Effect of Meteorological Parameters on Crop Growth and Yield

Lecture-4

Contents

- Factors affecting photo synthesis
- Temperature and its Factors
- Effects of Photo-periodism on Crop Growth
- Soil temperature and its effect on crop germination
- Effect of Wind on crop growth and yield
- Shelter belts effects on plant growth
- Forms of Condensation: Dew, fog and humidity
- Drought and its effects on crop growth and yield

Factors affecting photosynthesis

❖Light Intensity

- Low light intensity lowers the rate of photosynthesis. As the intensity is increased the rate also increases.
- Very high intensity may, in fact, slow down the rate as it bleaches the chlorophyll.
- Normal sunlight (usually with an intensity of about 100,000 lux) is quite sufficient for a normal rate of photosynthesis.
  - ✓Lux is the unit for measuring light intensity

Carbon Dioxide Concentration

- In the atmosphere, the concentration of CO_2 ranges from 0.03 to 0.04 %.
  - ✓However, it is found that 0.1% of CO_2 in the atmosphere increases the rate of photosynthesis.
  - ✓This is achieved in the greenhouses which are enclosed chambers where plants are grown under controlled conditions
- Crops like tomatoes, lettuce are successfully grown in the greenhouses.
  - ✓These greenhouse crops are found to be bigger and better-yielding than their counterparts growing in natural conditions.

Temperature

- An optimum temperature from 25^{o}C to 35^{o}C is required for a good crop growth rate.
- At temperatures around 0^{o}C the enzymes stop working and at very high temperatures the enzymes are denatured.
- Since both the stages of photosynthesis require enzyme activity, temperature affects the rate of photosynthesis.

Chlorophyll Concentration

- The concentration of chlorophyll affects the rate of reaction as they absorb the light energy.
- Lack of chlorophyll in plant leaves results in chlorosis or yellowing of leaves.
  - ✓It can occur due to disease, mineral deficiency or the natural process of aging (senescence).
  - ✓Lack of iron, magnesium, nitrogen and light affect the formation of chlorophyll and thereby causes chlorosis.

Water

- Slight deficiency of water results in significant reduction in the crop yield.
- The lack of water not only limits the amount of water but also the quantity of carbon dioxide.
  - ✓This is because in response to drying the leaves close their stomata in order to conserve water being lost as water vapour through them.

Pollution

- Pollution of the atmosphere with industrial gases has been found to cause much as 15% loss.
- Soot can block stomata and reduce the transparency of the leaves.
  - ✓Some of the other pollutants are ozone and sulphur dioxide.
- Pollution of water affects the hydrophytes.
  - ✓The capacity of water to dissolve gases like carbon dioxide and oxygen is greatly affected.

Application

- Study of photosynthesis and the factors affecting it helps us to understand the most important biochemical life sustaining processes.
- All plants and animals are dependent on the sun for energy.
- This energy is made available to them by the process of photosynthesis.
  - ✓Man, like other animals, is dependent on the plants for his food.
- Scientists are constantly working towards developing new varieties of crops which give better yield of crops.
- All this has been possible so far with the understanding of the photosynthesis.

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- The rate of photosynthesis is not constant throughout the day. Its rate is affected by the intensity of light.
- The actual requirement of the light intensity for maximum photosynthesis in a plant depends on the type of plant and also on its habitat.
- The average sunlight intensity is sufficient for photosynthesis except on rainy or cloudy days.
- The rate of photosynthesis increases with increasing intensity of light and decreases with decreasing intensity of light.

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- During early morning or late evenings when the rate of photosynthesis becomes equal to the rate of respiration, there will not be any net exchange of gases (CO_2 and O_2) between the plant and the surrounding environment.
- The light intensity, at which the photosynthetic intake of carbon dioxide is equal to the respiratory output of carbon dioxide, is called the **compensation point** (Net co2 assimilation is zero).

