the desirable forest and wood land species. In wood lands, weeds reduce their recreational values.

In forests, dry weeds offer potential source of fire hazards. A weed like *Lantana camara* can catch fire even when green. Weed free buffer strips are essential in forest woodlands for preventing fire hazard.

In West Bengal, 11 % of high forest area and 38 % plantation forest have been affected by *Mikania micrantha*. Lantana made large areas of forest and pastures useless. Now carrot grass is entering forest areas in a big way. *Chromolena odorata* suppressed native forest species in high altitudes of Assam and West Bengal.

### **CLASSIFICATION OF WEEDS**

There are many ways weeds can be grouped for the convenience of planning, interpreting and recording control measures against them. Some important classification of weeds used by weed scientists all over the world for different purposes are as follows.

#### **1. Ontogeny or life cycle:**

Depending upon their life cycle, weeds can be classified as annual, biennial and perennial weeds.

**Annual weeds:** Annual weeds grow and mature within a year of their germination, but more commonly they complete their life cycle in one season or they grow and mature in the same season of germination. They are small herbs, with shallow root system and weak stem. They propagate by seeds which are produced in abundance and after seed production weeds die and the seeds germinate in the next season.

*Argemone mexicana, Cleome viscosa, Digera arvensis, Legasca mollis,*

*Xanthium strumarium*

There are *kharif*, winter and summer annuals depending upon part of the year when it putforths its major growth.

Winter annuals germinate in winter, complete seed production in early summer and remain dormant till next winter. Ex. *Phalaris minor*, *Chenopodium album*, *Vicia sativa*, *Carthamus oxycantha*. Summer annuals include *Trianthema protuloastrum*, *Digera arvensis*, *Setaria glauca* while *Amaranthus viridis* is seen round the year.

Majority of the annual weeds take one full season to mature, though a weed like *Phyllanthus niruri* completes its seed to seed cycle within 2-4 weeks. Such short lived annuals are called ephemerals. The ephemerals can escape even closely spaced weeding and drought periods.

Another important characteristic of many annual weeds is that they fail to regrow when they are cut close to the ground level. Such annual weeds are called simple annuals. However, there are several annual weeds which possess crown buds which sprout into new shoots soon after the mother plant is topped. Ex *Parthenium*, *Amaranthus*, etc.

**Biennial weeds:** These weeds complete their life cycle in two years, in the first year they remain vegetative and in the second year they produce flowers and set seeds. These weeds must be controlled in the first year of growth before they have a chance to store food in their roots. The usual pattern or feature of biennial weeds to flower in second year of growth limits their dispersal through crops very much. It is so, because they get harvested along with the crop plant before they get a chance to set seeds. (The influence of environment however, may alter this usual behavior of biennial weeds when they may either bolt in the first year itself or may delay flowering upto the third year of their growth).

Wild carrot (*Daucus carota*)

Chicory *Chicorium intybus*

*Alternanthera echinata*

*Taraxacum officinale*

*Plantago media*

**Perennial weeds:** They grow for three or more years before they wither away. Usually, these weeds flower for the first time in the second year of their growth and thereafter flower each year regularly. Worst weeds belong to this group. They are well adapted to withstand adverse conditions. They propagate through seed or underground portion. These may be further sub divided into

#### **i) Herbaceous perennials**

- a) Simple perennials: They reproduce by seeds only, except when roots or crown are cut during cultivation. Ex *Sonchus arvensis*
- b) Bulbus: They reproduce by bulbs, bulblets and seeds. Ex Wild garlic (*Allium vineale*)

- c) Creeping perennials: They reproduce by rhizomes, stolons, roots and seeds.  
Ex Field bind weed (*Convolvulus arvensis*), quack grass (*Agropyron repens*)
- d) Tuber perennials: They reproduce by tubers or seeds. Ex. Nutsedge

## ii) Woody perennials:

They do not produce seeds for the first two years, but when they are mature they produce seeds. Ex Wild ber (*Zyziphus rotundifolia*) Difficult perennial weeds are also called as pernicious weeds.

## 2. Morphology or Cotyledon character:

It has two groups monocotyledons and dicotyledons. This classification is important to plan control measure as the morphological properties are related to herbicidal absorption, retention and translocation in the plant body. Hence, weeds within this group have the same reaction to control measures of cultural, mechanical and chemical methods.

**Grasses:** They are monocots and the leaves arise alternately at the solid nodes. They are narrow, long, upright with parallel venation. Leaves are comprised of two distinctive parts. The lower is called leaf sheath and the upper leaf blade. The margins of the sheath overlap to form a tube around the stem. On the upper surface of the sheath at the junction of leaf blade and sheath, a membranous often hairy growth is seen called Ligules. The apical meristem is protected by leaf sheath and the portion of stem between two nodes is hollow. Grasses are usually propagated by stem cuttings, seeds, rhizomes, stolons, etc. Ex Barnyard grass (*Echinochloa crusgalli*), Bermuda grass (*Cynodon dactylon*)

**Broadleaf weeds:** Weeds of dicot have broad and horizontal leaves. They have netted or reticulate venation and exposed apical meristem. They have tap root system. These are the weeds consisting of two cotyledons in the seeds. Ex *Amaranthus viridis*, *Parthenium hysterophorus*.

**Sedges:** Similar to grasses, but leaves occur in two or more rows. Stems are solid and triangular in cross section. The leaf sheaths are fused to form a tube around the stem. Ligule is absent. Sedges are narrow leaved, but are not grasses. Ex Nutsedge (*Cyperus rotundus*) and Cattail (*Typha angustata*).

Weeds like *Eichhornia crassipes*, *Commelina benghalensis*, *Cyanotis axillaris* are monocots but they are broad leaf plants.

## CROP-WEED COMPETITION

**Competition** is struggle between two organisms for a limited resource that is essential for growth. Water, nutrient, light and space are the major factors for which usually competition occurs.

**Crop weed competition:** Competition between crop plants and weeds is known as crop weed competition. It is most severe when they have similar vegetative habit and common demand for available growth factors.

Weeds appear much more adapted to agro-ecosystems than our crop plants. Without interference by man, weeds would easily wipe out the crop plants. Generally, an increase in one kilogram of weed growth will decrease one kilogram of crop growth.

### **I. Principles of crop weed competition are**

1. Competition for nutrients
2. Competition for moisture
3. Competition for light
4. Competition for CO<sub>2</sub>

#### **1. Competition for nutrients**

It is an important aspect of crop weed competition. Weeds usually absorb mineral nutrients faster than crop plants. Usually weeds accumulate relatively larger amounts of nutrients than crop plant. Nutrient removal by weeds leads to huge loss of nutrients in each crop season, which is often twice that of crop plants.

*Amaranthus* accumulate over 3 % nitrogen in their dry matter and this fall under category of nitrophylls. *Digitaria* spp accumulates more phosphorous content of over 3.36 %. *Chenopodium* and *Portulaca* are potassium lovers, with over 4.0 % K<sub>2</sub>O in their dry matter. *Setaria lutescens* accumulates as high as 585 ppm of zinc in its dry matter. This is about three times more than by cereal crop.

#### **2. Competition for moisture**

Crop weed competition becomes critical with increasing soil moisture stress. In general for producing equal amount of dry matter weeds transpire more water than field crops. Therefore, the actual evapotranspiration from the weedy crop fields is much more than the evapotranspiration from a weed free crop field. Consumptive use of *Chenopodium album* is 550 mm as against 479 mm for wheat crop. Further it was noted that weeds remove moisture evenly from up to 90 cm soil depth. Weeds growing in fallow land are found to consume as much as 70- 120 ha mm of soil moisture and this moisture is capable of producing 15 -20 q of grain per ha in the following season.

#### **3. Competition for light (Solar energy)**

Plant height and vertical leaf area distribution are the important elements of crop weed competition. When moisture and nutrients in soil are plentiful, weeds have an edge over crop plants and grow taller. Competition for light occurs during early crop growth season if a dense weed growth smothers the crop seedlings. Crop plants suffer badly due to shading effect of weeds. Cotton, potato several vegetables and sugarcane are subjected to heavy weed growth during seedling stage. Unlike competition for nutrients and moisture once weeds shade a crop plant, increased light intensity cannot benefit it.

#### **4. Competition for space (CO<sub>2</sub>)**

Crop-weed competition for space is the requirement for CO<sub>2</sub> and the competition may occur under extremely crowded plant community condition. A more efficient utilization of CO<sub>2</sub> by C<sub>4</sub> type weeds may contribute to their rapid growth over C<sub>3</sub> type of crops.

#### **Critical period of crop-weed competition**

The period at which maximum crop weed competition occurs is called critical period. Critical period of CWC is the shortest time span in the ontogeny of crop growth when weeding results in highest economic returns.

#### **Critical period of crop-weed competition in some crops**

1. Rice
  - Transplanted : Up to 6 WAT (weeks after transplanting)
  - Direct sowing : Up to 6 WAS (weeks after sowing)
2. Wheat and Ragi : Up to 5 WAS
3. Maize : 2 to 6 WAS
4. Bajra : Up to 4 WAS
5. Jowar and Sesame : 2 to 5 WAS
6. Sugarcane : 12 to 14 WAS
7. Sunflower : 2 to 4 WAS
8. Groundnut : 4 to 7 WAS
9. Greengram and Blackgram : 4 to 6 WAS
10. Red gram : Up to 7 WAS
11. Horse gram : 3 to 6 WAS
12. Cotton : 6 to 9 WAS
13. Castor : 3 to 9 WAS
14. Tobacco : Up to 9 WAT

## **Lecture 21:**

### **WEED CONTROL METHODS**

Weed control is the process of limiting weed infestations so that crops could be grown profitably and other activities of man can be conducted efficiently.

Weed eradication is complete removal of all live plant parts and seeds of a weed infestation from an area.

Weed Management is a systemic planning done for handling the weed populations round the year, employing a combination of good crop husbandary practices, preventive measures and direct weed control methods in right proportion and at right times keeping in view the weed flora and crop biological ecosystems.

A right plant at the right place and time and in right amount of growth should be our ultimate goal, to achieve proper vegetation management on earth.

#### **Principles of weed management**

- i) Weed control results from a series of manipulations of habitat and not out of any single activity.
- ii) Weed control should be directed to reduce the survival mechanism of weeds
- iii) Weed control measures should be placed according to crop production techniques and the crop production techniques should not allow the establishment of weeds.
- iv) There is no single method that can completely avoids the weeds in the crop field.
- v) Control measures should be performed in all the crops during all the seasons to eliminate the weeds.

Preventing, eradication and control are the three fundamental objectives for combating weeds.

#### **PREVENTIVE METHODS:**

The process of stopping the contamination of an area from weeds is called prevention.

1. Use of clean seed
2. Don't feed grains or hay without destroying the viability of weed seeds by cooking or grinding or ensiling.
3. Don't permit livestock entering from infested areas to clean areas.

4. Don't use manure that contain viable weed seed without destroying their viability by proper fermentation or by treating with chemicals like metham, mylone, aerocynamide, ammonium thiocyanate which destroys weed propagules.
5. Keep irrigation channels, ditch banks free from weed seed.
6. Clean harvesters and other farm implements before moving them from infested areas.
7. Avoid use of gravel, sand and soil from infested areas to the new areas.
8. Keep fence corners, fence sides, road sides and all other uncropped areas free from weeds.
9. Inspect nursery for the presence of weed seeds, tubers and rhizomes of perennial weeds.
10. Keep non cropped areas clean
11. Keep vigilance
12. Legal measures

## **PHYSICAL METHODS**

Physical control of weeds is as old as agriculture. It began in the form of hand pulling in about 10,000 BC when men started to cultivate crops. Interestingly enough, the primitive practice of weeding exists with us even today particularly in nurseries, lawns and flower beds.

Physical control of weeds involves use of manual or mechanical energy for destroying weeds. The implements used for physical control of weeds vary from simple hand tool to complex multistoried tractor drawn implements. With these tools or implements, the weeds are lifted from the soil or cut off or buried. The physical methods are the oldest and practical methods that are commonly used even today.

Hand weeding

Spudding

Hand hoeing

Mowing

Cutting

Dredging and chaining

Burning and flaming

## **CULTURAL METHODS**

Some important crop husbandry practices that can lead to the suppression of weeds and which can be easily incorporated in practical weed control programmes in farming systems are

Proper crop stand and early seedling vigour

Selective crop stimulation

Crop rotation

Stale seed bed

Summer fallowing

Minimum tillage

Solarisation

Proper planting time

Flooding and drainage

Mulching

Proper planting method

## **BIOLOGICAL METHOD**

Biological control of weeds involves the use of living organisms such as insects, herbivorous fish, disease organism, other animals and competitive plants to limit weed infestation.

The objectives of biological control are not eradication but reduction and regulation of the weed population below the level of economic injury.

Bioagent is a living organism employed to control a pest.

### **Kinds of bioagent:**

Insects: *Crociosema lantana*

Carp fish: common carp (*Cyprinus carpio*) and white amur (*Ctenopharyngodon idella*)

Snails: (*Marisa cornuarieties*)

Mites: Spider mite (*Tetranychus desertorum*)

Fungi: *Puccinia chondrillina*

Competitive plants: Slender spike rush (*Eleocharis acicularis*) and *Cassia sericea*

### Criteria for selection of bioagent:

A successful bioagent is host specific, hardiness, ease of multiplication and rapid feeding habit.

### Bioherbicides:

Native pathogens cultured artificially and sprayed like post emergence herbicides each season on the target weed, particularly in crop areas are called bioherbicides. Ex: Devine, Collego, Bipolaris, Biolophos, Biomal, Velgo, Dr Biosedge, Conway, Cast, etc.

### Outstanding examples of biological control of weeds

<b>Lantana (<i>Lantana camara</i>):</b>	moth <i>Crociosema lantana</i>
<b>Prickly pear (<i>Opuntia</i> spp):</b>	moth borer ( <i>Cactoblastis cactorum</i> ) and conchineal scale insect ( <i>Dactylopius tomentosus</i> )
<b>Alligator weed (<i>Alternanthera philoxeroides</i>):</b>	flea beetle ( <i>Agasicles hygrophyla</i> )
<b>Water hyacinth (<i>Eichhornia crassipes</i>):</b>	Hyacinth weevils ( <i>Neochetina eichhorniae</i> and <i>Neochetina bruchi</i> )
<b>Water fern (<i>Salvinia molesta</i>):</b>	Curculinoid weevil ( <i>Cyrtobagous salviniae</i> )
<b>Nutsedge (<i>Cyperus rotundus</i>):</b>	Moth borer ( <i>Bactra verutana</i> )
<b>Congress weed (<i>Parthenium hysterophorus</i>):</b>	Beetle ( <i>Zygogramma bicolorata</i> )
<b>Puncture vine (<i>Tribulus terrestris</i>) :</b>	Weevil ( <i>Microlarinus lypriformis</i> )

## **Lecture 22:**

### **CHEMICAL METHOD OF WEED CONTROL**

A herbicide is a chemical used to kill some target plant/s. In agriculture, these target plants are weeds. Thus, when we talk of herbicides, we mean chemical warfare against weeds to the extent of killing or severely stunting these, depending upon our objective.

#### **Advantages:**

1. In monsoon season, incessant rainfall may make physical weeding infeasible. Herbicides can be used to ensure freedom of crops from weeds under such a condition. Also during the early crop growth period when many fields need weeding simultaneously, even in labour rich countries like India, Pakistan, Bangladesh, Nepal, Nigeria and Sudan, there is certainly a weeding bottleneck in crop production. The soil applied herbicide can be of great help in these regions in boosting crop production.
2. Herbicides can be employed to control weeds as they emerge from the soil to eliminate weed crop interference even at a very early stage of crop growth. But by physical methods weeds are removed after they have offered considerable competition to the crops, and rarely at the critical time. Thus, herbicides provide benefits of timely weed control.
3. Herbicides can kill many weeds that survive by mimicry, for example, wild oat in wheat and barnyard grass in rice. Weeds that resemble crop plants usually escape physical weeding.
4. Herbicide control does not dictate row spacing. In physical weed control, on the other hand, the crop rows have to be sufficiently wide to accommodate weeding implements.
5. Herbicides bring about longer lasting control of perennial weeds and brushes than is possible with any physical control method. Many modern herbicides can translocate considerably deep in the underground system of weeds and damage them.
6. Herbicides are convenient to use on spiny weeds which cannot be reached manually.
7. Herbicides are safe on erodible lands where tillage may accelerate soil and water erosion.
8. Herbicides kill weeds in situ without permitting their dissemination. Tillage on the other hand, may fragment the vegetative propagules of the weeds and drag them to new sites.

9. Some other benefits of using herbicides include
  - Fewer labour problems
  - Greater possibility of farm mechanization
  - Easier crop harvesting and
  - Lower cost of farm produce

**Limitations:**

1. Availability of agricultural labour at a comparatively cheap rate makes farmer rely on traditional methods of hand weeding for weed control.
2. Cost of chemical is rather high, the farmer is reluctant to use herbicides extensively. Most of the herbicides are imported.
3. Farmers generally follow a mixed cropping pattern of both monocots and dicots in which herbicides cannot be conveniently adopted. Herbicides differ widely in their selectivity to crops and weeds.
4. Not much safe to man and animals.
5. The use of herbicides requires some technical knowhow on the part of the farmer in respect of the choice of particular herbicides, their appropriate time and method of application and precautions required in their storage and use.

The success of a herbicide is greatly dependent on the soil type, crop and its variety to be treated, weed flora present and the prevailing environmental conditions. A farmer must understand these implications well before introducing any herbicide on his farm.

6. Over and under dosing of herbicides can make a marked difference between the success and failure of obtaining selective weed control.
7. Certain herbicides because of their long residues in soil may impose limitations on the choice of crop rotations of the farm.
8. Herbicides drift to crops growing in the neighbourhood can invite unhealthy quarrels.
9. Military use of herbicides is the greatest misfortune of their discovery. In Vietnam, 2,4-D and 2,4,5-T were used for defoliating forests and crops leading to miseries to the innocent people.

## **Classification of herbicides based on mode of action**

### **Selective herbicide:**

It is one that will kill some plant species when applied to a mixed plant population without causing serious injury to other species. Ex. 2,4-D, atrazine, EPTC, Trifluralin, alachlor. Selective herbicides are used in crop areas, lawns, gardens and grass lands. Certain selective herbicides when applied at high rates act as non selective plant killers. Ex Simazine, diruon

### **Non Selective herbicide:**

It is one that kill plants without regard to species. Ex. Paraquat, glyphosate, sodium chlorate, acrolein. They are generally employed for general vegetation control on non crop situation like industrial site, fallow land, roadside and in aquatics.

### **Foliage active herbicide:**

Herbicides that are applied to weeds after their emergence from soil. They are absorbed by plant foliage and in many cases these are translocated to other plant parts. At normal rates, the foliage active herbicides are most effective against young weeds in their seedling stage but at high rates these may kill even the established weeds. Ex. Paraquat, diquat, amitrole, MCPB, 2,4,5-T, etc.

### **Soil active herbicides:**

Herbicide that is applied primarily to the soil rather than to the vegetation. Inside the soil it kills weeds as they germinate or inhibit sprouting of their rhizomes, stolons and tubers. Therefore, in crop fields a soil active herbicide eliminates early weed crop competition for the period it remains active in soil. This period is usually 6-8 weeks, depending upon the herbicide and its rate used. The soil active herbicides are largely applied at the time of planting of crops. Ex. Alachlor, Simazine, EPTC, Trifluralin.

Reasons for the popular use of soil active herbicide compared to foliar herbicides

- Controls weeds before they germinate thus eliminating early period weed competition
- Maintain weed control for considerable period after application
- Provide better selectivity to the treated crops

### **Contact herbicide:**

Herbicide that kill plants primarily by contact with plant tissue which means that adequate coverage of the foliage is essential. Thus, a contact herbicide applied to the foliage of a plant will not kill its roots though in simple annuals the roots of treated plants may die because they are deprived of their shoots. The established weeds will regrow from their crown buds, roots or rhizome, shortly after treatment with a contact herbicide. Ex Parquat, diquat, propalin

**Translocated herbicide:**

These herbicides move within the plant from the point of treatment to the other plant parts. It kills the entire plant even if only a portion of the plant was treated with the herbicide. Therefore, translocated herbicides are of particular importance in controlling the perennial weeds. The translocated herbicides can be applied in low volume sprays to control annual weeds because they need to wet only a portion of the plant foliage as against contact herbicides which must drench the weeds fully for their effective kill.

Some herbicides may exhibit both contact and translocated properties. Ex. Atrazine is a translocated herbicide when absorbed from soil but a contact herbicide when sprayed on plant shoots.

**Fumigant:**

Volatile chemicals applied to the soil to produce a gas that will destroy weed seeds and act as a soil sterilant. These are good for killing deep rooted perennial weeds and for eliminating weed seeds from soil. Ex. MB, Metham, Dazomet, Chloropicrin, etc.

**Residual herbicide:**

They maintain their phytotoxic effects in soil for a considerable time after their application. The residue period may be three to four weeks in some herbicides such as 2,4-D and EPTC and much longer upto several months in others. In intensive crop rotations usually herbicides with 3-6 weeks of residual activity in soils are used.

**Non residual herbicide:**

These herbicides are inactivated in soil immediately or within a few days after they reach the soil. Ex. Paraquat, diquat, Amitrol, DSMA, etc.

**Classification based on chemical nature**

Herbicides are primarily grouped into inorganic and organic herbicides.

**Inorganic herbicides** do not contain carbon atoms in their molecules. They were the first chemicals used for weed control. Arsenic acid, sulphuric acid are acid type of inorganic herbicides. Where as sodium arsenate, sodium chlorate, copper sulphate, etc. are inorganic salts.

**Organic herbicides:** These herbicides contain carbon atoms in their molecules. They may be oils or non oils. Ex. diesel oil, xylene type of aromatic oils. Majority of present day herbicides are non oils.

There are about 150 herbicides are available. They differ each other like behavior in soil, plants, mode of action etc. based on this chemical nature; the herbicides are grouped into 31 classes.

## Organic herbicides

S. No.	Group	Herbicides
1	<b>Aliphatic acids</b>	Dalapon, TCA, Glyphosate, Methyl bromide Cacodylic acid , MSMA, DSMA
2	<b>Amides</b>	Alchlor, Butachlor, Propachlor, Metalachlor, Diphenamide, Propanil
3	<b>Benzoics</b>	2,3,6, TBA, Dicamba, tricamba, Chloramben
4	<b>Bypyridillums</b>	Paraquat, Diquat
5	<b>Carbamates</b>	Propham, Chlorpropham, Barban, Dichlormate, Asulam
6	<b>Thiocarbamates</b>	Butylate, Diallylate, EPTC, Molinate, Triallate, Benthiocarb, Metham
7	<b>Dithiocarbamates</b>	CDEC, Metham
8	<b>Nitriles</b>	Bromoxynil, Ioxynil, Dichlobenil
9	<b>Dintroanilins</b>	Fluchloralin, Trifluralin, Pendimethalin, Nitralin Isoproturon
10	<b>Phenols</b>	Dinoseb, DNOC, PCP
11	<b>Phynoxy acids</b>	2,4-D, 2,4,5-T, MCPA, MCPB, 2,4-DB, Dichlorprop
12	<b>Traizines</b>	Atrazine, Simazine, Metribuzine, Amytrin, Terbutrin
13	<b>Ureas</b>	Monuron, Diuron, Linuron, Metoxuron, Isoproturon, Methabenz thiozuron
14	<b>Uracils</b>	Bromacil, Terbacil, Lenacil
15	<b>Diphenyl ethers</b>	Nitrofen, Oxyfluorfen, Nitrofluorfen
16	<b>Aryloxyphenoxy propionate</b>	Diclopop , Fenoxaprop-p, Quizalofop-p, Haloxyfop-p Fluazifop-p
17	<b>Cyclohexanedione</b>	Sethoxydim, Clethodim, Tralkoxydim, Cycloxidim
18	<b>Imidazolines</b>	Imazapyr, Imazamethabenz, Imazaquin, Imazamax imazethapyr
19	<b>Isoxazolidinones</b>	Clomazone
20	<b>Oxadiazoles</b>	Oxadiazon
21	<b>Oxadiazolides</b>	Methazole
22	<b>N-phenylphthalamides</b>	Flumiclorac

S. No.	Group	Herbicides
23	<b>Phenylpyridazones</b>	Sulfentrazone
24	<b>Phthalamates</b>	Naptalam
25	<b>Pyrazoliums</b>	Difenzoquat, Metflurazone
26	<b>Picolinic acids Pyridine</b>	Picloram , Dithiopyr, Pyrithiobac, Fluridone
27	<b>Quinolines</b>	Quinclorac
28	<b>Sulfonylureas</b>	Bensulfuron, Chlorimuron, Metsulfuron, Sulfosulfuron, Triasulfuron
29	<b>Triazolinones</b>	Pyridates
30	<b>Cineoles</b>	Cinmethylin
31	<b>Others</b>	Picloram, Pyrazon, Endothal, Oxadiazon, Amitrole, Anilofos

#### **Based on time of application:**

**Pre plant herbicide:** A herbicide applied before a crop is planted is called pre plant herbicide. There are two types of pre plant treatments i.e. pre plant desiccation and pre plant incorporation. In the former method, herbicides are applied to destroy the existing vegetation as an aid to seed bed preparation. In the pre plant incorporation method, herbicides are mixed with weed free seed beds to obtain residual control of weeds during the crop season. The herbicide is usually incorporated into the soil to reduce volatility and photo decomposition losses. Ex EPTC, Fluchloralin, Trifluralin, Molinate, etc.

**Pre emergence herbicide:** Herbicides that are applied soon after planting of a crop are called pre emergence herbicides. This herbicide is most effective when applied before the emergence of crop and weeds. A fine clod free soil tilth is the first requirement of a successful pre emergence herbicide. Besides, there must be adequate moisture in the soil to seep the herbicide 2-3 cm deep. Ex. Atrazine, Nitrofen, TCA, etc.

