## Meaning and scope of Agricultural Meteorology

Meteorology comes from Greek word "Meteoro" means 'above the earth's surface' (atmosphere) "logy" means 'indicating science'. Branch of science dealing with the properties of atmosphere is known as meteorology. Lower atmosphere extending up to 20km from earth's surface is where frequent physical process takes place. Meteorology is a combination of both physics and geography. This science utilizes the principles of Physics to study the behaviour of air. It is concerned with the analysis of individual weather elements for a shorter period over a smaller area. In other words, the physical state of the atmosphere at a given place and time is referred to as "weather". The study of weather is called 'meteorology'.

Agrometeorology, abbreviated form of agricultural meteorology and also referred to as agroclimatology has been defined in several ways. The name itself implies that it is the study of those aspects of meteorology which have direct relevance to agriculture. Agrometeorology puts the science of meteorology to the service of agriculture, in its various forms and facets, to help the sensible use of land, accelerate production of food and to avoid the irreversible abuse of land resources. It is a science investigating the meteorologic, climatologic and hydrologic conditions which are significant for agriculture due to their interaction with the objects and processes of agricultural production. The task of an agrometeorologist is to apply every relevant meteorological skill to help the farmer to make the most efficient use of his physical environment for improving agricultural production both in quality and quantity.

For optimum crop growth specific climatic conditions are required. Agrometeorology thus becomes relevant to crop production because it is concerned with the interactions between meteorological and hydrological factors on the one hand and agriculture, in the widest sense including horticulture, animal husbandry and forestry, on the other. Its objective is to discover and define such effect and thus to apply knowledge of the atmosphere to practical agricultural use.

#### Fields of interest

The field of interest of agrometeorology extends from the soil surface layer to the depth upto which roots penetrate. In the atmosphere it is interested in air layer near the ground in which crops and higher organisms grow and animals live, to the highest levels in the atmosphere through which transport of seeds, spores, pollen and insects may take place.

## Inter-disciplinary aspects

Agrometeorology is an inter-disciplinary science in which the main scientific disciplines involved are atmospheric sciences and soil sciences which are concerned with the physical and chemical environment, and the plant sciences and animal sciences which deal with the contents of the biosphere.

## Stage-wise approach in agrometeorological study

Though interdisciplinary in nature, agrometeorology is now a well defined science. It has a set approach in theory and methodology. Its subject matter links together the physical environment and biological responses under natural conditions. Using a four stage approach, an agrometeorologist first formulates an accurate description of the physical environment and biological responses. Secondly, he interprets biological responses in terms of physical environment. Thirdly, it makes crop and weather forecasts. Its final goal is the control of physical environment of crop fields.

## Practical utility

1. The science of agrometeorology has great practical utility in protection against, or avoidance of adverse climatic risks involving

- a) Conditions favorable for incidence of pest and disease
- b) The pollution of air and soil
- c) All farm operations
- d) Incidence and effect of drought
- e) Soil erosion from wind and water
- f) Frequency and extent of frost
- g) Dangers of forest or bush fire
- h) Losses during storage and transport

2. When specifically, tailored weather support is readily available to the needs of agriculture, it greatly contributes towards making short term adjustments in daily agricultural operations which minimise losses resulting from adverse weather conditions like

- a) Flash flood
- b) Untimely rains

c) Hails and storms

d) Heat and cold wave

3. Based on forecast of these elements' decisions can be taken in advance in agricultural operations and planning so as to make the best use of favourable weather conditions and make adjustments for adverse weather. Weather support provide guidelines for long range or seasonal planning in agriculture related to

- a) Selection of crops and varieties
- b) Time of sowing
- c) Use of farm input
- d) Area coverage under particular crops

4. Based on the meteorological knowledge available some improvement can be made on the following agrotechniques

- a) Irrigation
- b) Shelter from wind or cold
- c) Shade from excessive sun
- d) Anti-frost measure like choice of site
- e) Anti-erosion measure like mulching
- f) Plant cover using glass or plastic materials
- g) Artificial climate of growth chamber
- h) Animal housing
- i) Climate control in storage and transport
- 5. Agrometeorological methods can be used in efficient land use planning like
  - a) Determination of suitable crops for a region
  - b) Risk analysis of climatic hazard and profit calculation in farming
  - c) Generating regional crop production forecasts
  - d) Adoption of suitable farming methods
  - e) Choice of appropriate farm machinery

## SCOPE OF AGRICULTURAL METEOROLOGY

- 1. To study climatic resources of a given area for effective crop planning.
- 2. To evolve weather based effective farm operations.
- 3. To study crop weather relationships in all important crops and forecast crop yields based on agro climatic and spectral indices using remote sensing.
- 4. To study the relationship between weather factors and incidence of pests and diseases of various crops.
- 5. To delineate climatic/agro ecological/agro climatic zones for defining agro climatic analogues so as to make effective and fast transfer of technology for improving crop yields.
- 6. To prepare crop weather diagrams and crop weather calendars.
- 7. To develop crop growth simulation models for assessing/obtaining potential yields in different agro climatic zones.
- 8. To monitor agricultural droughts on crop-wise for effective drought management.
- 9. To develop weather based agro advisories to sustain crop production utilizing various types of weather forecast and seasonal climate forecast.
- 10. To investigate microclimatic aspects of crop canopy in order to modify them for increased crop growth
- 11. To study the influence of weather on soil environment on which the crop is grown
- 12. To investigate the influence of weather in protected environment (eg. Glass houses) for improving their design aiming at increasing crop production.

#### THE SUN: THE SOURCE OF ENERGY

The sun is the nearest star to the earth, and its radiant energy is practically the only energy source to the earth. Very small and insignificant quantities of energy are available from other sources such as the interior of the earth, the moon, and other stars. The mean sunearth distance, also known as one astronomical unit (1 AU), is  $1.496 \times 10^8$  km or, more accurately, 149, 597, 890 ± 500 km. The earth revolves round the sun in an elliptical orbit. The minimum sun-earth distance is about 0.983 AU and the maximum approximately 1.017 AU. The earth is at its closest point to the sun (perihelion) on approximately January 3 and at its farthest point (aphelion) on approximately July 4. The sun is a completely gaseous body. The chemical composition of the outer layers is (by mass) 71 percent hydrogen, 26.5 percent helium, and 2.5 percent heavier metals. Its physical structure is complex, although several regions, including the core, photosphere, reversing layer, chromosphere, and corona, are well recognized. The core temperature is in the range of  $15 \times 10^6$  to  $40 \times 10^6$  C. Outside the core is the interior which contains practically all of the sun's mass. The core and interior are thought to be a huge nuclear reactor in which fusion reactions take place. These reactions supply the energy radiated by the sun. The most important reaction is the process by which hydrogen is transformed to helium. The energy is first transferred to the surface of the sun and then radiated into space. The radiation from the core and interior of the sun is thought to be in the form of X rays and gamma rays.



The surface of the sun, called the *photosphere*, is the source of most of the visible radiation arriving at the earth's surface. The photosphere is the source of radiation flux to space because it has the capability to emit and absorb a continuous spectrum of radiation.

#### Solar Constant

The sun is the source of more than 99 percent of the thermal energy required for the physical processes taking place in the earth-atmosphere system. The solar constant is the flux of solar radiation at the outer boundary of the earth's atmosphere, received on a surface held perpendicular to the sun's direction at the mean distance between the sun and the earth. The value of the solar constant is 1,370 W m<sup>-2</sup> (about 2 cal·cm<sup>-2</sup>·min<sup>-1</sup>), giving an average flux of solar energy per unit area of the earth's surface equal to 350 W m<sup>-2</sup>. The solar constant is only

approximately constant. Depending on the distance of the earth from the sun, its value ranges from approximately 1360 to 1380 W m<sup>-2</sup>. Of this energy, approximately 31 percent is scattered back to space, 43 percent is absorbed by the earth's surface, and the atmosphere absorbs 26 percent. The ratio of outward to inward flux of solar radiation from the entire earth's surface (termed *albedo*) is about 0.31, leaving an average around 225 W m<sup>-2</sup> (range 220 to 235 W m<sup>-2</sup>) that is available for heating, directly and indirectly, the earth-atmosphere system. The irradiation amount at the earth's surface is not uniform, and the annual value at the equator is 2.4 times that near the poles. The solar energy incident upon a surface depends on the geographic location, orientation of the surface, time of the day, time of the year, and atmospheric conditions.