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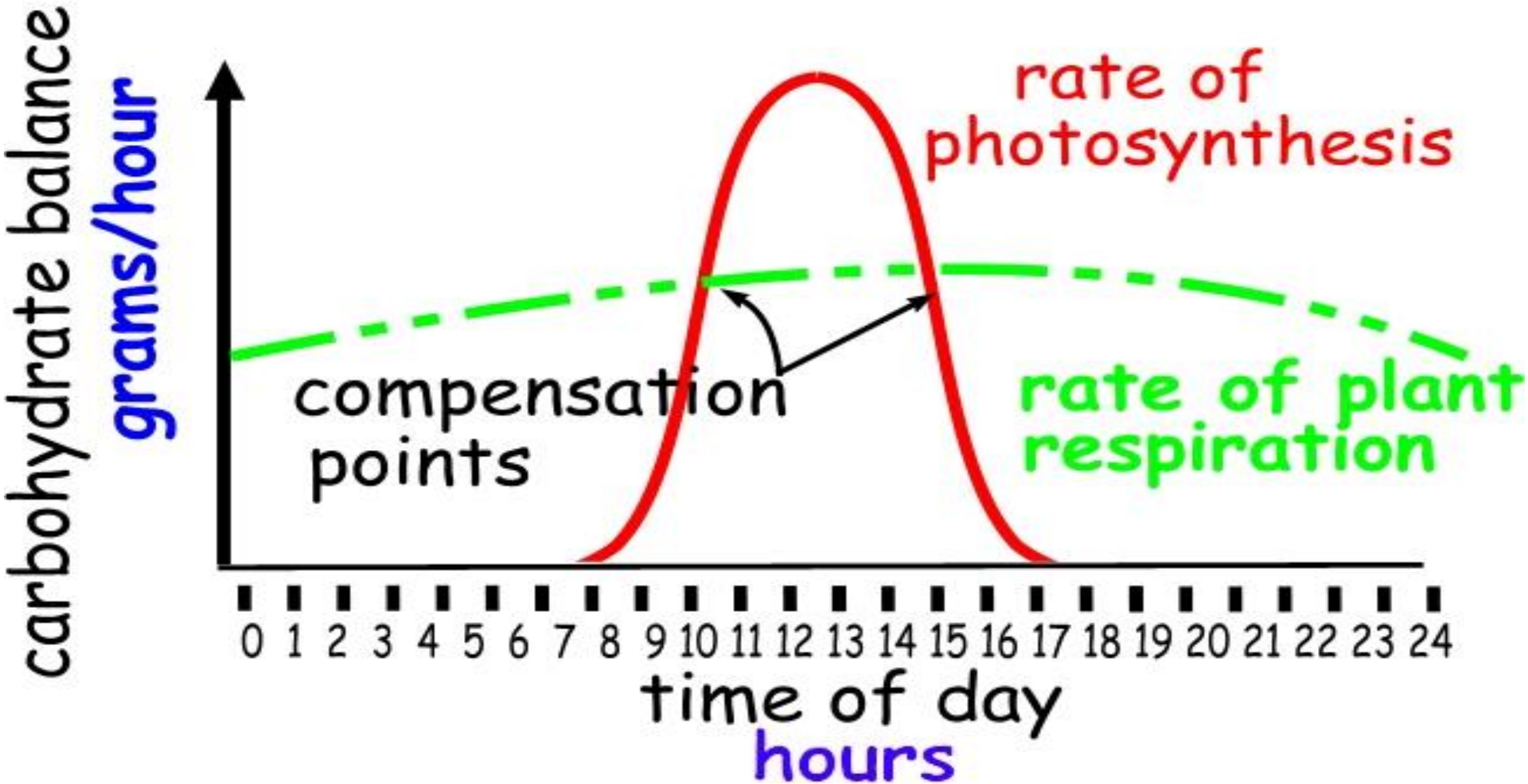
carbohydrate balance
grams/hour
rate of photosynthesis
compensation points
rate of plant respiration
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
time of day
hours

Temperature and its Effect

- An increase in temperature will speed up development of crop or plant.
- In the case of an annual crop, the duration between sowing and harvesting will shorten depending on available temperature.
- The shortening of harvesting cycle could have an adverse effect on productivity because senescence would occur faster.
- Most plants function in a relatively narrow range of temperatures.
  - ✓The extremes of this range may be considered killing frosts at about 0℃ and death by heat and drying at about 45℃.

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- Optimum Air Temperature - Each kind of crop grows and develops most rapidly at a favorable range of temperatures is called **optimum temperature range.**
- **Soil Temperature -** Soil temperature has direct dramatic effects on
  - ✓Microbial growth and development, organic matter decay, seed germination, root development, and water and nutrient absorption by roots.
  - ✓It is defined as the temperature of the root zone environment of the plant.