**Post emergence herbicide:** Herbicides that are applied after the emergence of crop as well as the weeds. But when the weeds grow before the crop plants have emerged through the soil and these are knocked with a herbicide, than it is called early post emergence herbicide. These early post emergence herbicides are usually non residual types. Ex. Asulam, Dalapon, Paraquat, Diquat, Glyphosate, Isoproturon, etc,

Herbicides that inhibit germination or absorbed through the roots are usually applied as pre emergence whereas those herbicides which are absorbed and translocated through the leaves are applied as post emergence. Alachlor and Atrazine are applied as PPI, Pre emergence and early post emergence.

**Layby application:** Application of herbicides after the last cultivation in crops such as after ridging in sugarcane and cotton.

### **Methods of application of herbicides:**

Method of application of herbicide are decided largely by their mode of action, selectivity, environmental factors, convenience and cost and several other factors. An improper method of application of a herbicide can result in poor weed control and or severe crop injury.

**Broadcast:** Application of herbicide over an entire area.

**Band application:** Application of herbicide to restricted area along the crop rows. This method reduces cost since treatment is confined to a portion of the total area.

**Basal application:** Application of herbicides to stems or trunks at or just above the groundlevel by sprayer or paint brush.

**Spot treatment:** Application of herbicides to small patches of weeds leaving the weed free gaps untreated.

**Soil treatment:** Application of herbicides to the soil.

**Soil injection:** Herbicides like ethylene are applied beneath the soil surface by soil injections at prescribed spacings before planting of crops.

**Foliar application:** Application of herbicide to the foliage of plants.

**Directed spraying:** Application of herbicides to chiefly the weeds growing in the inter rows of crops avoiding the crop foliage as much as possible. Thus, it is possible to use non selective herbicide in a selective manner.

## **INTEGRATED WEED MANAGEMENT**

System approach also called as integrated weed management. Integrated method is a system which brings all feasible methods of weed control harmonizing them into a single and co-ordinated system designed to maintain weeds below those levels at which they cause economic loss”.

### **Principles of Integrated weed management**

1. IWM place the crop in competitive advantage over the weeds by manipulating the crop habitat by utilizing some biological differences between crops and weeds.
2. In IWM measures should be directed to reduce the survival mechanism of weeds in the soil.
3. Crop cultural practices should be incorporated to discourage the establishment of the perennial and parasitic weeds. Eg: Crop rotation
4. Any individual element of the weed management should be eco friendly and it should not be harmful to the environment.

5. Weed management practices should be flexible to accommodate possible innovations and experiences of progressive farmers.

### **Advantages**

1. It shifts the crop-weed competition in favour of crop
2. Prevents weed shift towards perennial nature
3. Prevents resistance in weeds to herbicides
4. No danger of herbicide residue in soil or plant
5. No environmental pollution
6. Gives higher net return
7. Suitable for high cropping intensity

## Lecture 23:

### IRRIGATION MANAGEMENT

It is defined as “artificial application of water to soil for the purpose of supplying the moisture essential for normal plant growth and development”. In other words it is the human manipulation of hydrological cycle to improve crop production and quality and to decrease the economic effects of drought. However, a broader and more meaningful definition is that irrigation is the application of water to the soil for the following purposes:

- ◆ To add water to the soil for supplying moisture essential for normal plant growth and development
- ◆ To provide crop insurance against short duration droughts
- ◆ To leach or dilute excessive salts in the crop root zone, thereby providing a favourable environment in the soil profile for absorption of water and nutrients
- ◆ To soften tillage pans
- ◆ To cool the soil and atmosphere, thereby making more favourable microenvironment for plant growth

#### **Importance of irrigation water management**

The importance of irrigation in the world is well stated by N.D. Gulhati of India: “Irrigation in many countries including India is an age - old art - as old as civilization - but for the whole world it is a modern science - science of survival”.

The pressure of survival and the need for additional food supplies are necessitating a rapid expansion of irrigation throughout the world including India. Production and productivity of agricultural lands is primarily dependent upon the availability of irrigation water to crops. Expansion of irrigation has paid rich dividends in India. After independence, production registered nearly 6 six times increase from around 50.8 million tons in 1950-51 to about 308 million tons in 2020-21. This has been mainly attributed to three factors viz., high yielding cereals, expansion of area under irrigation and fertilizer use. Irrigation may be considered as the major factor of modern intensive agriculture as it aids in efficient use of costly fertilizers and other inputs besides meeting crop water needs.

On the other hand, improper irrigation causes wastage of large amounts of water, leach mineral nutrients from the root zone into the deeper layers contaminating groundwater, and impairs the productivity of soil, or yield losses may occur if insufficient water applied. Excessive application of water causes waterlogging and increase high water tables or seepage spots to develop which may be corrected only by the construction of expensive drainage systems. In addition, salts accumulate and an

alkali soil may develop. Water for irrigation and other uses is becoming more and more valuable due to increasing cost of irrigation projects and a limited supply of good quality water. Therefore, we must learn how to make optimal use of water to prevent an excessive wastage to preclude the degradation of the land and bring about its improvement for maximizing water productivity.

### **Objectives of irrigation**

The broad objectives of irrigation are as follows:

- a) To increase crop production on sustainable basis where water is a limitation
  - To increase national income/national cash-flow
  - To increase labour employment
  - To increase standard of living
- b) Modification of soil & climatic environment
  - For leaching of salts
  - For reclamation of sodic soils
  - For frost protection
- c) To mitigate i.e., lessen the risk of catastrophes caused by drought
  - To overcome food shortages
  - To protect high value crops/trees
- d) To increase population of arid and sparsely populated areas
  - For national defense
  - For population re-distribution
- e) National security i.e., self sufficiency in food grain production

### **Factors influencing irrigation water management**

#### **Nature of crop**

1. Water requirement of crop varies with type of crop, duration, growth stages and rooting pattern
2. Crops with longer duration requires more water for completion of life cycle while the short duration crops require less water
3. Crops require less water during early stages of crop growth and more water at later stages because of increase in the volume i.e. depth and distribution of root growth
4. Depending upon the crop, the depth and distribution of root system will vary

- i, Shallow rooted crops (60 cm) - Rice, cabbage
- ii. Moderately deep rooted crops (90 cm) - Castor, tobacco
- iii. Deep rooted (120 cm) - Sugarcane, maize

### **Nature of soil**

1. Based on the soil the number of irrigation and irrigation interval will vary.
2. Soil contains sand, silt and clay. Soils with equal proportion of sand, silt and clay are good soils and the crop growth and productivity will be high because of high water holding capacity, exchange of air between soil and air and provision of drainage
3. Soils with higher percentage of sand are called light or coarse textured soils and soils with high percentage of clay are called heavy or fine textured soils
4. Sandy soils has relatively low total porosity, higher macropore space and less micropore space because of which the WHC is less and the number of irrigations will increase with lesser irrigation interval
5. Heavy soils or clay soils or fine textured soil has higher total porosity, lesser macropores and higher micropores because of which the WHC is more and the number of irrigations will decrease with greater irrigation interval
6. If soil is wet upto 30 cm depth, sandy, loamy and clay soils will retain 2.5 cm, 3.75 cm and 5.0 cm respectively

### **Nature of climate**

1. Irrigation frequency majorly depends on climatic factors.
2. Among different climatic factors temperature is major contributing factor. Higher temperatures result in loss of water from soil (evaporation) as well as loss of water from plant (transpiration).
3. More frequent irrigations required during summer (March, April and May) months due to higher temperatures.
4. Similarly, relative humidity and wind velocity also influence irrigation requirement.
5. More frequent irrigations required under higher wind speed. Hot and dry area surrounding the irrigated area increases evaporation.

### **Critical growth stages**

The crop plants in their life cycle pass through various phases of growth, some of which are critical for water supply. The most critical stage of crop growth is the one at which a high degree of water stress would cause maximum loss in yield. Further, studies on irrigation at growth stages may give an indication as to whether scarce water can be used more efficiently by scheduling irrigation's at critical stages.

Scheduling of irrigations on the basis of critical growth stages is simple and easy for the farmers. However, it does not take into account the available soil water in the crop root zone depth. Excessive irrigations without significant soil/ plant water deficit could be harmful to crop plants and might reduce their yield under certain situations. The criterion may not hold well in long duration crops like sugarcane, cotton; crops requiring frequent irrigation's viz., potato or standing/nearly standing water (rice) and where there is interference by rainfall of different amounts. The critical growth stages of various crops for moisture supply are presented in Table 23.2.

**Table 23.2. Critical growth periods of crops for water supply**

<b>Crop</b>	<b>Critical growth period for water supply</b>
Rice	Primordial development, Heading & Flowering
Sorghum	Booting, Blooming, Milky & Dough stages
Ragi	Primordial initiation & Flowering
Maize	Tasseling, Silking & Pollination
Bajra	Heading & Flowering
Wheat	Crown root initiation, Shooting & Earing
Groundnut	Flowering, Peg penetration & Pod development
Sesame	Flowering to Maturity
Sunflower	Star formation, Flowering & Seed development
Safflower	Rosette, flowering and Seed development
Soybean	Flowering & Seed formation
Cotton	Flowering & Boll development
Sugarcane	Formative & Stem elongation
Tobacco	Rapid growth & Topping stage
Chillies	Flowering & Fruit development
Potato	Tuber initiation to Tuber maturity
Onion	Bulb enlargement to Ripening
Tomato	Flowering & Fruiting
Citrus	Flowering, Fruit set & Fruit enlargement
Banana	Adequate soil moisture throughout growth period & fruit development
Mango	Flowering & fruit development

## Lecture 24:

### WATER REQUIREMENT OF CROPS

Water requirement is the quantity of water regardless of source, needed for normal growth and yield, that may be supplied entirely by precipitation or irrigation or by both

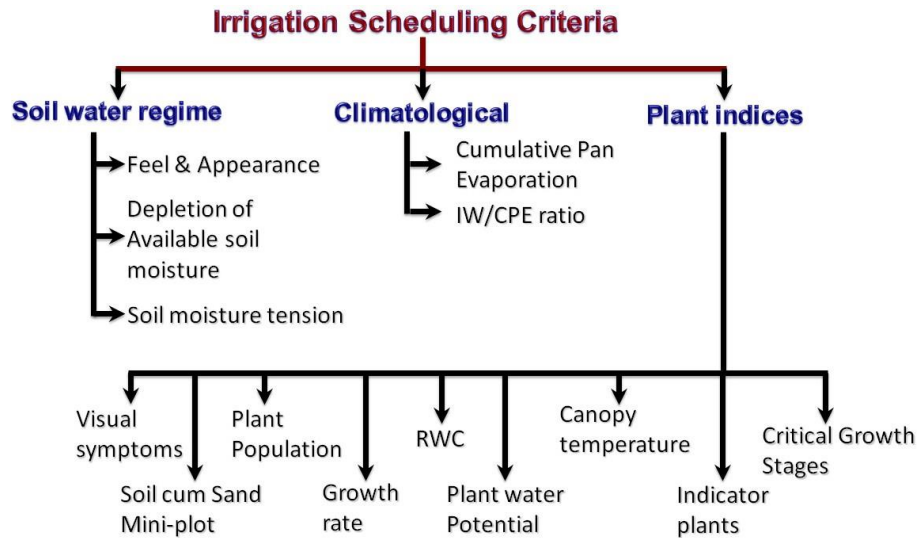
Table 24.1 Water requirement of different crops

S. No.	Crop	Water requirement (mm)
1	Rice	1200
2	Maize & sorghum	450-600
3	Ragi	400-450
4	Bajra	400-450
5	Groundnut & sunflower	500-700
6	Cotton	650-850
7	Sugarcane	1500-2500
8	Tobacco	400-600
9	Sesamum	300-500
10	Castor	500
11	Redgram	350-450
12	Greengram & blackgram	200-400
13	Bengalgram	350
14	Tomato	350-500
15	Onion	450-550
16	Chilli	550-650
17	Turmeric	1200-1400

## Scheduling of Irrigation to Crops

### Criteria for scheduling irrigation

Criteria for scheduling irrigation can be broadly classified into the following three categories:



However, criteria most suitable for scheduling irrigation's would vary with soils, plants, climatic and management factors.

### 1. Soil water regime approach

#### a. Feel and appearance of soil

This is one of the oldest and simple methods of determining the soil moisture content. It is done by visual observation and feel of the soil by hand (Fig. 24.1). The accuracy of judgement improves with experience.



Fig. 24.1. Feel and appearance of soil

Based on several years of experience guidelines have been developed (Table 1) which help the farmers to judge the soil moisture present in the soil samples drawn from the crop root zone depth and based on depletion of available soil moisture (DASM) irrigations are scheduled. Though it is a crude method it can be used satisfactorily for some purpose if experience is backed by other local information. Further this method is subjective. Thus, different people who examine the same soil condition may obtain different answers.

Table 24.2. Guidelines for judging soil moisture by feel & appearance of soil

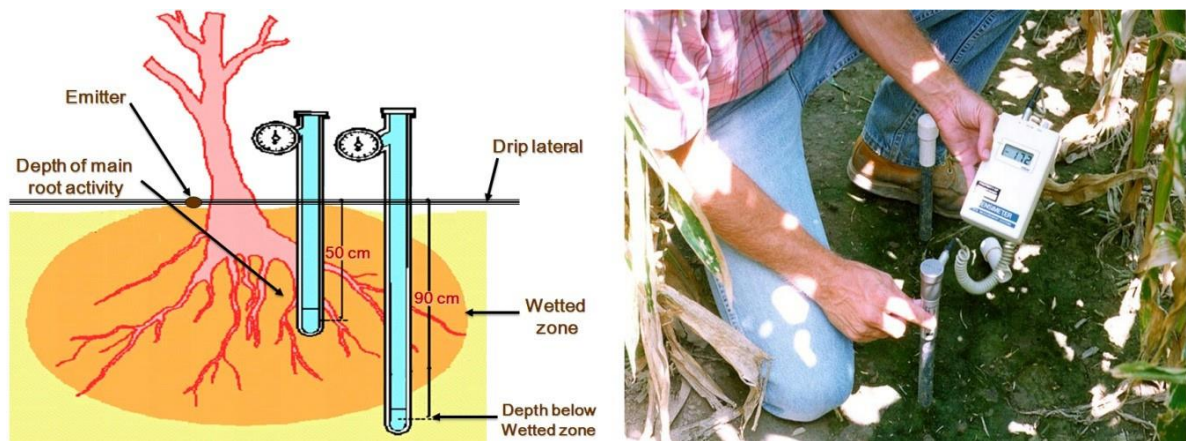
Available soil moisture range	Coarse texture (loamy sand)	Moderately coarse (sandy loamy)	Medium texture (loamy and silt loamy)	Fine texture (clay loamy and silty clay loamy)
Above field capacity	Free water appears when soil is banded in hand	Free water is released with kneading	Free water can be squeezed out	Puddles; free water forms on surface.
At Field capacity (100%)	On squeezing no free water appears on soil, but wet outline of ball is left on hand	Same as for coarse textured soils at field capacity	Same as for coarse textured soils at field capacity	Same as for coarse textured soils at field capacity
75% to 100%	Tends to stick together slightly, may form a very weak ball under pressure	Forms weak ball that breaks easily, does not slick	Forms a ball, very pliable, sticks readily if relatively high in clay	Easily ribbons out between fingers; has a slick feeling
50% to 75%	Appears to be dry, does not form a ball under pressure	Forms a ball under pressure but seldom holds together	Forms a ball under pressure; somewhat plastic, slicks slightly under pressure	Forms a ball; ribbons out between thumb and forefinger
25% to 50%	As above, but ball is formed by squeezing very firmly	Appears to be dry, do not form a ball unless squeezed very firmly	Somewhat crumbly but holds together with pressure	Somewhat pliable, forms a ball under pressure
0 to 25%	Dry, loose & single grained, flows through fingers.	Dry and loose, flows through fingers	Powdery dry, sometimes slightly crusted, but breaks down easily into powder.	Hard, baked and cracked, has loose crumbs on surface in some places

### b. Depletion of the available soil moisture (DASM)

In this method the permissible depletion level of available soil moisture in the effective crop root zone depth is commonly taken as an index or guide for scheduling irrigations to field crops. In general, for many crops scheduling irrigation's at 20–25 % DASM in the soil profile was found to be optimum at moisture sensitive stages. While at other stages irrigations scheduled at 50 % DASM were found optimum.

### c. Soil moisture tension

Soil moisture tension a physical property of film water in soil, as monitored by tensiometers (Fig. 24.2) at a specified depth in the crop root zone could also be used as an index for scheduling irrigations to field crops.



**Fig. 24.2. Tensiometers for irrigation scheduling**

Tensiometers are installed in pairs, one in the maximum rooting depth and the other below this zone. Whenever critical soil moisture tension is reached say for example 0.4 or 0.6 or 0.75 bars etc in the upper tensiometer the irrigation is commenced. While the lower one (tensiometer) is used to terminate the irrigations based on the suction readings in the below soil profile zone. It is generally used for irrigating orchards and vegetables in coarse textured soils because most of the available soil moisture is held at lower tensions.

## **2. Climatological approach**

### **a. Potential evapotranspiration (PET)**

Penmen (1948) introduced the concept of PET and he defined it as “the amount of water transpired in a unit time by short green crop of uniform height, completely covering the ground and never short of water”. He further stated that PET cannot exceed pan evaporation under the same weather conditions and is some fraction of pan evaporation. PET can be estimated by several techniques *viz.*, lysimetric methods, energy balance, aerodynamic approach, combination of energy balance and empirical formulae etc., and irrigation’s can be scheduled conveniently based on the knowledge of PET or water use rates of crops over short time intervals of crop growth.

### **b. Lysimeter**

By isolating the crop root zone from its environment and controlling the processes that are difficult to measure, the different terms in the soil water balance equation can be determined with greater accuracy. This is done in lysimeters where the crop grows in isolated tanks filled with either disturbed or undisturbed soil.

Different types of lysimeters vary widely in the accuracy with which changes in soil water are detected. In precision weighing lysimeters, where the water loss is directly measured by the change of mass, evapotranspiration can be obtained with an accuracy of a few hundredths of a millimetre, and small time periods such as an hour can be considered. In non-weighing lysimeters the evapotranspiration for a given time period is determined by deducting the drainage water, collected at the bottom of the

lysimeters, from the total water input.

A requirement of lysimeters is that the vegetation both inside and immediately outside of the lysimeter be perfectly matched (same height and leaf area index). Lysimeters provide the direct estimates of water balance components viz., E, T, ET, drainage, runoff, effective rainfall etc in a cropped field against which other methods can be tested and calibrated. As lysimeters are difficult and expensive to construct and as their operation and maintenance require special care, their use is limited to specific research purposes.

### **c. Cumulative pan evaporation**

Earlier investigations have shown that transpiration of a crop is closely related to free water evaporation from an open pan evaporimeter. Thus, the open pan evaporimeter being simple and as they incorporate the effects of all climatic parameters into a single entity i.e., pan evaporation could be used as a guide for scheduling irrigation's to crops. For example, sunflower required 60 mm CPE at Bangalore

Based on the same analogy, an alternative, simple can evaporimeter was devised by Jain (1975). The evaporation from it was shown to be closely related to pan evaporation as well as soil moisture depletion, hence it could also be satisfactorily employed in place of evaporimeter for scheduling irrigation to crops.

### **d. IW : CPE ratio**

Prihar *et al.* (1974) advocated irrigation scheduling on the basis of ratio between the depth of irrigation water (IW) and cumulative evaporation from U.S.W.B. class A pan evaporimeter minus the precipitation since the previous irrigation (CPE). An IW/CPE ratio of 1.0 indicates irrigating the crop with water equal to that lost in evaporation from the evaporimeter. Ex. 0.75 to 1.0 IW/CPE ratio depending on groundnut crop developmental stages in Andhra Pradesh, Maharashtra & West Bengal

## **3. Plant indices approach**

The plant in one form or the other expresses water deficits in the soil, since it is the one, which is affected by the water stress. Any plant character, related directly or indirectly to water deficits and which responds readily to the integrated influences of soil water, plant and environmental parameters may serve as a criterion for timing irrigation to crops. Some of the plant indices commonly used are discussed below:

### **a. Visual plant symptoms**

In this method the visual signs of plants are used as an index for scheduling irrigations. For instance, plant wilting, drooping, curling and rolling of leaves in maize is used as indicators for scheduling irrigation (Fig. 24.3). Change in foliage colour and leaf angle is used to time irrigations in beans. Water stress in some crops leads to appearance of carotenoid (yellow and orange colour) and anthocyanin pigments; shortening of internodes in sugarcane and cotton; retardation of stem elongation in grapes; leaf abscission and lack of new growth and redness in terminal growth points of almond, which can be used as indices for scheduling irrigations to crops.



**Fig. 3. Rolling of leaves in maize and change of leaf angle in beans**

#### **b. Soil-cum-sand mini-plot technique**

This method is also referred to profile modification technique and is commonly used for scheduling irrigations to crops. The principle involved in this technique is to reduce artificially the available water holding capacity of soil profile (i.e., effective root zone depth) in the mini-plot by mixing sand with it. When this is done plants growing on the sand mixed plot show wilting symptoms earlier than in the rest of the field. An area of 1.0 x 1.0 m is selected in the field and a pit of 1.0m depth is excavated. About 5% of sand by volume is added to the dug up soil and mixed well. The pit is then filled back with the mixture and while filling up every 15 cm layer is well compacted, so that the soil in the pit retains the original bulk density as that of surrounding soil. Crop is sown normally and is allowed to grow as usual with the rest of the field. As and when the plants in the mini-plot show wilting symptoms it is taken as a warning of impending water need and cropped field is irrigated.

#### **c. Plant population**

Increase in plant population by 1.5 to 2.0 times that of optimum in some representative spots of (1 m x 1m area) in the cropped field alternative to mini-plot technique also serves as a reliable index for scheduling irrigation's to crops. This happens because when more plants are there per unit area, the available water within that zone is depleted rapidly as compared to other area wherein optimum number of plants is maintained per unit area. This result in drooping or wilting of plants earlier, which can be taken as an indication of water deficits and accordingly irrigations are scheduled to crops.

#### **d. Rate of growth**

Growth of a plant is dependent on turgor, which inturn is dependent on a favourable soil water balance. So fluctuations in the water balance are reflected by parallel fluctuations in the growth rate of expanding organs. Stem elongation is markedly reduced when the available soil moisture level approaches the critical level, but accelerates again after irrigation.

In cotton elongation of internodal length by 0.5 to 1.0 cm day<sup>-1</sup> indicated the approach of critical available soil moisture level. Likewise in oranges, when the growth rate of fruit circumference falls below 0.2 to 0.3 mm d<sup>-1</sup>, irrigations have to be scheduled.

#### **e. Relative water content**

This concept was proposed by Weatherly (1950). It is the actual water content of the leaf or plant when sampled relative to water at saturation or turgid. It is expressed as relative water content (RWC) and is calculated as follows:

$$\text{RWC} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}}$$

It depends on the lag between evaporative demand of the atmosphere and the rate of water absorption by the roots and has been found to be one of the reliable indices of plant water stress for scheduling irrigation. For instance the critical RWC level (below which reduction in growth occurs) for cotton and sesame was 72% and 75% respectively. Whenever the plant exhibits these values, irrigations can be scheduled. However, the main drawback is it is tedious and time consuming.

#### **f. Plant water potential**

This method measures the energy status of plant water analogous to the tension of film water in the soil, and serves as a better index of physiological and bio-chemical phenomena occurring in the plant. Plant or leaf water potential can be precisely measured either by a pressure bomb or pressure chamber apparatus in situ or by the dye method in the laboratory.

The critical plant water potential values for cotton below which yield reductions are expected were 1.2 to 1.25 MPa throughout the crop life. While for sunflower they were 1.0, 1.2 and 1.4 MPa at vegetative, pollination and seed formation, respectively.

#### **g. Canopy temperature**

Several studies have shown that plant temperature or canopy temperature adequately reflects the internal water balance of the plant, and can be used as a potential indicator for scheduling irrigation to crops. It can be measured by several instruments, which are commercially available *viz.*, porometer, infrared thermometer, etc.

For maize it is shown that if the canopy temperature rises to more than 0.7° C over ambient temperature during 1330 to 1400 hour's irrigations need to be scheduled. However, tomato showed no sensitivity to water stress with respect to temperature variations.

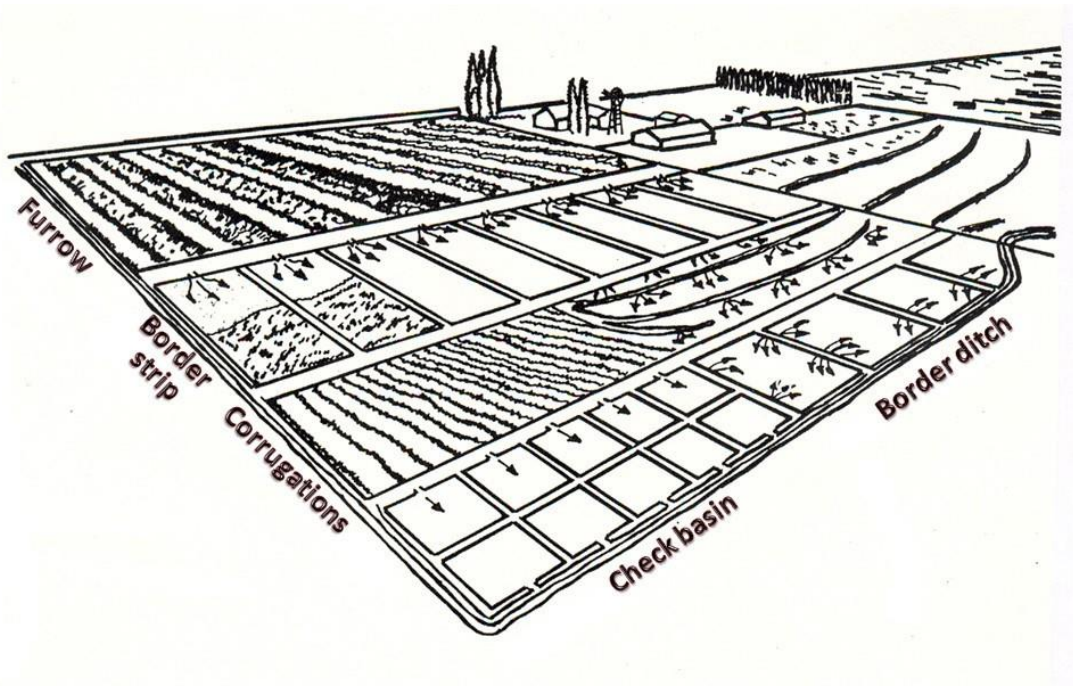
#### **h. Indicator plants**

Some workers have suggested the use of indicator plants as a guide for scheduling irrigations. In wheat, scheduling irrigations on the basis of wilting symptoms in maize and sunflower gave the highest grain yields.