**Radiation flux** is a measure of the amount of **radiation** received by an object from a given source per unit time. This can be any type of **radiation**, including electromagnetic, sound, and particles from a radioactive source. Unit: Watt (Jules.Sec<sup>-1</sup>).

**Radiation Flux Density (Irradiance)**: radiant flux received per unit area of a surface from all direction. Unit: Watt.m<sup>-2</sup>

Units	Cal cm <sup>-2</sup> min <sup>-1</sup>	J cm <sup>-2</sup> min <sup>-1</sup>	W cm⁻²
Cal cm <sup>-2</sup> min <sup>-1</sup>	1	4.1868	0.069
J cm <sup>-2</sup> min <sup>-1</sup>	0.238	1	0.00165
W cm <sup>-2</sup>	14.3	60.6	1

#### Radiation units and their interrelationship

#### Insolation

Insolation is the solar radiation that reaches the earth's surface. It is measured by the amount of solar energy received per square centimeter per minute. Insolation affects temperature. The more the insolation, the higher the temperature. In any given day, the strongest insolation is received at noon.

### Factors affect insolation

The actual amount of insolation received at a place on the earth varies according to the conditions of the atmosphere as well as the seasons. The following astronomical and geographical factors govern the amount of insolation received at any point on the earth's surface:

### Angle of incidence

The altitude of the sun, i.e. the angle between its rays and a tangent to the earth's surface at the point of observation, controls the amount of insolation received at the earth's surface. As the elevation angle decreases, the area over which the radiation is distributed increases. The vertical rays of the sun heat the minimum possible area, but on the contrary, the oblique rays are spread over a relatively larger area, so that the amount of area over

which the available solar energy has to be distributed in increased and the energy per unit area on the earth's surface is decreased.

#### Duration of sunshine

The duration of sunlight hours determines the length of the day, which also affects the amount of solar radiation received at the surface. Undoubtedly, the longer period of sunshine ensures larger supply of radiation which a particular area of the earth will receive. Obviously, the latitudes exercise the most dominant control over the duration of sunshine and thereby the length of the day.

#### Solar constant

As the energy emitted by the sun varies, the amount of insolation received at the surface also changes. But the percentage of change in the solar constant is rather negligible. The variations in the solar constant are caused by periodic disturbances and explosions in the solar surface.

#### Distance between the earth and the sun

Since the earth revolves around the sun in an elliptical orbit, the distance varies during the course of a year. The mean distance between the earth and sun is about 149,000,000 kilometers. Although the amount of incoming solar radiation received at the outer boundary of the atmosphere is a little greater (7 percent) in January than in July, there are other major factors, such as the angle of incidence and the duration of sunshine that more than offset its effect on seasonal temperature variations.

#### Transparency of the atmosphere

Transparency of the atmosphere is an important control on the amount of insolation which reaches the earth's surface. Reflection from dust, salt, and smoke particles in the air is an important mechanism for returning shortwave solar radiation to space.

#### **Transfer of heat**

All matter, at a temperature above the absolute zero, imparts energy to the surrounding space. Three processes viz. conduction, convection and radiation are involved in heat flow or heat transfer.

#### Conduction

Heat transfer through matter without the actual movement of the substances or matter. Heat flows from the warmer to cooler part of the body so that the temperatures between them are equalize, eg., The energy transmission through an iron rod which is made warmer at one end.

#### Convection

It is the processes of transmission of heat through actual movement of molecules of the medium. This is predominant form of energy transmission on the earth as all the weather related processes based on convection, e.g., boiling of water in a beaker.

### Radiation

Transfer of energy from one body to another without the aid of the material medium (solid, liquid or gas). Radiation is not heat, only when radiation is absorbed by surface of a body heat is produced, eg., the energy transmission through space from the sun to the earth.

**Shortwave radiation** (SW) is radiant energy with wavelengths in the visible (VIS), nearultraviolet (UV), and near-infrared (NIR) spectra. There is no standard cut-off for the nearinfrared range; therefore, the shortwave radiation range is also variously defined. It may be broadly defined to include all radiation with a wavelength between  $0.1\mu m$  and  $5.0\mu m$  or narrowly defined so as to include only radiation between  $0.2\mu m$  and  $3.0\mu m$ .

**Long wave radiation (LW)** Long wave radiation, from the earth surface and from the atmosphere is radiant energy mostly in the infra-red spectra. For the temperatures existing at the earth's surface, in the troposphere and in the stratosphere (approximately 200-330°K) the greater proportion (up to 99%) of the long wave radiation lies in the wavelength range from 4 to 40 microns ( $\mu$ m).

## Outgoing long wave radiation

After being heated by solar radiation, the earth becomes source of radiation. Average temperature of the earth's surface is  $285^{\circ}$  K ( $12^{\circ}$  C). 99% of radiation is emitted in the form of IR range (4 to  $120 \,\mu$ m). About 90% of the outgoing radiation is absorbed by the atmosphere.

Water vapour absorb in wavelengths of 5.3 to 7.7  $\mu$  and beyond 20 $\mu$ . Ozone 9.4 to 9.8  $\mu$ . CO<sub>2</sub> – 13.1 to 16.9  $\mu$ Clouds – in all wavelengths

Long wave radiation escapes to the space between 8.5 and 11  $\mu$  and this is known as the **atmospheric window.** Atmosphere for this spectrum acts as transparent medium instead of absorbing. This spectral region is used in microwave remote sensing to monitor the features of the sky in case of overcast sky. A large part of the radiation absorbed by the atmosphere is sent back to the earth's surface as counter – radiation. This counter radiation prevents the earth's surface from excessive cooling at night.

## Albedo

It is the percentage of reflected radiation to the incident radiation. (Varies with colour and composition of the earth's surface, season, angle of the sun rays). Value is Highest in winter and at sunrise and sunset. Pure water – 5-20%, Vegetation 10-40%, Soils 15-50%, Earth 34-43% and clouds 55%. High albedo indicates that much of the incident solar radiation is reflected rather than absorbed.

## Factors affecting albedo

1. Angle of incidence of radiation: Albedo increase with decreasing elevation of sun with minimum during noon.

- 2. Physical characteristics of surface
- 3. Season
- 4. Time of the day

For plant community, albedo depends upon

- 1. Age of the crop
- 2. Percentage of ground cover
- 3. Colour and reflectivity of the foliage

## NATURE AND LAWS OF RADIATION

The behavior of electromagnetic radiation may be summed up in the following simplified statements:

- 1. Every item of matter with a temperature above absolute zero emits radiation.
- 2. Substances that emit the maximum amount of radiation in all wavelengths are known as black bodies. Such bodies will absorb all radiation incidents upon them. A black body is thus a perfect radiator and absorber.
- 3. Substances absorb radiation of wavelengths, which they can emit.
- 4. The wavelengths at which energy is emitted by substances depend on their temperature—the higher the temperature, the shorter the wavelength.
- 5. Gases emit and absorb radiation only in certain wavelengths.
- 6. The amount of radiation absorbed by a gas is proportional to the number of molecules of the gas and the intensity of radiation of that wavelength.

#### Wavelength

The wavelength of electromagnetic radiation is given by the equation

$$\lambda = c/v$$

Where,  $\lambda$  is the wavelength, the shortest distance between consecutive crests in the wave trans; *c* is the constant equal to the velocity of light,  $3 \times 10^{10} \text{ cm} \cdot \text{sec}^{-1}$ ; and *v* is the frequency, the number of vibrations or cycles per second.

#### Planck's Law

Electromagnetic radiation consists of the flow of quanta or particles, and the energy content (E) of each quantum is proportional to the frequency given by the equation

$$E = hv$$

Where, *h* is Planck's constant (having a value of  $6.625 \times 10^{-27} \text{ erg} \cdot \text{sec}^{-1}$ ) and *v* is the frequency. The equation indicates that the greater the frequency, the greater is the energy of the quantum.