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- **Chilling Injury -** Most crops are injured (damaged) at temperatures or slightly below freezing.
  - ✓Plant death of damage at temperatures above freezing but below10^{o} C can occur for tropical plants.
- **Heat (High Temperature) Stress -** When temperatures rise too high, heat destruction of the protoplast results in desiccation or plant cell death.
  - ✓This occurs in the range of (45-55^{o} C).
- **Vernalization -** is the exposure of plants to low temperatures for extended periods of time,
  - ✓Which then induces or accelerates flowering (or bolting). Bolting is unwanted flowering.

Effects of Photo-periodism on Crop Growth

- The length of daily exposure to light is known as photoperiod while the response of crop development to a photoperiod is called photo-periodism.
- Photoperiod has an effect on the formation of flowers, fruits and seeds.
  - ✓It also influences vegetative growth, the formation of buds, tuber, the character and extent of branching, leaf shape, pigment formation, root development dormancy and death.

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- Garner and Allard divided plants into three groups on the basis of their response to the photoperiod:
  - ✓**Long-day plants, short-day plants and day neutral plants**.
- Long -day crops flower only under day-light less than 14 hours. Examples are wheat, mustard, oats, burkey, rye and clover.
- In short day- crops flowering are induced by short photoperiods of less than 10 hours. Examples are cotton, millet, corn, beans, cucumber and sweet potatoes.
- The day neutral crops can form the flower buds under any period of illumination. Examples are tomato and carrot.

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- Later Allard (1938) added the fourth group which is designated as intermediate.
- The intermediate crops flower at a day length of 12-14 hours but are inhibited in reproduction by day lengths either above or below this duration.
- Photoperiodism is an important factor in the natural distribution of plants.
  - ✓In general plants that have originated in low latitude require short- day for flowering while those from high latitudes are long- day plants.

Growing Degree-Day (GDD)

- Three temperatures of vital plant activity have been recognized, which are often termed cardinal points.

- ✓ Any plant growth has three cardinal temperatures.

1. A minimum temperature below which no growth occurs:
   - ❖ For typical cool-season crops, it ranges between 0 ℃ and 5 ℃, and for hot-season crops between 15 ℃ and 18 ℃.

Cont. . .

2. An optimum temperature at which maximum plant growth occurs:
   - ❖For cool-season crops, it ranges between 25℃ and 31℃, and for hot-season crops between 31℃ and 37℃.
3. A maximum temperature above which the plant growth stops:
   - ❖For cool-season crops, it ranges between 31℃ and 37℃, and for hot-season crops between 44℃ and 50℃.

- ➢Over the adapted range, vegetative growth of plants increases with temperature.

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- So crop cycle can be longer at low temperatures. Often convenient to measure life cycle of a crop is in terms of heat units.
- Heat Unit = days or hours of accumulated temperature above some threshold (but below max. limits).
  - ✓It measured in degree-days or degree hours.
  - ✓Lower temperature is called the threshold or base temperature. Heat Unit (Degree Day) can be calculated as

$$DD = \sum_{i=1}^{d} (T_{mean} - T_{base})$$

Sum over number of days

Degrees above base temp

T_{base} = min. temp. for plant growth

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$

Cont. . .

	Max Temp	Min Temp	Mean	DD	
Sunday	22	18	20	10	
Monday	28	18	23	13	
Tuesday	34	30	32 --30	20	
Wednesday	25	17	21	11	
Thursday	20	8	14	4	
Friday	10	8	9	0	
Saturday	12	6	9	0	
				58	DD=58
		Tbase	10		

If mean > upper limit, round to upper limit

If mean < base temp., 0 DD

Upper limit and base temperature of the crop is 30 and 10^{o}c respectively

Accumulation degree day

Applications and Limitations of GDD Methods

- The **Applications** of degree-days for calculating the temperature-dependent development of insects, birds, and plants is widely accepted as a basis for building phenology and population dynamics models.
- The simplicity of the degree-day method has made it widely popular in guiding agricultural operations and planning land use.
- Most applications of the growing degree day concept are for the forecast of crop harvest dates, yield and quality.
  - ✓It helps in forecasting labor needs for factories, and in reducing harvesting and factory costs.