## Lecture 25:

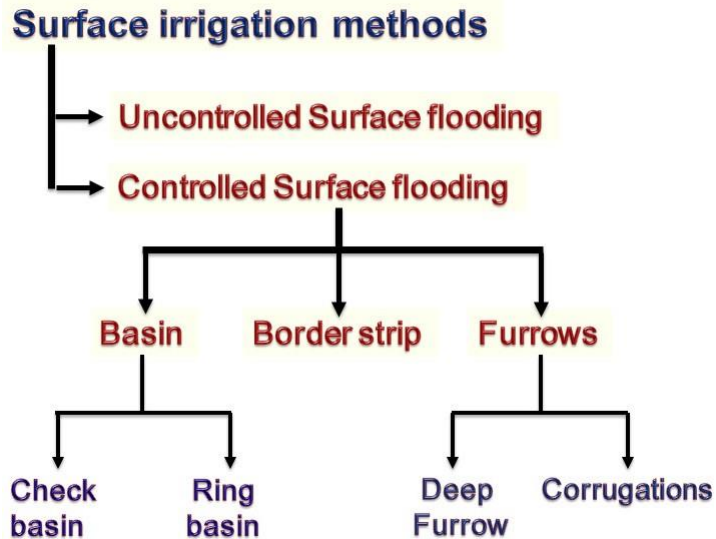
### METHODS OF IRRIGATION

Surface irrigation method refers to the manner or plan of water application by gravity flow to the cultivated land wetting either the entire field (uncontrolled flooding) or part of the field (furrows, basins, border strips). Most irrigated areas have characteristic land features and differ from those in other areas. Hence, for efficient application of water it is important to select such method of irrigation, which fits one's own land. In doing so it may be necessary, or desirable, to use more than one method of irrigation in an area or a given farm (Fig. 25.1).



**Fig. 25.1. Different methods of irrigation on a farm**

The adoption of a certain method need not be necessarily based on convention or that followed in the adjoining farm. The factors, which determine the suitable method of irrigation are local conditions (soil type - its permeability & water storage capacity; land topography, climate, water availability & water quality), crop type, type of technology, previous experience with irrigation, required labour inputs etc. Good yield of crops can be obtained from irrigated land only if the water is applied judiciously to meet the needs of the plant, but not to cause waste and damage. Irrigation water is applied to cultivated land by the following surface methods of irrigation:



## 1. Wild flooding

It consists of applying water to the field without any bunds to guide the flow of water wetting the soil surface completely. Generally it is practiced only when irrigation water is abundant and where land levelling is not followed. Sometimes it is also adopted in the initial stages of land development. This method is most commonly used for irrigation of crops sown by broadcasting method *viz.*, rice, low value pastures, lawns and millets etc.

### Advantages

1. No land levelling & land shaping
2. Low labour and land preparation costs
3. Less skill required by irrigator

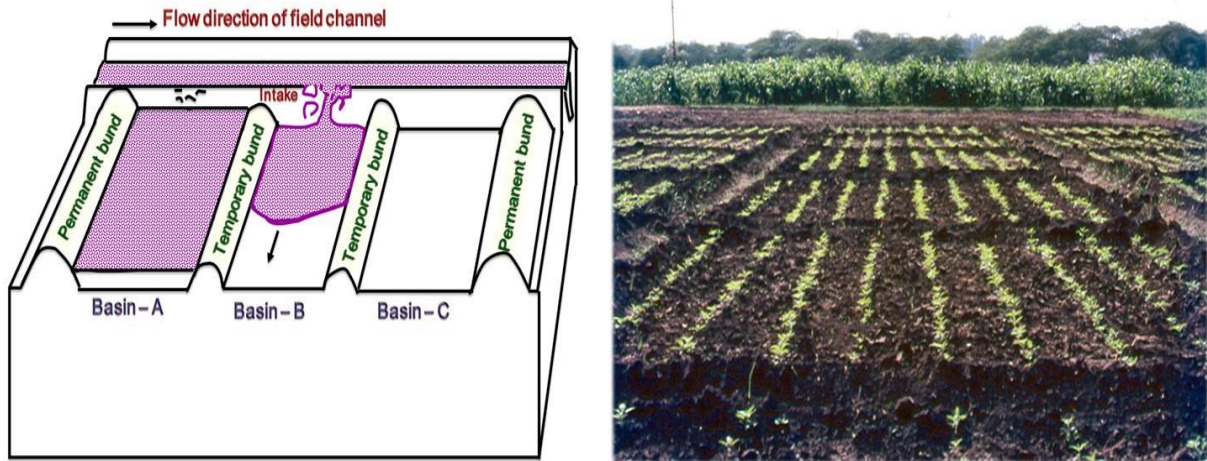
### Disadvantages

1. Applied water is lost by deep percolation & surface runoff
2. Low irrigation application efficiency

## 2. Controlled flooding

### a. Check basin method

In this method the field is divided into square or rectangular plots of 4 to 4000 m<sup>2</sup> guided by bunds on all the sides (Fig. 25.2). This method is usually practiced in nearly levelled lands, thus no run-off of soil or water takes place and wetting depth is more uniform. However, it is particularly useful on fine textured soils with low permeability rate where it is necessary to hold the water on the surface to secure adequate penetration. The field channels supply water to each basin, during which the basins are filled to desired depth and water is retained until it infiltrates into the soil. This method is most commonly used for irrigating crops like groundnut, finger millet, sorghum, vegetable crops etc. Check basins are also used for leaching salts below the crop root zone depth by percolating water in the reclamation of saline soils.



**Fig. 25.2. Check basin method of irrigation**

### **Advantages**

1. Water can be applied uniformly.
2. Even small streams can be used for irrigation of crops efficiently.
3. Simple and cheap when equipment is used for constructing bunds

### **Disadvantages**

1. Unless the land is levelled, distribution of water in plot is uneven.
2. Considerable area is lost under field channels and bunds i.e. nearly 30% of area.
3. Bunds interfere in working of inter-cultivation equipment.
4. More labour is required for field layout and irrigation.

### **b. Ring basin method**

This method is a modification of check basin method and is suitable for sparsely grown orchard crops and cucurbits (Fig. 25.3).



**Fig. 25.3. Ring basin method of irrigation**

In this method a circular bund is constructed around each tree/plant or group of plants/trees to create a basin for irrigation. These basins are suitably connected to irrigation conveyance channels in such a way that either each basin is irrigated separately or group of basins by flowing water from one basin to another through inter-connections. Advantages

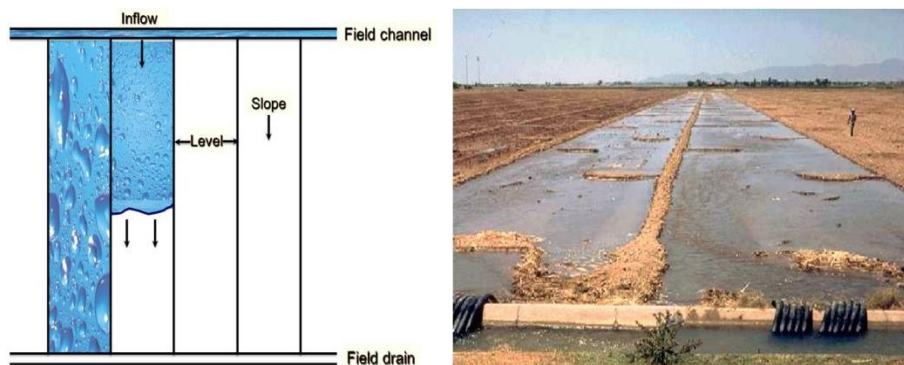
1. High irrigation application efficiency can be achieved with properly designed system
2. Unskilled labour can be used, as there is no danger of erosion

Disadvantages

1. High labour requirement
2. Bunds restrict use of modern machinery in the field
3. Limited to relatively uniform lands

### c. Border strip method

The cultivated field to be irrigated is divided into a number of long parallel strips, generally 5 to 15 m in width and 75 to 300 m in length separated by small border ridges or low dykes of about 15 cm high, laid out in the direction of the slope (Fig. 25.4).



**Fig. 25.4. Border strip method of irrigation**

The objective is to advance a sheet of water down the narrow strip of land, allowing it to enter the soil as the sheet advances. Irrigation water is released into each strip connected directly to irrigation channel situated at the upstream end of the border strip. After sufficient water has been applied to one strip, the irrigation stream is turned into another strip. A specific requirement in border irrigation is that the longitudinal slope must be uniform, and the transverse slope must be zero or negligible ( $< 0.03\%$ ). This method is suitable for irrigating a wide variety of close growing crops such as wheat, barley, groundnut, bajra and berseem.

### Advantages

1. Large water streams can be used safely
2. Provides uniform wetting of soil profile
3. Low labour requirement

## Disadvantages

1. Requires relatively large water streams for quick advance of water to minimize deep percolation losses at the upper end of the border strip.
2. Wastage of water by deep percolation in coarse textured soils.

## d. Deep furrow method

In furrow method of irrigation, the flat bed surface is converted into a series of ridges and furrows running down the slope (Fig. 25.5). The spacing of the furrow is ordinarily determined by the spacing of row crop. The length of the furrow and slope depends on several factors *viz.*, texture, intake rate etc.



**Fig. 25.5. Furrow method of irrigation**

Depending on the soil, crop spacing, farm equipment used etc spacing between furrows varies from 60 to 120 cm. Depending on the soil texture furrow length ranges from 20 to 300 m or even more. To avoid overtopping and scouring problems furrow inflow rates are normally limited to 2 to 15 m<sup>3</sup>/hr/furrow. This method can be used either with small or large streams of irrigation water because it can be diverted into any number of furrows. Slope along the furrows may range from 0.2 to 2%. Where the land is too slopy (>5%), the furrows must be constructed on contours. Among the various surface irrigation methods, there is a relative saving of water in furrow method; hence efficient use of water is possible. In case of limited water, alternate furrows may be irrigated without much adverse effect on the crop yield. This method is commonly used for irrigating crops like potato, sugarcane, maize, cotton, melons, sugarbeets and vegetables like lettuce.

When furrow irrigation is practiced under saline and alkaline conditions, the lateral movement of soil moisture coupled with evaporation causes salt to accumulate in the ridges between furrows. If the salt accumulation reaches harmful levels, planting is advocated on the relatively salt free bottom of the furrows following pre-plant irrigation.

### **Advantages**

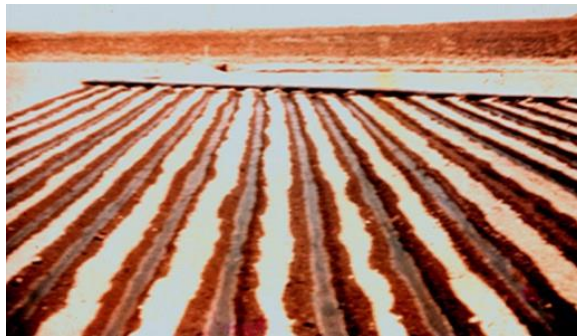
1. Fairly high irrigation application efficiency among surface irrigation methods
2. Furrows serve as field drains in areas of heavy rainfall
3. Low evaporation losses

### **Disadvantages**

1. Not suitable in coarse textured soils with high infiltration rates
2. Possibility of intra-furrow soil erosion
3. Labour intensive

### **e. Corrugations**

This is a special method of furrow irrigation. Corrugations or rills are shallow furrows running down the slope from head ditches or laterals, which are sometimes very close to each other (Fig. 25.6).



**Fig. 25.6. Corrugations method of irrigation**

Water moves down through several corrugations simultaneously and soaks laterally through the soil, wetting the area between the corrugations. This method is used for irrigating close growing crops, which do not require inter-culture operations and may also be used in conjunction with border irrigation. Corrugations are often used in fine textured soils that take water slowly and in soils, which tend to seal over and crust when flooded. The spacing and size of the corrugations vary with soil type, but in general, the more porous the soil, the more closely spaced the corrugations to permit rapid wetting between them without excessive deep percolation losses. The length of the corrugations should be such that upper end of the field has not been over irrigated by the time the lower end has received sufficient water.

### **Sub-surface irrigation**

Sub-irrigation is the method of applying water beneath the soil surface; close to the plant roots so that either water seeps from the sides of the channels towards the plant roots or through capillary movement upward. It is usually done by creating an artificial water surface at some pre-determined depth, about 30 – 75 cm below the ground, depending upon the texture and rooting characteristics of the crop. Application efficiencies vary from 30-80% depending upon conditions. Water having high salt content cannot be used. This method is expensive, difficult to maintain and operate, and suitable only for few crops. Because of high investment required, it has not been widely adopted in India.

## Lecture 26:

### SPRINKLER AND DRIP METHOD OF IRRIGATION

#### Sprinkler Irrigation

Sprinkler irrigation has been in use for many decades in many parts of the world. After 1946, use of sprinkler in large scale started, particularly USA and France. In about two decades 5-6 m ha of land was irrigated with sprinklers. Sprinkler irrigation is very popular in Israel as about 95 per cent of the total irrigated area is under sprinklers.

Sprinklers were introduced in India during early 50's. Now their use is gaining popularity in food crops like cotton, vegetables and orchards in addition to coffee, tea, chicory and cardomum, etc. where sprinkler is economically justifiable and technically feasible.

This is also referred to as over head method of irrigation. Water is conveyed under desired pressure (2 to 5 kg/cm<sup>2</sup>) developed by a pump through a network of pipes, called mainlines and sub mains to one or more laterals and is sprayed in to the air through sprinkler nozzles or perforations so that it breaks up in to small water drops (0.5 to 4 mm in size) which fall over the land or crop surface in an uniform pattern at a rate (0.06-5000 LPH) less than the infiltration capacity of soil.

A typical sprinkler system consist of pumping unit, main line, sub mains, laterals, riser and the sprinkler heads. Three types of sprinkler systems used are rotating head system, fixed jets and perforated pipes. Rotating head system is widely used. Sprinkler system can be portable, semi portable, semi permanent and permanent.



**Fig. 26.1. Sprinkler irrigation in maize and lettuce**

This method can be used advantageously under one or more of the following situations.

- i) Land unsuitable due to shallow soils or steep and undulating topography

- ii) Soils too porous, highly erodible and relatively impermeable so that it is difficult to irrigate by other methods
- iii) Need for light and frequent irrigation
- iv) Limited water supply and high cost of water
- v) Costly and unreliable farm labor

**Advantages:**

- i) Elimination of channels for conveyance, their maintenance and water losses in conveyance
- ii) Control of water application making convenient for giving light and frequent irrigations
- iii) Higher application efficiency
- iv) Areas located at higher elevation than the source can be irrigated.
- v) Sprinklers give a gentle rain that does not clog or compact the soil ensuring better and quicker germination of seeds resulting in more plants per unit area

**Special uses:**

- i) Fertilizers and amendments can be applied quickly, economically, easily and effectively
- ii) Plant protection
- iii) Crop cooling
- iv) Irrigation with high water content

**Limitations:**

- i) Uneven distribution of water caused due to high winds
- ii) Evaporation losses more when operating under high temperature
- iii) Initial investment is high
- iv) Operation and maintenance cost is high
- v) Water must be clear and free of sand
- vi) A stable water supply is needed for the most economical use
- vii) Use of saline water for irrigation is not possible since it will be harmful to crops

**Suitable crops**

Sprinkler irrigation is suited for most field crops viz., wheat, lucerne, groundnut, bengal gram, green gram, black gram, potato, leafy vegetables, sunflower, barley, bajra, maize, wheat etc wherein water can be sprayed over the crop canopy.

**Drip irrigation:**

Drip irrigation, also called trickle irrigation is one of the recently developed irrigation method. It was originally developed in Isreal by Simcha Blass, a water engineer as early as 1959. It involves precise, slow and frequent application of small quantities of water to the soil in the form of discrete drops, continuous drops, and tiny streams through emitters to the plant root zone through a net work of tubing. Water is conveyed through 12-16 mm pipes under pressure until it reaches the point of dispersal where upon the water leaves the system through drip nozzles under no pressure.

The drip system i.e. distribution system and drip nozzles are placed on the surface of the soil along the crop or tree rows to be irrigated or at a depth not exceeding 5-10 cm. The discharge from nozzles ranges from 2-10 l h<sup>-1</sup>. The field crops like cotton, maize, sugarcane, banana and tomatoes and plantation crops like coffee, oranges, apples, etc. are quite suitable for this system of irrigation.

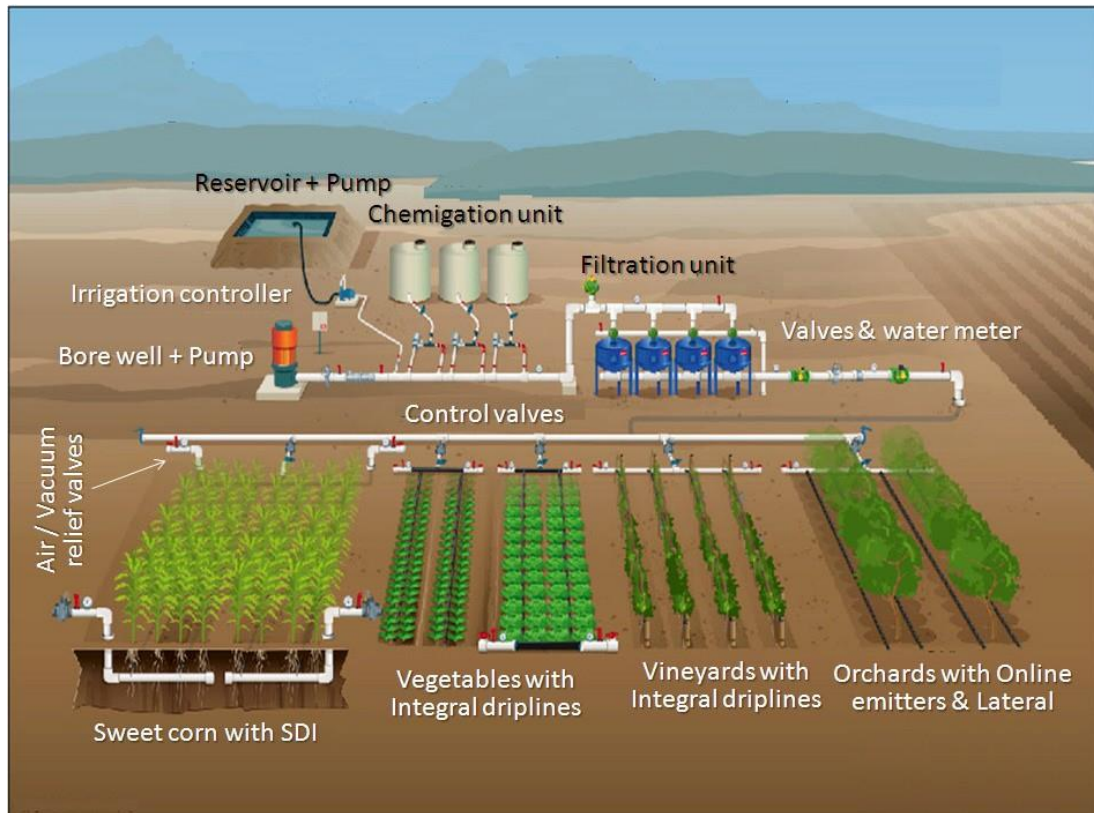
**Advantages:**

- i) Elimination of land leveling
- ii) Water distribution is in close proximity to plant roots and is uniformly distributed
- iii) The water losses like deep percolation, evaporation and soil erosion are minimized
- iv) It always keep the available soil moisture at high levels with small quantity of water
- v) Concurrent water and fertilizer application
- vi) Restriction of weed growth to wetland areas
- vii) Water economy and high water application efficiency
- viii) Reduced salinity hazards to crop plants when low quality saline water is used for irrigation
- ix) Suitable for irrigating high-value crops raised in greenhouses, plastic tunnels, potted plants and under plastic mulches
- x) Limited weed growth because only a fraction of the soil surface is irrigated
- xi) Feasible to irrigate crops raised in small & irregularly shaped narrow lawns, and on undulated land terrains

**Disadvantages:**

- i) Initial cost of installation is high
- ii) Problem of clogging of outlets

- iii) Rodent or animal damage
- iv) Operation and maintenance is costly



**Fig. 26.2. Drip head control unit and system components**

### **Suitable crops**

Drip irrigation, like other irrigation methods, will not fit every agricultural crop, specific site or objective. Presently drip irrigation has the greatest potential in the following crops:

- a) Fruit crops – Mango, citrus, grapes, guava, pomegranate, banana, papaya, watermelon, Litchi, Fig, Ber, Amla, Sapota etc
- b) Vegetable crops – Tomato, Brinjal, Bhendi, Cabbage, Cauliflower, Capsicum, Chillies gourds etc
- c) Plantation crops – Oil palm, Coconut, Arecanut, Cashewnut, Coffee, Tea etc
- d) Field crops – Cotton, Sugarcane, Tobacco, Sugarbeet, Castor etc
- e) Tuber & Bulb crops – Potato, Cassava, Onion, Sweet potato, Radish, Colocasia etc
- f) Spices – Turmeric, Ginger, Cardamom etc
- g) Flowers – Roses, Rose, Gerbera, Orchids, Anthurium, Gladiolus, Carnations, Jasmine, Chrysanthemum, Marigold etc.



**Fig. 26.3. Surface drip irrigation in bhendi and mango crop**

**Subsurface drip irrigation:**

Water is applied to the subsurface soil through underground perforated pipes. Water is also applied through deep trenches at 15-30 m intervals. Water gradually wets root zone through capillary movement. The surface soil is dry even when the root zone is wet and thus minimizing or eliminating evaporation losses. Weed problem is less due to dry surface soil. The trenches are also used for drainage.

However, maintenance of pipe lines is difficult and they interfere with cultivation. Subsurface irrigation through trenches causes deep percolation losses. This is costly system suitable only for small areas. This method is suitable where water table is shallow. Subsurface irrigation is practiced in a few places in Kerala for coconut gardens and in Kashmir for vegetables.

## Lecture 27:

### AGRICULTURAL DRAINAGE

Agricultural drainage is the artificial removal and safe disposal of excess water either from the land surface or soil profile, more specifically, the removal and safe disposal of excess gravitational water from the crop root zone to create favourable conditions for crop growth to enhance agricultural production.

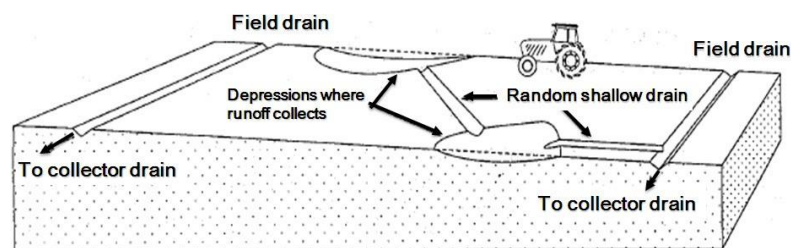
#### Types of drainage

Broadly drainage systems are of two types- Surface and Sub-surface.

#### Surface drainage systems

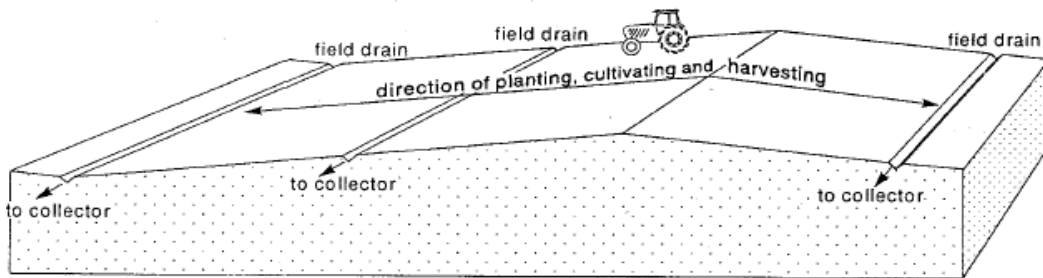
Safe removal and disposal of excess water primarily from land surface or cropped area by a net work of surface drains or constructed channels and through proper land shaping is known as surface drainage. There are four general types of surface drainage systems used in flat areas having a slope of  $< 2\%$  viz., (a) Random drain system (b) Parallel field drain system (c) Parallel open ditch system and (d) Bedding system.

- a) **Random drain system:** This system is usually adopted in areas where the ground surface is characterized by a series and depression (undulating land surface) and where small depressions are to be drained off (Fig. 27.1). Depending upon the possibility the field drains are designed in such a way to connect one depression to another and water is safely conveyed to lateral drains. These lateral drains ultimately guide the water to main outlet drain. The field drains besides occupying the land area are likely to interfere with farm operations.



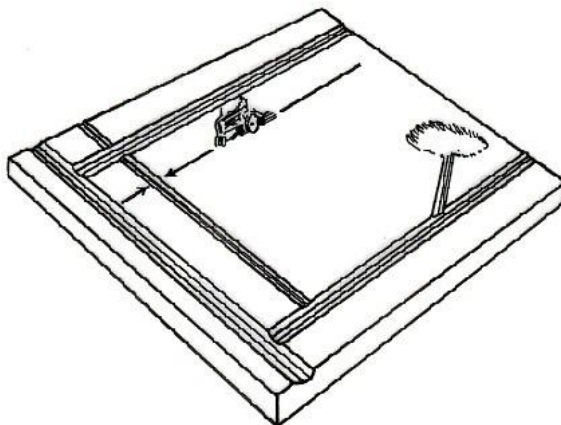
**Fig. 27.11. Random field drain system**

- b) **Parallel field drain system:** The parallel field ditch system is used in places where the surface is uniform and has few noticeable ridges or depressions (Fig. 27.2). In this system the surface of individual fields is graded in such a way so that the runoff water drains into field drains, which in turn discharge water into field laterals bordering the field and finally the laterals in turn lead water into the main outlet ditch through protected over falls. Laterals and mains should be deeper than field drains to provide free out-fall. Maximum spacing of parallel field drains is about 200 m for sandy soils and about 100 m for clay soils. It is the most desirable surface drainage method and is well suited both for irrigated and rainfed areas.