#### Kirchoff's Law

Any gray object (other than a perfect black body) that receives radiation disposes of a part of it in reflection and transmission. The absorptivity, reflectivity, and transmissivity are each less than or equal to unity. This law states that the absorptivity a of an object for radiation of a specific wavelength is equal to its emissivity e for the same wavelength. The equation of the law is

$$a(\lambda) = e(\lambda)$$

#### Stefan-Boltzman Law

This law states that the intensity of radiation emitted by a radiating body is proportional to the fourth power of the absolute temperature of that body:

Flux = 
$$\sigma T_a^4$$

Where,  $\sigma$  is the Stefan-Boltzman constant (5.67 × 10<sup>-5</sup> erg·cm<sup>-2</sup>·sec<sup>-1</sup>·K<sup>-4</sup>) and  $T_a$  is the absolute temperature of the body.

#### Wein's Law

The wavelength of maximum intensity of emission from a black body is inversely proportional to the absolute temperature (T) of the body. Thus,

# Wavelength ( $\lambda$ ) of maximum intensity ( $\mu$ m) = 2897 T<sup>-1</sup>

For the sun the wavelength of the maximum emission is near 0.5  $\mu$ m and is in the visible portion of the electromagnetic spectrum.

#### Energy balance or heat balance

The net radiation is the difference between total incoming and outgoing radiations and is a measure of the energy available at the ground surface. It is the energy available at the earth's surface to drive the processes of evaporation, air and soil heat fluxes as well as other smaller energy consuming processes such as photosynthesis and respiration. The net radiation over crop is as follows.

#### Rn = G + H + LE + PS + M

Rn is net radiation, G is surface soil heat flux, H is sensible heat flux, LE is latent heat flux, PS and M are energy fixed in plants by photosynthesis and energy involved in respiration, respectively. The PS and M are assumed negligible due to their minor contribution (about 1-2% of Rn). The net radiation is the basic source of energy for evapotranspiration (LE), heating the air (H) and soil (S) and other miscellaneous M including photosynthesis.

#### **Air Temperature**

Temperature is a measure of speed (mean kinetic energy per molecule of the molecules in a body) and heat is the energy arising from random motion of all the molecules in a body. Temperature is, therefore, the intensity aspects of heat energy to the biosphere.

#### Vertical Temperature Profile of Atmosphere

There are several ways of classifying the different layers of the atmosphere. The most common classification is based on the vertical distribution and variations of temperature in the atmosphere. In this classification, from the lowest layer to the highest layer are respectively the troposphere, the stratosphere, the mesosphere, and finally the thermosphere. The thickness and the boundary of each layer are not identical throughout the globe but vary in different time and places.

The troposphere is about 12 kilometers thick on average; it is thicker in summer than in winter. The troposphere over low latitude regions is usually thicker than over high latitude regions. The troposphere over the equator is about 18 kilometers thick, while its thickness in the regions nearest the two poles is only about eight to 9 kilometers. The temperature in the troposphere usually decreases with height at the average lapse rate of 6.5 °C per kilometer. The air in the troposphere is more unstable and with strong convection. Almost all the water vapor in the atmosphere exists within this layer; therefore, common weather phenomena such as clouds, fog, rain, and snow, occur only in this layer and more often than not in its lower part.

The stratosphere extends from 10 kilometers to 50- 55 kilometers above ground. Within the lower part which extends from the top of the troposphere to about 30-35 kilometers the temperature is almost constant, or increases slightly with height. Above 35 kilometers the temperature actually increases with height at the average rate of 5 °C per kilometer. Since almost no dust or water vapor from the land surface will reach the

stratosphere, the air flow in this layer is steady. The upper part of the stratosphere experiences an increase of temperature due to the fact that the sun's ultraviolet radiation is absorbed by the ozone layer.

The region of the mesosphere is about 50 to 80 kilometers in altitude. The temperature in this layer usually decreases as the height increases up to the top of the mesosphere where the temperature can be as low as -95°C or even lower. The composition of gases in the atmosphere from the ground to the top of the mesosphere, are almost identical except for water vapor and ozone. Therefore, the region below the mesosphere is also called the homosphere.

The thermosphere is the region above the top of mesosphere where the temperature begins to rise again. When sun activity is low, this layer can extend to 400 kilometers in altitude. During high sun activity periods the layer can reach around 500 kilometers in altitude. The air in the lower region of the thermosphere is extremely thin; Therefore, the particles in the air can easily be ionized, resulting in profuse free electrons in the air. Therefore, this layer is also called the ionosphere; It is very effective in reflecting radio waves.



#### Lapse Rate

Lapse rate, rate of change in temperature observed while moving upward through the Earth's atmosphere. The lapse rate is considered positive when the temperature decreases with elevation, zero when the temperature is constant with elevation and negative when the temperature increases with elevation (temperature inversion). The lapse rate of non-rising air—commonly referred to as the normal, or environmental, lapse rate—is highly variable, being affected by radiation, convection, and condensation; it averages about 6.5 °C per kilometer in the lower atmosphere (troposphere). It differs from the adiabatic lapse rate, which involves temperature changes due to the rising or sinking of an air parcel. Adiabatic lapse rates are usually differentiated as dry or moist.

The dry adiabatic lapse rate for air depends only on the specific heat capacity of air at constant pressure and the acceleration due to gravity. The dry adiabatic lapse rate for the Earth's atmosphere equals 9.8 °C per kilometre; thus, the temperature of an air parcel that ascends or descends 5 km would fall or rise 49 °C, respectively. When an air parcel that is saturated with water vapour rises, some of the vapour will condense and release latent heat. This process causes the parcel to cool more slowly than it would if it were not saturated. The moist adiabatic lapse rate varies considerably because the amount of water vapour in the air is highly variable. The greater the amount of vapour, the smaller is the adiabatic lapse rate. As an air parcel rises and cools, it may eventually lose its moisture through condensation; its lapse rate then increases and approaches the dry adiabatic value.

The difference between the normal lapse rate in the atmosphere and the dry and moist adiabatic lapse rates determines the vertical stability of the atmosphere—that is, the tendency of an air particle to return to its original position or to accelerate away from its original position after being given a slight vertical displacement. For this reason, the lapse rate is of prime importance to meteorologists in forecasting certain types of cloud formations, the incidence of thunderstorms, and the intensity of atmospheric turbulence.

## Factors Affecting the Air Temperature

The distribution of temperature over the earth surface depends on following factors:

## Latitude:

Highest temperatures are generally at the equator and the lowest at the poles. The temperature decreases with the increase of latitude. The tropical areas around the equator absorb much more radiant energy from the sun than they reflect. In contrast, the polar areas receive sunlight at an angle, so the light has to travel through a greater amount of atmosphere. For this reason, the polar areas absorb less heat from the sun than what they reflect.

## Altitude:

Temperature decreases with height in troposphere. Locally, temperature is affected by altitude. Higher elevations are cooler because of the change in air pressure. Compression of molecules causes heat. The higher air pressure at lower elevations results in higher air temperatures. The reverse is true at higher elevations. All other factors being equal, the air temperature decreases about seven degrees Fahrenheit for every 2,000 feet of altitude gain. Thus a temperature of 80°F degrees at sea level would be about 16oF degrees at 18,000 feet.

### Season:

Coldest temperatures are in winter and highest temperatures are in summer seasons.

## Distribution of land and water

Water bodies are great moderators of temperature. Because of high Specific heat of water, so on the oceans, the regularity in temperature is more as compared to continents. Areas close to the sea or ocean tend to have warmer winters and cooler summers than an area at the same latitude but away from the sea. Oceans cool down and heat up at a slower rate than land, causing coastal areas to behave in the same manner

### Topography:

Mountain ranges affect the temperature by acting as obstacles to the Flow of cold air cold air near the surface and they often set conditions of warm winds. 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

### **Ocean currents:**

Hot and cold ocean currents affect temperature e.g. Gulag Stream (Warm) in North Atlantic, Benguela current (cold) along West coast of South Africa, Peru Current (cold) along West Coast of South America. Sea currents follow the same pattern, carrying warmer water into cooler areas. A great example of this is the Gulf Stream, which moves warm water from the Caribbean and southern Atlantic up the coast of North America and into northern Atlantic waters. This constant movement of heat energy drives changing weather patterns.