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- A potential area of application lies in estimating the likelihood of the successful growth of a crop in an area in which it has not been grown before.
- The growing degree-day concept can also be applied to the selection of one variety from several varieties of plants to be grown in a new area.
- Another application of the concept can be to change or modify the microclimate in such a way as to produce nearly optimum conditions at each point in the developmental cycle of an organism.

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- The ***Limitations*** *of* the degree day concept is simple and useful, it lacks theoretical Soundness and has a number of weaknesses.
- Ranges of factors that influence the predictive capability of degree-day accumulations have been identified. Among these are;
  - ✓The conditions that affect the physiological state of an organism (such as nutrition and behavior-based thermoregulation).
  - ✓Error associated with the assumptions and approximation processes used in estimating.

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➢ **Excersice1.** Compute the growing degree-day **(GDD)** by using Standard degree-day method for Place A, based on information provided in the table below where base temperature **(Tb)** for Place A is 6℃.

Place	Month and Mean monthly temperature in ^{o}C											
A	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1.4	1.8	3.6	5.8	8.9	11.7	23.3	13.0	10.8	7.6	4.6	6.8

Effect of Wind on crop growth and yield

- Wind is an important factor of the environment of insects, and it influences insect pulsations in a number of ways.
  - ✓It is a vital component of broad weather patterns, giving rise to fronts an convergence zones.
- Low-pressure systems and anticyclones in temperate regions determine migration trajectory of insects,
  - ✓While trade winds and monsoons determine the trajectories in tropical and subtropical areas.

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- Wind causes insect displacement and therefore affects population changes by influencing the numbers moving into or out of an area.
  - ✓It can carry them considerable distances away to new habitats and regions.
  - ✓Many insects and pathogens appear to undertake enormous migrations covering hundreds if not thousands of kilometers on occasions.

Shelter belt effects on plant growth

- Plant growth and development are primarily governed by the environmental conditions of the soil & climate.
  - ✓The success or failure of farming is intimately related to the prevailing weather conditions.
- Weather assumes significance in nearly every phase of agricultural activity from the preparatory tillage to harvesting and storage.
- Shelter belt is a mechanism of covering grass or the leaves of the plant on the surface of soil to minimize soil evaporation.
  - ✓It is the most important adaptation method of soil moisture conservation/ water-management practices.

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- The soil moisture in the root zone of plant will be evaporated rapidly when the day temperature of the surface increases.
  - ✓If the root zone of crop is covered with grasses or the leaves of plants it conserve the soil moisture from rapid evaporation and activate the growth of plant.
- Therefore, shelter belt is the important way of improving soil water conservation and can modify the yield of crop.

Forms of Condensation: Dew, fog and Frost

- Condensation can be defined as the formation of water droplets when air has been cooled beyond its dew point.
- Each form of cooling may produce condensation of different degrees and with different results.
- For condensation to take place, it is necessary for some kind of nuclei to be present on which the droplets can form.
- These nuclei include particles of dust and smoke, salt from the ocean, pollen, and negative ions produced by the passage of radiation through the atmosphere.

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- The condensed droplets when formed are so minute that they float in the air as fog or clouds.
- Larger drops form on leaves and grass as dew, or hoar-frost if temperature is below freezing point.
- The main forms of condensation include dew, frost, fogs and clouds.
- Frost is a climatic hazard that causes serious damage to standing crops in temperate and subtropical climates.

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- Frost can be a white frost (also known as hoarfrost) or a black frost.
- White frost occurs when atmospheric moisture freezes in small crystals on solid surfaces.
- Black frost occurs when few or no ice crystals are formed because air in the lower atmosphere is too dry, but the damaging effect of the low temperature on vegetation is the same as that of white frost.
- Frost damages to plants occur because it results in freezing of the Plant tissues.

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- Freezing of plant tissues is a physical process triggered by ice nucleating bacteria, the intensity and duration of the night temperature to which the plants are exposed, and the plant growth stage.
- Green plants contain mostly water, and on freezing, the water expands and ruptures the cell walls of the plant tissues.
  - ✓Because of the presence of chemicals in the sap, plant tissues freeze at temperatures lower than 0℃, the freezing temperature of water.