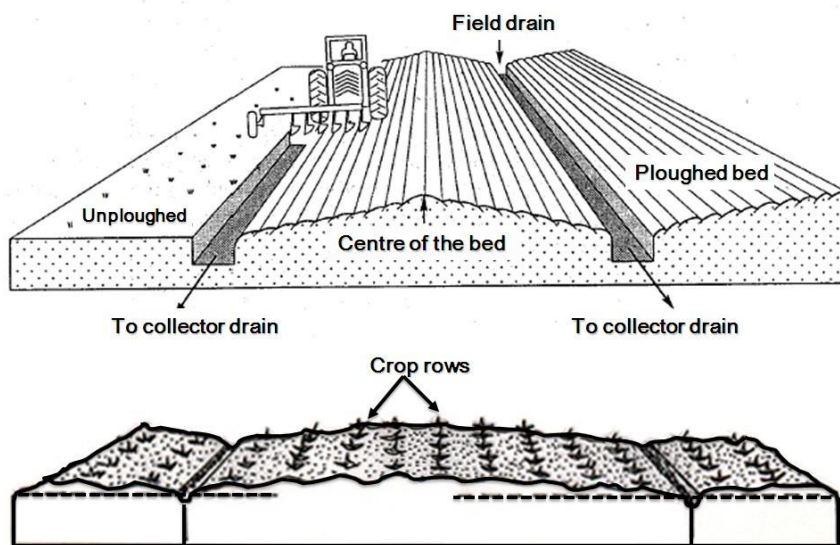


**Fig. 27.2. Parallel field drain system**

- c) **Parallel open ditch system:** The parallel open ditch system is similar to parallel field drain system in all respects except that the drains are replaced by open ditches which are comparatively deeper and have steeper side slopes than the field drains (Fig. 27.3). Maximum length of grade draining to ditch should not be  $> 180$  m. The spacing of the ditches depends upon the soil and water table conditions and may vary from 60 – 200m. This system is applicable in soils, which require both surface and sub-surface drainage.



**Fig. 27.3. Parallel open ditch system**



**Fig. 27.4. Bedding system**

- d) **Bedding system:** This system is usually adopted in fields with very little slope, usually 0.5 % or less and slowly permeable soils. It is essentially a tillage operation wherein the land is ploughed into a series of parallel beds separated by dead furrows, which run in the direction of greatest slope and lateral drains are located perpendicular to slope (Fig.27.4). The ploughing operations are to be carried out parallel to the furrows. The bed width and length varies between 8 to 30 m and 10 to 300m respectively depending upon field conditions i.e., land use, slope, soil permeability and farming operations. While bed height should not exceed 40 cm.

### Sub-surface drainage systems

The removal and safe disposal of excess water that has already entered the soil profile is considered sub-surface drainage. Though several sub-surface systems are available, the most commonly used and effective ones are Tile drainage and Mole drainage systems.

### Tile drainage systems

Tile drains removes excess water from the soil through a continuous line of tiles (pipes) laid at specified depth and grade. The pipes are made of either concrete or burnt clay. Free water enters through the tile joints and flows out by gravity, so that the water table is lowered below the root zone of the plants. The common tile drainage system layout followed is: Random or natural system, Parallel lines system and Cut off or intercepting system.

- a) **Random system:** The random system is used in areas that have scattered wet areas somewhat isolated from each other (Fig. 27.5). Tile lines are laid more or less at random to drain the wet patches.

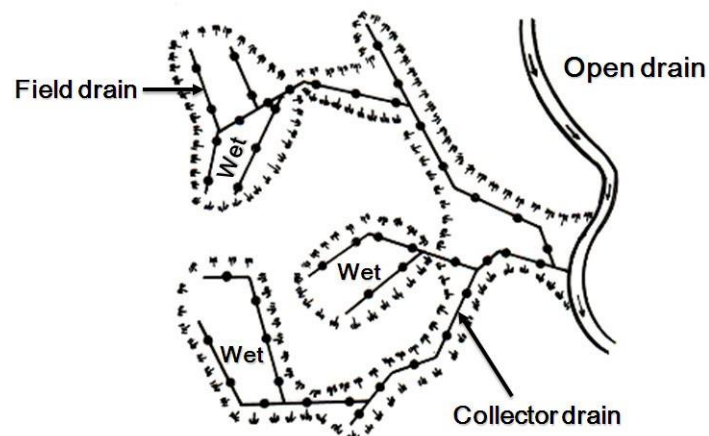


Fig. 27.5. Random tile drain system

- b) **Herringbone system:** The system is applicable in places where the main or sub-main is located in a narrow depression i.e., in areas that have a concave surface or a narrow depression with the land sloping to it from both directions (Fig. 27.6). The parallel laterals enter the sub-main from both sides. It is less economical,

because considerable double drainage occurs where the laterals and mains join.

- c) **Gridiron and parallel systems:** The gridiron and parallel systems are similar to that of herringbone system except that the laterals enter the main or sub-main from only one side (Fig. 27.6). It is the most economical arrangement than herringbone system because one main or sub-main serves as many laterals as possible.

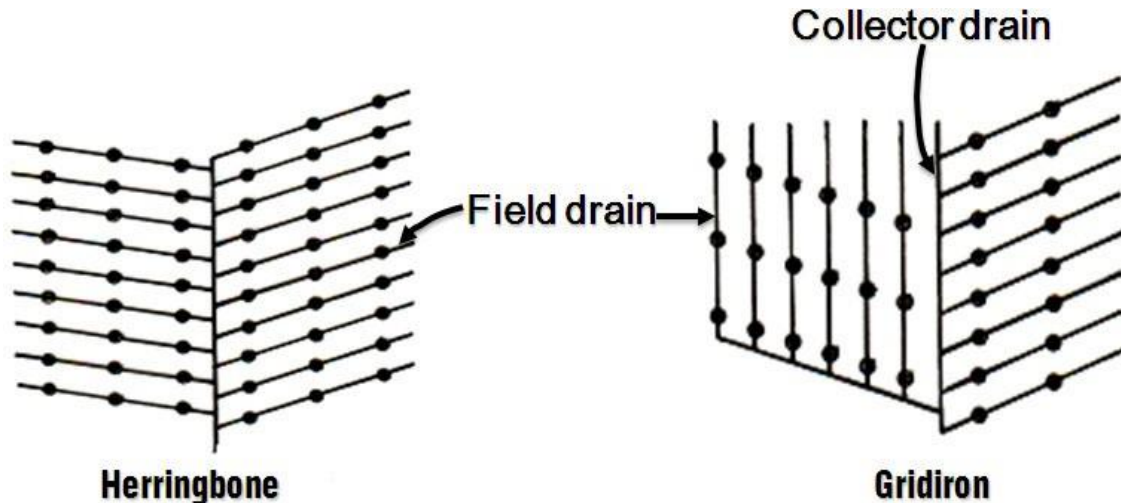
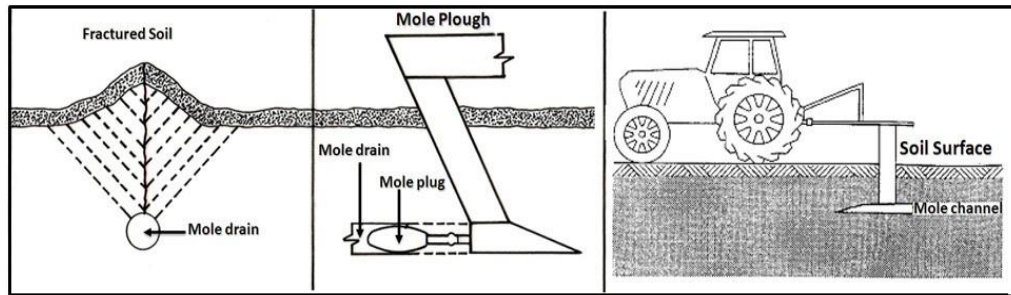


Fig. 27.6. Herringbone and Gridiron tile drain systems

- d) **Double main system:** The double main system is a modification of the gridiron system. It may be used where the sub-main is in a broad, flat depression, which frequently is a natural watercourse and sometimes may be wet because of small amounts of seepage water from nearby slopes.
- e) **Intercepting system:** This system involves the interception of seepage water that flows over the surface of an impervious sub-soil. The tile line is placed approximately at the impervious layer along which the seepage water travels, so that water will be intercepted and wet condition is relieved. The tile line should be located in such a way that there is at least 60 cm of soil cover over the top of the tile.

### Mole drainage system

Mole drainage is a semi-permanent method of sub-surface drainage, similar to tile drain in layout and operation (Fig. 27.7). Instead of permanent tiles a continuous circular mole drain (channel) is prepared below the ground surface in the soil profile at desired depth and spacing using a special implement known as mole plough. The depth of the mole drain varies from 4.5 cm to 120 cm depending on the moling equipment and water table. Diameter of the mole varies from 7.5 to 15 cm. The life the mole drain is 10-15 years. It is adapted to a particular type of soil because the soil stability is more important in this type of sub-surface drainage.



**Fig. 27.7. Mole plough**

### **Drainage coefficient**

It is defined as the depth of water (cm) to be removed in 24 hours period from the entire drainage area. It ranges from 0.6 to 2.5 cm/day and in extreme cases 10 cm day<sup>-1</sup>.

### **Benefits of drainage**

- a) It provides better soil environment for plant growth by creating favourable soil aeration conditions
- b) It improves the soil structure and in turn increases the soil infiltration
- c) High infiltration capacity reduces soil erosion.
- d) It hastens the warming of the soils and maintains desirable soil temperature, which accelerates plant growth and bacterial activity
- e) It promotes increased leaching of salts and prevents accumulation of salts in the crop root zone
- f) In well drained soils, less time and less labour are required for tillage operations

### **Problems or effects of ill-drainage**

- a. Limitation of aeration
- b. Reduced water uptake due to reduced activity of roots as a result of oxygen stress
- c. Reduced nutrient uptake
- d. Development of soil salinity and alkalinity
- e. Anaerobic condition and prevalence of plant diseases
- f. Stunted plant growth and development which results in reduced yield

## Lecture 28:

### HARVESTING OF CROPS

Process of removal of entire plants or economic parts after maturity from the field is called harvesting. Portion of the stem that is left on the field is known as stubble. The economic product may be grain, seed, leaf, root or entire plant.

#### Time of Harvesting:

Harvesting of the crop at right time is very essential to obtain good quality grain and higher yields.

If the crop is harvested early,

- the produce contain high moisture and more immature grains
- the yields will be low due to unfilled grains
- very difficult to store the produce as shriveled grains with high moisture are prone to primary infection of pest
- quality of grain as well as germination percentage are reduced

If the crop is harvested late,

- results in shattering of grain, germination even before harvesting during rainy season
- breakages during processing

Determination of harvesting date is easier for determinate crops and difficult for indeterminate crops. At a given time, the indeterminate plants contain flower, immature and mature pods and fruits. If the harvesting is delayed for sake of immature pods, mature pods may shatter. If harvested earlier, yield is less due to several immature pods. This problem can be overcome by harvesting pods or ears when 75 per cent of them are mature and periodical harvesting or picking of pods.

Crops can be harvested at physiological maturity or at harvest maturity. Physiological maturity stage refers to a developmental stage after which no further increase in dry matter occurs in the economic part i.e. the translocation of photosynthates are stopped to the economic part. Crop is harvested at physiological maturity when there is need to vacate the field for sowing another crop. Physiological maturity symptoms (external) are

Sorghum and maize - black layer formation beneath the ear

Bajra - bleaching of peduncle beneath the ear

Pulses - turning of green pods to brown colour

Harvest maturity occurs seven days after physiological maturity. The important process during the period is loss of moisture from the plants. The general symptoms of harvest maturity are yellowing of leaves and drying of grain or pods. Under all situations, it is advisable to follow harvest maturity.

**Method of harvesting:**

Harvesting of crops is done by either manually or by mechanical means depending on the crop. Cutting of the crop with sickles leaving small stubbles near the ground is the common method of harvesting and sickle is the most important tool which is sharp, curved and serrated for efficient harvesting. This method is followed in crops whose maturity is almost uniform and occurs at a time. In indeterminate plants harvesting is done at intervals as the economic product comes to maturity at different periods. Pods or fruits are picked at periodical intervals.

Method of harvesting in

- greengram, blackgram, cotton, etc. is called picking
- sugarcane is cutting with knife
- groundnut it is pulling
- rice it is cutting with sickle

Combined harvesters or simple combiners are used for harvesting. It performs several operations at a time i.e. cuts the crop, separate the grain from straw, cleaning it from chaff and transport grain to the storage tank.

## **Lecture 29:**

### **MATURITY SYMPTOMS OF IMPORTANT CROPS**

Maturity symptoms of some important crops are as follows

#### **Paddy:**

- Hardening of seed
- Seed coat turns to light yellow or light red colour

#### **Groundnut:**

- Pods turn dark from light colour
- Dark coloured patches inside the shell
- Kernels red to pink
- On pressing the kernels, oil is observed on fingers

#### **Sugarcane:**

- Leaves turn yellow
- Sucrose content more than 10 per cent
- Brix reading more than 18 per cent

#### **Finger millet:**

- Brown coloured ears with hard grains

#### **Wheat:**

- Yellowing of spikelet's

#### **Tobacco:**

- Leaves slightly yellow in colour
- Specks appear on the leaves

#### **Blackgram and greengram:**

- Pods turn brown or black

#### **Redgram:**

- 35-40 days after flowering
- 80-85% pods turn brown

**Sorghum:**

- 40 days after flowering
- Moisture content of grains

**Maize:**

- Moisture content of grains < 22-25%
- Husk colour turns pale brown
- 25-30 days after tasseling

## **Lecture 30:**

### **THRESHING, WINNOWING, DRYING AND STORAGE**

#### **Threshing and winnowing**

The process of separating fruits or seeds from the plants or ears is called threshing. Threshing is done immediately after harvest of the crop or it may be done at later stage. Threshing of cereals, millets and few pulses are done by beating against stones or any other hard material or by beating with mallets or by treading under the feet of cattle or tractor tyres by spreading in a circular path and of required thickness. Other threshers include Olpad thresher (wheat, barley, oats), Japanese rotary paddy thresher and rollers made of stones (sorghum, bajra and ragi). Threshing is followed by winnowing.

Winnowing is the process of separating grain or seed from chaff. Wind power is used to separate husk and grain since husk is lighter than grain or seed.

#### **Drying:**

It is the process by which moisture content from grain is reduced to safe limit. It is basically the transfer of heat by converting the water in grain to vapour and transferring it to the atmosphere. Moisture content of grain at the time of harvesting of crops is about 18-20 per cent and for safe storage it should be brought down to 14 per cent for most of the crops.

Drying is done either by using solar energy or by artificial heating. In case of sun drying, the produce is spread on the hard floor or threshing yard around 10 cm thickness and is allowed to dry by heat supplied by the sun. The produce is stirred at two hourly intervals to have uniform and quick drying. In general, 4-5 days of sun drying is required for different produce to bring the moisture to a safe level. Sun drying is cheaper. The traditional sun drying technique is labour intensive and requires a lot of land for drying. Artificial drying uses steam to dry the produce and it can be done at any time of the year, but it is expensive.

#### **Storage:**

Harvesting of crop is seasonal, but consumption of the food grain is continuous. The market value of the produce is generally low at harvesting time. Therefore, it is necessary to store the produce for different periods. The different categories of agriculture produce needing storage are food grains, oilseeds, pulses and fodder. During storage food grains are subjected to several losses. The losses due to different pest during storage is 6.5 per cent. In addition to loss in quantity, quality of food grain is also affected. Several factors that influence the storage of food grains are moisture content, quality of produce, climate and storage conditions.

Food grains and oilseeds are stored either in bags or in bulk. The storage of produce in bags is called bag storage and without bagging, it is called bulk storage. Grains are stored in underground as well as above ground (godown) storage structures in India. Bins made of mud, steel, aluminium and RCC are also used for storage of grains.

## Lecture 31:

### DRYLAND AGRICULTURE

Agriculture is the single largest livelihood sources in India with nearly two thirds of people depend on it. Rainfed agriculture is as old as agriculture it self. Growing of crops entirely under rainfed conditions is known as dryland agriculture.

#### Progress of dryland Agricultural Research in India

- Though dryland farming is as old as agriculture, the systematic research work was started only from 1923 with the start of Research Centre at Manjri near Pune, in Bombay province by V.A. Tamhane.
- Later Imperial Council of Agricultural Research (presently Indian Council Agricultural Research) started research schemes at Bombay, Madras, Hyderabad and Punjab provinces.
- Around 1933, systematic work was started on different aspects of crop production under rainfed conditions.
- The findings of the period were related to rainfall analysis.
- It was found that rainfall was not only scarce but also erratic.
- The dry spells during the crop period ranged from 20 to 55 days.
- Therefore, the emphasis on research was given to conserve soil moisture and to reduce evaporation.
- Based on the studies conducted between 1933 and 1943, package was developed for better crop production under rainfed conditions. The important practices are:
  1. Formation of contour bunds.
  2. Repeated harrowing in black soils to conserve moisture.
  3. Addition of farm yard manure to maintain the soil fertility.
  4. Wider spacing for crops grown on residual moisture.

The package of practices were named after the province from which they were developed as Bombay dry farming practices, Madras dry farming practices, Hyderabad dry farming practices and Punjab dry farming practices. The adoption of these practices was low due to marginal increase in yield. Government programmes mainly concentrated on contour bunding which provided employment during drought periods. During 1954, the soil conservation training and demonstration centres were established by Indian Council of Agriculture Research at eight locations. These centres concentrated on soil conservation techniques and training of officers on soil

conservation, while crop production received low importance. During 1970, ICAR started All India Coordinated Research Project on Dryland Agriculture at 23 locations spread all over India. Under the scheme, an integrated approach was adopted to solve the problems of dryland agriculture, by including the disciplines of agronomy, soil science, plant breeding and agricultural engineering. The important practices developed under the scheme are contingent cropping, efficient crops and cropping systems, water harvesting and supplemental irrigation, drought resistant varieties, fertilizer recommendation and agricultural implements. Watershed approach was followed to popularise these technology by including soil conservation practices with improved dryland practices, alternate crops and other ancillary enterprises. In 1983, 47 model watersheds were developed. Based on the success of this approach in increasing the productivity of drylands, the national watershed development programme for dryland agriculture was started throughout the country.

The chronology of events in dryland agricultural research in India is as follows.

- 1920 Scarcity tract development given importance by the Royal Commission on Agriculture
- 1923 Establishing Dryland Research Station at Manjri (Pune) by Tamhane
- 1933 Research Stations established at Bijapur and Solapur
- 1934 Research Stations established at Hagari and Raichur
- 1935 Research Station established at Rohtak (Punjab)
- 1942 Bombay Land Development act passed
- 1944 Monograph on dry farming in India by N.V. Kanitkar (Bombay, Hyderabad, Madras Dry Farming Practices)
- 1953 Establishing Central Soil Conservation Board
- 1954 Establishing Central Soil Conservation Centres
- 1970 Research Centres established under AICRPDA in 23 locations
- 1972 Establishment of ICRISAT
- 1976 Establishment of Dryland Operational Research Projects
- 1983 Starting of 47 model watersheds under ICAR
- 1984 Initiation of World Bank assisted Watershed Development Programmes in four states. Establishing Dryland Development Board in Karnataka
- 1985 Birth of Central Research Institute for Dryland Agriculture at Hyderabad
- 1986 Launching of NWDPRAs programmes by Government of India in 15 states.

Recognizing the importance of rainfed agriculture, the ICAR gave a new impetus by launching the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in 1970, based at Hyderabad with 23 cooperating centres spread across the country. Pooling of expertise and leveraging the strengths of AICRPDA net work eventually resulted in the establishment of Central Research Institute for Dryland Agriculture (CRIDA) at Hyderabad, on April 12, 1985 to provide leadership in basic strategic research in dryland agriculture while continuing research on location specific ORP's at AICRPDA centres. At present the AICRPDA centres are located at 25 places.

## Lecture 32:

### **DRYLAND CLASSIFICATION AND IMPORTANCE**

Depending on the amount of rainfall received, dryland agriculture can be grouped into three categories:

- a) **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.
- b) **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 semi arid 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 or black soils.
- c) **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.

#### **Importance of dry farming in Indian Agriculture**

1. About 70% of rural population lives in dry farming areas and their livelihood depend on success or failure of the crops.
2. Dryland agriculture plays a distinct role in Indian Agriculture occupying 60% of cultivated area and supports 40% of human population and 60 % livestock population.
3. The contribution (production) of rainfed agriculture in India is about 42 per cent of the total food grains, 75 per cent of oilseeds, 90 per cent of pulses and about 70 per cent of cotton.
4. By the end of the 20th century the contribution of drylands will have to be 60 per cent if India is to provide adequate food to 1000 million people. Hence, tremendous efforts both in the development and research fronts are essential to achieve this target.
5. More than 90 per cent of the area under sorghum, groundnut, and pulses is rainfed. In case of maize and chickpea, 82 to 85 per cent area is rainfed. Even 78 percent of cotton area is rainfed. In case of rapeseed/mustard, about 65.8 per cent of the area is rainfed. Interestingly, but not surprisingly, 61.7, 44.0, and 35.0 per cent area under rice, barley and wheat, respectively, is rainfed.

6. At present, 3 ha of dryland crop produce cereal grain equivalent to that produced in one ha irrigated crop. With limited scope for increasing the area under plough, only option left is to increase the productivity with the modern technology and inputs, since the per capita land availability which was 0.28 ha in 1990 is expected to decline 0.12 ha in 2025.
7. The productivity of grains already showed a plateau in irrigated agriculture due to problems related to nutrient exhaustion, salinity build up and raising water table. Therefore, the challenges of the present millennium would be to produce more from drylands while ensuring conservation of existing resources. Hence, new strategies would have to be evolved which would make the fragile dryland ecosystems more productive as well as sustainable. In order to achieve evergreen revolution, we shall have to make grey areas (drylands) as green through latest technological innovations.
8. Drylands offer good scope for development of agroforestry, social forestry, horti-sylvi-pasture and such other similar systems which will not only supply food, fuel to the village people and fodder to the cattle but forms a suitable vegetative cover for ecological maintenance.

## Lecture 33:

### PROBLEMS OF CROP PRODUCTION IN DRYLANDS

#### Problems or constraints for crop production in dry farming regions

Most of the cropping in the arid and semi arid regions continues to be under rainfed conditions. A majority of the farmers are small farmers with meagre resources. The poor resource base permits only low input subsistence farming with low and unstable crop yields. The low productivity of agriculture in dry farming regions is due to the cumulative effect of many constraints for crop production. The constraints can be broadly grouped in to

- a) Climatic constraints,
- b) Soil related constraints,
- c) Traditional cultivation practices
- d) Heavy weed problem
- e) Lack of suitable varieties and
- f) Socio economic constraints.

#### a) Climatic constraints

- A) Rainfall characteristics: Among the different climatic parameters rainfall is an important factor influencing the crop production in dry regions
- (i) Variable rainfall: Rainfall varies both in time and space dimension. Annual rainfall varies greatly from year to year and naturally its coefficient of variation is very high. Generally, higher the rainfall less is the coefficient of variation. In other words, crop failures due to uncertain rains are more frequent in regions with lesser rainfall. The average annual rainfall of India is 1192 mm where as in Andhra Pradesh it is 890 mm. Based on the average annual rainfall, the India can be divided into four zones. More than one third of total geographical area in India receive rainfall less than 750 mm (Table 32.1).

**Table 32.1. Classification of India into different zones based on rainfall**

<b>Zone</b>	<b>Average annual rainfall (mm)</b>	<b>Per cent of geographical area</b>
Zone I (very low rainfall area)	< 350	13
Zone II (low rainfall area)	350 to 750	22
Zone III (Medium rainfall area)	750 to 1125	36
Zone IV (High rainfall area)	> 1125	29

- (ii) Intensity and distribution: In general, more than 50 per cent of total rainfall is

usually received in 3 to 5 rainy days. Such intensive rainfall results in substantial loss of water due to surface runoff. This process also accelerates soil erosion. Distribution of rainfall during the crop growing season is more important than total rainfall in dryland agriculture.

(iii) Aberrations or variations in monsoon behaviour

(a) Late onset of monsoon: If the onset of monsoon is delayed, crops/varieties recommended to the region cannot be sown in time. Delayed sowing lead to uneconomical crop yields.

(b) Early withdrawal of monsoon: This situation is equally or more dangerous than late onset of monsoon. Rainy season crops will be subjected to terminal stress leading to poor yields. Similarly, post-rainy season crops fail due to inadequate available soil moisture, especially during reproductive and maturity phases.

(c) Prolonged dry spells: Breaks of monsoon for 7-10 days may not be a serious concern. Breaks of more than 15 days duration especially at critical stages for soil moisture stress leads to reduction in yield. Drought due to break in monsoon may adversely affect the crops in shallow soils than in deep soils.

B) High atmospheric temperature: Because of high atmospheric temperature the atmospheric demand for moisture increases causing high evapotranspiration losses resulting in moisture stress.

C) Low relative humidity: Low relative humidity results in high ET losses causing moisture stress whenever moisture is limiting.

D) Hot dry winds: Hot dry winds causes decicassion of leaves resulting in moisture stress. High turbulent winds especially during summer months cause soil erosion resulting in dust storms and loss of fertile soil.

E) High atmospheric water demand: Due to high atmospheric water demand the potential evapotranspiration (PET) exceed the precipitation during most part of the year.

**b) Soil constraints**

The different soil groups encountered in dryland areas are black soils, red soils and alluvial soils. The constraints for crop production are different in different soil groups. The predominant soil group is alluvial where the problems for crop production are not so acute as in red and black soils .The different soil constraints for crop production are

a) Inadequate soil moisture availability: The moisture holding capacity of soils in dry regions is low due to shallow depth especially in alfisols (red soils), low rainfall and low organic matter content.

b) Poor organic matter content: The organic matter content in most of the

soils under dryland conditions is very low (< 1 %) due to high temperature and low addition of organic manures. Poor organic matter content adversely affects soil physical properties related to moisture storage.