### Winds:

Various types of wind affect temperature. Wind currents carry the excess heat energy from tropical areas to cooler areas around the planet.

### **Cloudiness:**

Clouds by obstructing the heat from the Sun and rains by cooling the Atmosphere, affect the temperature. Cloud cover affects local temperatures as well, because the clouds absorb the sunlight before it reaches the earth's surface. Other particles suspended in the air can have an impact on temperature, too. Clouds of dust from surface storms or ash from volcanic eruptions can significantly change local air temperatures. Like clouds, these particles prevent the sun's energy from reaching the surface. 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.

### Man- made structures:

Man-made structures also have a great impact on local temperatures. In large cities where there is a concentration of stone, concrete, and asphalt-covered streets, the huge amount of radiant energy absorbed by these materials makes cities much warmer than surrounding countryside. In rural areas, a large amount of the radiant energy is used to evaporate moisture from vegetation and soils, leaving less heat to warm the countryside.

## Diurnal and seasonal variation of air temperature

- The minimum air temperature occurs at about sunrise, after which there is a constant rise till it reaches to maximum.
- The maximum air temperature is recorded between 1300 hrs and 1400 hrs although the maximum solar radiation is reaches at the noon.
- A steady fall in temperature till sunrise is noticed after is attains maximum. Thus, the daily March displays one maximum and one minimum. The difference between the two is called the diurnal range of air temperature.
- The diurnal range of air temperature is more on clear days while cloudy weather sharply reduces daily amplitudes.
- The diurnal range of temperature is also influenced by soils and their coverage in addition to seasons.
- Addition of daily maximum and minimum temperature divided by two is nothing but daily mean / average temperature.
- In northern hemisphere winter minimum occurs in January and summer maximum in July.

### Temperature inversion

Occasionally at some altitude the temperature abruptly increases instead of decreasing. This condition in which this abrupt rise instead of fall in temperature occurs in the air is known as the temperature inversion. This may occur under the following conditions.

- When the air near the ground cools off faster than the overlying layer, because of heat loss during cooling nights.
- When an actual warm layer passing over a lower cold layer
- Cold air from hill tops and slopes tend to flow downward and replaced by warm air.

## Significance of Temperature inversion

- Cloud formation, precipitation and atmospheric visibility are greatly influenced by inversion phenomenon
- Fog formation may take place near the ground which may affect the visibility to both human beings and animals. Affects air navigation.
- Diurnal temperature is affected by temperature inversions.
- The incoming solar radiation and its conversion in to heat is affected

## LIGHT – EFFECT OF LIGHT INTENSITY, QUALITY, DIRECTION AND DURATION ON CROP PRODUCTION

## Light

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.

## Effect of quality

## Solar spectrum:

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 length are as follows:

Colour	Wavelength range(nanometer)
Violet	400 – 435
Blue	435 – 490
Green	490 – 574
Yellow	574 – 595
Orange	595 – 626
Red	626 – 750

### Spectrum of radiation and their importance

Band	Spectrum	Wavelength (nm)	Importance
	Cosmic Ray	<5	Shorter wavelengths
	Gamma Ray and X-Ray	5-200	of the spectrum and
Ultra	Ultraviolet Ray	200-390	chemically active, unless filtered there is danger of life on earth
Visible	Violet	390-420	Visible spectrum,
	Blue	420-490	known as light
	Green	490-540	essential for all plant
	Yellow	540-590	processes
	Orange	590-650	
	Red	650-760	
Infra Red	Infra Red Rays	>760	Essential for thermal
			energy of the plant
			(Source of heat)

### **Common Wavelength Units**

Unit	Symbol	Length(m)	Type of radiation
Angstrom	А	10 <sup>-10</sup>	X-Ray
Nanometer	nm	10 <sup>-9</sup>	Ultraviolet, Visible
Micrometer	μm	10-6	Infrared
Millimeter	mm	10 <sup>-3</sup>	Infrared
Centimeter	cm	10-2	Microwave
Meter	m	1	TV, Radio

### **Shorter than visible range**: (<400 nm)

- Chemically very active
- When plants are exposed to this radiation the effects are detrimental.
- Atmosphere acts as regulator for this radiation and none of cosmic, Gamma and X-rays reaches to the earth.
- The UV rays of this segment reaching to the earth are very low and it is normally tolerated by the plants.

### Higher than visible wavelength (>700 nm)

- Referred to IR radiation
- It has thermal effect on plants
- In the presence of water vapour, this radiation does not harm plants; rather it supplies the necessary thermal energy to the plant environment.

### Visible spectrum (400-700 nm)

- Between UV & IR radiation and also referred as light
- All plant parts are directly or indirectly influenced by the light
- Intensity, quality and duration are important for normal plant growth
- Poor light leads to plant abnormalities
- Light is indispensable to photosynthesis
- Light affect the production of tillers, the stability, strength and length of Culms It affects the yield, total weight of plant structures, size of the leaves and root development.

### Absorption of radiation by plants as a function of its quality

The plant leaf strongly absorbs blue and red wavelengths, less strongly absorbs the green, very weakly absorbs the near infrared, and strongly absorbs in the far-infrared wavelengths. Because the absorption of the near-infrared wavelengths (which contain the bulk of energy) by the leaf is limited, by discarding this energy it prevents the internal temperature from becoming lethal. At the infrared wavelengths, the plant leaf is an efficient absorber, but in these wavelengths the energy at the surface is small, with the result that the

plant is a good absorber in the far infrared. It is an equally a good radiator at these wavelengths.



Wavelength range (mm)	Physiological response of plants
Greater than 1.000	Most of this radiation absorbed by plants is transformed into heat without interfering with the biochemical processes
1.000 to 0.700	Elongation effects on plants
0.700 to 0.610	Very strong absorption by chlorophyll, the strongest photosynthetic activity, and in many cases strong photoperiodic activity
0.610 to 0.510	Low photosynthetic effectiveness in the green segment and weak formative activity
0.510 to 0.400	Strong chlorophyll absorption, strong photosynthetic activity, and strong formative effects
0.400 to 0.315	Produces fluorescence in plants and a strong response by photographic emulsions
0.315 to 0.280	Significant germicidal action. Practically no solar radiation of wavelengths shorter than 0.29 $\mu m$ reaches the earth's surface
Shorter than 0.280	Very strong germicidal action. It is injurious to eyesight and when below 0.26 $\mu$ m can kill some plants. No such radiation reaches the earth's surface

## Physiological responses of plants towards solar spectrum

The solar spectrum can be divided into the following eight broad bands on the basis of the physiological response of plants:

- 1. Wavelength greater than 1.000  $\mu$ m: Most of this radiation absorbed by plants is transformed into heat without interfering with the biochemical processes.
- 2. Wavelength 1.000 to 0.700  $\mu$ m: Elongation effects on plants.
- 3. Wavelength 0.700 to 0.610  $\mu$ m: Very strong absorption by chlorophyll, the strongest photosynthetic activity, and in many cases strong photoperiodic activity.
- 4. Wavelength 0.610 to 0.510  $\mu$ m: Low photosynthetic effectiveness in the green segment and weak formative activity.
- 5. Wavelength 0.510 to 0.400  $\mu$ m: Strong chlorophyll absorption, strong photosynthetic activity, and strong formative effects.
- 6. Wavelength 0.400 to 0.315  $\mu$ m: Produces fluorescence in plants and a strong response by photographic emulsions.
- 7. Wavelength 0.315 to 0.280  $\mu$ m: Significant germicidal action. Practically no solar radiation of wavelengths shorter than 0.29  $\mu$ m reaches the earth's surface.
- 8. Wavelength shorter than 0.280  $\mu$ m: Very strong germicidal action. It is injurious to eyesight and when below 0.26  $\mu$ m can kill some plants. No such radiation reaches the earth's surface.