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- Frost protection methods may be divided into **passive** and **active** forms.
- **Passive protection** involves methods such as site selection and variety selection and several cultural practices such as brushing and soil surface preparation.
  - ✓These methods do not require expenditure of outside energy sources.
- **Active protection** systems replace radiant energy loss by using methods such as irrigation, heaters, and wind machines.
  - ✓Active methods require outside energy to operate.

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- The proper choice of a protection method depends on many factors, such as
  - ✓Site, crop, advantages and disadvantages of the protection methods, relative costs, and operating principles of the method.
- The following methods are the main frost protecting methods.
  - ❖**Site Selection,** Before planning a crop or an orchard, the best method of frost protection is careful selection of the site.
  - ✓The site should be selected taking into account the climatic conditions prevailing in that location, its slope, and the soil characteristics.

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- ❖**Frost-Resistant Cultivars,** Planting frost-resistant cultivars and crop varieties is one approach to avoid frost damage to fruit trees and field crops.
- ❖**Optimizing Sowing Dates,** The best and most cost-effective strategy to save field crops from frost is the choice of the optimum dates for planting crop.
- ✓As crops enter the flowering and grain forming stage, their tolerance to frost is drastically reduced.
- ✓If the sowing dates of crops are adjusted in such a way that these stages do not fall in the period of heavy frost, and then its damaging action is avoided.

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- **Storing Heat in the Soil,** Frost frequency and intensity is greater in orchards, in which the soil is cultivated, dry, and covered with weeds or mulch as compared to orchards in which the soil is moist, compact, and weed (unwanted plant) free.
- ✓This is because soil that is bare or weed free, compact, and moist stores more heat during the daytime than soil that is covered with shade and is dry.
- ✓ At night, this heat is released to the lower layers of the air surrounding the crop plants and fruit trees, minimizing the damage from frost.

Drought and its effects on crop growth and yield

- Drought is a period of abnormal dry weather that causes serious hydrological imbalance of the area.
- Generally, it originates from deficiency of precipitation over extended period of time, resulting in water shortage for some activity, group, or environmental sector.
- It is classified in to four general types:
  - ✓Meteorological drought
  - ✓Hydrological drought
  - ✓Agricultural drought
  - ✓Socio-economic drought

Cont. . .

- **Meteorological drought**: It simply implies rainfall deficiency where the precipitation is reduced by more than 25% from normal in any given area.
- **Hydrological drought:** These are associated with the deficiency of water on surface or subsurface due to shortfall in precipitation.

- Although all droughts have their origination from deficiency in precipitation.
- Hydrological drought is mainly concerned about how this deficiency affects components of the hydrological system such as
  - ✓Soil moisture, stream flow, ground water and reservoir levels etc.

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- **Agricultural drought**: This links various characteristics of meteorological or hydrological drought to agricultural impacts.
  - ✓Focusing on precipitation shortages, differences between actual potential evapotranspiration, soil, soil water deficits, and reduced ground water or reservoir levels.
- Calculation of Agricultural drought uses **s**oil water balance and computation of WRSI.
  - ✓If WRSI <50% there is total crop failure or using moisture index

$$\frac{Raifall}{ETo} < 0.5, \text{ Moderately dry } , \frac{Rainfall}{ETo} < 0.25 \text{ very dry}$$

Cont. . .

- **Socio-economic drought**: It is associated with the demand and supply aspect of economic goods together with elements of meteorological, hydrological and agricultural drought.

- This type of drought mainly occurs when the demand for an economic good exceeds its supply due to weather related shortfall in water supply.

Drought Management

- The strategy for making drought prone areas less vulnerable to drought associated problems should include the following measures:
  - ✓Creation of storages through water resources development, wherever feasible
  - ✓Inter basin transfer of surface waters from surplus water areas to drought prone areas
  - ✓Development of ground water potential

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- ✓Development of appropriate water harvesting practices
- ✓Soil moisture conservation measures
- ✓Minimization of evaporation losses from water bodies
- ✓Encouraging pasture, forestry and other modes of development which are relatively less water demanding

Flood and drought monitoring and Effect on water balance

- Flood and drought situations can be monitored from meteorological observations.
- Drought phenomenon is monitored considering long period meteorological record but flood event should be monitored for short observation period of meteorological record.
- Heavy rainfall for short duration in the upstream catchment may be responsible for flash flood in the downstream catchment for which hourly rainfall record with runoff generation may be helpful for efficient flood management programmer.