- c) Poor soil fertility: Due to low accumulation of organic matter and loss of fertile top soil by soil erosion the dry land soils are poor in fertility status. Most of the dry land soils are deficient in nitrogen and zinc.
- d) Soil deterioration due to erosion (wind, water): In India nearly 175 m.ha of land is subjected to different land degradations, among them the soil erosion is very predominant. The erosion causes loss of top fertile soil leaving poor sub soil for crop cultivation.
- e) Soil crust problem: In case of red soils, the formation of hard surface soil layers hinders the emergence of seedlings which ultimately affect the plant population. Crusting of soil surface after rainfall reduces infiltration and storage of rainfall, due to high run off.
- f) Presence of hard layers and deep cracks: Presence of hard layers (pans) in soil and deep cracks affect the crop production especially in case of black soils.

### c) Cultivation practices

The existing management practices adopted by the farmers are evolved based on long term experience by the farmers.

The traditional management practices are

- Ploughing along the slope
- Broadcasting seeds/ sowing behind the country plough leading to poor as well as uneven plant stand
- Monsoon sowing
- Choice of crops based on rainfall
- Application FYM in limited quantity
- Hand weeding
- Mixed cropping
- Use of conventional system of harvesting
- Traditional storage system

**d) Heavy weed infestation:** This is the most serious problem in dryland areas. Unfortunately the environment congenial for crop growth is also congenial for weed growth. Weed seeds germinate earlier than crop seeds and try to suppress the crop growth. The weed problem is high in rainfed areas because of continuous rains and

acute shortage of labour. The weed suppression in the early stage of crop growth is required to reduce the decrease in crop yields.

**e) Lack of suitable varieties:** Most of the crop varieties available for cultivation in dry lands are meant for irrigated agriculture. There are no any special varieties exclusively meant for dryland areas. Hence, still more efforts are required to develop varieties in different crops exclusively meant for dryland agriculture.

**f) Socio-economic constraints:** The economic condition of the dryland farmers is very poor because

- a) Less access to inputs
- b) Non availability of credit in time
- c) The risk bearing capacity of dryland farmer is very low

Hence, the dryland farmers resort to low input agriculture which results in poor yields.

## Lecture 34:

### MOISTURE CONSERVATION PRACTICES IN DRYLANDS

Soil conservation is using and managing the land based on the capabilities of the land itself involving application of the best management practices leading to profitable crop production without land degradation.

Measures of water erosion control

1. Agronomic measures
2. Mechanical measures (Engineering measures)
3. Forestry measures
4. Agrostological measures

#### 1. Agronomic measures of soil conservation

In soil and water conservation programmes agronomic measures have to be considered in co-ordination with others for their effectiveness. These measures are effective in low rainfall areas particularly in fairly erosion resistant soils having gentle slope (< 2 %).

The different agronomic measures include

1. Land preparation
  2. Contour cultivation
  3. Choice of crops
  4. Strip cropping
  5. Crop rotation / cropping systems
  6. Cover crops
  7. Mulching
  8. Application of manures and fertilizers
  9. Application of chemicals
- a) **Land preparation:** Land preparation including post harvest tillage influence intake of water, obstruction to surface flow and consequently the rate of erosion. Deep ploughing or chiseling has been found effective in reducing erosion. Rough cloddy surface is also effective in reducing erosion.
- b) **Contour cultivation (Contour farming):** A line joining the points of equal elevation is called contour. All the cultural practices such as ploughing, sowing, intercultivation etc. done across the slope reduce soil

and water loss. By ploughing and sowing across the slope, each ridge of plough furrow and each row of the crop act as obstruction to the runoff and provide more time for water to enter into the soil leading to reduced soil and water loss (Fig. 34.1).



**Fig. 34.1. Contour Cultivation**

- c) **Choice of crops:** Row crops or tall growing crops such as sorghum, maize, pearl millet etc., are not effective in conserving soil as they expose majority of the soil and hence, they are known as erosion permitting crops. Whereas close growing crops such as cowpea, groundnut, green gram, black gram etc., which protect soil are known as erosion resisting crops as they are very effective in reducing soil loss by minimizing the impact of rain drop and acting as obstruction to runoff.
- d) **Strip cropping:** It is a system of growing of few rows of erosion resisting crops and erosion permitting crops in alternate strips on contour (across the slope) with the objective of breaking long slopes to prevent soil loss and runoff. Close growing erosion resisting crops reduce the transporting and eroding power of water by obstructing runoff and filtering sediment from runoff to retain in the field. The width of the erosion permitting and erosion resisting crops vary as per the slope of the field. The strip cropping resembles the intercropping.

Slope (%)	Width of crops (m)	
	Erosion resisting	Erosion permitting
Up to 1 %	9.0	45.0
1 to 2 %	6.0	24.0
2 to 3 %	4.0	12.0

With increase in per cent slope of the soil, the width of erosion permitting and erosion resisting crops decreases. The normal ratio between the erosion resisting crops and erosion permitting crops is 1:3. Among the different crops the anti- erosion value of pillipesara is highest, where as cotton crop recorded the lowest value. The strip cropping is divided into four types as follows

- i) **Contour strip cropping:** The erosion permitting crops and erosion resisting crops are grown in alternate strips along the contours.
- ii) **Field strip cropping:** Alternate strips of erosion permitting crops and erosion resisting crops are raised across the general slope not necessarily on exact contour
- iii) **Wind strip cropping:** Strip cropping of erosion permitting and erosion resisting crops across the direction of the most prevailing wind irrespective of the contour.
- iv) **Buffer strip cropping:** This type of strip cropping is practiced in areas having steep slopes and badly eroded soils where strips of permanent cover crops or perennial legumes or grasses or shrubs are alternated with field crops.

The strip cropping is simple, cheap and effective soil conservation practice and can be adopted by the farmers.

- e) **Crop rotation / cropping system:** Monocropping of erosion permitting crops accelerates soil and water loss year after year. Intercropping of erosion permitting crops and erosion resisting crops or their rotation has been found effective for reducing soil and water loss. Inclusion of legumes like lucerne in crop rotation reduces soil loss even in soils having 13 % slope.
- f) **Cover crops:** Good ground cover by canopy gives the protection to the land like an umbrella and minimize soil erosion. Besides conserving soil and moisture, the cover crops hold those soluble nutrients, which are lost by leaching. The third advantage of the cover crops is the addition of organic matter. The legumes provide better cover and better protection. Among the legumes cowpea has been found to produce maximum canopy followed by horsegram, green gram, black gram and dhaincha.
- g) **Mulching:** Mulching of soil with available plant residues reduce soil loss considerably by protecting the soil from direct impact of raindrop and reducing the sediment carried with runoff .A minimum plant residue cover of 30 per cent is necessary to keep runoff and soil loss within the acceptable limits. Vertical mulching also reduce soil loss particularly in vertisols by increasing infiltration.

- h) **Application of manures and fertilizers:** Organic manures besides supplying nutrients improve soil physical conditions thereby reduce soil loss. Fertilizers improve vegetative canopy, which aid in erosion control.
- i) **Use of chemicals:** Breakdown of aggregates by the falling raindrops is the main cause of detachment of soil particles. Soils with stable aggregates resist breakdown and thus resist erosion. Aggregate stability can be increased by spraying chemicals like poly vinyl alcohol @ 480 kg/ha (rate will depend on the type of soil). Soils treated with bitumen increase water stable aggregates and infiltration capacity of the soil.

## **2. Mechanical measures**

When Agronomic measures alone are not adequate, mechanical measures are to be adopted to supplement the agronomic measures. Mechanical measures usually involve construction of mechanical barriers across the direction of flow of rainwater to retard or retain runoff and thereby reduce soil and water loss. The mechanical measures include:

- Contour bunding
- Graded bunding
- Bench terracing
- Gully control / plugging
- Vegetative barriers etc.

A bund or terrace is an earthen embankment or a depression or a combination of both constructed across the land slope to control runoff and minimize soil erosion by reducing the length of slope. By reducing the slope, the velocity of runoff is not allowed to attain critical value, which initiates scouring.

### **Contour bunding**

It is most popular in the country. Contour bunding consists of narrow based trapezoidal bunds on contours to impound runoff water behind them so that it can gradually infiltrate into the soil for crop use. Contour bunding is generally recommended for areas receiving <600 mm rainfall (low rainfall areas) and for permeable soils up to slopes of about 6%.

The height of the contour bunds depends on slope of land, spacing of bunds and maximum intensity expected. In deep black soils, contour bunds have been a failure due to cracking of bunds during dry months and water stagnation above the bunds for prolonged periods during rainy season (Fig. 34.2).



**Fig. 34.2 Contour bunding**

**Graded bunding:**

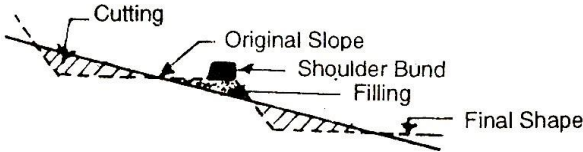
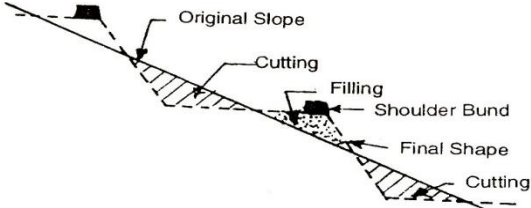
Graded bunds or channel terraces are constructed in high rainfall areas of >600 mm where excess water has to be removed safely of the field to avoid water stagnation. In case of highly impermeable soils like deep black soils graded bunds are recommended even in lesser rainfall area (500 mm) as in case of Bellary region of Karnataka. Water flows in graded channels constructed on upstream side of bunds at non-erosive velocities and is led to safe outlets or grassed waterways. Channel portion of the graded bunds is put under cultivation and the grassed waterways are permanently kept under grass.

**Bench terracing:**

Bench terracing is practiced in steep hill slopes, where mere reduction of slope length is not adequate for reducing the intensity of scouring action of runoff flowing down. In addition to slope length reduction, the degree of slope is also reduced. Bench terracing consists of transforming relatively steep land into a series of level strips or platforms across the slope to reduce the slope length and consequently erosion. The field is made into a series of benches by excavating soil from upper part and filling in the lower part of terrace. It is normally practiced on slopes > 14% i.e. from 16 to 33%.

Depending on soil, climate and crop requirements bench terraces may be table top or level, sloping outwards or sloping inwards (Fig. 34.3).

Type of bench terrace	Suitability
<p style="text-align: center;">Table top or level terraces</p>	<p style="text-align: center;">Suitable for medium rainfall areas (750mm) with even distribution and highly permeable deep soils.</p>

Type of bench terrace	Suitability
<p data-bbox="379 259 734 293">Sloping outwards terraces</p> 	<p data-bbox="890 259 1433 371">Constructed in low rainfall areas (&lt;750 mm) with permeable soils of medium depth.</p>
<p data-bbox="389 517 724 551">Sloping inwards terraces</p> 	<p data-bbox="877 517 1430 584">Constructed in heavy rainfall areas (&gt;750 mm) and soils with poor infiltration rate.</p>

**Fig. 34.3 Types of bench terraces**

**Gully control:**

Gullies the result of sheet and rill erosion left unchecked. The basic approach to gully control involves reduction of peak flow rates through the gully and provision of channel for the runoff water. Agronomic measures of soil conservation like contour cultivation, strip cropping, cover crops, mulching etc., aid in reducing the peak flow rates through gullies. The provision of the stable channel for the flow that must be handled is accomplished by stabilizing the gully sides and bed by establishing vegetation. Temporary structures such as brush check wood dams, loose rock dams, rock fill dams and woven wire dams, and permanent structures such as chute spill ways, drop spill ways, concrete check dams and pipe spill ways are practiced for reducing channel gradient to maintain velocities below erosive level (Fig. 34.4 and 34.5).



**Fig. 34.4. Concrete check dam for gully control**



**Fig. 34.5 Loose boulder check dam for gully erosion control**

### **Vegetative barriers:**

These are the rows of closely planted grass or shrub along the contours for erosion control in agricultural lands. They check the velocity of runoff and retain the sediment by acting as barrier to runoff. Khus Khus (*Vetiveria zyzynoides*) is the most recommended plant for this purpose.

**Grassed waterways:** These are drainage channels either developed by shaping the existing drainage ways or constructed separately for effecting drainage of agricultural lands. They are used to handle runoff, discharge from graded bunds, broad base terraces and bench terraces. Objectives of grassed waterways

1. To provide drainage to agricultural lands
2. To convert unstable channels or gullies into stable channels by providing grass cover
3. For leading water at non erosive velocity into farm ponds

Grassed water ways are normally dug to a shallow depth of 0.15 to 0.5 m. They are constructed one or two seasons ahead of the construction of channel terraces.

### **3. Forestry Measures:**

Forest lands are usually found at higher elevations where the slopes are steepest, soils are less stable and easily eroded and precipitation is heavy. The leaves and branches of trees and shrubs intercept the rain and reduce the impact of raindrops. Contour trenching and afforestation is recommended for improving the productivity of forests. Contour trenching is done by excavating a trench along the contour and forming soil bank. Rain water thus held up in these trenches for some time and facilitate the growth of vegetation. Plants are sown in trenches taking advantage of water (Fig. 34.6 and 34.7). Tree species suitable are *Pinus patula*, *Pinus kesia*, *Acacia nilotica*, *Eucalyptus camaldulensis* etc.



**Fig. 34.6. Regenerating degraded land with contour trenching in Anantapuramu, A.P**



**Fig. 34.7 Continuous contour trenching**

#### **4. Agrostological Measures:**

Grasses prevent erosion by intercepting rainfall and by their binding power of the soil particles. A grass-legume association is ideal for soil conservation. Legumes build up soil fertility by fixing atmospheric N in root nodules. Grasses have several uses in soil conservation like:

- Stabilizing the surfaces of water ways, contour bunds and front faces of bench terraces
- Stabilizing the gully slopes and sides
- Preventing wind erosion

The desirable characters of grasses for soil conservation are:

- Should be perennial
- Drought resistant
- Rhizomiferous
- Develop good canopy
- Deep root system
- Prostrate growth habit
- Less palatable to cattle
- Useful for cottage industries

**Useful grasses:**

*Cenchrus ciliaris, Chloris guyana, Cynodon dactylon, Dicanthium annulatum, Heteropogan contortus, Iseilema laxum, Panicum antidotale*

**Legumes:**

*Atylosia scarbaeoides, Centrosema pubescence, Stylosanthes hamata*

**Grass + legume**

*Cenchrus ciliaris + Stylosanthes hamata* is best for A.P.

## Lecture 35:

# CONTINGENT CROP PLANNING FOR ABERRANT WEATHER CONDITIONS

### Effect of aberrant weather conditions on crops

Rainfall behaviour in dry farming areas is erratic and uncertain. The deviations in rainfall behaviour commonly met with in dry areas include delayed onset, early withdrawal and intermediary dry spells during rainy season. The adverse effect of these rainfall aberrations on crop growth vary with the degree of deviation and the crop growth stage at which such deviations occur (Table 35.1). Suitable manipulations in crop management practices are needed to minimize such adverse effects of abnormal rainfall behaviour. These management decision, constitute contingency planning. Such management practices done after crop establishment and in the middle of crop growth are called mid season or mid term corrections.

**Table 35.1 Effect of rainfall aberrations on crops**

<b>Rainfall aberration</b>	<b>Effect on crops</b>
Delay in onset of rainfall	Length of cropping season or cropping duration is reduced - crop sowing is delayed
Early withdrawal or cessation of rainfall	Moisture stress at maturity grain filling is affected (terminal stress)
Intermediate dry spells	
a. Immediately after sowing	Germination will be affected, plant population will be reduced
b. At vegetative phase	Affects stem elongation, leaf area expansion, branching or tillering
c. At flowering	Affects anthesis and pollination, grain / pod number is reduced
d. At ripening	Grain filling and grain size reduced

### Contingency cropping

Contingency cropping is growing of a suitable crop in place of normally sown highly profitable crop of the region due to aberrant weather conditions. In dryland agriculture, contingency of growing another crop in place of normally grown crop arises due to delay in the onset of monsoon. Depending upon the date of receipt of rainfall, crops are selected. It is assumed that the rainfall for the subsequent period is normal and depending upon the economic status of the farmer, certain amount of risk is taken to get good profits if season is normal or better than normal.

Contingency cropping is highly location specific due to variation in amount and distribution of rainfall. Especially in arid regions, the spatial distribution of rainfall is highly variable. It is common to observe that rainfall received varies from field to field in the same location. Temperature gradually falls from August onwards reaching minimum in November and December. Contingency plan and midterm corrections vary with the type and time of occurrence of rainfall aberration (Table 35.2).

**Table 35.2. Contingency crop plan for different abnormalities**

<b>Rainfall abnormality</b>	<b>Contingency plan and midterm correction</b>
1. Delayed onset of rainfall	
a) Delay exceeding-4 weeks	Alternate crops of short duration to be sown
Delay in South west monsoon Normal - June Delay - July Delay - August	Groundnut Ragi / pearl millet Little millet / Cowpea Castor
Delay in North east monsoon Normal - October Delay - Early November	Cotton / Sorghum Sunflower / Pearl millet / Ragi / Coriander / Bengalgram
b) Delay of 1 to 2 weeks	Alternate varieties of short duration of same crop Ex. Sorghum-Co 19 (150 days) and Co 25 (110 days), Red gram-local (180 days)- and Co 5 (130 days)
2. Early withdrawal of rainfall	Antitranspirant spray, harvesting for fodder (millets), harvesting at physiological maturity
3. Intermediary dry spell	
a. Immediately after sowing	Gap filling with subsequent rains if stand reduction is less than 20%. Re-sowing if stand reduction is more than 20%, mulching between crop rows. Stirring soil surface to create dust mulch to reduce evaporation
b. At vegetative phase	Mulching, antitranspirant spray, spraying Potassium chloride, thinning of 33-50 % population
c. At flowering	Antitranspirant spray, harvesting for fodder and ratooning with subsequent rains in millets (Ex. Sorghum)
d. At ripening	Antitranspirant spray, harvesting for fodder, harvesting at physiological maturity

Crops have to be selected with suitable crop duration to coincide with the length of the growing season. Generally short duration pulses like greengram, blackgram and cowpea may suit the situation. However, if the monsoon turns to be extraordinarily good, opportunity is lost if only short duration crops are sown. Farmers with economic strength and motivation for high profits with some amount of risk can go for crops of long duration. The long duration crops with flexibility or elasticity in yield are more suitable. For example, pearl millet, and sorghum can be ratooned if monsoon extends. Sunflower can be introduced for higher profits with certain amount of risk. Crops like sorghum, pearl millet, can be grown for grain if monsoon extends and if not, fodder can be obtained.

Contingency crops for different situations and regions of Andhra Pradesh and other states are suggested in Tables 35.3.

Table 35.3 Suggested contingency cropping for different situations in Andhra Pradesh

Time of onset of sowing rains	Crop	Varieties	Regions/situation
May	Sesamum	Madhavi, Gowri	Medium black soils, medium and deep red soils
June	Sorghum	CSH-5, CSH-9, CSH-10, CSH-11, CSV-1.1, CSV-12, SPV-462, SPV-475	Red soils, light black soils.
	Castor	Kranthi, Haritha	Telengana region
July	Groundnut	TMV. 2, Tirupati-1, Vemana,	Scarce rainfall zone of A.P.
August	Cotton	Mahanandi, NHH-4, Jayadhar, MCU-5	
	Groundnut	TMV-2,	First fortnight of August, Arid
	Pearl millet	ICTP 8203 WCC-75	Regions of Anantapur Red soils.
	Sunflower	MFSH-1, MFSH-8, MFSH-17, APSH-1L	Red soils and black soils
	Setaria	Lepakshi, Prasad, Srilakshmi	Black soils, deep red soils
September	Sunflower	MFSH-1, MFSH-8, MFSH-17, APSH-1J, Adarsha	Black soils .
	Redgram	LRG-30, LRG-41	Red soils in regions receiving North- East Monsoon rainfall
	Sorghum	NTJ-1, NTJ-2, M-35-1, CSH-5	Red and Black soils
	Tobacco	Natu special, Sun cured natu	Black soils, deep red soils
October	Sorghum	M-35-1, CSH-7R, CSH-6R, CSH-13R, NTJ-1, NTJ-2, N-13, N-14	Black soils
	Coriander	CS-4, CS-6	Black soils

## Lecture 36:

### CROPPING SYSTEMS-I

#### Cropping pattern:

- The yearly sequence and spatial arrangement of crop or crops and fallow on given area or the proportion of the area under different crops at any given point of time in a unit area is cropping pattern.

#### Cropping system:

- Cropping pattern used on the farm and their interaction with farm resources, farm enterprises and available technology which determine their make up.

#### Monoculture / monocropping:

- Repetitive growing of the same crop on the same field year after year is called – monoculture.
- It may either be due to climatological limitation or due to specialization by a farmer to grow a particular crop.
- Long duration varieties of paddy in delta regions i.e. rice-rice (Godavari delta) and groundnut in Rayalaseema *i.e.* Anantapuramu.

#### Disadvantages:

- Build up of pests and disease is high
- Specific weeds are likely to become a problem
- Imbalance use of the soil mineral nutrition and moisture from the soil

#### Types of cropping system:

##### Sole / solid / pure cropping:

One crop variety grown alone in pure stand at normal density in a given area

##### Multiple cropping:

- Growing of two or more crops on the same piece of land in a farming year
- It is the intensification of cropping in time (temporal-sequence cropping) and space dimension (spatial-simultaneous cropping) *i.e.* more number of crops within a year and more number of crops on the same piece of land
- It includes sequence cropping, intercropping and mixed cropping

**Intercropping:**

- Growing of two or more crops simultaneously on the same field with or without distinct row arrangement (mixed and row intercropping)
- Crop intensification is by both time and space dimension
- There is interrow competition throughout or part of the crop growth period
- Farmer manages more than one crop at a time on the same field
- It is meant for rainfed farming and as insurance against aberrant weather conditions
- Groundnut + redgram in 7:1 ratio or Korra + redgram in 5:1 ratio
- Additive or replacement series

**Mixed intercropping:**

- Growing component crops simultaneously with no distinct row arrangement. This is commonly used in labour intensive subsistence farming situations.

**Row intercropping:**

- Growing two or more crops simultaneously on the same field with definite row arrangement. This is used in mechanized agriculture.

**Strip intercropping:**

- Growing component crops in different strips wide enough to permit independent cultivation but narrow enough to the crop to interact agronomically.

**Relay cropping:**

- A system of growing succeeding crop in the standing preceding crop in which growing periods of both the crops overlap for a short period of 2-3 weeks. Sowing of blackgram in the standing rice crop.

## Lecture 37:

### CROPPING SYSTEMS-II

#### Sequence cropping:

- Growing of two or more crops in sequence on the same land in a farming year is called sequential cropping
- Depending on the number of crops grown in a year it is called double, triple and quadruple cropping involving two, three and four crops respectively
- It is possible only under irrigated condition
- It is crop intensification in time dimension only
- There is no intercrop competition and farmer manages only one crop at a time in the same field

#### Mixed cropping:

- Growing of two or more crops simultaneously on the same field with seeds of crops to be grown mixed and broadcasted or line sowing

#### Ratoon cropping:

- Cultivation of crop regrowth after harvest although not necessarily for grain purpose is called ratoon cropping. Ex. sugarcane, jowar and rice.

#### Multistoried cropping:

- The practice of growing different crops of varying height, rooting pattern and duration simultaneously in the same field
- It is practiced mostly in perennial plantations
- In Kerala - coconut, cocoa, pepper and pineapple
- In Andhra Pradesh - coconut, banana and rice (E and W Godavari)

#### Mixed farming:

- It is defined as a system of farming on a particular farm (regardless of size) which includes crop production, raising of livestock, poultry, fish and bee keeping, and/or trees to sustain and satisfy as many necessities of the owner (farmer) as is possible
- Subsistence is the main objective
- It is based on the principle of give and take
- Farm animals feed on farm produce and in return manure is given to the crops

### **Staggered planting:**

- It means sowing of a crop is spread over and around optimum period of planting either to minimize risks or to use labour & machinery more effectively or to minimize competition (in inter-cropping) or to prolong the period of supply to the market or the factories.

### **Crop rotation:**

- Growing of different crops in recurrent succession on same piece of land in a year or several years
- The objective is to get maximum benefit from least investment without impairing soil fertility
- One year crop rotation in irrigated agriculture i.e. rice (K)-groundnut (R)-sesamum (S)
- Only one crop is taken in one year in rainfed condition i.e. groundnut / sunflower / cotton (K)
- Two year crop rotation is the safest i.e. I year (C1-C2-C3) and II year (C1-C2-C3)

### **Principles:**

- A crop with tap root system should be followed by the crop with fibrous root system as far as possible
- Legume crop should be grown after a non legume crop
- An exhaustive crop should be always followed by a less exhaustive crop
- A monocot crop should be followed by a dicot crop as far as possible. They will extract the nutrients and moisture from different layers of the soil
- Crops of the same taxonomic family should not be grown in succession because they act as an alternate host for insect pest and disease pathogens
- Selection of the crop should be based on the local demand
- Crops should be selected based on the existing problems of the area
  - Saline soils                      - saline tolerant crops
  - Acidic / alkali soils           - suitable crops
  - Sandy soils                       - groundnut
- An ideal crop rotation is the one which generates maximum employment to the family and farm labour throughout the year and can utilize the farm resources very effectively

## Lecture 38:

# INTEGRATED FARMING SYSTEMS

## Farming

It is a process of harnessing solar energy in the form of economic plant and animal products.

## System

A system is a set of inter-related, interacting and interdependent elements acting together for a common purpose and capable of reacting as a whole to external stimuli.

Farm is a system because several activities are closely related to each other by the common use of farm labour, land and capital by risk distribution and by the joint use of the farmers management capacity. Farming system approach relates to the whole farm rather than individual system or element.

## Integrated Farming System

It is defined as a population of individual farm system that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints and for which similar development strategies and interventions would be appropriate (FAO-Farming System).

It is a resource management strategy to achieve economic and sustained agricultural production to meet diverse requirements of farm livelihood while preserving resource base and maintaining a high level of environment quality (Lal and Miller, 1990).