## Effect of light intensity

- 1. The intensity of light is measured by comparing with a standard candle. The amount of light received at a distance of one metre from a standard candle is known as "Metre candle or Lux". The light intensity at one foot from a standard candle is called 'foot candle' or 10.764 lux and the instrument used is called as lux meter.
- 2. About one percent of the light energy is converted into biochemical energy.
- 3. Very low light intensity reduces the rate of photosynthesis resulting in reduced growth.
- 4. Similarly, very high intensity is detrimental to plant in many ways as below.
- 5. It increases the rate of respiration.
- 6. It also causes rapid loss of water i.e., increases the transpiration rate of water from the plants.
- 7. 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.
- 8. 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.
- 9. The intensity of light falls at exponential rate with path length through absorbing layers according to Beer's law. i.e., the relative radiation intensity decreases exponentially with increasing leaf area.
- 10. 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)

### Effect of 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.

**Long day plants** --The plants which develop and produce normally when the photoperiod is greater than the critical minimum (greater than 12 hours). eg. Potato, Sugarbeet, Wheat, Barleyetc.

**Short day plants** --The plants which develop normally when the photoperiod is less than the critical maximum (less than 12 hours). Rice, Sorghum, cotton, Sunflower

**Day neutral plants / Indeterminate** --Those plants which are not affected by photoperiod. (eg) Tomato, Maize

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 is 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.

## **Temperature and Crop plants**

Temperature is a measure of speed (mean kinetic energy per molecule of the molecules in a body) and heat is the energy arising from random motion of all the molecules in a body. Temperature is, therefore, the intensity aspects of heat energy to the biosphere. Temperature is of paramount importance for organic life because of the following factors.

1. Physical and chemical processes within the plants are governed by temperature and these processes in turn control biological reactions that take place within the plants.

2. The diffusion rate of gases or liquids changes with temperature.

3. Solubility of different substances is dependent upon temperature.

4. The rate of reactions varies with variations in temperature.

5. Equilibrium of various systems and compounds is a function of temperature.

6. Temperature affects the stability of enzyme systems.

## Role of temperature in crop production

1. Temperature influences distribution of crop plants and vegetation.

2. The surface air temperature is one of the important variables, which influences all stages of crop during its growth development and reproductive phase.

3. Air temperature affects leaf production, expansion and flowering.

4. Biochemical reactions in crops (double or more with each 10°C rise) are influenced by air temperature.

5. Temperature affects the stability of enzymatic systems in the plants.

6. Most of the higher plants grow between  $0^{\circ}C - 60^{\circ}C$  and crop plants are further restricted

from 10 – 40°C, however, maximum dry matter is produced between 20 and 30°C

7. At high temperature and high humidity, most of the crop plants are affected by pests and diseases.

8. High night temperature increases respiration and metabolism.

9. A short duration crop becomes medium duration or long duration crop depending upon its environmental temperature under which it is grown.

10. Most of the crops have upper and lower limits of temperature below or above which, they may not come up and an optimum temperature when the crop growth is maximum. These are known as cardinal temperatures and different crops have different cardinal temperatures.

## Thermo periodic response

Response of living organism to regular changes in temperature either day or night or seasonal is called thermoperiodism.

## **Heat Units**

- It is a measure of relative warmth of growing season of a given length. Normally it is indicated as Growing Degree Days (GDD). A heat unit is the departure from the mean daily temperature above the minimum threshold temperature.
- The minimum threshold temperature is the temperature below which no growth takes place.
- Usually ranges from 4.5 to 12.5 °C for different crops (Varies from 4.5 to 12.5 °C)

## Degree Day

A degree day is obtained by subtracting the threshold temperature from daily mean temperature. Summation of the daily values over the growth period gives degree days of the crops.

$$T_{max} + T_{min}$$

$$GDD = \sum_{2} \cdots T_{b}$$

Where

 $T_{max}$  – Maximum air temperature of the day

T<sub>min</sub> – Minimum air temperature of the day

T<sub>h</sub> - Base temperature of the crop

The base temperature is the threshold temperature.

## Advantages / Importance of growing degree Day Concept

- 1. In guiding the agricultural operations and planting land use.
- 2. To forecast crop harvest dates, yield and quality
- 3. In forecasting labour required for agricultural operations
- 4. Introduction of new crops and new varieties in new areas
- 5. In predicting the likelihood of successful growth of a crop in an area.

### **High-Temperature Injury to Plants**

Thermal death point of active cells ranges from 50 to  $60^{\circ}$  C for most plant species, but it varies with the species, the age of tissue, and the length of time of exposure to high temperature. It has been reported that most plant cells are killed at a temperature of 45 to  $55^{\circ}$  C.

- 1. High temperature results in the desiccation of the plant and disturbs the balance between photosynthesis and respiration. Once the temperature exceeds the maximum up to which growth takes place, plants enter a state of quiescence (period of inactivity). When the temperature becomes extremely high, a lethal level is reached. At temperatures higher than the optimum cardinal, the physiological activity declines as a consequence of inactivation of enzymes and other proteins.
- 2. High temperature just before or during flowering decreases pollen size, causes a shortage of starch in pollen, and increases the proportion of anthers that did not dehisce
- 3. The higher the temperature, the greater is the rate of respiration, which results in the rapid exhaustion of food reserves of seeds. Temperatures on the sunny side of the bark or stems during hot afternoon and late night undergo great fluctuations. The

injury inflicted because of this short period fluctuation in temperature is known as *sun scald* 

4. Exceptionally high temperature at the soil surface and the adjoining laminar sublayer of the air frequently scorches the short stems. The scorching of the stem is known as *stem girdle* 

## Low-Temperature Injury to Plants

Exposure to extremely low temperatures and heavy snowfall damages the plant in several ways including suffocation, desiccation, heaving, chilling, and freezing.

## Suffocation

Small plants may suffer from deficient oxygen when covered with densely packed snow. When suffocated, certain toxic substances accumulate in contact with roots and crowns and tend to inhibit the diffusion of carbon dioxide.

## Physiological Drought and Desiccation

Spring drought sometimes occurs in cool temperate climates. This results from excessive transpiration and a time lag in absorption of moisture from the soil, caused by a warm period when the soil is still frozen. The result is an internal moisture deficit sufficient to cause death of the twigs. The decreased water absorption by plants at low temperatures is the combined effect of the decreased permeability of the root membrane and increased viscosity of water. This results in increased resistance to water movement across the living cells of the roots.

### Heaving

Injury to a plant is caused by the soil layer lifting upward from the normal position and causing the root to stretch or break at a time when the plant is growing. Sometimes the roots are pushed completely above the soil surface. After thawing, it is difficult for the roots to become firmly established, and the plants may die because of this mechanical damage and desiccation

### Chilling

Plants of tropical origin are damaged by exposure to mild chilling for two to three days. Plants of temperate origin withstand chilling for long periods without suffering any injury. Rice, cotton, and cowpea are killed when exposed to temperatures near 0°C for about two to three days. Chilling injury of fruits is of particular interest because they are often stored and shipped at low temperatures. Symptoms of chilling injury to fruits include surface pitting, lesions, discoloration, susceptibility to decay organisms, and shortening of storage life. Fruits subjected to chilling injury do not ripen normally. The critical temperature at which chilling injury occurs is 8 to 12°C for tropical fruits such as banana, avocado, and mango, and 0 to 4°C for temperate zone fruits such as apple

### Soil temperature

The soil temperature is one of the most important factors that influence the crop growth. The sown seeds, plant roots and microorganisms live in the soil. The physico-chemical as well as

life processes are directly affected by the temperature of the soil. Under the low soil temperature conditions germination is inhibited and the intake of water by root is reduced. In similar way extreme soil temperatures injures plant and affect its growth.

### Importance of soil temperature on crop plants:

#### The soil temperature influences many processes as follows

- 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. (inc with inc in temp)
- 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.)