It is a set of agro-economic activities that are interrelated and interact with themselves in a particular agrarian setting. It is a mix of farm enterprises to which farm families allocate its resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of the farm. These farm enterprises are crop, livestock, fishery, agroforestry and agri-horticulture (Sharma *et al.*, 1991).

It represents an appropriate combination of farm enterprises (crop, livestock, fishery, poultry, forestry, horticulture, etc.) and the means available to the farmer to raise them for profitability. It interacts adequately with environment without dislocating the ecological and socioeconomic balance on one hand and attempts to meet the national goals on the other (Jayanthi *et al.*, 2002).

It is a mix of farm enterprises such as crop, livestock, fishery, agroforestry and fruit crops to which farm family allocates its resources in order to efficiently manage the existing environment for the attainment of the family goal (Pandey *et al.*, 1993).

## **Advantages of integrated farming system**

### **1. Productivity**

Farming system provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Time concept by crop intensification and space concept by building up of vertical dimension through crops and allied enterprises.

### **2. Profitability**

The system as a whole provides an opportunity to make use of produce/waste material of one enterprise as an input in another enterprise at low/no cost. Thus by reducing the cost of production the profitability and benefit cost ratio works out to be high.

### **3. Potentiality**

Soil health, a key factor for sustainability is getting deteriorated and polluted due to faulty agricultural management practices viz., excessive use of inorganic fertilizers, pesticides, herbicides, high intensity irrigation etc. In farming system, organic supplementation through effective use of manures and waste recycling is done, thus providing an opportunity to sustain potentiality of production base for much longer time.

### **4. Balanced food**

In farming system, diverse enterprises are involved and they produce different sources of nutrition namely proteins, carbohydrates, fats & minerals etc from the same unit land, which helps in solving the malnutrition problem prevalent among the marginal and sub-marginal farming households.

### **5. Environmental safety**

The very nature of farming system is to make use or conserve the byproduct/waste product of one component as input in another component and use of bio-control measures for pest & disease control. These eco-friendly practices bring down the application of huge quantities of fertilizers, pesticides and herbicides, which pollute the soil water and environment to an alarming level. Whereas, IFS will greatly reduce environmental pollution.

### **6. Income/cash flow round the year**

Unlike conventional single enterprise crop activity where the income is expected only at the time of disposal of economic produce after several months depending upon the duration of the crop, the IFS enables cash flow round the year by way of sale of products from different enterprises viz., eggs from poultry, milk from dairy, fish from fisheries, silkworm cocoons from sericulture, honey from apiculture etc. This not only enhances the purchasing power of the farmer but also provides an opportunity to invest in improved technologies for enhanced production.

## **7. Saving energy**

Availability of fossil fuel has been declining at a rapid rate leading to a situation wherein the whole world may suffer for want of fossil fuel by 2030 AD. In farming system, effective recycling of organic wastes to generate energy from biogas plants can mitigate to certain extent this energy crisis.

## **8. Meeting fodder crises**

In IFS every inch of land area is effectively utilized. Alley cropping or growing fodder legume along the border or water courses, intensification of cropping including fodder legumes in cropping systems helps to produce the required fodder and greatly relieve the problem of non availability of fodder to livestock component of the farming system.

## **9. Solving timber and fuel crises**

The current production level of 20 million m<sup>3</sup> of fuel wood and 11 million m<sup>3</sup> of timber wood is no match for the demand estimated or 360 m<sup>3</sup> of fuel and 64,4 million m<sup>3</sup> of timber wood in 2000 AD. Hence, the current production needs to be stepped up several-fold. Afforestation programmes besides introduction of agro-forestry component in farming system without detrimental effect on crop yield will greatly reduce deforestation, preserving our natural ecosystem.

## **10. Employment generation**

Various farm enterprises *viz.*, crop + livestock or any other allied enterprise in the farming system would increase labour requirement significantly and would help to solve the problem of under employment. An IFS provides enough scope to employ family labour round the year.

## **11. Scope for establishment of agro-industries**

When once the produce from different components in IFS is increased to a commercial level there will be surplus for value addition in the region leading to the establishment of agro-industries.

## **12. Enhancement in input use efficiency**

An IFS provides good scope for resource utilization in different components leading to greater input use efficiency and benefit- cost ratio.

### **Characteristics of farming system**

- Farmer oriented and holistic approach
- Effective farmers participation
- Unique problem solving system
- Dynamic system

- Gender sensitive
- Responsible to society
- Environmental sustainability
- Location specificity of technology
- Diversified farming enterprises to avoid risks due to environmental constraints
- Provides feed back from farmers

### **IFS for different situations**

Evolving strategies for the enhancement of the quality of life of the marginal and small farmers have been the foremost priority. Smaller sized holdings coupled with the irregular and inadequate monsoons make it difficult for the marginal and small farmers to meet both the ends with the income from cropping alone. Hence, it is imperative to focus attention on the whole farm approach by integrating various allied enterprises with cropping for better security, sustenance and productivity. Integration of various enterprises in a farm ensures recycling of residues, optimum resource use, higher employment, minimization of risk and uncertainties and increased farm income. Integrated farming systems research in wetlands, garden land and rainfed ecosystems have demonstrated the technical feasibility and economic viability through linking of different components.

### **Wetland**

#### **Crop-Fish-Poultry System**

When crop and fish culture is integrated with chicken rising on/near the pond dykes, additional advantages include

- As usual, food crops (rice, maize, pulse crops, groundnut, etc.) meets the need of the family
- Grain and other by-products of the crops meets the need of poultry feed
- Direct discharge of fresh and chicken manure to the fish pond reduces enough natural fish feed organisms without the use of any additional manure/fertilizer
- Nutritive value of applied fresh manure is much higher than dry and mixed with bedding materials (saw dust or rice husk)
- No supplementary feed is needed for the fish
- Some parts of the manure are consumed directly by the fish
- No extra space is required for chicken farming. Chicken sheds can be constructed over the pond water or on the dyke

- More production of animal protein will be ensured from the same area of minimum land
- The overall farm production and income will increase

### **Crop-Livestock-Poultry-Fish System**

Livestock and crop production systems are an integral part of one another. Crop residues provide fodder for livestock while occasionally grain provides supplementary feed for productive animals. Animals improve soil fertility through manures and urine deposition and animal power for farm operations and transport. Sale of animals sometimes provide cash for farm labour and agricultural inputs. Introduction of poultry and fishery components in crop livestock system leads to additional benefits.

- Reduced cost of feeding and production due to more intensive use of available indigenous feeds
- Ruminants to utilise non marketable crop residues in situ, the manure production from which can be used by fish
- Use of purchased concentrate supplements to fish and poultry components is restricted to dairy cattle
- Benefits in terms of significant income generation from the sale of crops, animals, fish and some by-products like rice bran
- With small farms, the meagre resources are put to more effective
- Flow model indicates efficient use of resources for improving farm productivity, employment generation and minimising the effects of climate change

### **Irrigated land**

#### **Crop livestock farming system:**

Diversified systems consist of components such as crops and livestock that coexist independently from each other. In this case, integrating crops and livestock serves primarily to minimise risk and not to recycle resources. In an integrated system, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources. Crop residues can be used for animal feed, while livestock and livestock byproduct production and processing can enhance agricultural productivity by intensifying nutrients that improve soil fertility, reducing the use of chemical fertilizers. A high integration of crops and livestock is often considered as a step forward, but small farmers need to have sufficient access to knowledge, assets and inputs to manage this system in a way that is economically and environmentally sustainable over the long term.

Livestock provide dairy products and meat to household besides supplying dung for biogas and manure to the crops. Crops provide grains, vegetables and fruits to household.

## **Dryland**

### **Crop-Livestock-Forestry System**

This system combines cropping, livestock and forestry activities to promote the recovery of degraded pastures. Each farm will have a varied production system, such as grains, fibres, meat, milk and agro-energy. It also aims to improve soil fertility with the use of adequate cropping systems and techniques to optimise and intensify its use. Therefore, it allows the diversification of economic activities on farm and minimises income risks due to climate and or market changes. The system consists in growing forest species simultaneously with commercial crops like soybean, maize or beans added for the first 2-3 years. After crop harvest, the area is planted with forages for livestock, associated with maize or sorghum. After grain harvesting, the pasture is already established between the tree rows enabling grazing, until wood is harvested.

Forestry component supplies feed to the livestock and nutrients to the crops. Livestock supply manure to forestry as well as crops. The crops supply feed to the livestock.

### **Measurable outcome**

- Increase in overall farm productivity and income of small farmers by 50 percent over conventional system.
- Enhancement of family employment by 40 percent over conventional system
- Nutritional security for human and livestock by inclusion of nutrient rich food and fodder crops and livestock components.
- Enhancement in soil fertility through organic bio-resource recycling through vermicompost
- Socio-economic upliftment of small farmers by improving their livelihood.

## Lecture 39:

### SUSTAINABLE AGRICULTURE

Sustainable agriculture refers to a range of strategies for addressing many problems that effect agriculture. Such problems include loss of soil productivity from excessive soil erosion and associated plant nutrient losses, surface and ground water pollution from pesticides, fertilizers and sediments, impending shortages of non-renewable resources, and low farm income from depressed commodity prices and high production costs. Furthermore, “Sustainable” implies a time dimension and the capacity of a farming system to endure indefinitely (Lockertz, 1988).

The successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource - base and avoiding environmental degradation (TAC-CGIAR, 1988).

A sustainable agriculture is a system of agriculture that is committed to maintain and preserve the agriculture base of soil, water and atmosphere ensuring future generations the capacity to feed themselves with an adequate supply of safe and wholesome food (Gracet, 1990).

A sustainable agriculture system is one that can indefinitely meet demands for food and fibre at socially acceptable, economic and environment cost (Crosson, 1992).

A broad and commonly accepted definition of Sustainable Agriculture is as follows:

Sustainable agriculture refers to an agricultural production and distribution system that:

- Achieves the integration of natural biological cycles and controls
- Protects and renews soil fertility and the natural resource base
- Reduces the use of nonrenewable resources and purchased ( external or off-farm) production inputs
- Optimizes the management and use of on-farm inputs
- Provides an adequate and dependable farm income
- Promotes opportunity in family farming and farm communities, and
- Minimizes adverse impacts on health, safety, wildlife, water quality and the environment

#### Current concept of sustainable agriculture

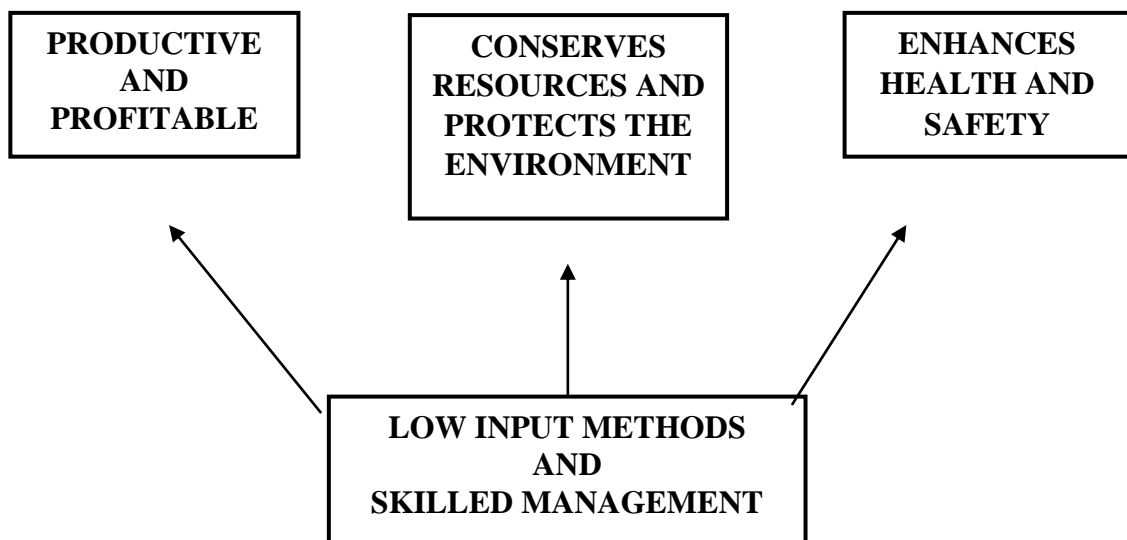
A Current concept of sustainable agriculture in the United States showing the ends and the means of achieving them through low- input methods and skilled management is shown in Fig. 39.1.

The ultimate goal or the ends of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment, and enhance health and safety, and to do so over the long-term. The means of achieving this is low input methods and skilled management, which seek to optimize the management and use of internal production inputs (*i.e.*, on-farm resources) in ways that provide acceptable levels of sustainable crop yields and livestock production and result in economically profitable returns. This approach emphasizes such cultural and management practices as crop rotations, recycling of animal manures, and conservation tillage to control soil erosion and nutrient losses and to maintain or enhance soil productivity.

Low-input farming systems seek to minimize the use of external production inputs (*i.e.* off-farm resources) such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable:

- to lower production costs
- to avoid pollution of surface and groundwater
- to reduce pesticide residues in food
- to reduce a farmer's overall risk and
- to increase both short-term and long-term farm profitability.

Another reason for the focus on low-input farming systems is that most high input systems, sooner or later, would probably fail because they are not either economically or environmentally sustainable over the long-term.



- |  |                                   |
|--|-----------------------------------|
| 1. Reduced use of synthetic              | 7. Crop rotations                 |
| 2. Chemical inputs                       | 8. Use of organic wastes          |
| 3. Biological pest control               | 9. Crop-livestock diversification |
| 4. Soil and water conservation practices | 10. Mechanical cultivation        |
| 5. Use of animal and green manures       | 11. Naturally occurring processes |
| 6. Biotechnology                         |                                   |

**Fig. 39.1 A current concept of sustainable agriculture in The United States**

**Goals of sustainable agriculture**

A sustainable agriculture, therefore, is any system of food or fiber production that systematically pursues the following goals:

Productive and profitable

Conserves resources and protects the environment

Enhances health and safety

Low input methods and skilled management

- A more thorough incorporation of natural processes such as nutrient cycling, nitrogen fixation and pest-predator relationships into agricultural production processes
- A reduction in the use of those off-farm, external and nonrenewable inputs with the greatest potential to damage the environment or harm the health of farmers and consumers, and more targeted use of the remaining inputs used with a view to minimizing variable costs
- The full participation of farmers and rural people in all processes of problem analysis and technology development, adoption and extension
- A more equitable access to productive resources and opportunities, and progress towards more socially justifiable forms of agriculture
- A greater productive use of the biological and genetic potential of plant and animal species
- A greater productive use of local knowledge and practices, including innovation in approaches not yet fully understood by scientists or widely adopted by farmer
- An increase in self-reliance among farmers and rural people
- An improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels and

- Profitable and efficient production with an emphasis on integrated farm management and the conservation of soil, water, energy and biological resources

### **Elements of sustainability:**

There are many ways to improve the sustainability of a given farming system, and these vary from region to region. However, there are some common sets of practices among farmers trying to take a more sustainable approach, in part through greater use of on-farm or local resources each contributing in some way to long-term profitability, environmental stewardship and rural quality of life.

**a) Soil conservation** - Many soil conservation methods, including contour cultivates contour bunding, graded bunding, vegetative barriers, strip cropping cover cropping, reduced tillage etc help prevent loss of soil due to wind and water erosion.

**b) Crop diversity** - Growing a greater variety of crops on a farm can help reduce risks from extremes in weather, market conditions or crop pests. Increased diversity crops and other plants, such as trees and shrubs, also can contribute to soil conservation, wildlife habitat and increased populations of beneficial insects.

**c) Nutrient management** - Proper management of nitrogen and other plant nutrients can improve the soil and protect environment. Increased use of farm nutrient sources such as manure and leguminous cover crops, also reduces purchased fertilizer costs.

**d) Integrated pest management (IPM)** - IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in way that minimizes economic, health and environmental risks.

**e) Cover crops** – Fast growing plants such as sunhemp, horsegram, pillipesara in the off season after harvesting a grain or vegetable crop can provide several benefits, including weed suppression, erosion control, and improved soil nutrients and soil quality.

**f) Rotational grazing** - New management- intensive grazing systems take animals out barn into the pasture to provide high-quality forage and reduced feed cost .

**g) Water quality & water conservation** - Water conservation and protection have important part of agricultural stewardship. Many practices have been developed to conserve *viz.*, deep ploughing, mulching, micro irrigation techniques etc. protect quality of drinking and surface water.

**h) Agroforestry** - Trees and other woody perennials are often underutilized *viz.*, agri-silviculture, silivi-pastoral, agri-silvi-past-horticulture, horti/silvipastoral, alley cropping, tree farming , ley farming that help conserve soil and water.

**i) Marketing** - Farmers across the country are finding that improved marketing way to enhance profitability, direct marketing of agricultural product from farmers to consumers is becoming much more common, including through Rythu bazaar road side stands.

## **Status of sustainable agriculture in India:**

The survival and well being of the nation depends on sustainable development. It is a process of social and economic betterment that satisfy needs and values of interest groups without foreclosing options. Suitable development of India demands access to state of are 'clean' technologies and have as strategic role in increasing the capabilities of the country both the environment as well as to provide thrust towards conservation and sustainable agriculture.

Current research programmes towards sustainable agriculture are as follows:

1. Resistant crop varieties to soil, climatic and biotic stresses
2. Multiple cropping system for irrigated areas and tree based farming system rainfall area.
3. Integrated nutrient management
  - a. Combined use of organic and inorganic sources of nutrients
  - b. Use of green manures (Sesbania, Crotalaria etc)
  - c. Inclusion of pulse crops in crop sequence
  - d. Use of bio fertilizers
4. Integrated pest management
  - a. Microbial control
  - b. Use of botanicals
  - c. Use of predators
5. Soil and water conservation
  - a. Watershed management
  - b. Use of organics as mulch and manure
  - c. Use of bio-fencing like Khus grass (*Vetiveria zizanioides*.)
6. Agroforestry systems in dry lands/ sloppy areas and erosion prone areas
7. Farm implements to save energy in agriculture
8. Use of non-conventional energy in agriculture
9. Input use efficiency
  - a. Water technology
  - b. Fertilizer technology
10. Plant genetic resource collection and conservation

Technology generated and implemented for increasing agricultural productivity during past three decades resulted in depletion of natural resource base besides creating several environmental and ecological problems. In contrast, the demand scenario features a growth rate in food requirements to meet the ever-increasing demand of the growing population. The total food grain demand of India by 2050 is estimated at 333 million tonnes as against the present 308 million tonnes (2020-21), which has to come from the almost static net cultivated area of about 142 million ha. This improvement in food grain production has to be achieved while dealing with the factors affecting the ecological balance and sustainability of agricultural resources.

**Major factors affecting the ecological balance and sustainability of agricultural resources are:**

- a) Land/soil related problems
  - Soil degradation
  - Deforestation
  - Accelerated soil erosion
  - Siltation of reservoirs
  - Wind erosion
- b) Irrigation related problems
  - Rise in groundwater table & water logging
  - Soil salinization & alkalization
  - Over- exploitation of groundwater
- c) Indiscriminate use of agro-chemicals
  - Fertilizer pollution
  - Pesticide pollution
- d) Environmental pollution
  - Greenhouse effect
  - Depletion emissions
  - Methane emission
  - Eutrophication
- e) Erosion of genetic biodiversity

## Lecture 40:

### ORGANIC AGRICULTURE

There is not one universally accepted definition of organic farming. Most organic farmers and organic consumers expect that organic farming methods should include natural, not chemical growth and production methods such as crop rotation, mechanical cultivation, animal manures, green manure and integrated pest management.

In 1980, the USDA released a landmark report of organic farming. The report defined organic farming as a production system, which avoids or largely excludes the use of synthetic organic fertilizers, pesticides, growth regulators and livestock feed additives. Organic farming systems largely depends on crop rotations, crop residues, animal manures, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and aspects of biological control to maintain soil productivity, supply plant nutrients and to control insects, pathogens and weeds (Sharma, 2002).

According to Codex definition (FAO), organic agriculture is production management system, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and biological activity. It emphasizes the use of management practices in preferences to the use of off-farm inputs, taking into account that regional conditions require locally adopted systems. This is accomplished by using, where possible, on-farm agronomic, biological and mechanical methods, as opposed to using synthetic materials to fulfill any specific function within the system.

**Organic farming** is the form of agriculture that relies on crop rotation, green manure, compost, biological pest control, organically approved pesticide application and mechanical cultivation to maintain soil productivity and control pests, excluding or strictly limiting the use of synthetic fertilizers and synthetic pesticides, plant growth regulators, livestock antibiotics, food additives, and genetically modified organisms

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organization for organic organizations established at France on 5<sup>th</sup> November, 1972. IFOAM defines the overarching goal of organic farming as follows:

"Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.." —IFOAM.

## **Principles**

The principles of organic agriculture serve to inspire the organic movement in its full diversity. They are the roots from which organic agriculture grows and develops. They express the contribution that organic agriculture can make to the world and a vision to improve all agriculture in a global context. The principles of organic agriculture serve to inspire the organic movement in its full diversity.

### **The principle of health**

Organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This principle points out that the health of individuals and communities cannot be separated from the health of ecosystems - healthy soils produce healthy crops that foster the health of animals and people. Health is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health. Organic agriculture is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

### **The principle of ecology**

Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling. Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

### **The principle of fairness**

Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings. This principle emphasizes that those involved in organic agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties - farmers, workers, processors, distributors, traders and consumers. Natural and environmental resources that are used for production and consumption should be managed in a way that is socially and ecologically just and should be held in trust for future generations. Fairness requires systems of production, distribution and trade that are open and equitable and account for real environmental and social costs.

## **The principle of care**

Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well being of current and future generations and the environment. Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions. Practitioners of organic agriculture can enhance efficiency and increase productivity, but this should not be at the risk of jeopardizing health and well-being. This principle states that precaution and responsibility are the key concerns in management, development and technology choices in organic agriculture. Science is necessary to ensure that organic agriculture is healthy, safe and ecologically sound.

## **Concept of organic farming**

Organic farming endorses the concept that the soil, plant, animals and human beings are linked. Therefore, its goal is to create an integrated, environmentally sound, safe and economically sustainable agriculture production system. Soil is a living system linked to an organism with different components. Human interact with these natural components (minerals, organic matter, micro-organisms, animals and plants) to achieve harmony with nature and create a sustainable agricultural production. A key feature of organic farming is the primary dependence on natural resource and those developed locally (green manures, crop residues, farm wastes etc.), rather than external inputs (especially synthetics). The farmer manages self-regulating ecological and biological processes for sustainable and economic production of products. Organic farming systems do not use toxic agrochemical inputs (pesticides, fungicides, herbicides and fertilizers). Instead, they are based on development of biological diversity and the maintenance and replenishment of soil productivity.

The concept of organic farming is based on following principles:

1. Nature is the best role model for farming, since it does not use any inputs nor demand unreasonable quantities of water.
2. The entire system is based on intimate understanding of nature's ways. The system does not believe in mining of the soil of its nutrients and do not degrade it any way for today's needs.
3. The soil in this system is a living entity.
4. The soil's living population of microbes and other organisms are significant contributors to its fertility on a sustained basis and must be protected and nurtured at all cost.
5. The total environment of the soil, from soil structure to soil cover is more important.

Thus in today's terminology it is a method of farming system which primarily aims at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic

wastes) and other biological materials along with beneficial microbes (biofertilizers) to release nutrients to crops for increased sustainable production in an eco-friendly pollution free environment.

### **Benefits of organic farming**

- Environment-friendly.
- Promotes sustainable development.
- Healthy and tasty food.
- Inexpensive process.
- It uses organic inputs.
- Generates income.
- Generates income through exports.
- Source of employment.

### **ORGANIC AGRICULTURE PRODUCTS CERTIFICATION**

Certification is a certification process for producers of organic food and other organic agricultural products. In general, any business directly involved in food production can be certified including seed suppliers, food processors, retailers and restaurants. Requirement varies from country to country, generally involves a set of production standards for growing, storage, processing, packaging and shipping that include

1. Avoidance of synthetic chemical inputs and GMO' s
2. Use of farmland that has been free from chemicals for a number of years
3. Keeping detailed written production and sales records
4. Maintaining strict physical separation of organic products from non-certified products
5. Undergoing periodic onsite inspection

### **Purpose of certification**

Organic certification addresses a growing worldwide demand for organic food. It is intended to assure quality and prevent fraud. For organic producers, certification identifies suppliers of products approved for use in certified operations. For consumers, 'certified organic' serves as a product assurance, similar to 'low fat', '100 % whole wheat' or 'no artificial preservatives'. Certification is essentially aimed at regulating and facilitating the sale of organic products to consumers. Individual certification bodies have their own service marks, which can act as branding to consumers. Most certification bodies operate organic standards that meet the government's minimum requirements.

## The certification process

In order to certify a farm, the farmer is typically required to engage in a number of new activities, in addition to normal farming operations:

1. Study: the organic standards, which cover in specific detail what is and is not allowed for every aspect of farming, including storage, transport and sale.
2. Compliance: Farm facilities and production methods must comply with the standards, which may involve modifying facilities, sourcing and changing suppliers, etc
3. Documentation: Extensive paper work is required, detailed farm history and current setup, and usually including results of soil and water tests
4. Planning: a written annual production plan must be submitted, detailing everything from seed to sale: seed sources, field and crop locations, fertilization and pest control activities, harvest methods, storage locations, etc.
5. Inspection: annual on-farm inspections are required, with a physical tour, examination of records and an oral interview
6. Fee: Fee is to be paid by the grower to the certification body for annual surveillance and for facilitating a mark which is acceptable in the market as symbol of quality.
7. Record-keeping: Written, day to day farming and marketing records, covering all activities must be available for inspection at any time.

In addition short notice surprise inspections can be made, and specific tests (soil, water, plant tissue) may be requested. For first time farm certification, the soil must meet basic requirements of being free from use of prohibited substances (synthetic chemicals etc) for a number of years. A conventional farm must adhere to organic standards for this period, often, 3 years. This is known as being in transition. Transitional crops are not considered fully organic. A farm already growing without chemicals may be certified without this delay.

Certification for operations other than farms is similar. The focus is on ingredients and other inputs and processing and handling conditions. A transport company would be required to detail the use and maintenance of its vehicles, storage facilities, containers and so forth. A restaurant would have its premises inspected and its suppliers verified as certified organic.

In some countries, certification is overseen by the government, and commercial use of the term *organic* is legally restricted. Certified organic producers are also subject to the same agricultural food safety and other government regulations that apply to non-certified producers.

## **Participatory certification**

*“Participatory Guarantee Systems (PGS) are locally focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange”* (IFOAM definition, 2008).

Participatory Guarantee Systems (PGS) represent an alternative to third party certification, especially adapted to local markets and short supply chains. They can also complement third party certification with a private label that brings additional guarantees and transparency. PGS enable the direct participation of producers, consumers and other stakeholders in:

- the choice and definition of the standards
- the development and implementation of certification procedures
- the certification decisions

Participatory Guarantee Systems are also referred to as “participatory certification”.

## **Certification & product labeling**

In some countries, organic standards are formulated and overseen by the government. The United States, the European Union, Canada and Japan have comprehensive organic legislation, and the term "organic" may be used only by certified producers. Being able to put the word "organic" on a food product is a valuable marketing advantage in today's consumer market, but does not guarantee the product is legitimately organic. Certification is intended to protect consumers from misuse of the term, and make buying organics easy. However, the organic labeling made possible by certification itself usually requires explanation. In countries without organic laws, government guidelines may or may not exist, while certification is handled by non-profit organizations and private companies.

With these recognitions, Indian organic products duly certified by the accredited certification bodies of India are accepted by the importing countries. "In March 2000, the Ministry of Commerce launched NPOP (National Programme for Organic Production) design to establish national standards for organic products which could then be sold under the logo **India Organic**. For proper implementation of NPOP, NAPP (National Accreditation Policy and Programme) has been formulated, with Accreditation Regulations announced in May 2001. These make it mandatory that all certification bodies whether internal or foreign operating in the country must be accredited by an Accreditation Agency. The regulations make provision for export, import and local trade of organic products. However, currently only the exports of organic products come under government regulations.

Thus, an agricultural product can only be exported as an organic product if it is certified by a certification body duly accredited by APEDA. Organic crop production, organic animal production, organic processing operations, forestry and wild products are the categories of products covered under accreditation.

## **ORGANIC CERTIFICATION MARK**

### **ORGANIC LOGO**

A trademark – “India Organic” will be granted on the basis of compliance with the National Standards for Organic Production (NSOP). Communicating the genuineness as well as the origin of the product, this trademark is owned by the Government of India. Only such exporters, manufacturers and processors whose products are duly certified by the accredited inspection and certification agencies, will be granted the license to use of the logo which would be governed by a set of regulations.

#### **The responsible body and certification decisions:**

- (a) Certification decisions are not only limited to initial approval of licensed operators, but also approval of products, changes in production, disciplinary measures etc.
- (b) The Authorized Inspection and Certification Agencies shall ensure that each decision on certification is taken by person(s) different from those who carried out the inspection or assessment.
- (c) The agency responsible for certification decisions shall reflect a diversity of stakeholders, without any single interest predominating.
- (d) Where certification decisions are delegated to a small committee or officers, the Authorized Inspection and Certification Agencies shall demonstrate reporting and review functions that enable the agency responsible for certification to exercise ultimate control and responsibility for such decisions.

#### **Exceptions:**

If exceptions are granted, clear criteria and procedures for granting exceptions shall be evolved.

- (a) Exceptions shall be clearly limited in time.
- (b) The rationale for any exception shall be properly recorded.

#### **The certification process:**

The certification policies and procedures shall be well documented and shall, interalia, include:

- (a) all procedural steps in processing the application, until final certification;
- (b) that the certification status of all licensed operators and their production be indicated throughout the certification process
- (c) the procedures for extension and updating certification, including certification of individual products; [Note: The Authorized Inspection and Certification Agencies shall require the licensed operator to inform of any changes in production as modification to the products, the manufacturing process,

extension of acreage etc. The Authorized Inspection and Certification Agencies shall determine whether the announced changes require further investigations. In that case, the licensed operator shall not be allowed to release certified products resulting from such changes until the Authorized Inspection and Certification Agencies have notified the licensed operator accordingly].

- (d) that the certification decisions be recorded and clearly communicated to the licensed operator
- (e) that, where certification is denied, the reason so shall be clearly stated
- (f) that the Authorized Inspection and Certification Agency shall be able to impose conditions and restrictions. Mechanisms for monitoring compliance with such conditions and restrictions shall be in place.
- (g) that the Authorized Inspection and Certification Agency shall be able to impose conditions and restrictions. Mechanisms for monitoring compliance with such conditions and restrictions shall be in place.
- (h) that the criteria for the acceptance of applicants, formerly certified by other certification system shall be documented. Relevant records from the other certification system must be requested
- (i) that, when asked for by the licensed operator, relevant records are released to another Authorized Inspection and Certification Agency
- (j) that, when asked for by the licensed operator, relevant records are released to another Authorized Inspection and Certification Agency
- (k) that processing of inspection reports and certification decision shall be done in a timely manner
- (l) that processing of any issue related to violations shall be done with highest priority.

## Lecture 41:

# FORESTRY

The word forest is derived from Latin word 'Foris' means outside. Therefore, forests are areas covering practically all uncultivated and untended lands fairly extensive stretch of land covered with rather tall and dense tree growth.

Forests are also defined as an area set aside for the production of timber and other forest produce and is under woody vegetation for certain benefits which it provides.

Forestry stands for the theory and practice of constitution and management of forests and utilization of their products. It also stands for scientific management of forests for the continuous production of goods and services.

### History of Indian forestry

Estimates of area currently classified as forest land in India vary widely from as high as 75 million hectares which accounts to 23 per cent of total land area of the country (327.7 M.ha). National forest policy 1988 enunciated 33.3 % area under forest to maintain the ecological balance. Forest area in A.P. is 3.66 m.ha covering 22.51 % of the total geographical area of 16.27 m.ha as compared to the world average of 1.6 ha per capita forest area. India has 0.11 ha per capita forest area mainly due to the population increase. The country has lost about 43.4 m.ha of forest area during 1951-52 to 1982-83 @ 1.5 m.ha / annum, the main reasons being excessive biotic interference, removal of cut forest exceeding than the forests could.

### Branches of Forestry :

**1. Silviculture:** Refers to certain aspects of theory and practice of raising forest crops method of raising tree crops, their growth and aftercare upto the time of final harvesting.

**2. Forestry soils :** Refers to the composition, physical and chemical characters and behavior of the soil upon which forest is to be established.

**3. Dendrology :** Refers to description, classification and recognition of tree species.

**4. Forest mensuration:** Deals with the measurement of forest produce.

**5. Forest Management:** Is the practical application of science, technique and economics to a forest estate for the production of certain desired results.

**6. Forest utilization:** Branch of forestry dealing with the harvesting, marketing, conversion and putting the forest produce for a variety of uses like timber, fuel, pulp wood etc.

**7. Wood technology :** Deals with the structure, physical, mechanical properties and behaviour of wood under varying conditions.

**8. Forest policy and administration :** Deals with the rules, regulations, laws and procedures that helps to conserve forests.

**9. Forests protection :** Knowledge of the behaviour of the forest enemies *viz.*, fire, insects, diseases, wind, animal and protection from them.

**10. Agroforestry:** Deals with the integration of crops, forest plants or livestock simultaneously or sequentially on the same piece of land for sustainable land management.

## Lecture 42:

# FORESTS

Forests cover about 1/4<sup>th</sup> of the land mass on the earth. In India however they cover only about 1/5<sup>th</sup> of the area. Forests are one of the most predominant geographic features of this planet and greatest bounty of mankind and influence the lives of human beings in several ways. They moderate the extremes of local climate, reduces wind velocity, intercepts precipitation, reduces impact of rain drops, reduce soil erosion, regulates stem flow in forested area, improves quality and quantity of water supply and finally provides important forest products.

### The various aspects of forest influences are as follows :

1. **Forests and climate :** The macro-climate of a given area depends upon its latitude and altitude whereas the micro-climate depends upon topography and vegetation. The various aspects of climate are :
  - a) **Temperature and radiation :** Dense forests with heavy foliage have greatest influence on air temperature. On monthly maximum temperatures, the effect is greater than on monthly minimum temperatures. The maximum temperatures are lower and minimum temperature are higher and the net effect of the forest cover is to reduce the range of temperatures at all periods of the year. Studies carried out at New Forest (Dehradun) inside *Pinus roxburghii* and *Dendrocalamus strictus* showed that temperature in forest and open area varies from 1.4°C to 3.1°C. Evergreen forests have greater influence than the forests of deciduous foliage.
  - b) **Wind movement :** Forests offer a mechanical obstruction and deflect upwards the moving masses of air and slow down the velocity of that part which enters the forests. Dense forests with greater foliage have more effect. It was reported that velocity of wind in the interior of forests may be 1/10 to 2/3 of that in the adjacent open area. Thus effect is being also felt to a considerable distance in the leeward side. In a study the reduction in wind velocities at different height are as follows :
    1. At the top of canopy - 43 % of that open (21 meters above ground)
    2. At the midpoint of canopy - 14 % of that open (9 meters above ground)
    3. At bottom of canopy - 20 % of that open (3 meters above ground)
  - c) **Humidity :** In general the air in a forest is somewhat moist than the open in view of the large amounts of water transpired by the trees. Relative humidity may be about 5-10 % more in the forest than in open area. Forest air being more humid proves to be heavier and sinks down in the neighbouring open areas thus resulting in descending currents of air above the forests and cooling the adjacent tree less areas.

- d) **Precipitation** : The influence of forests on rainfall is more controversial, But in India even today it is believed that forests increase rainfall. Precipitation depend upon not only on the amount of moisture content in the clouds but also on the conditions favourable for its release. Forests act as barrier across the horizontal path of wind causing more rainfall. Studies conducted in forest and non-forested area have shown that annual rainfall increased by 173 mm or 12 % in forested area. Thus it is inferred that forests increase the precipitation. According to some scientists the forests slow the movement of air by orographic obstacles and cause ascending currents which results in cooling of the air, formation of clouds and additional amount of rainfall.

## 2. Forests and soil conditions :

- a) **Soil composition and structure** : Forest soils are more friable and crumbly. Forests make lighter soil (sandy) heavier and heavy soils (clay) lighter. The roots loosen the soil mass and when die add organic matter to the soil. Porosity in the forest soils is increased because of effect of organic matter addition through root system.
- b) **Soil temperature** : It is affected by forest cover due to reduction in insulation and radiation by the over head forest cover and partly due to the insulating effect of the leaf litter and humus of forest cover.
- c) **Soil moisture** : Forest tend to decrease the amount of soil moisture by intercepting precipitation, retaining water in the forest floor (litter) and by transpiration. They tend to increase the amount of soil water by reducing surface run off, increasing permeability, decreasing evaporation and by increasing water holding capacity and storage capacity of soil.
- d) **Water table** : Forests lower the water table under all soil climatic conditions due to the effect of higher evapotranspiration and greater moisture uptake. It has been reported that trees such as Sal, Teak and oak spread their roots in an area of 100 Sq. meters and go more than 8 meters deep.
- e) **Chemical properties of soil** : The forest also improves the chemical properties of soil N, Ca, P, K, Mg and other elements which are made available in larger proportions. The C.E.C. of soil is also improved. pH of the forest soil is generally acidic in nature.
- f) **Water regime** : Quality of water flowing in forested area is better. It was reported from Deharadun that water flowing out of forest area was of high purity and pH was tending to be slightly acidic. The calcium oxide was the highest among the dissolved chemicals.
3. **Forests and floods** : Forests play a vital role in controlling floods, hence mass scale afforestation of catchments of major rivers is generally advocated. Forest are capable of checking the occurrence of floods by the following ways.

1. Consuming large amount of moisture by evapotranspiration
  2. Withholding rain water from reaching soil surface by interception
  3. Increasing infiltration capacity of soil
  4. Increasing underground run-off and decreasing the surface run-off
  5. Reducing erosion and thus, reducing the silting of river beds
  6. Improving soil characteristics for building underground water reservoirs
- 4. Forests and erosion :** Forests play an important role in checking the erosion of both water and wind. The main effect of vegetation is in improving the infiltration so that there is less water to run off a source effect. It can also restrict the rate of flow, the channel effect to diminish the more erosive efficiency of the moving water. The impact of rain drop is also being reduced which further reduces the removal of soil particles. Forests with a density of 0.3 is not very effective to control the run-off. Small water sheds after afforestation in fully stocked plantation were effective in total reduction of 28 % in run-off and 73 % in peak rate of run off.
- 5. Forests and human health :** Noise and pollution of air are some of the reasons for many diseases. Forests generally filter the air. The dust carrying winds invade the forests and deposit the dust on trunks, branches, leaves and needles. Forests also check the wind velocity resulting in increased dust precipitation. According to a scientist the dust filtering capacity of forests is tremendous and a stand of one hectare of spruce collects about 32 tonnes of dust, pine collects 36.4 tonnes and beach 68 tonnes dust per hectare.

Forests offer protection against CO<sub>2</sub> created by combustion. During the assimilation process of vegetation the CO<sub>2</sub> is taken from the air and release O<sub>2</sub> into the air. The SO<sub>2</sub> which is harmful is also kept under control. Radioactive radiation is also being filtered by forests.

Higher noise of industrialization, mechanization and motorization increases the blood pressure. Noise exposure of 90 phones or more create reduction in hearing capacity. The forests absorb certain amount of noise, the denser the forests higher would be the sound absorbing capacity.

It has been proved that a park of 50 meter width can reduce traffic noise by 20-30 db (decibels). Forests have natural healing effect for a number of diseases. Coniferous forests are believed to have healing effect against bronchitis due to the ethereal oils present in these forests.

## Lecture 43:

### PRINCIPLES OF SILVICULTURE

The theory and practice of raising forest crops is the silviculture. On the other hand, silvics is the study of trees and forest as biological entities; the laws of their growth and development and impact of environment on them. Thus the silviculture can be described to include all the practical and theoretical aspects of silvics. It is science that combines biology, mathematics, management and economics. Therefore, the study of silviculture helps to attain the following objectives:

1. To derive environmental benefits
2. Raising species of more economic value
3. Production of high-quality timber
4. Production of more volume per unit area
5. Reduction of rotation period
6. Afforestation of blank areas
7. Creation of plantations
8. Introduction of exotics
9. Employment potential
10. Increase in the production of fuel and fodder
11. Development of forest industries

#### **Definition of silviculture:**

It is the science that deals with the establishment, development, care and reproduction of stands of trees. Its aim is the continuous production of wood.

It is under silviculture that we learn the growth habit of trees and techniques to raise them naturally and artificially.

#### **Stages of development of tree :**

Different terms are used for different stages of development of forest trees. Four main stages in growth and development of tree have been recognized.

1. **Seedling** : From germination upto a height of three feet (1m).
2. **Sapling** : From 3 feet or 1 m height till the lower branches begin to fall. A sapling is characterized by the absence of dead bark and by vigorous height growth.

3. **Pole :** From the fall of lower branches to the time when the rate of increase in height begin to fall off and crown expansion becomes marked.
4. **Tree :** After passing the pole stage beyond the time the rate of growth begins to slow down and expansion of the crown begins to attain predominance.

**Parts of a tree :**

1) **Crown :** The upper part of the tree comprising of branches and foliage is called crown.

Mode of branching, degree of branching, flexibility of branches, deciduous and evergreen type, persistence of evergreen leaves, twigs, shedding leaf, are the important features of crown which vary greatly with the species.

2) **Bole :** The lower portion of the stem upto the point where the main branches are given off is known as the bole. Some trees have inherent tendency to form a tall, erect, straight bole with relatively small branches when grown even in open Ex. Conifers, Eucalyptus, etc.

a) **Taper or Form factor :** The taper of the bole is commonly expressed as the stem form factor which is proportional to the actual volume, bears to the volume of cylinder of the same height on the same base.

b) **Buttressed stem :** In many species of wet tropical forests and few in drier tropics, the swellings at the base of the stem is far more pronounced and may even extend upto 15ft. or more up the stem. The form it takes is called buttressed.

c) **Fluted stems :** The bole above the basal swell may be smoothly rounded in section or it may show irregular involutions and swellings which are referred as flutings and this is a serious deflection for timber production.

**Structure :** The main stem and the branches of a tree consists of the central wood, the cambium and the bark (phloem). The wood constitutes (xylem) the timber.

**Annual rings :** In many species the predominant elements of the xylem are the tracheids. The marked differences in size, shape and cell wall thickness of the early and late wood tracheids produce growth rings or growth marks. One ring refers to the growth of the whole year. Tracheids are vertical thick walled dead cells of 0.5 – 15 mm length.

## Lecture 44:

### AFFORESTATION ON DIFERENT SITES

**1. Shifting sandunes:** Shifting sand dunes occupy an appreciable area in western Rajasthan and Haryana. The sand dunes are highly deficient in humus and soil moisture, water table 150 meters deep and climate of the area is highly unfavorable for any afforestation activity. The annual rainfall is about 150-250 mm temperature goes as high as 49°C during May-June and wind velocities are generally high.

Any afforestation on these sites calls for rapid stabilization of the drifting sand dunes and maximization of soil conservation and selection of suitable species etc. Shelter belts play an important role in sand dune fixation reduce the wind velocity and to check the shifting sand dunes in the leeward side. The species like *Acacia nilotica* and *Zizypus* spp., are found suitable.

**2. Saline and alkaline soils:** These sites are mostly located in arid and semi arid tropics of the country. High concentration of salts, lack of moisture availability, poor permeability, presence of hardpan, high pH, toxic effects of sodium are some of the inhibiting factors for plant growth. Species having tolerance to high salt concentration soil binding characters and fast growth should be selected for afforestation of saline and alkaline soils.

Species suitable are *Acacia nilotica*, *Prosopis juliflora*, *Azadirachta indica*, *Albizia procera*, *Butea monosperma*, *Pongamia pinnata* and *Ailanthus excelsa*.

**3. Ravine lands:** Ravines are net work of deep gullies. The whole land mass is cut by a no.of deep gullies. These lands mainly occur on the banks of rivers of Jammuna Chembal in the states of Uttar Pradesh, Rajasthan, Gujarat and Madhya Pradesh. The soil is generally calcareous and compact with wide various in texture. The ravines are characterized by absence of vegetation of any type the run off maximum, slopes are steep and gullies are varying in depth from few meters to 100 meters or more in order to achieve better results the afforestation of ravines may be accompanied by proper management of agricultural lands.

It has been observed that prevention of erosion by easing of the slopes of gullies and by diverting the surface flow is an essential pre-requisite for any successful afforestation programme. The gullies have to be plugged with suitable mechanical measures to conserve soil and moisture. The sloppy areas of ravines have to be clothed with grasses and Agave etc.

The species which have been grown successfully in India are *Eucalyptus* spp., *Dalbergia sissoo*, *Dendrocalamus strictus*, *Acacia nilotica*, *Prosopis juliflora*, etc.

**4. Lateritic soils :** These soils are mainly located in the states of eastern central and southern regions of India. The low fertility status hard vesicular structure and

deficient moisture supply render many of these soils unsuitable for growth of tree species. *Tectona grandis* grown in lateritic soils of West Bengal gave encouraging results. Another two species of *Agave sisalana* *Agave cantula* grown on lateritic soils have been found successful. Other species like *Acacia auriculiformis*, *Eucalyptus spp*, *Grevillea robusta*, *Anacardium occidentale* have given good results in many parts of the country.

**5. Coastal sea sands:** Coastal sea sands occupy in the form of narrow strip along the eastern and western coasts of the country. The soil are generally alkaline in reaction, salt content is high, poor in nutrients, low in water holding capacity, water table is high at some places the conditions become water logged sea water causes high concentration of sodium salts.

The urgency of afforestation of coastal areas have been fast due to continuous occurrence of cyclone. Plantations of *Casuarina equisetifolia* can be raised successfully on large scale in the coastal sandy soils. Other species which have been encouraging are *Avicennia officianlis*, *Acacia auriculiformis*, *Eucalyptus spp* etc.

**6. Dry rocky and murrumy areas:** These soils are problematic and generally called skeletal soils. These soils are very shallow course, poor eroded and degraded. These soils occur both in high and low rainfall regions. Due to shallow nature of the soils the vegetation is xerophytic in nature such as *Euphorbia spp.*,

The selection of the species is carried out depending upon the rainfall and other climatic factors of the area. In low to medium rainfall area *Eucalyptus teritiocornis*, *Dendrocalamus strictus* *Ailanthus excelsa*, *Hardwickia binnata*, *Cassia siamea* have been successful. In high rainfall areas species such as *Eucalyptus globules* and *Acacia decurrens* were found suitable.

**7. Wet lands:** Wet lands may be defined as lands where soils is badly or imperfectly drained. These soils are generally found in high rainfall areas along canals etc. The problems are water logging, physiological drought, defective aeration, excessive salt concentration, poor nutrient availability. The total area of all kinds of wet lands in the country is about 20 m.ha. In water logged areas of India some of species which have yielded good results are *Erobusta*, *Sygzium cumini*, *Salix spp*, *Populus nigra*.

**8. Grass lands :** Grass lands may occur almost every where but are mostly concentrated on the Indo-Gangetic alluvium. The grass lands are problematic for afforestation because of dense growth of grasses. Grasses usually modify the structure of the soil and also affect the translocation of soluble salts and thus latter the morphology of the soil. Soil aeration drainage, biological conditons is largely poor. Many species of grasses like *Imperata*, *Ischaemum*, *Cymbopogon*, *Saccharus spp.*, form dense rhizomes., the root system of these grasses are difficult to remove even by ploughing.

The growth of grasses exerts inimical effects on the seedlings growth. Therefore it is essential that species selected should put forth fast growth so that it is not suppressed by the growth of grasses and shrubs. *Dalbergia sissoo*, *Acacia catechu*, *Bombax ceiba* and *Ailanthus excelsa* have been found successful.

**9. Denuded and eroded hill slope:** Denuded and eroded hill slopes are generally found in sub tropical and temperate regions of the country. The southern aspect of Himalayas is generally denuded. These denuded hill slopes are heavily grazed, frequently burnt and thus are liable for serious erosion. Denuded hill slopes are more common in western Himalayas than in Eastern Himalayas. These type of areas are largely found in states of J & K, H.P., and U.P.

The hills have been denuded by unrestricted fellings associated with excessive grazing and frequent fires. In most of the areas the surface soils has been eroded. The soil is poor in moisture and nutrients.

Before starting afforestation the area should be closed for grazing by fencing only hardly species are likely to succeed on exposed and eroded areas. *Pinus roxburghii* and other *Pinus spp* are quite hardly have been successfully used for afforestation of these areas in sub-tropical and temperature regions. In dry areas of N.W., India the species such as *Acacia modesta*, *Prosopis juliflora*, *Acacia catechu* have been successful. In peninsular region *Eucalyptu tereticornis*, *Anacardium occidentale*, *Prosopis spp.*, *Cassia siamea*, *Albizia lebbek* have been successful.

**10. Canal banks :** Strips of lands on the both the sides of the canal are generally left for the management of canal. These strips are used for roads, paths and for repairs of canals. The largest area under canal banks is in U.P.

The soil is characters by high amount of moisture in the surface due to seepage from the canal. The conditions become bad with the presence of higher amount of clay. Local alkaline and saline patches are also common. *Dalbergia sissoo*, *Acacia nilotica* and *Syzygium cuminii* may be planted.

**11. Road side areas:** Road side plantations have special problems of protection from local population and cattle. The road side soils are comparatively depressed because soil excavated from these areas is used to raised the level of road surface. Generally road side areas are well drained but many times water logged patches are also faced.

The species with proportions such as hardiness, fast growing, compact crown, less spreading branching behavior, evergreen or winter deciduous, wind firm with edible fruits may be preferred. The important species are *Mangifera indica*, *Tamarindus indica*, *Dalbergia sissoo*, *Ficus spp.*, and *Azadirachta indica*.

**12. Bio-aesthetic plantations :** Planting of trees is also undertaken because they are good to look at. They grown in beautiful shapes and curves. They are the cheapest large scale parasol shielding us from sun, rain, wind and other various factors. The trees are good screens and effectively shut out the view of an unsightly picture and structures such as buildings walls etc. Planting of trees for these purposes is undertaken by house owner, designers, managers of parks, town and country planners.

Trees like *Mangifera indica*, *Azadirachta indica*, *Tamarindus indica*, *Ficus spp.*, and *Grevillea robusta* may be selected for shade species such as *Polyalthia longifolia*, *Michalia champaca*, *Populus spp.*, *Saraca indica* and *Eucalyptus spp.* are generally grown for their shape of bole and crown. Flowering trees like *Delonix regia*, *Peltophorum spp.*, *Jacaranda mimosifolia*, *Cassia fistula*, *Erythrina indica*, *Spathodia companulata*, *Tecom spp.*, *Thespesia populanae* etc are grown for ornamental purpose.

### **Tending operations:**

Tending is a broad term given to operations which are carried out for the well being of a forest crop at any stage of its life involving operations both on the crop itself and on its competing vegetation. Tending is an important silvicultural operation which helps in the production of high quality timber, maximizing returns per unit area and ensures overall well being of the forest. The various operations of tending are :

1) **Irrigation or watering** : For avenue plantations watering is advisable to ensure establishment of the plants. In case of block planting on village lands and in forest area it is better to plant a greater number to allow for causality. In forests watering is rarely done as it is a costly operation.

2) **Weeding** : To reduce the root competition and suppression of the plants from weeds and grasses, an area of about 1.5 meters diameter all around the plant is cleared of weed growth. This operation is done once in a month.

3) **Soil working** : This involves loosening the soil and working up the soil around the plant to prevent soil moisture loss. The operation should be carried out with all the weeding and particularly when there is a wide gap in the rains and at the beginning of the hot season. Mulching with twigs, brush wood, paddy husk etc is also carried out to prevent soil from hardening.

4) **Fire tracing** : A belt of 2 meters diameter cleaned on all sides of the plant will prevent any direct damage from the fires. In case of block plantings a fire line of 4 meters width around the area should be cleared so that no fire enters the area.