### **Relative Humidity**

The ratio between the amount of water vapour present in a given volume of air and the amount of water vapour required for saturation under fixed temperature and pressure. There are no units and this is expressed as percentage. In other terms it is the ratio of the air's water vapour content to its maximum water vapour capacity at a given temperature expressed in percentage. The relative humidity gives only the degree of saturation of air. The relative humidity of saturated air is 100 per cent.

### Importance of Humidity on crop plants

The humidity is not an independent factor. It is closely related to rainfall, wind and temperature. It plays a significant role in crop production.

- 1. The humidity determines the crops grown in a given region.
- 2. It affects the internal water potential of plants.
- 3. It influences certain physiological phenomena in crop plants including transpiration

4. The humidity is a major determinant of potential evapotranspiration. So, it determines the water requirement of crops.

5. High humidity reduces irrigation water requirement of crops as the evapotranspiration losses from crops depends on atmospheric humidity.

6. High humidity can prolong the survival of crops under moisture stress. However, very high or very low relative humidity is not conducive to higher yields of crops.

7. There are harmful effects of high humidity. It enhances the growth of some saprophytic and parasitic fungi, bacteria and pests, the growth of which causes extensive damage to crop plants. Eg: a. Blight disease on potato. b. The damage caused by thrips and jassids on several crops.

8. High humidity at grain filling reduces the crop yields.

9. A very high relative humidity is beneficial to maize, sorghum, sugarcane etc, while it is harmful to crops like sunflower and tobacco.

10. For almost all the crops, it is always safe to have a moderate relative humidity of above 40%.

#### RAINFALL

Of the average annual rainfall of about 370 million hactare metre (m.ha.m) in India, it is estimated that about one-third is lost in evaporation at various levels, about one-fifth (80 m.ha.m) seeps into soil and about 178 m.ha.m. are free in flows of which about 40% is utilisable through irrigation. About 43 m.ha.m.(of that seeps into the soil) remains in root zone soil depth to contribute to soil moisture that supports crop growth. The agrometeorologist is concerned with the prediction of water absorbed and retained by the soil and devising means to minimise its loss by surface evaporation and transpiration in order to increase the water use efficiency of plants.

#### Rainfall characteristics important for agriculture

In India, the rainfall is seasonal, mostly in *kharif* (late summer) and partly in rabi (winter). It varied in intensity, duration, frequency and space. Even at places, a few kilometer apart, most rains are with variable rainy days and individual rain storms of short durations and varying intensities. In India the south-west monsoon is the most important rainfall phenomenon affecting crop production accounting for 80-95% of annual rainfall in most parts of the country. Since the rainfall has a dominating influence in crop production for nearly two-thirds of the world area, its study in agricultural climatology for its varied characteristics has been undertaken in all countries, including related rates of evaporation in all seasons.

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In arid and semi-arid regions, it becomes the limiting factor, superseding all other factors of crop production, due to total and seasonal amounts, frequencies, short time intensities, drought spells, wet spells and other variabilities. For this, a knowledge of the probable dates of commencement and end of rainy season and the duration of intermittent dry and wet spells, can be very useful for planning various agronomic operations like preparation of seed bed, manuring, sowing, weeding, transplanting, harvesting, threshing, drying etc. This results in minimised risk to crops, and to optimum utilisation of limited resources like labour, fertiliser, herbicides and insecticides. There are critical periods in the life history of each crop, from sowing to harvesting. Thus with a knowledge of dry spells, a farmer can adjust sowing periods in such a way, that moisture sensitive stages do not fall during dry spells. Most agricultural plants require moderate amount of water in soil, good aeration around their roots and a moderate humidity of atmospheric air which is of critical importance during the reproductive stage of plant growth.

Under irrigated farming, irrigation can be planned using data regarding consecutive periods of rainfall, to satisfy the demands for critical periods. The knowledge of wet and dry spells can also help a great deal in improving the efficiency of irrigation water utilisation. To study the characteristics of rainfall it is assumed that each year provides one observation for an event of characteristic interest, and the total observations are then analysed assuming that they are a simple random sample from a single distribution. The estimates of the probability of an event could then be made by fitting a suitable distribution.

#### Effect of rainfall on crop production

Crop production, when averaged over large areas like whole state or even a district, does not become sensitive to weather conditions normally occurring with shortages or excesses of rains in some locality or the other scattered widely in a large area. Further, the crops are not always grown as per soil type suitability or land capability. Hence every year in a large region some localities show limitation in yields due to rainfall shortages or excesses for the concerned soil types and rainfall frequencies, while other locations show higher yields due to adequate rainfall suitable to crop stages and soil conditions. The final effect is the little annual variation in the average for the whole large area, though individual small local areas may show high variation on the positive or negative side from the large area average.

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Rain in excess of the deficit in soil moisture or the infiltration rate at any time is lost in drainage and run-off, in both cases degrees vary aas per soil condition. The rainfall provides a variation in the evaporation and transpiration rates. Wet nights and clear days create more loss than when the reverse situation occurs. This affects the moisture availability to plants, and plant growth accordingly, and creates the need of irrigation water under obviously similar conditions.

The size of droplet and the ratio of fall give variations in soil wetting. Heavy rains penetrate deeper than light rains of the same total. The rate is more in lighter soil, diminishing very rapidly as the soil texture becomes finer. Very heavy fall creates puddling of the soil surface, reduction in infiltration rate, surface soil compaction with crust formation on drying, more soil erosion, more run-off and excessive evaporation losses.

Excessive rains during critical growth periods have detrimental effect on plant growth, particularly at seedling and flowering stages. It results in poor fruiting, delayed maturity, poor stand and stunted growth because of impeded drainage. This situation becomes very alarming in heavier soils. Besides creating waterlogging and affecting soil temperature, excessive rains also alter significantly the crop microclimate and air humidity condition normally harmful for good fertilization of flowers, good uptake of nutrients, and even translocation activities. Thus waterlogged conditions produce deleterious effect on the nutrition and health of most field crops and ultimately poor yields are obtained. Broadly the plant growth in wet soils can be attributed to the following four factors:

- 1. Development of toxic substances.
- 2. Insufficient oxygen for root respiration.
- 3. Lack of nitrate formation.
- 4. Limited root development with a corresponding large top growth.

This situation leads to excessive crop damage in the event of longer spell of dry period or drought. Moreover, plants from such wet soils become abnormally succulent, very susceptible to diseases and pests, and less productive than those growing in normal moisture condition.

### Behaviour of Indian monsoon rainfall and its implications in Indian agriculture

1. Rainfall received in most parts of different regions of India is between 50 and 100 cm within a period of 3-5 months.

2. The rainfall in most part is primarily only during high temperature period preceded by a much hotter period of about 3 months and followed by a short (3-5 weeks) hot period. It means this hotter rainy period causes high evapotranspiration rates than those in rabi (winter) rainy season demanding better conservation practices.

3. The long dry period of 7-9 months is with little and most erratically distributed rainfall and hence incapable to sustain a reasonable harvest of any crop growth during this period without protective irrigation.

4. Even within the main rainy season the rain distribution is so erratic that crop yields are highly fluctuating from year to year, even within different regions of the same district. This means that the total rainfall is much less efficient to produce crops, unless storage and conservation practices are efficiently managed.

5. The erratic distribution is frequently characterised by long wet spells alternated with long dry spells causing limitation in the choice of suitable crops and their varieties.

6. Early and late rains of the rainy season are most undependable as well as least predictable than those during July-August period. This gives further limitations to proper varieties every year with unpredictable harvests.

7. The dependable short period (2 to 2.5 months) rains are frequently with high intense showers that cannot be absorbed in soil causing high run-off losses. More of the total rainfall is received in a few days though total rainy days may be many more. As a consequence, erosion hazards, moisture deficiency in the later part of the season and fertility depletion are very common on unprotected lands.

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#### ASSESSMENT OF AGROCLIMATIC POTENTIAL BASED ON RAINFALL

#### Method uses by National Commission of Agriculture (NCA)

NCA assessed the climatic potential of each regions of India on the basis of rainfall and evaluated the relationship between patterns of rainfall and agriculture. Because of lower variability, ready availability and greater facility in handling --- monthly totals of rainfall formed the criteria of delimiting the regions. They have chosen limits which have closer relation in broad requirement of crops. Since the time span of most of the crops is usually of the order of 90 days or more, the following limits have been chosen by them.

(1) Rainfall of greater than 30 cm per month for at least three consecutive months would be suitable for a crop like paddy whose water need is high.

(2) Rainfall of 20-30 cm per month for not less than three consecutive months would be suitable for crops whose water need is high but less than that of paddy, e.g., maize, blackgram.

(3) Rainfall of 10-20 cm per month for at least 3 consecutive months is considered suitable for crops requiring less water, e.g., bajra and small millets.

(4) Rainfall of 5-10 cm per month is just sufficient for crops which have low water requirement like moth bean.

(5) Rainfall less than 5 cm per month is not of much significance for crop production.

Accordingly, they adopted the following symbolic presentation for rainfall types:

Symbol	Monthly Rainfall (cm)
A	> 30
В	20-30
С	10-20
D	5-10
E	< 5

In denoting years distribution of rainfall, the portion south-west monsoon months of June to September is given in the central position in brackets. To the right is the distribution for the post-monsoon months of October to January and to the left of that is that of premonsoon months, viz, February to May. The number of months in the respective season in which monthly rainfall is within the specific limit mentioned above is indicated by a number as a subscript to the symbols given above.

Thus, a rainfall pattern - E4 (D2E2) E4 indicates

(1) Rainfall less than 5 cm per month during post-monsoon months of October to January

(2) Rainfall less than 5 cm per month during pre-monsoon months of February to May.

(3) During rainy season of June to September two months are with rainfall 5-10 cm per month and another two months are with rainfall less than 5 cm.

#### WIND

Wind is atmospheric air mass caused by differences in pressure generated over vast distances due to differences in heat contents and temperature between two places. Heating and cooling of air in contact with earth cause rising of heated air mass to be replaced by cooler air mass. This causes air movements called winds.

In windy climates the plants are dwarfed. This due to small cell formation through reduced turgidity when cells are expanding and maturing. In some plants the maturity date is advanced, plants have an increased number of secondary branches and water requirement may be doubled. Wind also interferes with pollination resulting into low yield. Even a wind velocity of more than 3.5 miles/hr. can be harmful in flower fertilisation. High velocity dry winds reduce the efficiency of transpiration. Evaporating and transpiring powers are further increased by higher temperature resulting in desiccation of plant tissue. High drying winds hasten completion of a particular growth phase without proper development and speed up action through increased soil moisture evaporation. During seed development and milk stage of crops high drying winds are very harmful as these result into poor seed development and early drying of crops.

Wind velocity or momentum is primarily the cause for varying wind effects. Dry, hot and cold winds have humidity and temperature variation effect on soil, air and plant parts. With high velocities mechanical damage is the additional trouble. For most parts of the year and in most parts of India the wind velocities are fairly low. Mean monthly velocities of more than 10 miles/hr. are rare, though for a day or a few hours of a day it may be much more occasionally. The coastal areas are however, the only areas with higher wind velocities for larger part of the year and with more frequency of stormy windy days.

Wind or air movement is a very important parameter in crop canopy for CO<sub>2</sub> intake, transpiration and energy exchanges that are essential for photosynthetic and other physiological activities. Strong wind mix large volumes of air, resulting into lowered temperature and humidity. Calm air or light winds do little mixing and thus air layers down the crop canopy have high temperature. Frost occurrence is common in winter on light and calm winds as soon as air temperature approaches 0°C. Moderate to moderately strong winds blowing continuously for weeks or months together are a real problem to soil and growing crops. These lift soil particles and cause erosion, desiccation of plants during summer season, frost troubles during winter season, and disturbs the whole microclimate of the crop.

With low humidity wind place plants under high desiccating transpiration stress and soil under high surface evaporation causing soil moisture stress, lodging of crops, breaking of plant parts, shriveling of maturing grain, wilting of plants, poor drifting of pollinating insect activities for flower fertilisation.

Thus, effect of wind on crop plants can be summarized as:

1) Transports heat in either sensible or latent heat form from lower to higher altitudes

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2) Wind affects the plant directly by increasing transpiration and the intake of CO2 and also causes several types of mechanical damage.

3) Wind helps in pollination and dispersal of seeds.

4) Light and gentle winds are helpful for cleaning the agricultural produce.

5) Hot dry winds frequently do much damage to vegetation in the growing crops by promoting excessive water loss.

6) Wind has powerful effect on humidity.

7) Long, continued warm, dry winds injured blossoms by evaporating the secretion of the stigma.

8) Provides moisture which is necessary for precipitation

9) Wind prevents frost by disrupting atmospheric inversion

10) Causes soil erosion

### DEW

It is an important form of precipitation during winter season in the tropical climate and in temperate region in dry summer season. Dew does not fall, but it occurs. Dew is condensation of vapour on solid surface that gets cooled due to heat loss by nocturnal radiation below the point of condensation of water vapour in surrounding air in contact with them. The vapour in the air condenses by the release of latent heat of condensation. On clear nights such rapid cooling by back radiation is of common occurrence. Naturally half of the dew is from soil moisture evaporation, the other half being from air moisture.

The beneficial effect of dew on vegetation are

(1) Direct use by plants from absorption by leaf surface.

(2) Reduction in transpiration.

(3) More photosynthesis by plants in forenoon hours due to water saturation of leaves during night.

Intense dew formation helps in developing rise in or reducing the plant leaf temperature, respiration and transpiration. Through this action it helps in increased net

photosynthesis for better development of fruits and grains. Thus, though dew is generally an insignificant source of water in water budget, it derives importance for plant survival, some growth and grain or fruit development in arid or semi-arid tropics when much nocturnal radiative cooling takes place frequently. Different species show wide variations in the degree of such benefits from dew, it being much less for those having leaves with waxy coatings and/or thick hairy coating. Unfortunately dew also promotes certain plant diseases by providing suitable environment.

In India, under rainfed condition with nearly no winter rains for most parts and in areas away from large water bodies dew is of much less significance. Arid and semi-arid areas that are reasonably close to sea shore or large water bodies, dew can be of common occurrence due to blowing of winds carrying adequate vapour load from these water surfaces. Much of this dew water does not find its way into plant body due to quicker evaporation after sunrise. Thus only high and frequent dew occurrences can really benefit plants.

#### FOG

Fog is of much rare occurrence in tropics and hence a least disturbing factor in local agriculture. Coastal areas are more affected by fog because of humid sea-breeze front following clear, calm winter nights. In temperate and sub-tropical cold areas fog is frequent, denser and of longer duration. Whenever it is dense and of long duration it is of paralysing influence on farming business. There is some fog precipitation much in forest and little in fields which is of significance as fog vapour is entrapped and water drops fall to ground.

Mist is differentiated from fog due to better and longer distance visibility. Fog is very dense with high relative humidity and very poor visibility even for very short distance. Both fog and mist results from condensation of water vapour in air on the surface of either land or water due to cooling of moisture in warm saturated air replacing cool dry air mass over a cool surface during clear sky, weak radiation and no windy conditions. If fogs are frequented the relative humidity of the air surrounding plants becomes high and this induces more disease incidences. Hence fog is of greater interest to plant pathologists. If the fog develops during night the cooling near the surface is much restricted and it prevents the ground temperature to fall appreciably.

#### SNOW

Snowfall is of importance to crops in regions where the occurrence of freezing and sub-zero temperature allows very little time for a crop to be sown and harvested. In this the crop is sown before snowfall commences and the young crop is protected from frosts by snow cover as the temperature at the ground (below the snow ) remain higher as compared to that in the overlying air. Later, when warmer temperature occur, the snow melts provides sustenance soil moisture to the crops and enables it to mature. Over large tracts of Europe and other temperate regions cereals can be grown only under snow cover. A snow layer exerts its beneficial effect through its low heat conductivity which is nearly 1/10 th.of that of soil. As the supply of water to the soil by snow melt is gradual and as the soil protected from freezing can allow more rapid infiltration snow water is more effective than equivalent precipitation.