5) **Singling** : In case of double or more coppice shoots, it is advisable to remove all retaining the best one so that the establishment is quicker and growth is faster.

6) **Brushing or low pruning** : In the 2nd or 3rd year if there are any lower branches they should be pruned by saw or by a sharp implement without damaging the plant upto a height of 2 meters. This helps for straight and better growth of the tree.

7) **Climber cutting** : The climbers are harmful particularly when the trees are young. In older trees they constrict the stem and deteriorate the value of wood. *Bauhinia vahlii*, *Butea parviflora*, *Vitis spp.*, *Ipomea spp.* and *Acacia spp.* are some of the climbers.

## Lecture 45:

### SOCIAL FORESTRY

The forests managed to cater the needs of the local population for small timber, bamboo for agriculture and other domestic requirements like fuel wood, fodder, grazing recreation and aesthetic purpose are usually referred as Social forestry.

Social forestry is a forestry having social content achieved through the participation of the people and intended for meeting the various requirements of people and it is for the people of the people and by the people. The concept of social forestry was enunciated in a comprehensive manner by Mahatma Gandhi, the Father of the Nation.

The credit for coining the social forestry for the first time goes to Mr. Westoby (1968) who defined it as forestry, which aims at producing flow of protection and recreation benefits for the community.

#### **Objectives of Social Forestry:**

1. To develop tree consciousness and love for tree cultivation amongst the masses
2. To provide fodder, firewood and small timber for the rural population.
3. To provide timber for sustaining and creating village level cottage industries based on wood.
4. To improve the socio-economic level of the village through increased avenues of gainful employment.
5. To optimize the use of agricultural land through agroforestry practices and to stabilize the farmers income.
6. To improve the income from marginal agricultural lands through tree cultivation.
7. To create recreational forests in urban areas.
8. To raise green belts around industrial locations to control atmospheric and noise pollution and also to absorb toxic effluents.
9. To help in planting all available land in the urban areas to improve the urban environment.
10. To help in augmenting the supply of industrial raw material from non-forest areas to bridge the gap between demand and supply and to lessen the pressure on reserved forests.
11. To make vast saline and alkaline lands productive through afforestation.
12. To afforest the eroded and ravine lands.

## **Reasons for deforestation**

1. Approximately 75% of rural people depend on forests for their fuel wood requirements
2. Animal grazing in the prohibited forest lands is another cause for deforestation

**Scope of social forestry:** The broad base given to the social forestry by the National Commission on Agriculture (NCA) was extended to urban forestry as well because it is a forestry practice outside the forest areas and designed for the benefit of a community therefore the NCA defined the scope of social forestry as follows:

**1) Community forestry:** Practice of forestry in community lands in which planting, management, harvesting and marketing of forest products are carried out by rural community members by themselves or by a state forest service on their behalf for benefit the community rather than individuals.

**2) Farm forestry:** Practice of forestry on farm lands in which individual land owners are encouraged by training and incentives to plant the trees along field boundaries at farm wood lots. Raising of windbreaks and shelterbelts is also included in farm forestry.

**3) Extension forestry:** Practice of forestry outside the farm lands and outside the reserve forests includes raising of trees on canal banks, railway lines, road sides, under high tension lines, foreshore areas of tanks, reservoirs and on marginal lands not suitable for agriculture.

**4) Recreation and amenity forestry:** Creation and maintenance of trees for recreational purpose and for improvement of local amenity conditions.

**5) Rehabilitation forestry:** Creation of forests or raising of trees in degraded forests and degraded land to have both the benefits of direct productive and indirect social benefits.

**6) Compensatory plantations:** Creation of forestry for supplementing the natural regeneration to conserve the natural forests with the benefits of gene conservation for supplies of medicines and protection.

**7) Agroforestry:** A form of mixed cropping where in the trees are integrated with agricultural crops / pastures / animals on arable lands for sustainable agriculture.

**8) Urban forestry:** Growing of trees in urban areas for beauty and climatic amelioration.

## **Lecture 46:**

### **VAN MAHOTSAV**

- "Someone's sitting in the shade today because someone planted a tree a long time ago." Warren Buffett

Van Mahotsav is generally celebrated only once in a year. Van Mahotsav or forest festival is an annual tree-planting festival celebrated in the month of July in which thousands of trees are planted all over the country. Van Mahotsav week is celebrated from 1 July to 7 July to spread awareness of forest conservation and to save the environment. The Van Mahotsav week is a reminder that we must protect forests and stop deforestation and practice the 3R rule-reduce, reuse and recycle. During this week, one can find children and elders planting saplings and taking part in the plantation drive to raise awareness about the importance of trees. It was a process of land transformation to create forests. India has taken a target of creating additional 2 billion carbon sequestration by 2030.

#### **History of Van Mahotsava:**

The history of Van Mahotsav day dates back to 1947 when it was first organized by Punjabi botanist MS Randhawa from 20 to 27 July. The then Delhi Police Commissioner Khurshid Ahmad Khan inaugurated the first event of Van Mahotsava on 20<sup>th</sup>, July 1947 to stress the impact of deforestation on flora and fauna. A flourishing plantation drive was undertaken by national leaders like Dr Rajendra Prasad and Jawaharlal Nehru.

Since then, the tradition of celebrating van mahotsav and planting trees has continued. In 1950, it was declared as a national activity by the Minister of Food and Agriculture, Kanaiyaka Maneklal Munshi (K.M.Munshi). Later on, the festival was moved to the first week in July and was renamed to van mahotsav in 1950. The father of van mahotsava or Forest festival is K.M. Munshi.

In van mahotsav, central government encouraging those who are participating in planting programme as well as look after the planted saplings with awards in their names at village level, district level, university level instituted trophy's specially in the names of Sri Jawahar Lal Nehru, Sardar Patel and Munshi. This will encourage people to actively participate in the van mahotsava program.

#### **Main objectives :**

1. Afforestation of saplings in vacant fields, private, public building compounds, along the roadside and around the wells.
2. Motive of promoting afforestation around the surrounding and preventing people from deforestation or the clearing of forests and greenery around them.

3. Increasing the area under trees to safeguard the environmental balance.
4. Provide fuel, fodder and raw material for making agricultural implements.
5. Provide employment to the rural poor during off season.
6. To prevent soil erosion by planting trees.
7. To develop the degraded lands by planting trees
8. Help conservation of soil and prevent further deterioration of soil fertility.
9. To develop socio economic conditions of villagers through production of food, fruits and minor forest produce
10. Help creation of shelter-belts around agricultural fields to increase their productivity.
11. Provide shade and ornamental trees for the landscape.
12. Inculcate tree consciousness and love of trees amongst the people.
13. Popularize the planting and tending of trees in farms, villages, municipal and public lands for their aesthetic, economic and protective needs.

#### **Pre requisites for planting of tree saplings**

1. Identified lands should be ploughed after clearing thorny bushes and weeds.
2. Digging of pits of size 30 cm x 30 cm x 45 cm should be taken up during May-June.
3. Depending up on the type of trees, according to spacing number of pits will be made. Ex. If 2 m x 2 m spacing is adopted then the number of pits required for one acre field would be 1000.
4. Each dug out pit should be filled with 4 kg of well decomposed FYM, 0.5 kg neem cake, 50 g of DAP, 100 g of methyl parathion powder as well as black soil of sufficient quantity.
5. Planting should be taken up of desired plants during June-July.

#### **Management of social forestry**

**1) Fertilisers :** 100 g of DAP should be applied twice for each plant during July (rainy season) and December months.

**2) Water management:** Whenever plants experienced dry spell of 2-3 weeks during first year, irrigation should be arranged through mud pots. During summer season always provide irrigation for 7-8 times with interval of 15-20 days.

**3) Weeding:** Field should be weed free for better development of tree saplings. Weeds should be cleared in the tree basins 2-3 times which results in good development of saplings.

**4) Pruning of branches:** During the early stages, side branches should be pruned so that plants will grow straight.

**5) Moisture conservation methods:** Most of the forest soils are light and less fertile soils unable to hold water for longer periods. Hence, it is necessary to follow methods which can hold moisture for longer periods. Use of rice husk or hydrogel (jalshakti) or mud pots with drip by using cloth wick at the bottom of pot can hold water for more period. Rice husk should be placed to a depth of 8 cm in tree basins since it is cheaply available. Those plants covered with rice husk should be watered once in three weeks. Methyl parathion @100 g should be applied before application of rice husk so as to avoid the termite attack on saplings. Application of rice husk not only retains the moisture but also controls the weeds effectively.

## Lecture 47:

### FARM FORESTRY

**Need for farm forestry:** The total forest cover in India is about 11-14 % as against 33.3 % (1/3<sup>rd</sup>) required to maintain the ecological balance.

Farm forestry is defined as the practice of forestry in all its aspects on farm and village common lands more or less integrated with the farm operations or an integration farming with forestry practices on the farm to benefit the agriculture (Randhawa, 1988) or farm forestry is the name commonly given to programmes which promotes commercial tree growing farmers on their own land.

**Scope :** The farm forestry has a scope around well, tube wells, water channels, field boundaries, farm roads and marginal and sub-marginal lands uneconomical for crop culture. Farm forestry is one of the easiest components of social forestry to implement. It is very much similar to agriculture except that the period of gestation is fairly long. In some of the states such as Jammu and Kashmir, Tamil Nadu, Karnataka people have been practicing farm forestry for decades. In U.P. and Gujarat wind breaks and shelter belts are widely used for protection of sugarcane fields.

#### **Objectives of farm forestry:**

1. To meet the requirement of organic manures
2. To maintain balance in soil fertility for enhanced agricultural productivity their by reducing the soil and water problems
3. To provide fuel wood, fodder, raw material for preparation of agricultural implements
4. To maintain weather abnormalities during summer *i.e* protection of crops from dry hot winds
5. To increase the underground water movement
6. To protect the soil from erosion due to heavy floods and rain water
7. To use cow dung as manure for increasing agricultural productivity

#### **Management considerations for success of farm forestry :**

1. The effect of farm trees on *kharif* crops is less marked than on growth of *rabi* crops. Therefore, deciduous narrow crowned trees like Mulberry, Bombax, Sissoo and *Acacia albida* should be preferred
2. Use of root cutters is recommended for eliminating root competition between adjoining trees and crops

3. Dense crowned shady fruit-cum-timber trees like Mango, Jamun, Jack fruit, Tamarind and Ber may be grown near the wells, tanks, tube wells, farmsteads and habitations.
4. The trees should be kept under regular surveillance and prophylactic sprayings or dustings should be adopted to avoid the risk of harbouring insect pests and diseases.
5. The trees with short sparse crown are not suitable for birds nesting. Such trees which are resistant to saline and alkaline conditions and fast growing should be preferred.

### **Characteristics of tree species suitable for farm forestry :**

- 1) Rapid growth and short rotations
- 2) Good keeping quality of wood
- 3) Combustibility with high calorific value
- 4) Ease of propagation and reproduction as by coppice root suckers and layering etc.
- 5) Low cost of production and maintenance.
- 6) Availability of seed
- 7) Proven techniques for establishing and maintenance.

**Species :** *Acacia spp.*, *Albizia lebbek*, *Azadirachta indica*, *Cassia siamea*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Eucalyptus globulus*, *Syzygium cumini*, *Morus alba*, *Prosopis spp.*, *Sesbania spp.*, *Glyricidia spp.*, *Leucaena luecocephala*, *Zizyphus spp.*, *Emblica officinalis*, etc.

### **Types of farm forestry**

Farm forestry may be grouped into 1) Commercial Farm Forestry 2) Non-Commercial Farm Forestry

**1) Commercial Farm Forestry (CFF) :** It is the terms applied to a process under which farmers grow trees on commercial basis. This programme is usually undertaken in areas where there is a ready market for wood and other forest based products. F.A.O (1980) describes this as turning peasants into entrepreneurs and producers.

Once the price available for poles, fuel wood and the forest products provides better rate of return to the farmer than traditional agricultural crops. Hence, the farmer is liable to alter his land use pattern.

## **The success of CFF depends upon:**

### **1) Finance viability:**

The finance viability of farm forestry projects of an individual farmer depends upon cost of labour, materials, cost of raising plantations. Returns depends upon the growth rate, yield prevailing prices and financial capacity of the farmer for whole rotation of the crop.

### **2) Input levels :**

**A) High input level :** The more prosperous a farmer is the more the resources available to him and larger are the alternatives available

1. Fertile agricultural lands may be diverted to farm forestry
2. Irrigation and fertilizers may be used to boost the growth of forest crop.
3. Labour may be hired to supplement the work of family
4. Financial stability enables rich farmers to take great risks as compared to poor farmers
5. Rich farmers can wait for long period and can bargain for a good price for his produce to obtain at least marginal gain

**B) Low input level :** It is absolutely impracticable for a small and marginal farmers to have various alternatives who is suffering to produce barely enough food for his household.

1. Unless alternative source of income is available it is not possible to divert good available land to tree plantations.
2. The tree planting is restricted to agriculturally infertile areas and waste lands.
3. Dearth of adequate finance and credit inhibits the taking of tree farming on large scale.
4. Long gestation period (Maturity period) is the most important factor influencing farm forestry by small farmers as they have to wait for 5-10 years to get returns.
5. Risk involved is also high, hence a small farmer cannot take up commercial farm forestry.

To be successful through low input approach a poor farmer requires

- 1) Addition financial resources
- 2) Extra land which is already limiting
- 3) Diversion of labour from traditional agriculture to tree plantation

4) More time to be spent by the farmer for raising the trees which may not be possible because labour intensive method of cost of production is adopted by marginal farmers in developing countries

5) Certain degree of technical know how which is not available among poor farmers.

However, it cannot be ruled out that all small farmers are not participating in farm forestry in a big way. Direct cash incentives were given and at the same time certain support services should also be provided for implantation of CFF. The various facilities required to be provided to a small farmer are credit marketing and tax incentives etc.

## **2. Non-Commercial Farm Forestry (NCFF) :**

The NCFF programmes aim at increasing the number of trees raised by individual farmers for their own needs such programmes are mainly based on non-commercial incentives and undertaken in areas of several fuel wood/agril, timber shortage and also where there is no commercial demand for wood.

Today NCFF is the main thrust of most of the social forestry projects in India. Forest department nurseries distribute the seedlings on free of cost. In certain parts of South India and holdings are already stocked with trees but there is always a willingness to plant few more.

**Wind Breaks:** Windbreak is a planting usually made up of one or more rows of trees or shrubs planted in such a manner as to provide shelter from the wind and to protect soil from erosion as well as crops.

**Shelter belts:** Shelter belts are rows of trees, usually along fence lines. They are planted mainly to protect animals or crops from cold winds, but also to give shade in hot weather. Shelter belts also reduce wind erosion.

### **Places where wind breaks and shelter belts are recommended:**

Dry areas where crop cultivation is difficult as well as wind velocity is more due to which there will be more loss of water through evaporation as well as transpiration. If area occupied by trees is less, more prone for soil erosion. Hence, in those areas wind breaks and shelter belts should be planted. Wind breaks should be planted opposite to the direction of wind as well as in the north-south direction. So that intensity of wind can be reduced.

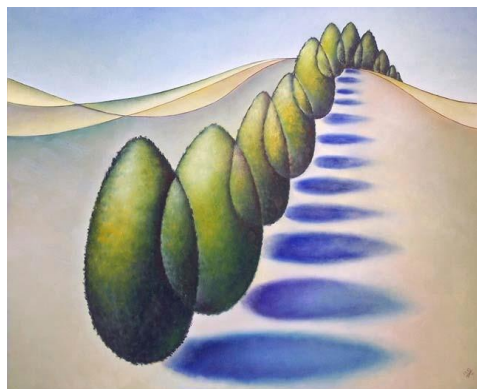
### **Advantages of windbreaks and shelter belts:**

- 1 Shelterbelts increase the moisture content of the soil on the leeward side and delay it's drying up during summer.
- 2 They also increase the underground water supplies by promoting infiltration in the soil.
- 3 Shelter belt has a moderating effect on air and soil temperature by lowering the maximum and raising the minimum.

- 4 Shelter belts increase the relative humidity from 1-50 %.
- 5 Soil erosion due to wind can be reduced due to windbreaks
- 6 Due to reduction in high wind velocity on leeward side up to distance of 15-20 times the height of trees, moisture lost through stomata will be reduced their by favorable conditions exist for crops.
- 7 Shelter belts promote dewfall in that area.
- 8 It will promote rainfall by obstructing the velocity of moisture laden air near the shelter belts.
- 9 Wind breaks will protect the animals from hot and cold waves
- 10 Shelter belts are more useful in fruit orchards by way of reducing the wind velocity so that flower and fruit drop can be drastically reduced.
- 11 Wind breaks gave shelter to many birds. These birds will in turn control harmful insects which damage the main crop.
- 12 Wind breaks will provide fuel wood, wood needs of villagers.
- 13 Soil moisture ranged from 0.3 to 7.8 % more available in areas protected by windbreaks as well as increases the agricultural crop production.



**Fig. 47.1 Shelter belt**



**Fig. 47.2 Wind break**

## Lecture 48:

### AGROFORESTRY

Agroforestry has been defined as sustainable land management system which increases yield of land combines production of crops forest plants and/or livestock together simultaneously or sequentially on the same piece of land and applies management practices that are compatible with the cultural practices of local population (King and Chander,1978).

#### **Classification of agroforestry systems :**

The definition of agroforestry shows that the component crops are arranged either temporarily or sequentially so that two crop arrangements can serve as principal categories as follows:

**I. Crop rotation systems** (Based on temporal arrangement of crops): As the name implies that this system includes all agroforestry systems / types where annual food or cash crops are alternated with tree crops over time. The two types under this are :

**a) Swidden or shifting cultivation :** This is the oldest known agroforestry practice (Mayer,1980). The forest is cut dried and burned to clear the land for planting and to return the nutrients trapped in the forest biomass to the soil to be used by the food crops. Cropping lasts for about 2-3 years after which the land is left over a long period (8-10 years) to forest fall in order to rejuvenate the soil and get it ready for the next cycle of burning and cropping. This practice was on it's sustainability in the recent past due to low pressure of population. But as the pressure mounted displaced low land farmers shortened or eliminated the forest fallows.

**b) Taungya system:** Started in Burma in the mid 1980's. This system is the first "modern" agroforestry practice. It was designed as a low cost governmental approach for afforestation of open lands. Farmers are temporarily allotted government lands and contracted to plant desired tree species while the trees are young and before the canopy closure (1-3 years) the farmers are allowed to plant food crops and the yield of which becomes their entirely and is regarded as their compensation for planting trees. When food cropping is no longer possible due to shading etc. The farmers are transferred to another open area where they repeat the process. Mean while, the abandoned area is by then a well established forest and will not be cultivated for annual food crop again until the planted area reach the maturity and are harvested.

#### **II. Intercropping** (Based on physical structure/spatial arrangements of crops):

Under this system, the annual perennial crop components are simultaneously present on site but are spaced in such a manner that they become mutually supportive rather than competing where they jointly yield higher outputs per hectare per year. Four sub-systems under this.

## **1. Border tree planting**

It is often found where farmers use lines of trees specially as boundary maker live fences, wind breaks or fire breaks. In addition to protection and stabilization of site they also produce green manure as organic fertilizer, fodder for farm animals and produce fuel wood. Border tree planting is gaining importance due to (a) rising prices of energy including biomass energy (b) need for permanent fence posts around farm or house gardens.

## **2. Alternate strips or Alternate row planting** (Strip consists of 2 or more rows):

It is also referred as “Alley” or Avenue corridor zonal or Hedge row cropping. When positioned across the slopes and along the contours they are found most effective for erosion control and slope stabilization. Most modern agroforestry system being advance through government programmes are of these two sub- systems and the multiple objectives are food, fodder production and site stabilization.

**3. Random mix:** It displays no specific or orderly placement of the component crops while the arrangement appears in utter confusion, the plants actually occupy their own special ecological niche (influence) and are able to coexist very well. For badly eroded and depleted soils random mix may not be as effective as alley cropping (alternate strips).

**4. Multi-storied cropping :** The multi – storied / tiered crowns of the integrated plants ranging from root crops to grain crops, small fruit trees (Cocoa, etc.) to dominant coconuts are close replicas of multi-storied tropical rain forest and represent highly efficient for utilization of soil surface vertical space, nutrient and moisture and solar energy. This system is mostly practiced in Kerala. For this reason it is sustained over many decades in much of Asia.

## **III. Based on component combinations:**

Agroforestry systems are classified as below :

**1. Agri-silviculture :** It is system of integration of forestry trees with arable crops mostly on the arable lands to get both food and wood. Mostly nitrogen fixing trees (NFT's) are intercropped with arable crops which not only provides rich organic matter and atmospheric nitrogen but also improves the soil structure. NFT's offer immense possibility of supplementing the nitrogen requirements of crops through leaf fall loppings or green leaf manuring. In semi arid tropics it is not possible to have a residual build up of organic matter and therefore, it important that organic mater supplies are to be renewed every year. Moreover, in dry lands the farmers with their frugal resources can not afford to apply costly nitrogen fertilizer because of the risk involved that they may go as waste leaving them in debts owing to unreliable and undependable rains. The advantage of nitrogen fertilizer to the crops can be taken by growing NFT's in association with the field crops.

**2. Alley cropping :** It is a type of agri-silviculture system where in food crops are grown in alley formed by hedge rows of trees or shrubs. The space between two hedge rows of trees is called “Alley”. The essential feature of this system is that the hedge rows are cut back and kept pruned during cropping to prevent shading to reduce the competition with food crops.

**Advantages :**

- 1) It provides higher total biomass per unit area than arable crops alone
- 2) It utilizes the off season precipitation which otherwise would go waste
- 3) It provides green fodder during lean period
- 4) It provides additional employment during off season
- 5) When planted along the contours on also land it serves as a vegetative barrier reduces the run off and conserves moisture
- 6) Provides green manure to component food crops
- 7) Pruning material when applied as surface mulch suppress weeds and prevent hardening of soil
- 8) Reduces soil temperature and provides favorable conditions for soil macro and micro-organisms
- 9) Provides biologically fixed nitrogen to associated food crops.

This system is mostly suitable for arable lands especially for marginal and sub-marginal lands of arid regions.

**3. Agri-horticulture:** It is a system of integration of fruit trees with food crops. It is also termed as food fruit system in which short duration arable crops are grown in inter spaces of fruit tree. Most of the fruit plants develop full canopy after several years and some of them required regular pruning thus permitting an intercrop. Inter cropping provides weed free area and yield obtained will be a bonus to the farmers. The concept is to encourage small farmers to take up tree planting and ensure good returns. Scope of fruit farming is hardy species like Ber, Guava, Pomegranate, Custard apple and Phalsa etc. are chosen. Inter cropping of fruit trees with short duration legumes and vegetable proved beneficial. It is not desirable to grown cereals in orchards.

**4. Silvipastoral system :** It is two-tier model of fodder based agroforestry system and is suitable for class IV and above lands. This system essentially integrates top-feed tree species with ground storey forage crops to support livestock and to prevent land degradation. The water holding capacity and nitrogen content of these soils is very low too. Besides the SAT regions are facing acute shortage of fodder because of which most of the dry land framers can not afford to own a pair of bullocks.

**5. Hortipastoral system :** It is a two tier model for fruit-cum-fodder based agroforestry system. Horti-pastoral system is defined as one of the agro-forestry system which integrates fruit trees with grasses / pasture species. This system works best in medium soils. Slow growing and later bearing fruit tree species like Tamarind, Jamun, Anola, Bael, Cashew and Wood apple are highly suitable. In a low input management system with continuous grazing custard apple will be most appropriate.

**6. TIMFIB (Timber-cum-fiber system):**

This is one of the agroforestry system mostly suitable for non-arable lands i.e. degraded soils. It involves integration of some timber yielding tree species with fiber yielding plants like sisal (*Agave spp.*). It was proved more remunerative than arable cropping. In Bijapur dry farming Research Station, Karnataka intercropping of subabul with sisal is found to be beneficial than arable farming.

**7. Agri-silvipastoral system :** It is a system integration of trees with grasses having cattle component in it where the cattle are allowed to graze. Sometimes arable crops are grown as under storey crops with the trees and grasses like Panicum and Elephant grass are being grown along the rows of trees which serves as vegetative barrier to control the erosion. In European countries under the coniferous trees like Larches and even under *Alnus spp.*, Panicum grass is being allowed to grow where the cattle will graze. Thus various agroforestry systems are developed both for arable and non arable lands as follows based on components.

**Disadvantages of agroforestry systems :** Through there are several advantages of agro-forestry systems there are few disadvantages which include:

1. Prolific seeding habit of subabul resulting in weedy growth depresses the yield of arable crops.
2. Root and shade effect of trees on cultivated crops even up to 20 m in case of Babul (*Acacia nilotica*).
3. Trees harbour for some kinds of pests and diseases as well as birds.
4. Agroforestry systems are labour intensive and reduces the scope of farm mechanization.
5. Allelopathic effect of trees on crops Ex. Eucalyptus spp.

**Advantages of agroforestry systems :**

**I. Multiple needs :**

It yields extended range of products viz., food, fodder, fuel, fibre, fruits and fence.

Presence of trees gives extended range of management options and trees can be harvested as per farmers choice and market demands.

## **II. Soil and water conservation:**

- Trees stabilize the soil conservation structures and make productive use of land.
- Act as vegetative barrier and check run off.
- Reduce rain drop impact and control soil loss.
- Trees utilize off season precipitation.
- Serves as a shelter belt and reduce wind velocity.

## **III. Nutrient recycling:**

- ✓ Trees recycle the nutrients both from atmosphere and lower soil layer.
- ✓ *In situ* green leaf manuring through leaf drop.
- ✓ Green leaf mulching by applying lopped foliage.
- ✓ Trees check the increase in soil temperature specially in summer months there by protect the soil microflora and fauna.

## **IV. Employment generation**

- ✓ Off season family labour utilization
- ✓ Assured income for the labourers round the year
- ✓ Prevention of labour migration

## **V. Drought proofing:**

- ✓ It imparts stability besides resulting in risk reduction even one component fails the other would give a harvest.
- ✓ Results in improved and stable income.

## **VI Bio-aesthetic:**

- ✓ It can be devised for landscaping and beautification of country side which provide recreation and increase aesthetic value.
- ✓ Conserving the ecosystem.

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