However, snow can exert deleterious effect also. Sudden thawing of snow especially when the spring is approaching and the snow cover is not uniform lead to standing water in the field and results in death of plants due to oxygen deficiency. Snow can delay field preparation during spring and interfere with pastoral grazing during winter. In case of trees snow loading can lead to breaking of branches which may start at the periphery and extends towards the centre.

#### AGROCLIMATIC NORMALS FOR SOME IMPORTANT FIELD CROPS

Different crops require varied optimal climatic condition for better growth and development. It is important to select the crops according to the climatic suitability so that crop yields will be high.

#### RICE

Rice is indigenous to humid regions of tropics and subtropics. The crop requires a relatively high temperature of 20-40°C for the optimum growth and development. A mean temperature of 22°C is required during growth period. Higher mean temperature may reduce the growth duration and accelerate flowering. Low temperature depresses the rate of germination, slows down the growth process and delays the maturity. Spikelet sterility is more if the temperature exceeds 35°C at anthesis and lasts for more than one hour. If the

night temperature falls below 15°C during the vegetative phase, rice yield is significantly reduced due to formation of sterile spikelets. Optimum temperature requirements for the important growth stages are as follows:

Germination -- 20-35°C Seedling establishment -- 25-30°C Tillering -- 30-32°C Panicle initiation -- 32-34°C Anthesis -- 30-32°C Ripening -- 20-25°C

Solar radiation is another important parameter required for greater yield. The crop requires solar radiation of 300 Cal/cm<sup>2</sup>/day at the reproductive stage. Low temperature coupled with bright sunshine during the ripening phase is highly conducive for the development of carbohydrates. Rice crop requires an optimum photoperiod of 10-10.5 hours per day for normal flowering particularly for the season bound rice varieties. The crop is sensitive to photoperiod only after the completion of basic vegetative period.

Rice is a water-loving crop and is classified as hydrophyte. Under rainfed conditions rice is cultivated in places receiving an annual rainfall of 1000 mm. or more. Gentle winds are beneficial to rice plants. Heavy winds during cyclones may cause severe lodging and shattering. Wind damages may be of mechanical injury to leaves and panicles and also drying of leaves and earheads. Strong winds at the time of opening of flowers may induce sterility and increase the number of aborted endosperm. Heavy wind during ripening may lead to lodging.

### WHEAT

It requires relatively cool, moist growing season followed by dry, warm season for ripening. The crop is cultivated during the cool season with temperature of less than 25°C. Wheat requires a minimum temperature of 3-4°C, optimum of 25°C and a maximum of about 30-32°C. Prevalence of warm temperature during the early growth of wheat may retard heading. Temperature above 32°C prevailing 3-4 weeks after flowering ripens the grain prematurely. High temperature coupled with high humidity may encourage the spread of rust diseases causing reduction of yield. It requires approximately 100 frost-free days during the growing period.

The crop requires an average precipitation of 250-1750 mm. However, in most of the areas of wheat cultivation the rainfall ranges from 375-825 mm The optimum rainfall

requirement is 625-825 mm Moisture deficit at the time of heading stage result in shriveled grains and low yield.

#### RAPE/MUSTARD

This is basically a temperate crop and requires a moderate temperature below 25-28°C with optimum of 20°C during the growth period. It requires a temperature of 20-30°C for seed germination. The crop requires higher temperature for the completion of vegetative phase and cool temperature and clear sky during the reproductive phase for better development of seed and oil. Frost and cloudy weather during flowering is quite harmful; pest and disease incidence is more in such climate resulting in poor seed yield. Frost plays havoc, especially in brown sarson when it occurs at pod formation stage but raya has the recouping capacity and damage is very low compared to brown sarson. Mustard is a short-day plant. The crop has a very wide photoperiodic range and the regional cultivars are locally adapted. A well-distributed rainfall of 700 mm is optimum with 400-500 mm rainfall during the vegetative and flowering period. The crop should be moisture stress free during flowering and pod filling stage.

#### JUTE

It is a sub-tropical crop and requires humid, tropical to warm sub-tropical climate. The crop is mainly grown in the regions having a temperature range of 15-38°C. It requires high humidity (65-95%). It is a short-day plant and requires a critical photoperiod of 12.5 hours. The olitorious type is more sensitive to short days than the capsularis. The crop requires high rainfall of about 1500 mm distributed in such a way that most of the rainfall is received during the maturity phase. Jute is tolerant to water stagnation; however, it cannot withstand waterlogging at early stage of growth.

#### ΡΟΤΑΤΟ

Optimum soil temperatures for the potato crop vary for different stages of the plant. Young sprouts in the soil make rapid development at a constant temperature of about 24°C; however, the latter growth will be better at approximately 18°C. Soil temperature above 24°C cause excessive branching of the young sprouts, shortening of the internodes. The progressively lower tuber yields at higher temperature are due to a reduction in the synthesis of surplus carbohydrates over that consumed in respiration. Mild frost to the extent of -1°C partially damages the potato leaves but when temperature falls below -2°C the exposed parts of most of the varieties are damaged.

A rainfall of about 150-200 mm or an equivalent amount of irrigation is sufficient for a normal crop. The optimum soil moisture for a potato crop is 65-80% of field capacity.

## GRAM

Gram is grown in all climates which are sufficiently cool and humid for wheat cultivation. It has, however, much greater resistance to drought, but less resistance to humid weather when compared with wheat. Gram crop is moderately frost tolerant particularly at seedling stage. Young seedlings can withstand temperature as low as -8 to -10°C. However, at subsequent stages, low temperature and frost are injurious to the crop. The optimum temperature for early vegetative growth ranges from 21-32°C (night and day). Over the entire growth period, somewhat lower temperature (18-29°C) are optimum. Optimum temperature for nodule formation varies from 15-18°C in sub-tropical areas. Gram thrives best in scanty or low rainfall areas. Excessive rainfall immediately after sowing, at flowering and at fruiting stages cause heavy loss. Excessive atmospheric humidity appears to be a major limiting factor for seed setting in gram crops.

## Agrometeorology and Climate Change (1+1) Syllabus

### 4<sup>th</sup> Semester

## Theory

- Precipitation—process of precipitation, types of precipitation such as rain, snow, sleet and hail, cloud classification; Artificial rainmaking.
- ➢ Weather forecasting—types of weather forecast and their use
- Meaning and scope of agricultural meteorology
- Nature and properties of solar radiation, solar constant; Short wave, long wave and thermal radiation, net radiation, albedo;
- Atmospheric temperature, temperature inversion, lapse rate, daily and seasonal variations of temperature, vertical profile of temperature;
- Agriculture and weather relations;
- Climatic normal for rice, wheat, mustard, potato, jute and gram crop.
- > Earth atmosphere—its composition, extent and structure;
- Atmospheric Pressure, its variation with height; Wind—types of wind, daily and seasonal variation of wind speed, cyclone, anticyclone, land breeze and sea breeze;
- Atmospheric humidity, concept of saturation, vapour pressure, process of condensation, formation of dew, fog, mist, frost, cloud;

- ➢ Monsoon- its importance in Indian agriculture
- Weather hazards—Droughts, floods, frost, tropical cyclones and extreme weather conditions such as heat wave and cold wave
- Climate change, climatic variability, global warming, causes of climate change and its impact on agriculture

## Practical

- 1. Visit to Agrometeorological Observatory--Site selection, exposure of instruments and weather data recording.
- 2. Measurement of albedo and sunshine duration.
- 3. Computation of radiation intensity using bright sunshine hour data.
- 4. Measurement of maximum and minimum air temperature—its tabulation, trend and variation analysis.
- 5. Measurement of soil temperature.
- 6. Determination of vapour-pressure, relative humidity and dew point temperature.
- 7. Measurement of wind speed and wind direction. Preparation of wind rose.
- 8. Measurement, tabulation and analysis of rain.
- 9. Measurement of open pan evaporation.
- 10. Computations of evapotranspiration.

#### **Suggested Book:**

Agrometeorology: Principles and Applications of Climate Studies in Agriculture Author: Harpal S. Mavi & Graeme J. Tupper